APPENDIX A
GEOPHYSICAL DATA

APPENDIX A-1

SUPPORTING METHODS, CALCULATIONS AND TABLES

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A-1.0 SUPPORTING METHODS, CALCULATIONS AND TABLES

This supporting documentation to the 2017 Mobile Sediment Characterization Report provides additional details for the field methods and calculations. Organization is as follows:

- Section 2.0 – Geophysics and Suspended Material Collection presents the scope and methods used for geophysical surveys and suspended material collection.
- Section 3.0 – Erosional Indicator Measurements presents the scope and methods used to evaluate erosional indicators on intertidal mudflats.
- Section 4.0 – Estimation of Bedrock, Boulder, or Hardpan Areal Extent presents the scope and methods used to identify and map areas where bedrock, boulders, or hardpan are present and would create impediments to dredging operations
- Section 5.0 – References provides references for documents cited within this Appendix.

A-2.0 GEOPHYSICS AND SUSPENDED MATERIAL COLLECTION

A-2.1 Field Effort Summary

On-water field work conducted on July 21-31, 2017, and September 19, 2017 (suspended material collection only) focused on geophysical surveys and suspended material collection. The reaches investigated for the geophysical surveys are presented in **Figure 1-1** and described in more detail in the main body of the report.

Geophysical survey activities were conducted by Aqua Survey, Inc. (**Appendix A-2**) with oversight by Amec Foster Wheeler. The survey methods employed included real time kinematic global positioning (RTK), differential global positioning, dual-frequency bathymetry, and sub-bottom profiling. Survey transects were run perpendicular to shore at varied spacing throughout each river reach. Survey transect locations were pre-determined based on 500 to 1,000 feet spacing, or were chosen to intersect areas of interest or specific river bed features (e.g., Bucksport and Frankfort Flats reaches) where transect spacing may be less than 500 feet. The 2017 transect locations for both survey methods were also consistent with 2016 transect locations to allow data comparison, however, data comparison is limited to the areas where data collection was completed in 2016. The surveys were completed at speeds ranging from 2 knots to 4 knots. Project control was provided by a Hemisphere RTK system with centimeter accuracy. RTK corrections were supplied through KeyNET service. All results were produced in Maine East State Plane NAD83 coordinate system with units in US survey feet and North American Vertical Datum 1988 (NAVD88) with depths produced in US survey feet. Survey observations were recorded on field maps. Overall, the geophysical survey techniques employed were successful in mapping suspended material (by dual-frequency) and bedded materials (by sub-bottom profiling).

A second vessel and crew was employed during the geophysical survey efforts to perform suspended sediment collection. This crew used a 20-foot pontoon boat, a petite ponar, pump, rigid aluminum poles and weighted rig with hoses attached to capture the suspended material, underwater camera, sonde probe, sub-meter global positioning system (GPS)[1], and #40, #60, and #200 sieves. Dual-frequency data were used to identify locations and water depths where sediment and wood waste were in suspension above the mudline. Ponar grab samples were collected for visual classification. Observations and measurements were recorded on field forms. Laboratory samples were collected and analyzed by Alpha Analytical, Inc. for total mercury (adjusted method 7474-1631), total organic carbon (Lloyd Khan method), total suspended solids analysis (standard method 2540D), and total solids (standard method 2540G).

Additional suspended sediment sampling completed on September 19, 2017 included deployment of a sonde and sampling hose assembly to recover suspended sediment and wood

[1]Trimble R1 GNSS Receiver which provides sub meter accuracy. All GPS corrections were done in real time by Satellite-based augmentation systems.

waste at a water depth that corresponded to a measure of elevated turbidity (as determined by the sonde); and deployment of a net to recover samples of suspended sediment and wood waste.

Stations for deployment were based on dual-frequency records indicating an area of interest (AOI). At each station, the vessel was anchored, the sonde and hose assembly were lowered until the sonde registered elevated turbidity, and suspended material was pumped via the hose to a sieve stack assembly on the deck of the vessel. For some stations, sampling included the deployment of a net for a timed deployment.

A-2.2 Geophysical Surveys

Geophysical tools were used on a 22-foot vessel to characterize the river bottom, sub-bottom, and the depositional/suspended sediments along the shoreline and in coves, as well as to assess conditions where the mobile sediment pool was previously located by the Phase II Study Panel (PRMSP 2013) and the 2016 Mobile Sediment Characterization Report (Amec Foster Wheeler 2017). Dual-frequency data were collected in the following reaches: Bangor, Orrington, Winterport, Frankfort Flats, Mendall Marsh, Bucksport, Bucksport Thalweg, Bucksport Harbor, Verona West, Verona Northeast, Orland River, Verona East, Upper Penobscot Bay, and Fort Point Cove. Sub-bottom data were collected in the following reaches: Bangor, Orrington, Winterport, Frankfort Flats, Mendall Marsh, Bucksport, Bucksport Thalweg, Bucksport Harbor, Verona West, Verona Northeast, Orland River, Verona East, and northern Upper Penobscot Bay. Validation of geophysical findings were also performed through the collection of bedded sediment and suspended sediment.

To evaluate potential sources of instrumental error, data were collected on the first day from each survey method over the same transect running from west to east, and then from east to west. No difference in data collection was observed and it was concluded that survey direction from shore to shore does not affect data collection or resolution quality and that the collection of shore-perpendicular survey data from either a westerly or an easterly direction was acceptable.

In addition, some survey transects on the first day were completed using a boat speed of 2 knots while other transects were completed at 4 knots. No difference was observed in signal resolution or quality as a function of boat speed over the range of 2 knots to 4 knots.

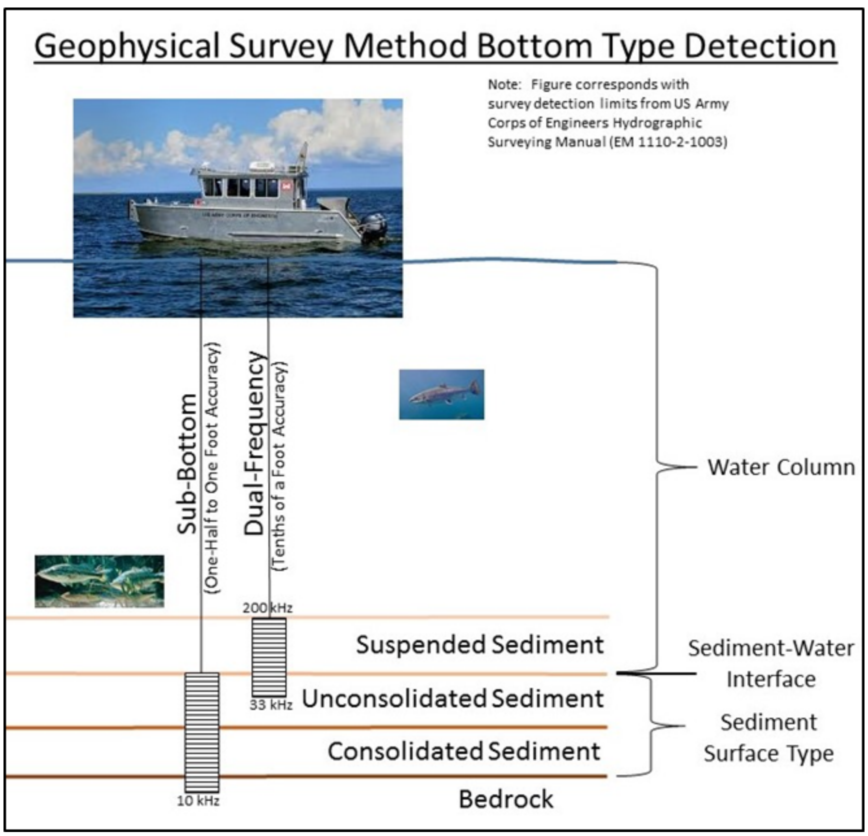
A.2.2.1 Survey Global Positioning System and Accuracy

Tracking of survey data was completed using real-time kinematic (RTK) GPS and differential GPS. The geophysical surveys were conducted by Aqua Survey, Inc., covering the specified project area along the river from Bangor to the southern tip of Verona Island. The survey area was approximately 30 miles, including Mendall Marsh and the Orland River.

Project control was provided by a Hemisphere RTK GPS unit with centimeter accuracy. RTK corrections were supplied through KeyNET service. Prior to commencing the survey, the RTK system was checked against a local National Geodetic Survey benchmark for positioning accuracy. The RTK antenna was mounted directly over the dual-frequency fathometer and sub-bottom profiler. All results are produced in Maine East State Plane North American Datum of 1983 (NAD83) coordinate system with units in US survey feet and North American Vertical Datum of 1988 (NAVD88) with depths produced in US survey feet.

The illustration below depicts the detection limits of each geophysical survey method and how they compare relative to each other. The illustration corresponds with the survey detection limits from the United States Army Corps of Engineers (U.S. Army Corps of Engineers, 2013). Each survey method was used to detect and evaluate the differences between sediment layers. Dual-frequency (one-tenth of a foot accuracy) mostly detects the surface of suspended sediments and can penetrate the surface of unconsolidated, soft sediments. The 2016 Mobile Sediment Characterization Report determined that dual-frequency detected a sediment suspension layer above the estuary bed (Amec Foster Wheeler 2017). Sub-bottom profiling (0.5 – 1.0 foot accuracy) penetrates the mudline and records density differences within the upper layers of bedded sediment, as well as identifying the presence of buried boulders, and depth to bedrock.

Detection Capabilities of Geophysical Survey Methods



A-2.2.2 Dual-frequency

Dual-frequency is a common and proven method used to detect sediments in suspension. An Odom Echotrac CVM dual-frequency fathometer with 33 kHz (20-degree) and 200 kHz (4-degree) transducers was used for the dual-frequency survey. The 200 kHz frequency is typically used in studies to detect the surface of suspended sediments. Prior to the commencement of survey operations, a system calibration bar check was conducted to adjust for draft and speed of sound for both frequencies in order to insure accurate sounding data. A bar check was also conducted at the end of the day to assure consistency. Processing included removing erroneous data points and correcting the data to NAVD88 based on RTK GPS corrections. Each frequency was processed separately and the difference between the two return layers was calculated to provide a layer showing areas of separation. XYZ file records of high frequency depths, low frequency depths, and the separation between were provided for each reach. For this acoustical technique, high frequency measurements usually indicate the top layer of suspended sediment and low frequency measurements usually indicate a soft layer such as loose sediment or wood waste. Dense sediments will result in an overlap in signal return with minimal separation with a possible error of a few tenths of a foot. Low frequency measurements may be lost or erroneous in high currents, turbulent waters, and areas without well-defined sediment layers.

A-2.2.3 Sub-bottom Profiling

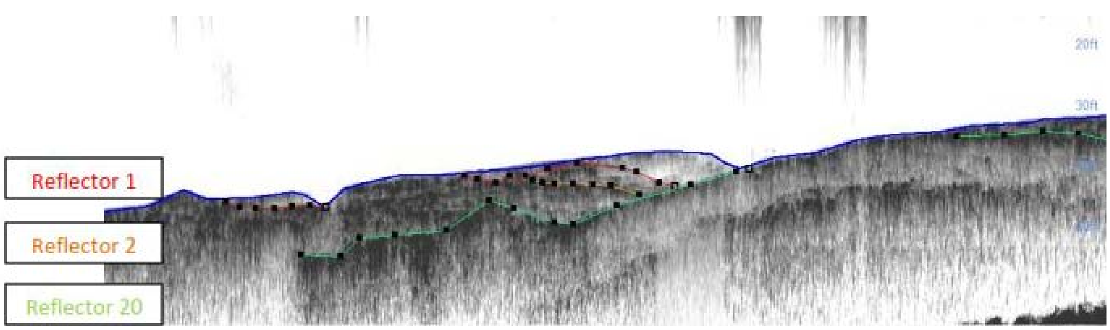
A SyQwest Stratabox sonar system with a 10 kHz transducer was used to collect the sub-bottom profiling data. During the survey, the transducer was hard-mounted to the side of the survey vessel with the navigational antenna mounted directly over the transducer to reduce offset errors. The sensor was deployed at a depth of at least 2 feet to minimize interference from the vessel. The navigational data was logged at one-second intervals by the Stratabox digital recording system and electronically paired with the sub-bottom data to allow geo-referencing of all data collected. Sub-bottom profilers use acoustic methods to generate high-resolution (on the order of 0.5-1 foot) cross-sectional images of the marine sub-bottom to depths up to 100 feet beneath the seafloor. The transmitted sound pulses travel through the water column and sub-bottom and are reflected when changes in acoustic impedance (equivalent to a material's sonic velocity times its density) are encountered. Acoustic impedance changes commonly occur at boundary interfaces (e.g., interfaces between water and sediments, sediments and gas, different types of sediments, and sediments and buried objects). The reflected sound pulses travel back to the profiler where their amplitudes, as a function of travel-time, are digitally recorded. Overall, sub-bottom profiling can detect density differences between bedded sediment layers. Since wood waste is less dense than mineral sediment, a mixture of sediment and bedded wood waste deposits can be differentiated from other sediment layers.

During data collection, the location of surficial sediment and wood waste deposits was identified and recorded. The purpose of mapping surface deposits was to establish the quantity of sediment and wood waste in accumulations greater than 1-foot thick for remedial evaluation. Surface deposits were evaluated by initially delineating the horizontal and vertical extent of each deposit during survey collection and then refining that delineation during post-processing of survey data. Following delineation, the mapped surface deposits were used to identify locations for ground-truth sampling, as well as for sediment coring. During a subsequent 2017 field program, sediment cores were collected from within the footprint of surface deposits for physical (i.e., grain size, bulk density, organic content) and chemical (i.e., mercury, total organic carbon) characterization of sediment (data presented in Amec Foster Wheeler 2018a).

The distribution of surface deposits is presented in **Figure A-1**. No surface deposits were identified in the Bangor, Mendall Marsh, or Bucksport Harbor reaches of the Estuary. Ground-truth sampling confirmed that the deposits were composed of sediment, a mixture of sediment and wood waste, or wood waste. Deposits appear to overlay dense clay or bedrock. Categorization of each surface deposit in terms of ‘traps’, ‘trenches’ or ‘layers’ was completed based on the shape and position of each deposit in sub-bottom imagery. The three categories of surface deposits are as follows: 1) trap: describes a partially exposed deposit located in a topographic depression on the estuary bed; 2) trench: classifies a partially exposed, but laterally confined deposit that is at least partially buried; and 3) layer: describes a potentially uniformly mixed discrete deposit on the estuary bed.

During post-processing of the sub-bottom data, Aqua Survey, Inc. identified three reflectors and confirmed that no other reflectors were distinguishable in the sediment profile (**Appendix A-2**; telephone communication, November 3, 2017). The sub-bottom layers or thicknesses that were identified are defined as Reflector 1, Reflector 2 and Reflector 20. Consistent with Aqua Survey, Inc. interpretation and following analysis of sediment cores collected and analyzed as a component of subsequent 2017 field sampling, Reflector 1 represents a layer of what appears to be soft, loose sediment and/or wood waste. Reflector 2 represents a layer seen throughout the survey area of soft mineral sediment including silt and/or clay. Reflector 20 represents a layer of possible bedrock or dense hard clay seen throughout most of the survey area. The graphic below shows an example of Reflectors 1, 2, and 20 within the Bucksport reach.

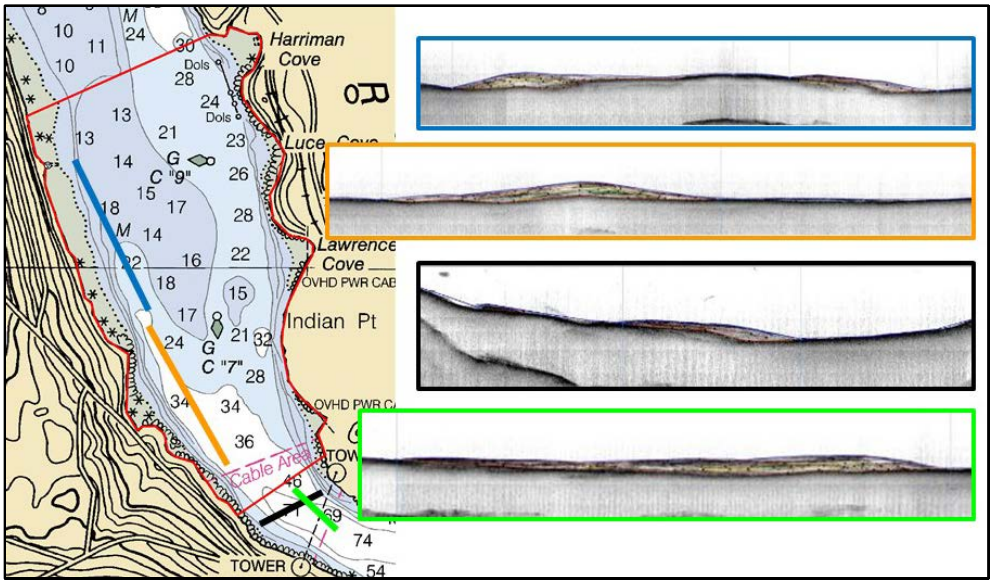
Example of Processed Sub-bottom Data Showing Reflector 1 (red), Reflector 2 (Yellow), and Reflector 20 (green)



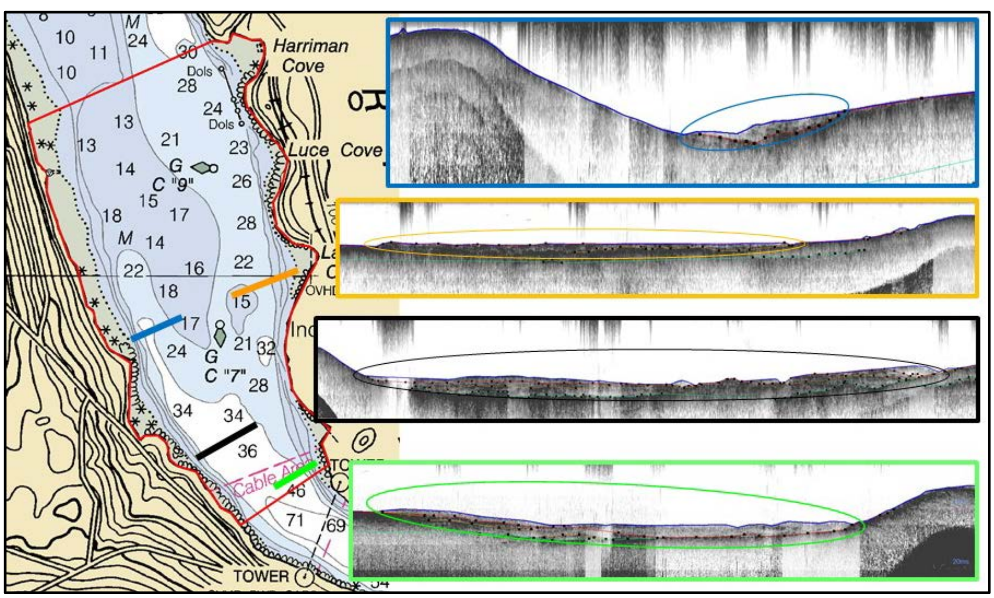
The main similarity observed between sub-bottom surveys conducted in 2016 and 2017 was that the sediment and wood waste deposits identified by Reflector 1 appear to be generally located within or adjacent to river channels. An example of a spatial overlap between the 2016 and 2017 sub-bottom survey is presented in the graphic below for the Bucksport reach. For each inset, the border color of each sub-bottom image corresponds to the matching transect path.

After data processing, all sub-bottom records were delivered as screen shot JPEG files. Sub-bottom reflectors or sediment layers were manually digitized and delivered as XYZ files.

2016 Sub-bottom Profile in the Bucksport Reach

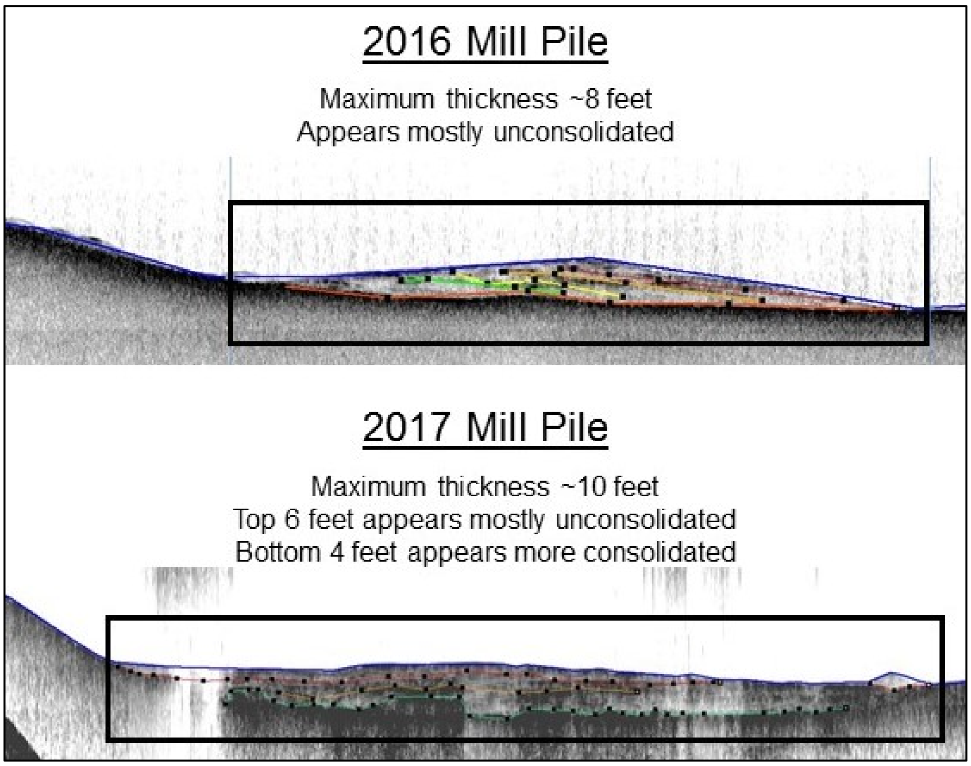


2017 Sub-bottom Profile in the Bucksport Reach



The most significant sub-bottom survey observation was the detection of a large potential wood chip deposit approximately 10 feet thick. This deposit was located in or between the southern Bucksport reach and northern Bucksport Thalweg reach and was adjacent to the site of a former paper mill. This deposit appears to be the same deposit identified as the "mill pile" in 2016 (inset figure below). Comparison of 2016 and 2017 sub-bottom imagery also highlights surface deposits of sediment and wood waste in the Frankfort Flats, Bucksport, and Verona East reaches that appear to be in the same location over the two survey periods.

2016 and 2017 Sub-bottom Data Comparison of the Mill Pile



Sub-bottom profiles were evaluated to determine whether geophysical data could be used to identify potential dredge depths based on sediment type/sediment characteristics. To this end, geophysical data were compared with sediment data from a subset of cores from the 2017 field sampling program for which geotechnical data were collected (**Table A-1**). The core data in full are presented in a parallel report (Amec Foster Wheeler 2018a). For those cores summarized in **Table A-1**, changes in sediment lithology and associated geotechnical properties at different depths in the core appear generally consistent with the sediment depths at which different Reflector layers (i.e, 1, 2 and 20) were identified in the field. From the preliminary geotechnical data presented in **Table A-1**, the layer of bedded sediment and wood waste identified by the Reflector 1 layer is characterized by a shear strength less than 300 pounds per square foot (psf) and a dry bulk density less than 0.7 grams per cubic centimeter (g/cm^3). As presented in **Table A-1**, it was not possible to evaluate shear strength in core increments dominated by wood waste.

Volume and mass estimates for suspended materials as determined from dual-frequency data are presented in **Table A-2**. Volume is estimated by multiplying the interpolated dual-frequency thickness by the area of the dual-frequency survey (**Figure 2-1**). Mass is calculated as presented in **Table A-2**. Data used in these calculations incorporated survey data from the following reaches: Bangor, Orrington, Winterport, Frankfort Flats, Mendall Marsh, Bucksport, Bucksport Thalweg, Bucksport Harbor, Verona Northeast, Orland River, Verona East, and Verona West. The dual-frequency data from the Fort Point Cove and Upper Penobscot Bay reaches were not included. Survey data in these two reaches was preliminary and of lower spatial resolution than survey data from other Estuary reaches; as such, the data for these two reaches were considered exploratory.

Table A-3 presents volume and mass estimates for bedded sediment and wood waste from Bangor to the southern tip of Verona Island as calculated from interpolation of the Reflector 1 layer thickness (**Figure 2-2**). Because the Reflector 1 layer was characterized as a mixture of sediment and wood waste at varying percentages throughout the estuary, average wet and dry densities were used in mass calculations.

Table A-4 presents volume and mass estimates specifically for areas identified as surface deposits of Reflector 1 material in the geophysical survey. These areas are presented on **Figure A-1**. Surface deposits are defined here as areas in which the Reflector 1 layer is at least 1 foot thick and confirmation sampling (presented in **Table A-1** and discussed above) suggests the bed material is a mixture of sediment and wood waste. The area of each deposit was determined by interpolation of geophysical survey transect data using ArcGIS. The volume of each deposit was calculated by multiplying the area times the Reflector 1 thickness. The difference between volumes presented in **Table A-3** and **Table A-4** is the result of locations in which the Reflector 1 layer is less than 1 foot thick and the corresponding material is considered as 'dispersed'. Dispersed deposits are accounted for in the post-processed sub-bottom data (e.g., **Figure 2-2**), but were not delineated in real-time during survey activities because they were not visually apparent. The refinement of area and volume estimates presented in this report, including calculation of associated mercury mass is presented in the 2017 Intertidal and Subtidal Sediment Characterization Report (Amec Foster Wheeler 2018a). A summary of volume estimates based on the integration of data from this report with the 2017 Intertidal and Subtidal Sediment Characterization Report is provided in **Appendix A-3**. The content of **Appendix A-3** has been provided to the Court as a component of the April 2018 request for information.

A-2.3 Suspended Material Collection

Suspended material sampling was undertaken to evaluate the material identified in the 2016 and 2017 dual-frequency geophysical survey programs. The material identified by the dual-frequency survey appears to be in suspension in the water column and is currently not well characterized. Characterization of this material is important for evaluating its contribution to the volume of mobile material in the Estuary and the potential significance of this material as a remedial target. As such, sampling was undertaken to evaluate composition and concentration in suspension, as well as for analysis of total mercury in recovered samples.

Suspended material was collected by time-integrated sampling with either a pump or a deployed net. The equipment was deployed using a winch aboard the vessel to control the rate of at which equipment was lowered through the water column. A water quality sonde (described further below) was used to measure water temperature, salinity and turbidity during deployments. The turbidity sensor was used to determine the water depth at which suspended material sampling (by either the pump or the net) was undertaken. Sample flow rates were determined from recording the duration of pumping and measuring the volume of water collected during pumping.

The downcast sonde data were used to identify the water depth where turbidity increased. The downcast sonde recordings showed distinct changes and increased yet variable turbidity readings at water depths consistent with expected suspended material concentrations near the estuary bed (**Appendix B**). High concentrations of suspended material fouled the sonde such that upcast data was not reliable. Upcast data were not used. Grab samples of suspended material were submitted to Alpha Analytical, Inc. for laboratory analysis. Sample analysis included total suspended solids (standard method 2540D), total solids (standard method 2540G), total organic carbon (Lloyd Khan method), and total mercury (adjusted method 7474-1631). A summary of results is presented in **Table A-5**. As illustrated on **Table A-6** through **Table A-8**, samples were collected at various points in the sampling process to compare methodology and results of field measurements.

A-2.3.1 Field Collection Methods

Three phases of field collection are described below; Table **A-5** summarizes sampling results.

<u>Phase 1: Rigid Poles</u>

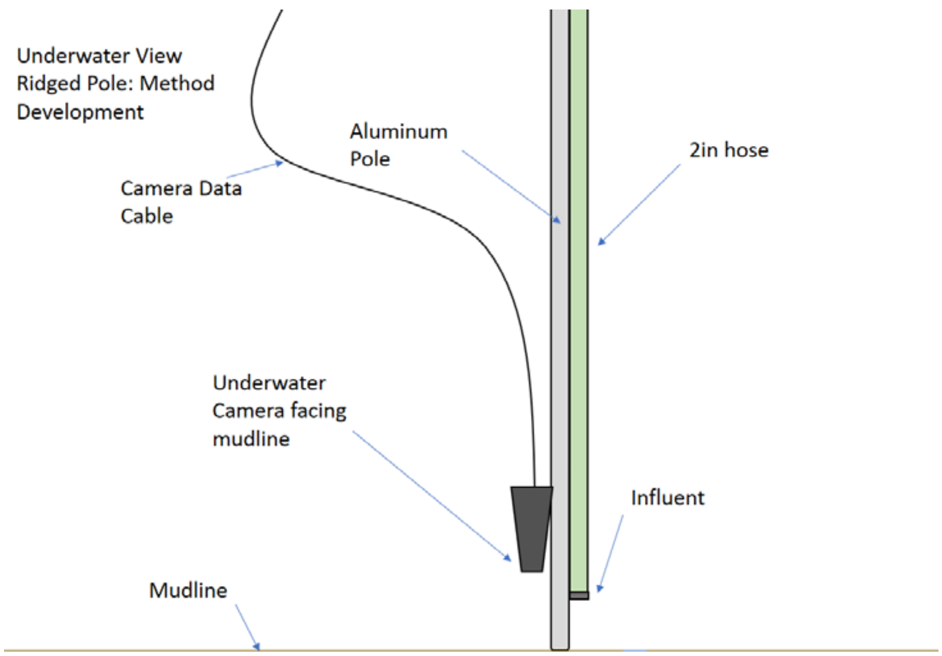
Equipment

- Aluminum Rods – Rigid pole structural support for suspended solids collection apparatus.
- Trash Pump
- 100 feet of ¾” hose
- 2” Hose- For collection of suspended sediments through the trash pump.
- Underwater Camera (streaming) - to verify that hose was not disturbing sediment bed
- 5 gallon (gal.) buckets
- Rope for securing equipment to vessel and extra leverage for lowering poles
- Ponar to confirm sediment characterization

Description of Method:

The hose and camera were secured to the rigid poles to ensure that the discrete target depth was sampled. While lowering the pole into the water column, observations were tracked on streaming camera. Once the pole was stable at the target water depth, the pole was further secured to the vessel with support ropes. After the pump was activated, the hose volume was purged three times to ensure that only the target depth suspended sediment was collected. At the effluent end of the hose, bulk material was collected in clean five gallon buckets. A sufficient number of buckets were filled to allow collection of suspended sediment for analysis. A ponar grab was attempted at the AOI locations to characterize the bedded sediment and to compare the composition of bedded sediment and suspended sediment. Due to issues with the rigid poles breaking and the pump being oversized for what was required, the phase 2 method was developed.

Rigid Pole Diagram (Phase 1)



Phase 2: Weighted Sonde with Hose

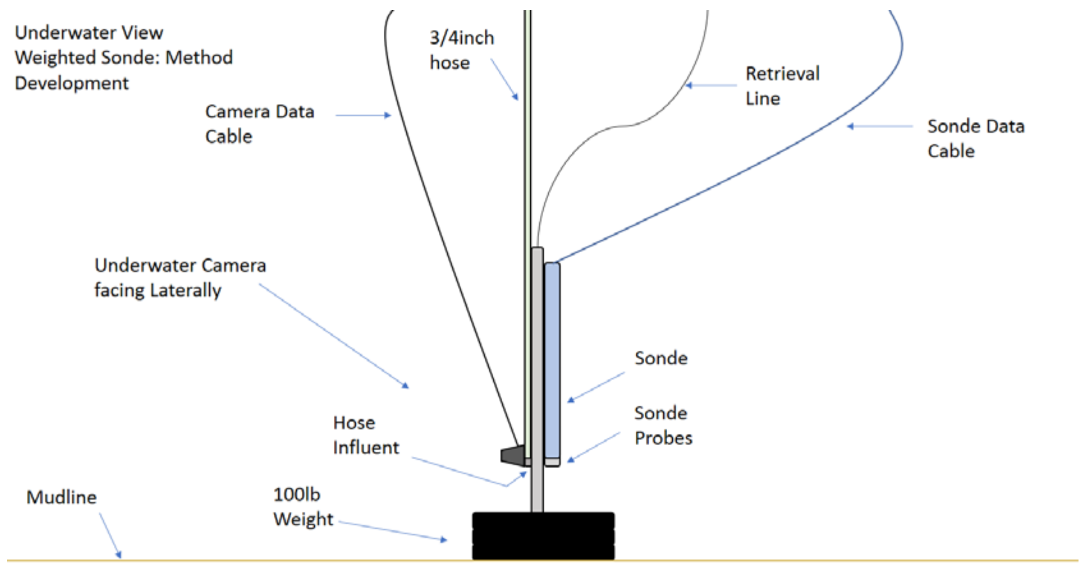
Equipment:

- YSI 6920 – v2 – 1 Multi-Parameter Water Quality Sonde with data logger
- 1/10 HP AC Drummond pump
- 100 feet of ¾" hose
- Underwater Camera (streaming) - to verify that hose was not disturbing sediment bed
- 5-gallon buckets
- Weighted anchor/platform
- Sieve stack- #40, #60, and #200

Description of Method:

This method utilized a smaller hose and a smaller pump. The sonde, hose, and camera were secured to a weighted platform. The height at which the equipment was secured to the weighted platform was adjusted dependent on the target AOI sampling depth. The integrated rig was then carefully lowered to the mudline utilizing the vessel winch. The sonde measured and recorded continuous *in situ* water quality parameters (i.e., temperature, salinity, and turbidity) within the water column during each deployment. Water column profiles of the water quality parameters are illustrated in **Appendix B**. Additionally, a second hose was secured to the bottom of the weighted platform in some instances to provide confirmation that the upper hose was not sampling the mudline. A ponar grab was completed at the AOI locations to characterize the bedded sediment and to compare the composition of bedded sediment and suspended sediment. Following pumping, suspended material was discharged into a sieve stack secured to a 5-gallon bucket. The volume of recovered material was calculated.

Weighted Sonde with Hose Diagram (Phase 2)



Phase 3: Adapted Sonde and Hose Sampling and Weighted Net Deployment

Equipment

- YSI 6920 – v2 – 1 Multi-Parameter Water Quality Sonde with data logger
- 1/10 HP AC Drummond pump
- 100 feet of ¾” hose
- Stream Bottom Sampling Net; 1 ft^2 fixed mouth opening; 3 ft length; 500-micron mesh
- 2-gallon buckets
- Weighted anchor/platform

Phase 3 sampling methods were used during the September 19, 2017 sampling event. As assembled and deployed, the sonde and sampling hose was lowered to within 2-3 feet of the sediment surface; the net was lowered to within 1 foot of the sediment surface. Deployment was for a timed duration. High tide on September 19, 2017 occurred at 10:30 AM and low tide occurred at 5:05 PM, thus sampling occurred during the interval from slack water high tide through the outgoing tide.

Adapted Sonde and Hose Sampling (Phase 3)

Weighted Rig: Method Development, September Adaptation

Weighted Net Deployment

Weighted Net: Method Development, September Adaptation

A-2.3.2 Sampling Results

Sampling results are presented in **Table A-5**. The water quality sonde data collected from the Phase 2 sampling suggest a mixed water column (**Appendix B**) with water temperature ranging from 14-18 degrees Celsius (°C) and salinity ranging from 20-30 practical salinity units (or parts per thousand). Field data records and turbidity profiles indicate that sampling equipment may have contacted the river bed at four of the eleven locations where turbidity profiles were collected (AOI-1A, AOI-1B, AOI-29, and AOI-MM-1), resulting in resuspension of sediment from the bed. The inclusion of resuspended bed sediment in measures of suspended material in the water column will bias results high. Differences in water depth measurements between field data records and profiles provided in **Appendix B** reflect instrumental differences; a depth finder aboard the vessel was used to record water depth on field data records, while the sonde was used to determine water depth on deployed sampling equipment. Field data records and a photographic log are provided in **Appendix C-1** and **D-1**, respectively.

For stations AOI-X1, AOI-25, AOI-27, and AOI-33 assessed using the Phase 3 method, the zone of elevated turbidity was within 1-2 ft of the sediment bed. For the Phase 3 sampling, the multi-parameter water quality sonde used was not capable of continuous data recording, thus water column profiles for these stations are not included in **Appendix B**. For the station with the greatest recovery following net sampling (Station AOI-25 within the Lawrence Cove Channel), recovery may have been influenced by the anchor weight hitting the bottom. The particles collected at Station AOI-25 were somewhat blocky, clearly identifiable as wood waste, and approximately 1/8" – 1/16" in size (see inset). Wood waste was also recovered at Station AOI-33 and Station AOI-X1. Recovery at Station AOI-33 was ~ 1.5 gallons of wood waste; recovery at Station AOI-X1 was less than ½ gallon of wood waste.

Suspended Wood Waste Collected by Net Deployment

Based on the deployment interval at AOI-25 (10 minutes), the size of the net opening (1 ft^2), the flow velocities of bottom currents (0.3-0.75 meter per second [m/s] as determined from acoustic doppler current profiler [ADCP] data), and the volume of wood waste recovered (~ 6 gallons at an assumed wet density of 1.5 grams per cubic centimeters [g/cm^3]), the concentration of suspended sediment and wood waste at this location was approximately 100-200 milligrams per liter (mg/L). As noted above, this concentration may reflect a combination of suspended sediment and resuspension of bedded material. Visual observations of suspended material collected via all sampling methods described in this report suggest that suspended material is dominated by wood waste.

For stations AOI-20 and AOI-21, the concentration of total suspended solids was calculated for material passing the #200 sieve (likely representing inorganic silt) and material retained by the #200 sieve. As presented in the 2016 Mobile Sediment Characterization Report (Amec Foster Wheeler 2017), visible wood waste is retained by the #200 sieve. The calculation of total suspended solids is as presented below and based on standard ASTM methods: D3977, D5907, and D4411 (ASTM 2013a; 2013b; and 2014, respectively). Field observations and measurements from stations AOI-20 and AOI-21 are provided in **Appendix C-1**.

Calculation of Total Suspended Solid Concentrations for Stations AOI-20 and AOI-21

Sample Fraction	Passing #200 Sieve		Retained on #200 Sieve		Total	
	Variables	Unit	Variables	Unit	Variables	Unit
Wet	F_w	g	C_w	g	W_w	g
	S	L	S	L	S	L
	$F_w / S = P_w$	g/L	$C_w / S = R_w$	g/L	$W_w / S = T_w$	g/L
Dry	F_d	g	C_d	g	W_d	g
	S	L	S	L	S	L
	$F_d / S = P_d$	g/L	$C_d / S = R_d$	g/L	$W_d / S = T_d$	g/L

S = Entire sample volume, in liters
F_w = Fine fraction wet weight (passing a #200 Sieve), in grams
P_w = Fine fraction wet weight total suspended solids, in grams per liter
C_w = Coarse fraction wet weight (retained on a #200 Sieve), in grams
R_w = Coarse fraction wet weight total suspended solids, in grams per liter
W_w = Wet weight of entire sample, in grams [$W_w = F_w + C_w$]
T_w = Total suspended solid concentration (wet weight), in grams per liter
F_d = Fine fraction dry weight (passing a #200 Sieve), in grams
P_d = Fine fraction dry weight total suspended solids, in grams per liter
C_d = Coarse fraction dry weight (retained on a #200 Sieve), in grams
R_d = Coarse fraction dry weight total suspended solids, in grams per liter
W_d = Dry weight of the entire sample, in grams [$W_w = F_w + C_w$]
T_d = Total suspended solid concentration (dry weight), in grams per liter

Flow diagrams illustrating the process by which suspended material was assessed at stations AOI-20, AOI-21, and AOI-OR-1 and presented in **Table A-6** through **Table A-8**, respectively. For stations AOI-20 and AOI-21, the concentration of total suspended solids ranged from 0.15 grams per liter (g/L) (AOI-21) to 1.7 g/L (AOI-20) (dry weight) and averaged approximately 1.0 g/L. Wet weight concentrations were 1.6 g/L (AOI-21) and 21.0 g/L (AOI-20), with an average of 11.3 g/L.

A-3.0 EROSIONAL INDICATOR MEASUREMENTS

A-3.1 Field Measurements

Field measurements of erosional indicators (i.e., mudflat rivulets) were completed during low tide conditions from September 23-27, 2017. Due to accessibility concerns, measurements and observations were only recorded in Orrington, Mendall Marsh, Bucksport, Frankfort Flats, and Verona Northeast reaches. **Table A-9** summarizes visual observations and field measurements; field data records are included in **Appendix C-2**. The visual depth measurements in **Table A-9** represent the depth of sediment that is potentially erodible. The ruler resistant depth measurements represent the sediment depth at which resistance was felt when a ruler was inserted into the sediment. A few larger semi-permanent erosional features (e.g., gullies) were evaluated during field activities for preliminary assessment purposes. Measurement of these features is outside the specific scope of this task and results are not included in the evaluation of system-wide erosion potential (as presented in the report).

A-4.0 ESTIMATION OF BEDROCK, BOULDER, OR HARDPAN AREAL EXTENT

A-4.1Methods

For subtidal areas, locations with exposed bedrock or an absence of soft sediment were identified based on the sub-bottom profiling data. These data were used in conjunction with additional data sources including the Phase II Study grab sample sediment classifications (PRMSP 2013), MEDEP Environmental and Geographic Analysis Database sediment sample classifications as of 2017 (EGAD 2017), and 2016 side-scan sonar bottom characterizations (Amec Foster Wheeler 2017).

For the intertidal zone, a Geographic Information System (GIS) was used to view low tide aerial imagery to generate the footprint of intertidal areas that contain boulders and/or bedrock. Low tide aerial imagery was reviewed at a 1:1,000 scale to establish a footprint around visible boulders and bedrock outcrops. An arithmetic-based evaluation was performed using the planimetric areas of the digitized polygons to define the percentage composition (by area) of exposed rocks in each study reach. The landward limit of the Geographic Information System evaluation was the US Geological Survey hydrologic break line defining the shoreline. The GIS based review of the intertidal zone was completed to evaluate the accuracy of visual field estimates.

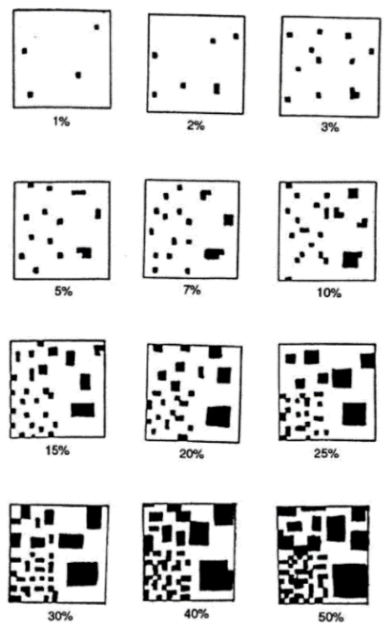
For field verification, a low draft vessel was utilized. Ten percent of the intertidal managements units were randomly selected (Keith 1991) and visually assessed during low tide conditions to estimate boulder/bedrock coverage. At the randomly selected locations, an approximate 100-foot segment of the intertidal shoreline was assessed for extent of boulder/bedrock coverage. Visual survey data included relative abundance of bedrock/boulders; GPS station location; a photograph of the shoreline assessed, and the directional view of the photograph. Photographs are presented in **Appendix D-2**. The classification criteria for how the shoreline boulder/bedrock coverage was estimated is presented below.

Intertidal Boulder/Bedrock Estimate Classification Criteria

Boulder/ Bedrock Extent	Percent Coverage				
Relative Percent	0-20 percent	20-40 percent	40-60 percent	60-80 percent	80-100 percent
Description of Shoreline	Dominated by soft sediment; no to very little boulder/ bedrock present	Dominated by soft sediment with little boulder/ bedrock	Even abundance of boulder/ bedrock to soft sediment	Dominated by boulder/ bedrock with little soft sediment	Dominated by boulder/ bedrock; no to very little soft sediment present

Additional interpretation of the intertidal boulder/bedrock coverage applied a visual technique for "[e]stimating proportions of mottles and coarse fragments" (Munsell Color (Firm), 1975). Applying this technique, intertidal zones characteristic of less than 50% boulder/bedrock coverage were representative of a mottle pattern used to designate an approximate percentage of boulder/bedrock coverage (see image below). Field based estimates were either validated by the mottling based percentages or corrected to better correspond to the mottling based estimate.

Mottle Patterns Used to Evaluate Intertidal Boulder/Bedrock Coverage



The field based percentages of intertidal boulder/bedrock coverage were further refined by applying a calculation multiplier equivalent to half of the percentage bracket value as presented in the table below. The calculation multiplier accounts for variability within each percentage bracket and represents the midpoint of each percentage range (e.g., 10%-25% = 17.5% or 0.175 calculation multiplier). Thus, for each area classified within a certain percentage bracket, the area square footage is adjusted by the calculation multiplier to represent the square footage of boulder/bedrock coverage within that area.

Criteria Used to Refine Field Based Estimates

Boulder/Bedrock Coverage Extent					
Percentage Bracket	0-10 percent	10-25 percent	25-50 percent	50-75 percent	75-100 percent
Calculation Multiplier	0.05	0.175	0.375	0.625	0.875

A-5.0 REFERENCES

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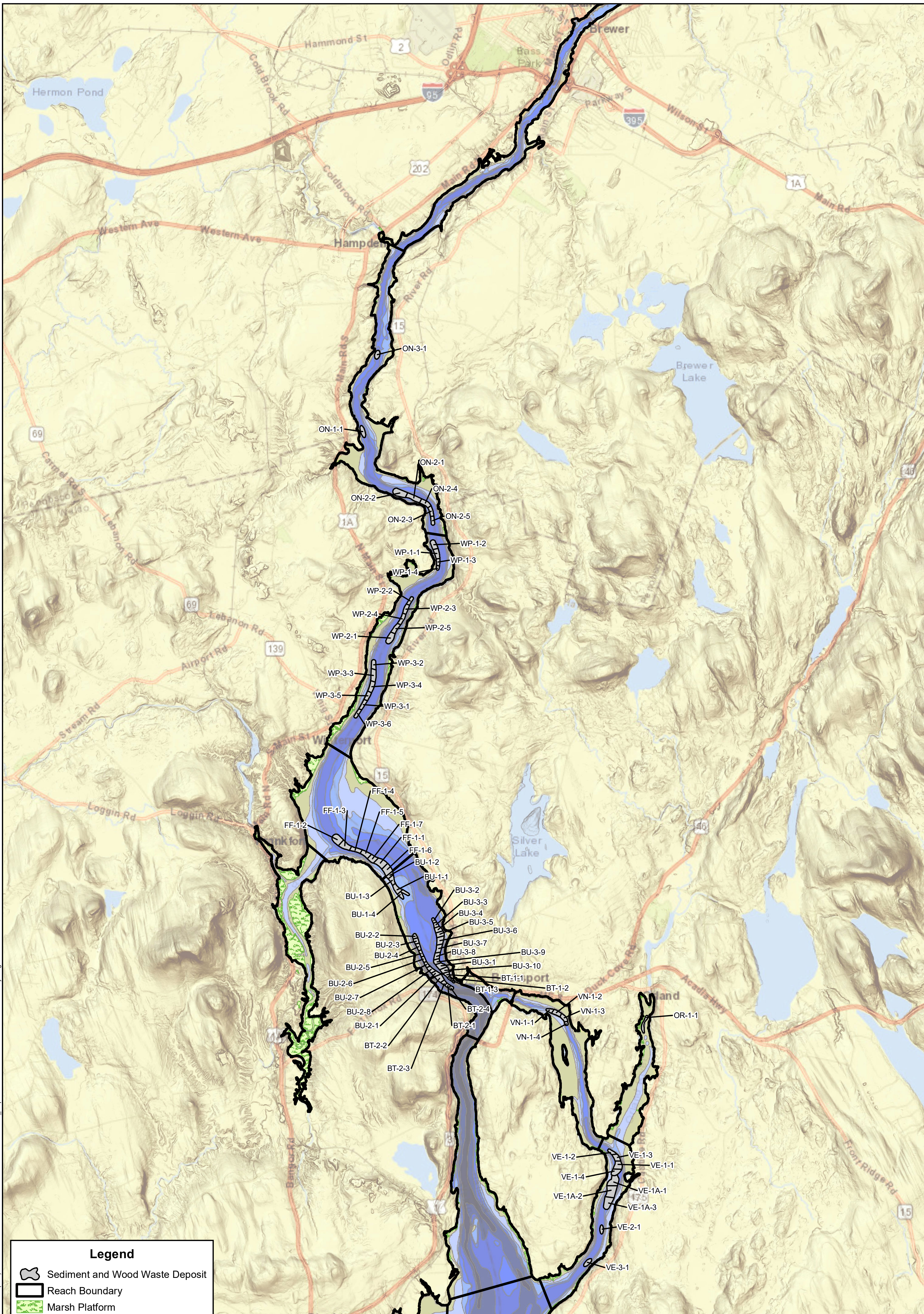
FIGURES



amec foster wheeler

N

0 0.5 1 2 Miles

0 1.25 2.5 5 Kilometers

Bathymetry

Water Depth feet (MLLW)

0 6 12 18 30 60 120 600

Figure A-1
Distribution of Sediment and Wood Waste Deposits from 2017 Sub-bottom Profiling Data

2017 Mobile Sediment Characterization
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: 5/21/2018	Checked/Date: 5/21/2018	NAD83 State Plane Maine East, US Survey Feet

Figure A-2
2016 versus 2017 Bucksport Mill Pile Thickness

2017 Mobile Sediment Characterization
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: 4/20/2018	Checked/Date: 4/20/2018	NAD83 State Plane Maine East, US Survey Feet

Document: P:\Comm-Ind\Projects\Clients M to S\Penobscot(GIS)\Work Order 4A-060\2017 Sub Bottom\2017 Sub Bottom_Mill Pile.mxd 4/20/2018 5:45:04 PM david.young2

TABLES

TABLE A-1

GEOPHYSICAL, SEDIMENT TYPE, AND GEOTECHNICAL DATA COMPARISON
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

				Geophysical Data					Sediment Data			Geotechnical Data							
		Core Collection		Dual-frequency	Sub-bottom Depth (ft)				Sediment Type			Depth of Shear Strength (ft)				Depth of Dry Bulk Density (ft)			
Core Station ID	Reach	Length Retained (ft)	Percent Recovery (%)	Layer Thickness (ft)	Insitu Thickness of Reflector 1 (ft)	Core Thickness of Reflector 1 (ft)[1]	Insitu Thickness of Reflector 2 (ft)	Insitu Thickness of Reflector 20 (ft)	Reflector 1	Reflector 2	Reflector 20	40 psf	75 psf	125 psf	300 psf	0.1 g/cm^3	0.4 g/cm^3	0.7 g/cm^3	1.0 g/cm^3
ON-18-01	Orrington	8.9	89	0.2	2	1.8	ND	3	Silt	ND	Silt/Clay	-	1.3	-	-	-	2	-	-
ON-18-02		NA	NA	0.3	2	NA	ND	3	Silt	ND	Silt/Clay	-	0.3	-	-	No results due to coarse content			
WP-02-01	Winterport	2.3	77	0.1	1	0.8	ND	2	Silt	ND	Silt/Clay	-	0.0	0.8	1.8	-	0.1	1	3
WP-06-02		5.2	87	0.2	2	1.7	ND	3	Silt	ND	Silt/Clay	0.0	2.5	4.0	-	-	1	2	5
FF-08-02	Frankfort Flats	6.2	68	0.3	1.4	1.0	ND	2.5	Silt & WCH Mix	Silt & WCH Mix	Clay	0.8	1.0	2.0	3.0	-	1	2.2	2.5
MM-04-01	Mendall Marsh	2.3	78	NA	NA	NA	NA	NA	NA	NA	NA	0	0.3	1	-	-	0.1	2	-
BU-02-01	Bucksport	3.2	91	0.2	2	1.8	3	8	Silt & WCH Mix	Silt & WCH Mix	NA	-	0.0	1.5	-	-	0.5	2	-
BU-08-01		1.9	80	0.25	1	0.8	3	16	Silt	WCH & Silt Mix	NA	-	-	-	0.0	-	0	0.3	1.5
VN-01-01	Verona Northeast	2.4	80	0.3	2.5	2.0	10	13	Silt	NA	NA	-	-	0.8	-	-	0	-	-
VN-02-01		2.4	78	0.3	2	1.6	NA	NA	Silt & WCH Mix	NA	NA	-	-	1.0	1.8	-	-	1.7	-
VN-02-03		2.9	97	0.7	2	1.9	9	22	Silt & WCH Mix	NA	NA	0.0	0.8	1.5	1.8	-	0.5	2.2	-
VN-02-04		2.9	97	0.5	2	1.9	NA	NA	Silt & WCH Mix	NA	NA	-	0.8	1.5	2.0	-	-	1.5	2.0
VN-08-01		2.2	72	0.2	2	1.4	9	15	Silt & WCH Mix	NA	NA	0.8	-	1.5	-	-	0.1	1	-
VE-09-01	Verona East	2.3	77	0.3	1	0.8	ND	4	Silt & WCH Mix	ND	Clay	-	0.8	1.0	1.3	-	0.5	1.6	-
VE-10-01		2.2	80	0.4	2	1.6	ND	3	Silt & WCH Mix	ND	Clay	-	-	-	-	No results due to abundant wood waste			
VW-14-01	Verona West	3.3	70	1	1	0.7	3	7	Silt & WCH Mix	Silt	NA	-	-	-	0.0	-	0	0.5	1

Notes:
1. Core Thickness of Reflector 1 represents exsitu thickness by multiplying core length retained and percent recovery.

Prepared by: DRY 1/9/2018
Checked by: BJW 1/9/2018

Abbreviations:
% = Percent
ft = feet
g/cm^3 = grams per cubic centimeter
NA = Not Available
ND = Layer not detected below sediment surface
psf = pounds per square foot
WCH = Wood chips

TABLE A-2

SUSPENDED SEDIMENT AND WOOD WASTE VOLUME AND MASS ESTIMATES FROM 2017 DUAL-FREQUENCY DATA
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

				Dual-frequency Mass[2,3]						
	Reach Area[1]	Dual-frequency Volume[1]		Average TSS (Dry Weight)[4] = 1.0			Average TSS (Wet Weight)[4] = 11.3			
Reach	Square Feet (ft^2)	Cubic Feet (ft^3)	Liters (L)	Grams (g)	Kilograms (kg)	US Tons	Grams (g)	Kilograms (kg)	US Tons	% of Total Mass
Bangor	19,981,959	3,546,355	100,421,425	100,421,425	100,421	111	1,134,762,105	1,134,762	1,251	2.9
Orrington	39,486,262	51,808,611	1,467,054,076	1,467,054,076	1,467,054	1,617	16,577,711,058	16,577,711	18,274	42.2
Winterport	31,366,103	4,986,667	141,206,452	141,206,452	141,206	156	1,595,632,909	1,595,633	1,759	4.1
Frankfort Flats	50,918,172	15,424,675	436,777,437	436,777,437	436,777	481	4,935,585,039	4,935,585	5,441	12.6
Mendall Marsh	8,120,159	1,348,005	38,171,188	38,171,188	38,171	42	431,334,424	431,334	475	1.1
Bucksport	24,694,836	6,671,828	188,924,819	188,924,819	188,925	208	2,134,850,456	2,134,850	2,353	5.4
Bucksport Thalweg	8,470,440	4,688,476	132,762,637	132,762,637	132,763	146	1,500,217,800	1,500,218	1,654	3.8
Bucksport Harbor	2,181,298	472,873	13,390,250	13,390,250	13,390	15	151,309,827	151,310	167	0.4
Verona Northeast	18,501,224	5,305,124	150,224,135	150,224,135	150,224	166	1,697,532,729	1,697,533	1,871	4.3
Orland River	11,829,957	3,149,345	89,179,372	89,179,372	89,179	98	1,007,726,909	1,007,727	1,111	2.6
Verona East	24,487,851	6,915,743	195,831,711	195,831,711	195,832	216	2,212,898,339	2,212,898	2,439	5.6
Verona West	59,595,596	18,395,136	520,891,387	520,891,387	520,891	574	5,886,072,674	5,886,073	6,488	15.0
Total	299,633,857	122,712,838	3,474,834,891	3,474,834,891	3,474,835	3,830	39,265,634,269	39,265,634	43,283	100.0
Approximated Total[5]	**299,630,000**	**122,710,000**	**3,474,830,000**	**3,474,830,000**	**3,470,000**	**4,000**	**39,265,630,000**	**39,270,000**	**40,000**	**100.0**
Uncertainty of Total[6]	NA	31,984,338	905,694,102	905,694,102	905,694	998	10,234,343,356	10,234,343	11,281	26.1
Approximated Uncertainty of Total[5,6]	**NA**	**31,980,000**	**905,690,000**	**905,690,000**	**910,000**	**1,000**	**10,234,340,000**	**10,230,000**	**10,000**	**26.1**

Prepared by: DRY 1/9/2018
Checked by: TNG 1/9/2018

Notes:
1. Area and volume estimates were determined using ArcGIS software analysis.
2. Mass was calculated using the following equation: mass (g) = liters (L) * total suspended solid concentration (g/L).
3. Mass was calculated using average wet and dry weight TSS concentrations determined from sample analysis (e.g., 1.0 and 11.3).
4. Determined from samples collected at two stations (AOI-20 and AOI-21), but each sample was representative of the suspended sediment and wood waste layer.
5. Mathematical calculation totals are presented and do not represent the accuracy of source data; the approximated values are rounded to the nearest 10,000 where applicable and are recommended for use.
6. Quantifies resolution uncertainty of survey equipment (i.e., 0.1 feet).

Abbreviations:
% = Percent
ft^2 = square feet
ft^3 = cubic feet
g = grams
kg = kilograms
L = liters
NA = Not Applicable
TSS = Total suspended solids in grams per liter (g/L)

TABLE A-3

BEDDED SEDIMENT AND WOOD WASTE VOLUME AND MASS ESTIMATES FROM 2017 SUB-BOTTOM PROFILING DATA[1,2,3,4]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Reach	Survey Limit Area[5]	Volume[5]			Mass		
	Square Feet (ft^2)	Cubic Feet (ft^3)	Cubic Yards (yds^3)	Cubic Meter (m^3)	US Tons (Wet Weight)	US Tons (Dry Weight)	% of Total
Bangor	19,981,959	7,412,951	274,553	209,911	270,029	130,965	4.2
Orrington	39,486,262	16,638,624	616,245	471,153	606,089	293,956	9.4
Winterport	31,366,103	20,150,549	746,316	570,600	734,017	356,001	11.4
Frankfort Flats	50,918,172	19,159,333	709,604	542,531	697,910	338,489	10.8
Mendall Marsh	8,120,159	1,147,848	42,513	32,503	41,812	20,279	0.6
Bucksport	24,694,836	20,788,774	769,954	588,672	757,265	367,277	11.7
Bucksport Thalweg	8,470,440	8,996,955	333,220	254,765	327,729	158,950	5.1
Bucksport Harbor	2,181,298	1,665,672	61,691	47,167	60,675	29,428	0.9
Verona Northeast	18,501,224	25,185,118	932,781	713,163	917,409	444,947	14.2
Orland River	11,829,957	5,528,175	204,747	156,540	201,373	97,667	3.1
Verona East	24,487,851	30,022,643	1,111,949	850,146	1,093,624	530,412	16.9
Verona West	59,595,596	20,685,094	766,114	585,736	753,489	365,445	11.7
Total	299,633,857	177,381,736	6,569,687	5,022,887	6,461,421	3,133,817	100
Approximated Total[6]	**299,630,000**	**177,380,000**	**6,570,000**	**5,020,000**	**6,460,000**	**3,130,000**	**100**
Uncertainty of Total[7]	NA	57,815,148	2,141,300	1,637,141	2,106,012	1,021,425	32.6
Approximated Uncertainty of Total[6,7]	**NA**	**57,820,000**	**2,140,000**	**1,640,000**	**2,110,000**	**1,020,000**	**32.5**

Prepared by: DRY 1/9/2018
Checked by: TNG 1/9/2018

Notes:
1. Volume in cubic feet was converted to cubic yards for remedial/dredge volume estimates.
2. Volume in cubic yards was converted to cubic meters to match density units and to perform volume/mass equations.
3. The equation density = mass/volume was used to calculate mass.
4. For mass calculations: wet density average = 1,167 kg/m^3, dry density average = 566 kg/m^3.
5. Area and volume estimates were determined using ArcGIS software analysis.
6. Mathematical calculation totals are presented and do not represent the accuracy of source data; the approximated values are rounded to the nearest 10,000 and are recommended for use.
7. Quantifies overlap detection uncertainty between survey methods (i.e., 0.5 feet).

Abbreviations:
% = Percent
ft^2 = square feet
ft^3 = cubic feet
kg/m^3 = kilograms per cubic meter
m^3 = cubic meters
NA = Not Applicable
yds^3 = cubic yards

TABLE A-4

VOLUME AND MASS ESTIMATES OF BEDDED SEDIMENT AND WOOD WASTE IDENTIFIED IN SURFACE DEPOSITS[1,2,3,4,5]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Reach	Deposit ID	Deposit Type	Deposit Area	Deposit Thickness	Volume			Mass				
								By Deposit		By Reach		
			Square Feet (ft^2)	Feet (ft)	Cubic Feet (ft^3)	Cubic Yards (yds^3)	Cubic Meter (m^3)	US Tons (Wet Weight)	US Tons (Dry Weight)	US Tons (Wet Weight)	US Tons (Dry Weight)	% of Total Surface Deposit Mass
Bangor	No Sub-bottom Deposits Observed				0	0	0	0	0	0	0	0
Orrington	ON-1-1	Trap	324,344	3.0	973,031	36,038	27,553	35,444	17,191	302,755	146,837	10
	ON-2-1	Trap	525,875	3.0	1,577,625	58,430	44,673	57,468	27,872			
	ON-2-2	Trap	662,271	3.0	1,986,813	73,586	56,260	72,373	35,101			
	ON-2-3	Trap	269,125	4.0	1,076,499	39,870	30,483	39,213	19,019			
	ON-2-4	Trap	359,378	3.0	1,078,133	39,931	30,529	39,273	19,047			
	ON-2-5	Trap	205,698	4.0	822,792	30,474	23,299	29,972	14,536			
	ON-3-1	Trap	265,488	3.0	796,465	29,499	22,553	29,013	14,071			
Winterport	WP-1-1	Trap	344,479	3.0	1,033,437	38,275	29,264	37,645	18,258	549,381	266,452	19
	WP-1-2	Trap	354,213	3.5	1,239,745	45,916	35,106	45,160	21,903			
	WP-1-3	Trap	169,057	3.5	591,701	21,915	16,755	21,554	10,454			
	WP-1-4	Trap	88,765	3.5	310,679	11,507	8,797	11,317	5,489			
	WP-2-1	Trap	482,599	3.0	1,447,797	53,622	40,997	52,738	25,578			
	WP-2-2	Trap	209,666	4.0	838,665	31,062	23,748	30,550	14,817			
	WP-2-3	Trap	289,070	2.0	578,140	21,413	16,371	21,060	10,214			
	WP-2-4	Trap	297,081	3.5	1,039,782	38,510	29,443	37,876	18,370			
	WP-2-5	Trap	320,667	3.5	1,122,333	41,568	31,781	40,883	19,828			
	WP-3-1	Trap	269,674	2.0	539,349	19,976	15,273	19,647	9,529			
	WP-3-2	Trap	298,108	3.5	1,043,380	38,644	29,545	38,007	18,433			
	WP-3-3	Trap	437,609	3.5	1,531,632	56,727	43,371	55,792	27,059			
	WP-3-4	Trap	372,080	3.0	1,116,239	41,342	31,608	40,661	19,721			
	WP-3-5	Trap	269,891	3.0	809,672	29,988	22,927	29,494	14,305			
	WP-3-6	Trap	229,913	8.0	1,839,306	68,122	52,083	67,000	32,495			
Frankfort Flats	FF-1-1	Layer	585,275	6.0	3,511,647	130,061	99,439	127,918	62,041	509,282	247,004	17
	FF-1-2	Layer	599,395	3.0	1,798,185	66,599	50,919	65,502	31,769			
	FF-1-3	Layer	509,199	2.0	1,018,399	37,718	28,838	37,097	17,992			
	FF-1-4	Layer	343,318	2.0	686,636	25,431	19,443	25,012	12,131			
	FF-1-5	Layer	352,475	5.0	1,762,376	65,273	49,905	64,197	31,136			
	FF-1-6	Layer	534,318	7.0	3,740,224	138,527	105,911	136,244	66,079			
	FF-1-7	Layer	365,894	4.0	1,463,576	54,206	41,444	53,313	25,857			
Mendall Marsh	No Sub-bottom Deposits Observed				0	0	0	0	0	0	0	0

TABLE A-4

VOLUME AND MASS ESTIMATES OF BEDDED SEDIMENT AND WOOD WASTE IDENTIFIED IN SURFACE DEPOSITS[1,2,3,4,5]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Reach	Deposit ID	Deposit Type	Deposit Area	Deposit Thickness	Volume			Mass – By Deposit		Mass – By Reach		
			Square Feet (ft^2)	Feet (ft)	Cubic Feet (ft^3)	Cubic Yards (yds^3)	Cubic Meter (m^3)	US Tons (Wet Weight)	US Tons (Dry Weight)	US Tons (Wet Weight)	US Tons (Dry Weight)	% of Total Surface Deposit Mass
Bucksport	BU-1-1	Layer	371,392	3.5	1,299,874	48,143	36,808	47,350	22,965	701,558	340,259	24
	BU-1-2	Layer	193,675	3.5	677,862	25,106	19,195	24,692	11,976			
	BU-1-3	Layer	268,614	3.0	805,841	29,846	22,819	29,354	14,237			
	BU-1-4	Layer	358,312	2.0	716,624	26,542	20,293	26,104	12,661			
	BU-2-1	Trap	228,889	5.0	1,144,445	42,387	32,407	41,688	20,219			
	BU-2-2	Trench	139,648	4.0	558,593	20,689	15,818	20,348	9,869			
	BU-2-3	Trench	188,429	5.0	942,146	34,894	26,679	34,319	16,645			
	BU-2-4	Trench	184,629	3.0	553,887	20,514	15,684	20,176	9,786			
	BU-2-5	Trench	147,311	3.0	441,933	16,368	12,514	16,098	7,808			
	BU-2-6	Trench	130,149	3.0	390,447	14,461	11,056	14,223	6,898			
	BU-2-7	Trap	136,287	3.0	408,862	15,143	11,578	14,893	7,223			
	BU-2-8	Trap	228,593	4.0	914,373	33,866	25,892	33,308	16,154			
	BU-3-1	Trap	332,042	5.0	1,660,209	61,489	47,012	60,476	29,331			
	BU-3-2	Trench	117,697	3.0	353,091	13,077	9,998	12,862	6,238			
	BU-3-3	Trench	171,088	2.0	342,177	12,673	9,689	12,464	6,045			
	BU-3-4	Trench	250,577	3.0	751,730	27,842	21,287	27,383	13,281			
	BU-3-5	Trench	298,303	4.0	1,193,213	44,193	33,788	43,465	21,081			
	BU-3-6	Trench	379,053	3.0	1,137,158	42,117	32,201	41,423	20,090			
	BU-3-7	Trench	311,015	4.0	1,244,058	46,076	35,228	45,317	21,979			
	BU-3-8	Trap	255,397	4.0	1,021,587	37,837	28,928	37,213	18,048			
	BU-3-9	Trap	214,495	5.0	1,072,477	39,721	30,369	39,067	18,948			
	BU-3-10	Trap	271,483	6.0	1,628,896	60,329	46,125	59,335	28,778			
Bucksport Thalweg	BT-1-1	Trap	175,835	6.0	1,055,007	39,074	29,874	38,430	18,639	139,108	67,468	5
	BT-1-2	Trap	80,005	6.0	480,030	17,779	13,593	17,486	8,481			
	BT-1-3	Trap	77,410	4.0	309,641	11,468	8,768	11,279	5,470			
	BT-2-1	Trap	117,653	2.0	235,306	8,715	6,663	8,571	4,157			
	BT-2-2	Trap	322,972	4.0	1,291,887	47,848	36,582	47,059	22,824			
	BT-2-3	Trap	123,932	2.0	247,864	9,180	7,019	9,029	4,379			
	BT-2-4	Trap	99,553	2.0	199,106	7,374	5,638	7,253	3,518			
Bucksport Harbor	No Sub-bottom Deposits Observed				0	0	0	0	0	0	0	0
Verona Northeast	VN-1-1	Trap	166,954	2.5	417,385	15,459	11,819	15,204	7,374	46,629	22,615	2
	VN-1-2	Trap	279,666	1.0	279,666	10,358	7,919	10,187	4,941			
	VN-1-3	Trap	245,168	2.0	490,336	18,161	13,885	17,861	8,663			
	VN-1-4	Trap	92,694	1.0	92,694	3,433	2,625	3,377	1,638			

TABLE A-4

VOLUME AND MASS ESTIMATES OF BEDDED SEDIMENT AND WOOD WASTE IDENTIFIED IN SURFACE DEPOSITS[1,2,3,4,5]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

			Deposit Area	Deposit Thickness	Volume			Mass				
								By Deposit		By Reach		
Reach	Deposit ID	Deposit Type	Square Feet (ft^2)	Feet (ft)	Cubic Feet (ft^3)	Cubic Yards (yds^3)	Cubic Meter (m^3)	US Tons (Wet Weight)	US Tons (Dry Weight)	US Tons (Wet Weight)	US Tons (Dry Weight)	% of Total Surface Deposit Mass
Orland River	OR-1-1	Layer	288,438	3.0	865,315	32,049	24,503	31,521	15,288	31,521	15,288	1
Verona East	VE-1-1	Layer	436,897	3.0	1,310,691	48,544	37,115	47,744	23,156	641,187	310,979	22
	VE-1-2	Layer	185,585	6.0	1,113,510	41,241	31,531	40,561	19,672			
	VE-1-3	Layer	299,683	3.0	899,049	33,298	25,458	32,749	15,884			
	VE-1-4	Layer	354,554	6.0	2,127,324	78,790	60,239	77,491	37,584			
	VE-1A-1	Layer/Trap	666,585	6.0	3,999,510	148,130	113,253	145,689	70,660			
	VE-1A-2	Layer/Trap	772,588	6.0	4,635,528	171,686	131,263	168,857	81,896			
	VE-1A-3	Layer/Trap	645,110	2.5	1,612,775	59,732	45,669	58,748	28,493			
	VE-2-1	Layer	192,284	3.0	576,852	21,365	16,335	21,013	10,191			
	VE-3-1	Layer	265,382	5.0	1,326,910	49,145	37,574	48,335	23,443			
Verona West	No Sub-bottom Deposits Observed				0	0	0	0	0	0	0	0
All Reaches	Total Surface Deposit Estimate	NA	21,400,951	3	80,200,125	2,970,372	2,271,013	2,921,421	1,416,902	2,921,421	1,416,902	100
	Approximated Total Surface Deposit Estimate[6]	**NA**	**21,400,000**	**3**	**80,200,000**	**2,970,000**	**2,270,000**	**2,920,000**	**1,420,000**	**2,920,000**	**1,240,000**	**100**

Prepared by: DRY 1/9/2018
Checked by: TNG 1/9/2018

Notes:
1. Volume in cubic feet was converted to cubic yards for remedial/dredge volume estimates.
2. Volume in cubic yards was converted to cubic meters to match density units and to perform volume/mass equations.
3. The equation density = mass/volume was used to calculate mass.
4. For mass calculations: wet density average = 1,167 kg/m^3, dry density average = 566 kg/m^3.
5. Source file = Figure A-1.
6. Mathematical calculation totals are presented and do not represent the accuracy of source data; the approximated values are rounded to the nearest 10,000 and are recommended for use.
Layer = Uniformly mixed deposit extending above grade compared to the river bottom.
Trap = Partially exposed in topographic depression of the river bottom.
Trench = Partially exposed, but laterally confined and extending below grade compared to river bottom.

Abbreviations:
% = Percent
ft = feet
ft^2 = square feet
ft^3 = cubic feet
kg/m^3 = kilograms per cubic meter
m^3 = cubic meters
NA = Not Applicable
yds^3 = cubic yards

TABLE A-5

SUSPENDED MATERIAL COLLECTION RESULTS SUMMARY[1,2,3]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Reach	Location	X Coordinate	Y Coordinate	Lab Sample ID	Date	Time	Matrix	Sample Method	Sample Depth above Mudline (feet)	Measured Water Depth (feet)[4]	Water Depth of Maximum Turbidity (feet)	Maximum Turbidity (NTU)	Turbidity @ TSS Sample Depth (NTU)	Discrete Grab TSS from Hose (mg/L)[5]	Time-Integrated		Total Mercury (ng/g)	TOC (%)	Total Solids (%)
															Grab TSS (mg/L)[6]	Calculated TSS (mg/L)[7]			
Frankfort Flats	AOI-1A	897393.4932	342695.243	No Lab Sample Collected	7/28/2017	10:15	-	Hose, Pump, and Sonde	2	25.1	24.3	43	-	-	-	-	-	-	-
	AOI-1B	896654.6098	343762.1521	AOI_1B_072817_SS_N15	7/28/2017	17:40	Liquid	Hose, Pump, and Sonde	1.5	20.5	20.0	107	7.9	51[9]	-	-	-	-	-
	AOI-2	899447.6562	344058.1424	AOI_2_072417_SS_N21	7/24/2017	12:24	Liquid	Rigid Poles	2.1	10.1	-	-	-	44[9]	-	-	-	-	-
	AOI-7	896627.6024	346789.2197	AOI_7_072417_SS_N10	7/24/2017	13:55	Liquid	Rigid Poles	1	6.4	-	-	-	34[9]	-	-	-	-	-
Mendall Marsh	AOI-MM-1	890213.4999	335280.1222	AOI_MM_1_072817_SS_N15	7/28/2017	16:20	Liquid	Hose, Pump, and Sonde	1.5	12.6	12.5	28	22	28[9]	-	-	-	-	-
Bucksport	AOI-25	902181.7219	333564.3319	No Lab Sample Collected	9/19/2017	13:30	-	Sonde and Net Deployment	2	31	31	3	-	-	-	100-200	-	-	-
Bucksport Thalweg	AOI-33	905902.4481	328587.9349	No Lab Sample Collected	9/19/2017	12:30	-	Sonde and Net Deployment	2	78	78	12	-	-	-	-	-	-	-
Verona Northeast	AOI-VN-1	914192.6014	324812.449	No Lab Sample Collected	7/29/2017	10:15	-	Hose, Pump, and Sonde	1.5	4.8	4.6	23	-	-	-	-	-	-	-
	AOI-10	912866.715	325972.8374	No Lab Sample Collected	7/25/2017	10:00	-	Hose, Pump, and Sonde	1.5	6.4	5.1	21	-	-	-	-	-	-	-
	AOI-11	913582.7885	321625.997	AOI_11_072517_SS_N08	7/25/2017	11:55	Liquid	Hose, Pump, and Sonde	0.8	11.3	9.6	27	21	38[9]	-	-	-	-	-
Orland River	AOI-OR-1	920498.4019	325861.2755	AOI_1_OR_072917_SS_N08_R1	7/29/2017	13:50	Liquid	Hose, Pump, and Sonde	0.8	8.3	8.2	1,972	639	160	-	-	-	-	-
				AOI_1_OR_072917_SS_N08_R2										750	-	-	-	-	-
				AOI_1_OR_072917_SS_N08_R3										710	-	-	-	-	-
				AOI_1_OR_080117_SS_N08	8/1/2017	10:40	Solids							-		-	1,680	36.35	10.2
																		39.8	
																		32.9	
	AOI-14	920562.7543	327265.9976	No Lab Sample Collected	7/25/2017	13:55	-	Hose, Pump, and Sonde	1.5	7.3	7.3	46	-	-	-	-	-	-	-
Verona East	AOI-20	917907.736	313578.3005	AOI20_P200_10082017_SW_R1	10/8/2017	18:20	Liquid	Hose, Pump, and Sonde	0.8	22.1	21.8	1,467	732	-	480	1,700	-	-	-
				AOI20_P200_10082017_SW_R2										-	470		-	-	-
				AOI20_P200_10082017_SW_R3										-	480		-	-	-
				VE_AOI20_072517_SS_N20	7/25/2017	19:00	Liquid		2.0					800	-	-	-	-	-
				AOI_20_072517_SS_N08_R1	7/25/2017	16:00	Liquid		0.8					1,500	-	-	-	-	-
				AOI_20_072517_SS_N08_R2										1,500	-	-	-	-	-
				AOI_20_072517_SS_N08_R3										1,300	-	-	-	-	-
				AOI_20_080117_SS_N08	8/1/2017	10:30	Solids							-		-	1,510	30.7	12.6
																		28.2	
																		33.2	
	AOI-21	915144.7489	306227.0558	AOI21_P200_10102017_SW_R1	10/10/2017	12:10	Liquid	Hose, Pump, and Sonde	0.6	49.4	44.0	1,832	578	-	53	160	-	-	-
				AOI21_P200_10102017_SW_R2										-	54		-	-	-
				AOI21_P200_10102017_SW_R3										-	77		-	-	-
				AOI_21_072617_SS_N06	7/26/2017	15:45	Liquid							440	-	-	-	-	-
				AOI_21_080117_SS_N06	8/1/2017	10:50	Solids							-		-	-	30.45	13.5
																		32.8	
																		28.1	
				AOI_21_080117_SS_N06_DUP										-	-	-	1,340	-	-
				AOI_21_080117_SS_N06_R1										-	-	-	1,820	-	-
				AOI_21_080117_SS_N06_R2										-	-	-	1,520	-	-
				AOI_21_080117_SS_N06_R3										-	-	-	1,780	-	-
Verona West	AOI-X1	904589.2915	315510.1923	No Lab Sample Collected	9/19/2017	11:30	-	Sonde and Net Deployment	2	84	84	5	-	-	-	-	-	-	-
	AOI-27	905084.1826	308341.4347	No Lab Sample Collected	9/19/2017	10:10	-	Sonde and Net Deployment	2	86	86	10	-	-	-	-	-	-	-
	AOI-29	908645.5878	307110.9374	No Lab Sample Collected	7/29/2017	12:00	-	Hose, Pump, and Sonde	1.5	22.6	0[8]	1,958[8]	-	-	-	-	-	-	-

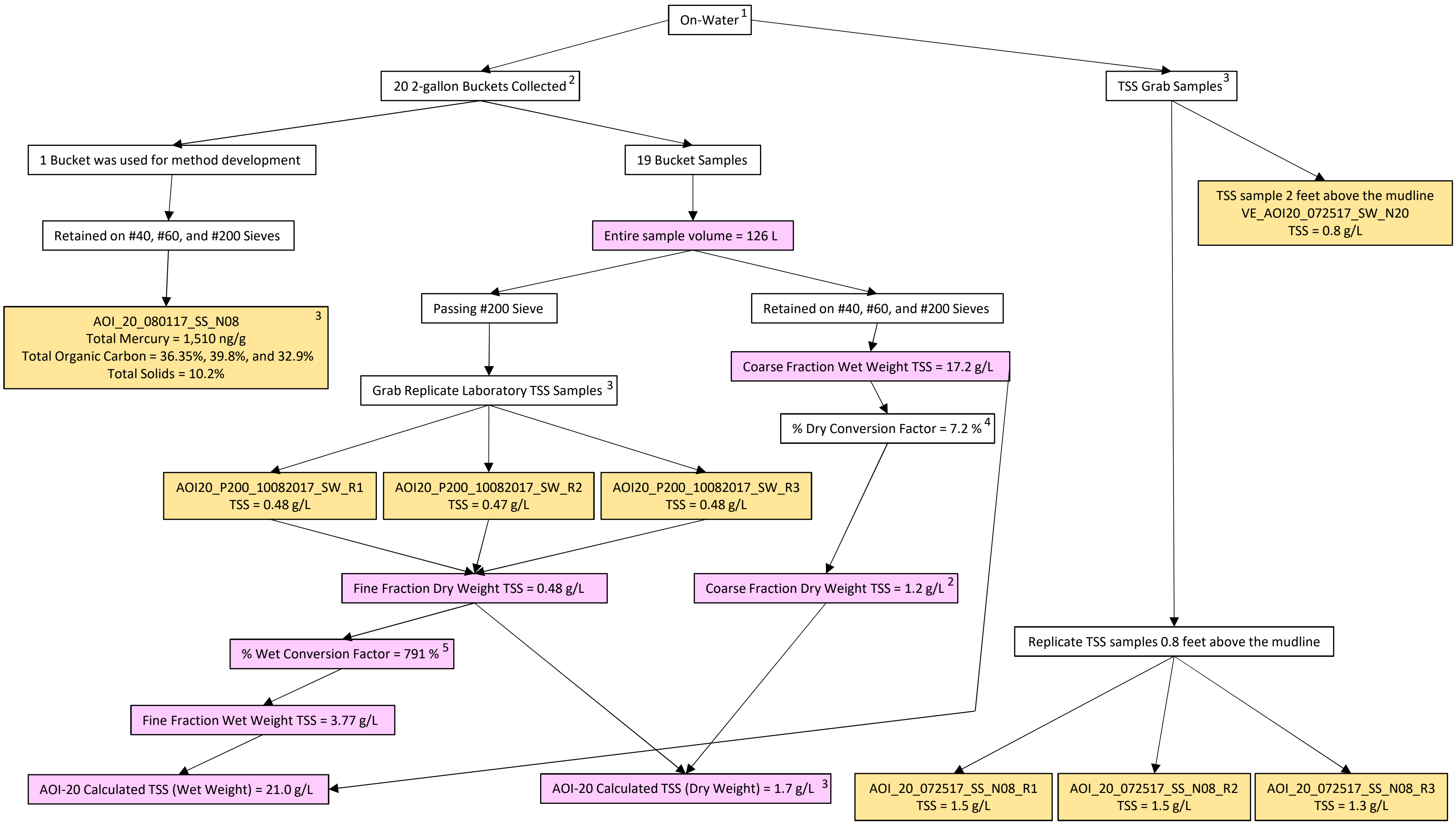
Notes:
1. Sample collection was completed during the sample tidal phase as the dual-frequency survey, unless noted otherwise.
2. Coordinates are displayed in Maine East State Plane North American Datum of 1983 (NAD83) with units in US survey feet.
3. Laboratory methods = Grab TSS (standard method 2540D), Total Solids (standard method 2540G), TOC (Lloyd Khan method), and total mercury (adjusted method 7474-1631).
4. Measured water depth at time of sampling.
5. Grab samples represent material passing the #200 sieve.
6. Calculated TSS is the sum of material retained on and passing the #200 sieve and averages from AOI-20 and AOI-21 were used in mass calculations.
7. Samples collected from material retained on #200 sieve.
8. Potential anomaly due to instrumental error.
9. Sample not collected within the dual-frequency related suspended material layer.

Prepared by: DRY 1/9/2018
Checked by: KMC 1/9/2018

Abbreviations:
- = Not analyzed
% = Percent
mg/L = milligram per liter
ng/g = nanogram per gram
NTU = nephelometric turbidity units
TOC = Total Organic Carbon
TSS = Total Suspended Solids

TABLE A-6

AOI-20 SUSPENDED MATERIAL FLOW DIAGRAM
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine



Notes:
1. Information is provided on the Suspended Solids and Ponar Grab Log in Appendix C-1.
2. Information is provided on the Suspended Sediment/Woody Debris Field Lab Processing Log in Appendix C-1.
3. Data results are provided in Table A-5.
4. Wet to dry weight conversion form in Appendix C-1.
5. Based on the wet chemistry bench sheet for sample AOI_20_080117_SS_N08 in the level four data validation report.

Abbreviations:
% = Percent
g/L = grams per liter
ng/g = nanogram per gram
TSS = Total Suspended Solids

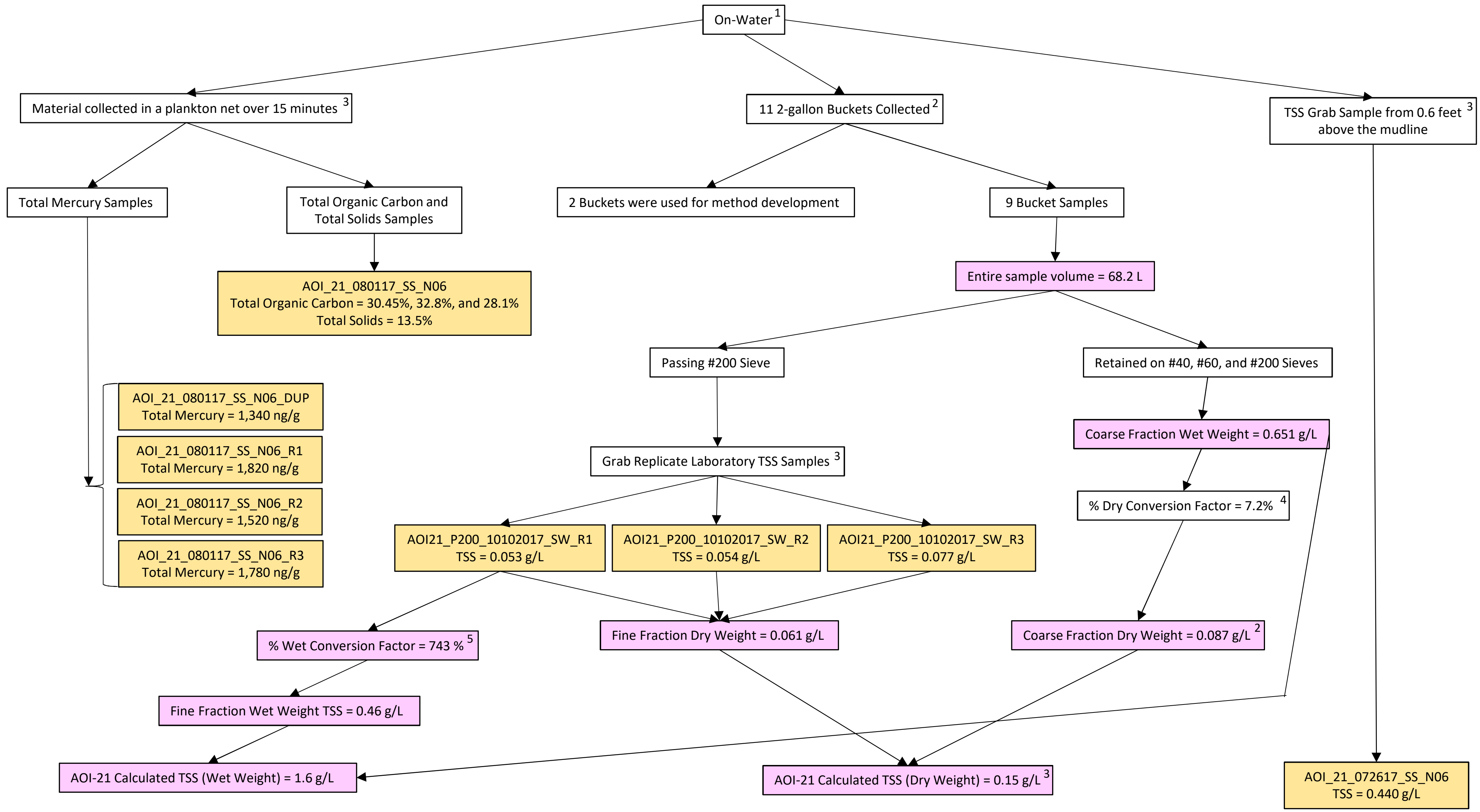
Symbol Key
Laboratory Reported Fields
Calculated Fields
Information/ Navigational Fields

Prepared by: KMC 5/8/2018
Checked by: DRY 5/8/2018

May 2018
Final

TABLE A-7

AOI-21 SUSPENDED MATERIAL FLOW DIAGRAM
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine



Notes:
1. Information is provided on the Suspended Solids and Ponar Grab Log in Appendix C-1
2. Information is provided on the Suspended Sediment/Woody Debris Field Lab Processing Log in Appendix C-1
3. Data results are provided in Table A-5
4. Wet to dry weight conversion form in Appendix C-1 .
5. Based on the wet chemistry bench sheet for sample AOI_21_080117_SS_N06 in the level four data validation report.

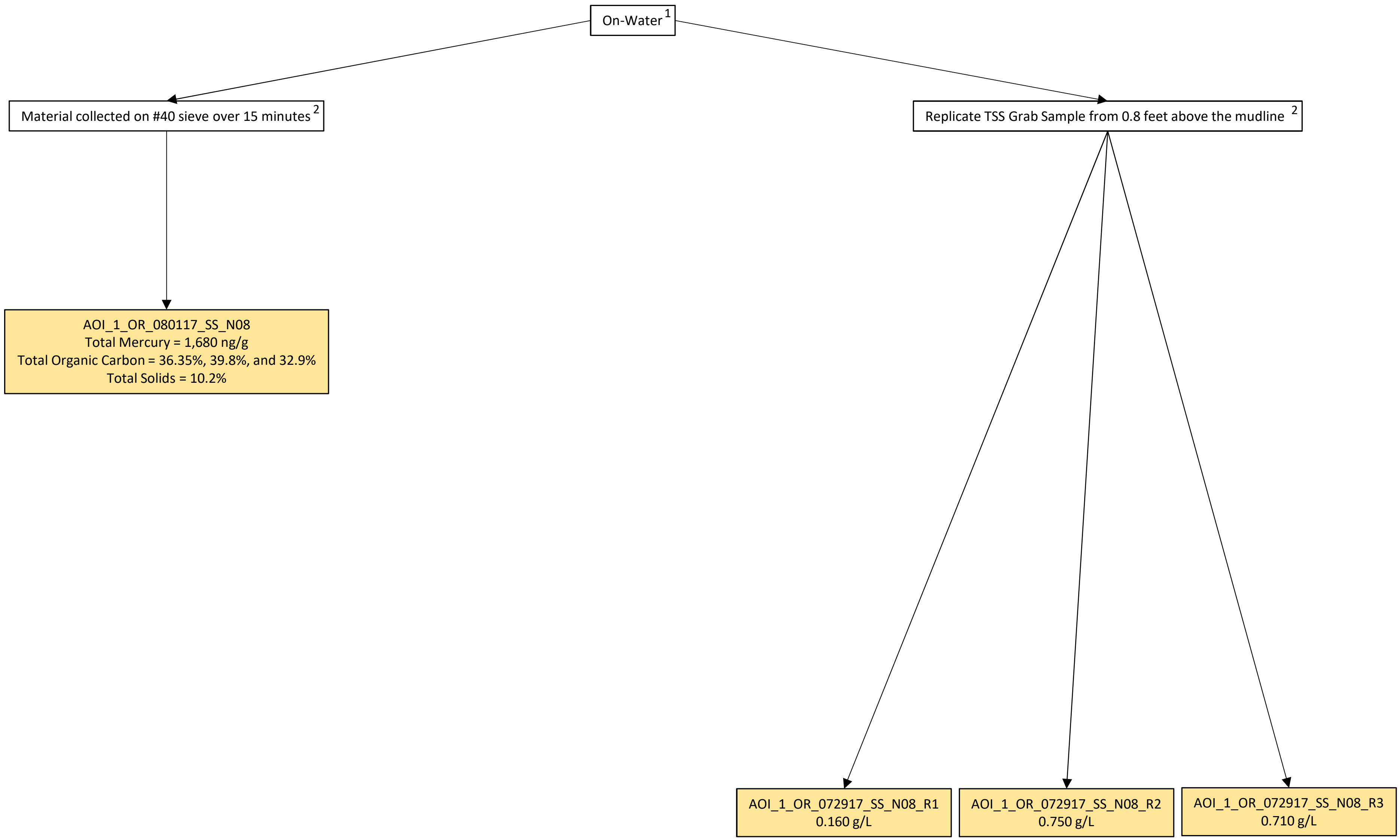
Abbreviations:
% = Percent
g/L = grams per liter
ng/g = nanogram per gram
TSS = Total Suspended Solids

Symbol Key
- Laboratory Reported Fields
- Calculated Fields
- Information/ Navigational Fields

Prepared by: KMC 5/9/2018
Checked by: DRY 5/9/2018

TABLE A-8

AOI-1-OR SUSPENDED MATERIAL FLOW DIAGRAM
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine



Notes:
1. Information is provided on the Suspended Solids and Ponar Grab Log in Appendix C-1
2. Data results are provided in Table A-5

Abbreviations:
% = Percent
g/L = grams per liter
ng/g = nanogram per gram
TSS = Total Suspended Solids

Symbol Key
Laboratory Reported Fields
Information/ Navigational Fields

Prepared by: KMC 5/9/2018
Checked by: DRY 5/9/2018

May 2018
Final

TABLE A-9

EROSIONAL INDICATOR MEASUREMENTS SUMMARY[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Rivulet or Gully	Reach	Rivulet ID	X Coordinate[2]	Y Coordinate[2]	Width (ft)	Visual Depth (ft)	Ruler Resistance Depth (ft)	Rivulet Volume (ft^3)[3,4]	Water Present in Rivulet?	Overlying Water Present?	Wood Waste Present?	Rivulet Orientation	Rivulet Water Source	Vegetation Present?	Boulders Present?
Rivulet[5]	Mendall Marsh	MM-RV-1	889872.15	337329.89	2.0	0.2	0.2	36.7	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-2	889845.40	337135.51	0.9	0.1	0.2	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-3	889855.97	336924.67	0.3	0.1	0.2	1.7	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-4	889869.26	336806.34	0.8	0.4	0.4	32.3	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-5	889877.38	336780.03	0.5	0.2	0.3	8.1	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-6	889411.09	338067.62	1.3	0.2	0.4	25.8	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-7	889368.75	337985.47	2.3	0.4	0.5	82.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-8	889335.78	337873.60	2.9	0.3	0.4	85.3	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-9	889301.27	337774.22	0.8	0.2	0.2	13.5	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-10	889288.87	337742.49	1.5	0.2	0.4	33.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	No
		MM-RV-11	891912.28	326502.44	0.4	0.1	0.2	5.2	Yes	No	Yes	Terraced, Zig Zag	Runoff from Upslope	No	No
		Reach Average			**1.2**	**0.2**	**0.3**	**30.6**	**Yes**	**Yes**	**Yes**	**Uniform, Zig Zag**	**Runoff from Upslope**	**No**	**No**
	Orrington	ON-RV-1	899636.44	394479.00	0.6	0.2	NA	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-2	899636.44	394479.00	0.2	0.2	NA	3.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-3	899636.44	394479.00	0.2	0.6	NA	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-4	900456.52	371295.47	0.6	0.6	NA	34.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-5	901638.69	369181.60	0.6	0.2	NA	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-6	896165.40	380308.39	2.3	0.4	NA	90.4	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-7	901088.12	372650.48	0.6	1.0	NA	58.1	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-8	897231.28	385745.96	0.6	0.2	NA	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-9	NA	NA	0.6	0.2	NA	11.6	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-10	898162.35	383609.48	1.0	0.2	NA	19.4	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		ON-RV-11	896323.91	380857.25	0.6	0.6	NA	34.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		Reach Average			**0.7**	**0.4**	**NA**	**27.2**	**Yes**	**Yes**	**Yes**	**Uniform, Zig Zag**	**Runoff from Upslope**	**No**	**Yes**
	Bucksport	BU-RV-1	899342.79	336273.53	1.8	0.3	0.4	48.2	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-2	899326.54	336283.13	1.1	0.2	0.2	18.3	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-3	899291.96	336325.13	1.3	0.2	0.2	25.2	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-4	900307.17	334358.94	1.8	0.2	0.2	40.7	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-5	899210.09	336418.22	3.3	0.6	0.6	193.8	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-6	NA	NA	0.2	0.2	NA	3.9	Yes	Yes	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-7	899697.76	335338.11	0.3	0.1	0.2	2.6	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-8	899680.18	335414.86	0.3	0.1	0.1	2.9	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		BU-RV-9	899650.30	335554.54	0.4	0.2	0.2	6.5	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
		Reach Average			**1.2**	**0.2**	**0.3**	**38.0**	**Yes**	**No**	**Yes**	**Uniform, Zig Zag**	**Runoff from Upslope**	**No**	**Yes**
	Verona Northeast	VN-RV-1	909556.94	328634.20	6.6	0.7	0.9	430.6	Yes	Yes	No	Uniform, Zig Zag	Runoff from Upslope	No	No
		VN-RV-2	910661.12	329157.66	3.3	0.3	0.5	96.9	Yes	Yes	No	Uniform, Zig Zag	Runoff from Upslope	No	No
		VN-RV-3	910768.19	329135.48	0.2	0.2	0.3	3.8	Yes	Yes	No	Uniform, Zig Zag	Runoff from Upslope	No	No
		VN-RV-4	911362.46	329070.80	0.4	0.2	0.2	6.5	Yes	Yes	No	Uniform, Zig Zag	Runoff from Upslope	No	No
		Reach Average			**2.6**	**0.3**	**0.5**	**134.4**	**Yes**	**Yes**	**No**	**Uniform, Zig Zag**	**Runoff from Upslope**	**No**	**No**
Gully[6]	Bucksport	BU-RV-10	899607.40	335740.99	55.8	18.0	NA	100,642.6	Yes	No	Yes	Uniform, Zig Zag	Runoff from Upslope	No	Yes
	Frankfort Flats	FF-RV-1	Eastern Shoreline		49.2	16.4	NA	80,729.3	Yes	Yes	Yes	Uniform, Eroded Bank	Runoff from Upslope	No	No
		FF-RV-2	Eastern Shoreline		49.2	16.4	NA	80,729.3	Yes	Yes	Yes	Uniform, Eroded Bank	Runoff from Upslope	No	No

Notes:
1. Measurements and observations were recorded from September 23-27, 2017.
2. Coordinates are displayed in Maine East State Plane North American Datum of 1983 (NAD83) with units in US survey feet and were collected at the waterline where measurements were recorded.
3. Approximate distance to vegetation, treeline, or rockline was visually estimated and generally appeared to be within 100 feet at all locations. For volume calculations, 100 feet was assumed for rivulet length.
4. Width and visual depth measurements were included in volume calculations.
5. Rivulet = Small erosional stream.
6. Gully = Semi-permanent erosional feature.

Prepared by: DRY 1/9/2018
Checked by: KMC 1/9/2018

Abbreviations:
ft = feet
ft^3 = cubic feet
NA = Not Available