APPENDIX F

Sediment Profile Image/Plan View Image Reports
(Baseline and Year 1)

BASELINE

2018

BASELINE SPI/PV DATA REPORT

ENHANCED NATURAL RECOVERY/ACTIVATED CARBON PILOT STUDY LOWER DUWAMISH WATERWAY

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1 INTRODUCTION

1.1 Background

The Lower Duwamish pilot study will test an innovative sediment technology in the field to evaluate the potential effectiveness of the technology in the Lower Duwamish Waterway (LDW). The study will compare the effectiveness of enhanced natural recovery (ENR) amended with activated carbon (AC) (ENR+AC) against that of ENR without added AC. This will be tested in three habitat types: the subtidal, the intertidal, and an area where vessel scour is possible. For the purposes of this project, ENR involves the placement of a thin layer of clean material over subtidal or intertidal sediments. ENR+AC involves the placement of a thin layer of clean material augmented with AC over subtidal or intertidal sediments.

This pilot study was specified under the Second Amendment (July 2014) to the Administrative Order on Consent (Order) for Remedial Investigation/Feasibility Study for the LDW, CERCLA Docket No. 10-2001-0055, issued on December 20, 2000. The Second Amendment to the Order, which is referred to as the Order Amendment, included a statement of work for the pilot study, including a general overview of the work to be performed, a list of study steps/tasks, and a schedule for deliverables.

The goals of the pilot study, as stated in the Order Amendment, are the following:

- Verify that ENR+AC can be successfully applied in the LDW by monitoring physical placement success (uniformity of coverage and percent of carbon in a placed layer).
- Evaluate performance of ENR+AC compared to ENR alone in locations with a range of polychlorinated biphenyl (PCB) concentrations.
- Assess potential impacts to the benthic community in ENR+AC compared to ENR alone.
- Assess changes in bioavailability in ENR+AC compared to ENR alone.
- Assess the stability of ENR and ENR+AC in scour areas (such as berthing areas).

1.2 Goals of the Baseline Sediment Profile Imaging/Plan View Survey

The goal of the sediment profile imaging/plan view (SPI/PV) baseline survey of the pilot project is to document the sediment types and biological communities present at each pilot area prior to the application of ENR and ENR+AC amendments. These data will be used as one line of evidence for evaluating benthic recolonization over time after the amendments are placed. In addition, other features such as stratigraphy, physical disturbance features, and sediment fabric may also be described to support an understanding of the physical processes at the pilot study placement areas.

2 METHODS

2.1 Field Collections

The baseline SPI/PV survey of the LDW pilot areas was conducted from July 12, 2016 to July 13, 2016. Surveys at all three plots were conducted aboard the R/V Carolyn Dow, owned and operated by Research Support Services (RSS) of Bainbridge Island, WA. All positioning and navigation during the survey was conducted by RSS using a differential global positioning system (DGPS). Scientists from Amec Foster Wheeler provided oversight of navigation and positioning during the survey as well as record keeping. Scientists from Browning Environmental Services (BES) operated the sediment profile and plan view camera apparatus, kept field notes, and ensured successful image acquisition.

A total of 36 stations, 12 from each pilot plot, were occupied using the SPI/PV camera during the baseline monitoring event. At each station, the research vessel was piloted to the target location and the SPI/PV system was lowered to the sediment bed only when within 3 meters of the target location. A minimum of three replicate image sets were collected at each target location. Therefore, accounting for triplicate image sets, a minimum of 36 SPI/PV images were collected at each pilot plot.[1] For all pilot plots, the 12 stations were apportioned such that 6 stations were occupied in the area that would become the ENR only subplot and 6 stations were occupied in the area that would become the ENR+AC subplot. The 12 stations were collected from "A" cells during the baseline sampling event. The SPI/PV locations for each plot are shown in Figures 2-1, 2-2, and 2-3.

Acquisition of high-resolution sediment profile images was accomplished using a Nikon D7100 digital single-lens reflex (DSLR) camera with a 24.1-megapixel image sensor mounted inside an Ocean Imaging Model 3731 pressure housing system. Camera settings were f8, ISO 640, and 1/320 shutter speed. A total of 111 sediment profile images were selected for analysis (3 replicate images from each of 33 stations and 4 replicate images from 3 stations).

Plan view images were collected using a Nikon D7100 DSLR camera with a 24.1-megapixel image sensor mounted inside an Ocean Imaging Model DSC2400 camera housing. For the baseline survey, a focal distance of 3 feet was utilized. In the subtidal and some intertidal areas, ambient turbidity prevented clear images from being collected. Also, turbidity clouds generated from the first replicate sampling often negatively affected the second and third replicate PV images collected at a target station. Throughout the survey, all images were downloaded in the field by BES to ensure successful image acquisition.

2.2 Sediment Profile and Plan View Image Analysis

Following completion of the field operations, the large (e.g., 32MB) image NEF (Nikon Electronic Format) files were white light equalized and converted to smaller (e.g., 12MB) jpegs to facilitate submission to and use by the client. The raw images were then converted to high-resolution Photoshop Document (PSD) format files using the minimal amount of image file compression, maintaining an Adobe RGB (1998) color profile for image analysis in Adobe Photoshop®. The PSD images were then calibrated by measuring 1-centimeter (cm) gradations from the Kodak® Color Separation Guide. Linear and area measurements were recorded as raw pixel counts and

[1] Note that four replicates were collected at stations IN-ENR-6-A, SU-ENR+AC-2-A, and SU-ENR+AC-3-A to insure three optimal images were obtained based on field observations that a replicate may have been dropped. All four images were subsequently analyzed to avoid selective biasing of the images analyzed.

then converted to scientific units using the calibration information. Measured parameters were recorded on a Microsoft Excel© spreadsheet.

2.2.1 Sediment Profile Imaging Parameters

2.2.1.1 Sediment Grain Size and Sediment Type

The sediment grain-size major mode and range were visually estimated from the color images by overlaying a grain-size comparator at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) with the SPI camera. Seven grain-size classes were on this comparator: >4 phi (silt-clay), 4-3 phi (very fine sand), 3-2 phi (fine sand), 2-1 phi (medium sand), 1-0 phi (coarse sand), 0-(-1) phi (very coarse sand), and <-1 phi (granule and larger).

The lower limit of optical resolution of the photographic system is about 62 microns, allowing recognition of grain sizes equal to, or greater than, coarse silt (≥4 phi). The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (Germano et al. 2011).

The comparison of the SPI images with Udden-Wentworth sediment standards photographed through the SPI optical system was also used to map near-surface stratigraphy such as sand-over-mud and mud-over-sand.

2.2.1.2 Prism Penetration Depth

SPI prism penetration depth was measured as the entire cross-sectional sediment represented in the image. The area of the image represented by sediment resting upon the faceplate was digitized and this digitized area was divided by the calibrated linear width of the image to determine the mean penetration depth for a given image. Linear maximum and minimum depths of penetration were also measured. All three measurements (maximum, minimum, and average penetration depths) were recorded in the data file.

Prism penetration is a noteworthy parameter; if the number of weights used in the camera remains constant throughout a survey, the camera functions as a penetrometer. Comparative penetration values provide an indication of the relative water content or bearing strength of the sediment. Highly bioturbated sediments and unconsolidated, newly deposited sediments often have the high water content, low load bearing capacities, and allow the deepest prism penetration depths. Conversely, compact sands and gravels resist prism penetration. In this study, relative penetration depths over time may provide a line of evidence for the presence of cap materials and natural sediment deposits.

2.2.1.3 Small-Scale Boundary Roughness

Surface boundary roughness was determined by measuring difference between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment profile images typically ranges from 0.02 to 3.8 cm and may be related to either physical structures (ripples, rip-up structures, mud clasts) or biogenic features (burrow openings, fecal mounds, foraging depressions).

In sandy sediments, boundary roughness can be a measure of sand wave height. On silt-clay bottoms, boundary roughness values often reflect biogenic features such as fecal mounds or surface burrows. The size and scale of boundary roughness values can have dramatic effects on both sediment erodibility and localized oxygen penetration into the bottom (Huettel et al. 1996).

2.2.1.4 Apparent Redox Potential Discontinuity Depth

Aerobic near-surface marine sediments typically have higher reflectance relative to underlying hypoxic or anoxic sediments. These differences in optical reflectance are evident in SPI images because oxidized surface sediment contains particles coated with ferric hydroxide (an olive or tan color), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black (Fenchel 1969; Lyle 1983). The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the *apparent* redox potential discontinuity (aRPD).

The depth of the aRPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment porewaters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 millimeters (mm) below the sediment-water interface (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment oxygen demand (SOD), the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the redox potential discontinuity (RPD) layer may be several centimeters. The actual RPD is the boundary or horizon that separates the positive Eh region of the sediment column from the underlying negative Eh region. The exact location of this Eh = 0 boundary can only be determined accurately with microelectrodes. For this reason, the optical reflectance boundary, as imaged and measured in SPI images is described as the “apparent” RPD (aRPD). In general, the depth of the actual Eh = 0 horizon (RPD) will be either equal to or slightly shallower than the depth of the optical reflectance boundary or aRPD (Rosenberg et al. 2001). This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the Eh = 0 horizon.

The rate of depression of the aRPD within the sediment is relatively slow in organic-rich muds, on the order of 200 to 300 micrometers per day; therefore, this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the aRPD is also slow (Germano 1983). Measurable changes in the aRPD depth using the SPI optical technique can be detected over periods of 1 or 2 months. This parameter is used effectively to document changes (or gradients) that develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, SOD, physical disturbance, and infaunal recruitment. Time-series aRPD measurements following a disturbance can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos (Rhoads and Germano 1986).

The mean aRPD depth also can be affected by local erosion. Scouring can wash away fines and shell or gravel lag deposits and can result in a very thin surface oxidized layer. During storm periods, erosion may completely remove any evidence of the aRPD (Fredette et al. 1988).

Because the determination of the aRPD requires discrimination of optical contrast between oxidized and reduced particles, it is difficult to determine the depth of the aRPD in well-sorted sands of any size that have little to no silt or organic matter in them. When using SPI technology on sand bottoms, mean aRPD depths are often indeterminate due to a lack of optical contrast with depth, although oxygen is no doubt penetrating the sand beneath the sediment-water interface due to physical forcing factors acting on surface roughness elements (Ziebis et al. 1996; Huettel et al. 1998) as well as biological activity.

2.2.1.5 Infaunal Successional Stage

Infaunal successional stages can be recognized in SPI images by the presence of certain organisms or organism assemblages (e.g., dense assemblages of near-surface tube-dwelling polychaetes or amphipods) and/or the presence of structures formed by the activities of infauna (e.g., burrows and subsurface feeding pockets or voids). The designation and mapping of successional stages is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a major sediment bed perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, the definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is presented in Pearson and Rosenberg (1978) and further developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

This continuum of change in benthic infauna communities after a disturbance (primary succession) has been divided subjectively into four stages: Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source; Stage 1 is the initial community of tiny, densely populated polychaete assemblages; Stage 2 is the start of the transition to head-down deposit feeders; and Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders.

After an area of bottom is disturbed by natural or anthropogenic events, the first invertebrate assemblage (Stage 1) appears within days after the disturbance. Stage 1 consists of assemblages of tiny tube-dwelling marine polychaetes that reach population densities of 10^4 to 10^6 individuals per square meter (m^2). These animals feed at or near the sediment-water interface and physically stabilize or bind the sediment surface by producing a mucous "glue" that they use to build their tubes. Sometimes deposited dredged material layers contain Stage 1 tubes still attached to mud clasts from their location of origin; these transported individuals are considered as part of the *in-situ* fauna in our assignment of successional stages.

If there are no repeated disturbances to the newly colonized area, then these initial tube-dwelling suspension or surface-deposit feeding taxa are followed by burrowing, head-down deposit-feeders that rework the sediment deeper and deeper over time and mix oxygen from the overlying water into the sediment. The animals in these later-appearing communities (Stage 2 or 3) are larger, have lower overall population densities (10 to 100 individuals per m^2), and can rework the sediments to depths of 3 to 20 cm or more. These animals "loosen" the sedimentary fabric, increase the water content in the sediment, thereby lowering the sediment shear strength, and actively recycle nutrients because of the high exchange rate with the overlying waters resulting from their burrowing and feeding activities.

In dynamic estuarine and coastal environments, it is simplistic to assume that benthic communities always progress completely and sequentially through all four stages in accordance with the idealized conceptual model. Various combinations of these basic successional stages are possible. For example, secondary succession can occur (Horn 1974) in response to additional labile carbon input to surface sediments, with surface-dwelling Stage 1 or 2 organisms co-existing at the same time and place with Stage 3, resulting in the assignment of a “Stage 1 on 3” or “Stage 2 on 3” designation.

While the successional dynamics of invertebrate communities in fine-grained sediments have been well-documented, the successional dynamics of invertebrate communities in sand and coarser sediments are not well-known. Subsequently, biological community structures and dynamics in sandy or coarse-grained bottoms are limited.

2.2.1.6 Using SPI to Evaluate Sedimentary and Biological Processes

The sediment bed may generally be considered long-term time integrator of sediment and overlying water quality; values for any variable measured in the sediment column are the result of physical, chemical, and biological interactions on time scales longer than those present in the overlying water column. Thus, the sediment bed is a good indicator of environmental quality, both in terms of historical impacts as recorded in the sediment column and potential future trends.

Physical measurements made with the SPI system from profile images provide background information about gradients in physical disturbance in the form of maps of sediment grain size, boundary roughness, sediment textural fabrics, and sediment structures. The concentrations of organic matter and the SOD can be inferred from the optical reflectance of the sediment column and the aRPD depth. Organic matter is an important indicator of the relative value of the sediment as a carbon source for both bacteria and infaunal deposit feeders. SOD is an important measure of ecological quality; oxygen can be depleted quickly in sediment by the accumulation of organic matter and by bacterial respiration, both of which place an oxygen demand on the porewater and compete with animals for a potentially limited oxygen resource (Kennish 1986).

The aRPD depth is useful in assessing the quality of a habitat for epifauna and infauna from both physical and biological points of view. The aRPD depth in profile images has been shown to be directly correlated to the quality of the benthic habitat in polyhaline and mesohaline estuarine zones (Rhoads and Germano 1986; Revelas et al. 1987; Valente et al. 1992). Controlling for differences in sediment type and physical disturbance factors, aRPD depths <1 cm can indicate chronic benthic environmental stress or recent catastrophic disturbance.

The distribution of successional stages in the context of the mapped disturbance gradients is one of the most sensitive indicators of the ecological quality of the sediment bed (Rhoads and Germano 1986). The presence of Stage 3 equilibrium taxa (mapped from subsurface feeding voids as observed in profile images) can be a good indication of high benthic habitat stability and relative quality. A Stage 3 assemblage indicates that the sediment surrounding these organisms has not been disturbed severely in the recent past and that the inventory of bioavailable contaminants is relatively small. These inferences are based on past work, primarily in temperate latitudes, showing that Stage 3 species are relatively intolerant to sediment disturbance, organic enrichment, and sediment contamination. Stage 3 species expend metabolic energy on sediment bioturbation (both particle advection and porewater irrigation) to control sediment properties, including porewater profiles of sulfate, nitrate, and RPD depth in the sedimentary matrix near their burrows or tubes (Aller and Stupakoff 1996; Rice and Rhoads 1989). This bioturbation results in an enhanced rate of decomposition of polymerized organic matter by stimulating microbial decomposition (“microbial gardening”). Stage 3 benthic assemblages are stable and are also called climax or equilibrium seres.[2]

2.2.2 Plan View Image Analysis

The PV images provide a much larger field of view than the sediment profile images and provide valuable information about the landscape ecology and sediment topography in the area where the pinpoint “optical core” of the sediment profile was taken. Surface sediment layers/textures or structures observed from the sediment profile images can be evaluated in the larger context of the PV images. In this study, the plan view images will be used to assist in understanding the ENR/AC layer distribution, sediment dynamics and biological activity as revealed by the presence of epifauna (e.g., demersal fish and invertebrates) as well as their burrows, tracks, and tubes.

[2] A sere is a natural succession of plant (or animal) communities, especially a full series from uncolonized habitat to the appropriate climax community.

3 RESULTS

A total of 111 images from 36 stations were analyzed for SPI and PV parameters (see Exhibit). Tabulated results for each pilot plot area are presented in Tables 3-1 through 3-4. Results for each pilot plot are discussed below.

3.1 Intertidal Plot

The base substrate at the intertidal plot was silt/clay throughout the entire area. All replicates at all stations showed a silt/clay substrate alone or with a thin veneer of fine sand at the sediment surface. Representative SPI and PV images from the intertidal ENR and ENR+AC subplots are shown in Figures 3-1 and 3-2[3].

Mean prism penetration depths ranged from 2.18 cm to 14.6 cm and the average mean penetration depth was 9.67 cm (n=37). Prism penetration showed a great deal of variation and this variation appeared to be related not only to sediment type and bearing strength but also to the presence and thickness of algal mats at the sediment-water interface. The dense algal mats inhibited prism penetration at several stations. In addition, at the stations with algal mats, the fine-scaled sedimentary features that allow for the determination of the aRPD and infaunal successional stage were disrupted. Representative images showing surficial algae at the intertidal stations are shown in Figures 3-1 and 3-2.

The aRPD measured from the intertidal plot ranged from 0.83 to 4.63 cm with a mean aRPD across the plot of 2.17 cm. At seven of the 37 replicates, aRPDs could not be measured due to the disturbance of the sediment-water interface associated with the dragging down of surficial algae with the camera prism.

Stage 3 infauna were observed at 8 of the 12 intertidal stations (15 out of 28 measurable replicates, 9 of the replicates were categorized as indeterminate due to sampling related disturbance obscuring fine-scaled sedimentary structures) indicating the presence of head-down deposit feeders and other infauna that burrow, rework or moved through subsurface sediment. At 3 of the 12 stations, infaunal successional stage could not be determined due to sampling related disturbance from the dense surficial algae. The widespread distribution of the higher level successional seres is indicative of either little or no disturbance to the benthic community at the time of the baseline survey.

3.2 Scour Plot

The base substrate at the potential scour area plot is predominantly subsurface silt/clay throughout the entire area with surficial veneers of sand and gravel. Only three of the 12 stations sampled at the scour area were composed of silts and clays without a sand or gravel layer at the surface (see Grain Size Major Modes in Table 3-3). Representative SPI images from the scour ENR and ENR+AC subplots are shown in Figures 3-3 and 3-4[4]. Representative PV images from the scour ENR and ENR+AC subplots are shown in Figures 3-5 and 3-6.

Mean prism penetration depths ranged from 0.29 cm to 16.56 cm and the average mean penetration depth was 13.81 cm (n=36). Prism penetration showed a great deal of variation and this variation appeared to be related to sediment type and the presence of surficial gravels.

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[3] The circular ring seen in the PV images is a lighting baffle that hangs down from the PV camera lens.

[4] The red cord is the left image in Figure 3-4 is the PV camera’s vinyl bounce switch line.

Every station and replicate that had a mean prism penetration of <10 cm had either coarse sand or gravel at the sediment-water interface. Representative images showing coarse sands and gravels from the potential scour plot are shown in Figures 3-3, 3-5, and 3-6.

The aRPD measured from the scour plots ranged from 1 cm to 2.82 cm with a mean aRPD across the plot of 2.02 cm. At 1 of the 36 replicates, aRPDs could not be measured because the surface was composed of lithic gravel with little or no fine-grained sediment (Figure 3-3).

Stage 3 infauna were observed at all 12 potential scour plot stations (32 out of 36 replicates) indicating the widespread presence of head-down deposit feeders and other subsurface-dwelling infauna. As with the intertidal plot, the presence of high-level successional stages is indicative of undisturbed or stable benthic conditions at the scour plot at the time of the baseline survey.

3.3 Subtidal Plot

The base substrate at the subtidal area plot is predominantly silts and clays throughout the entire area with scattered surficial veneers of fine sand. Representative SPI images from the subtidal ENR and ENR+AC subplots are shown in Figures 3-7 and 3-8. Representative PV images from the subtidal ENR and ENR+AC subplots are shown in Figures 3-9 and 3-10.

Mean prism penetration depths ranged from 5.78 cm to 21.61 cm and the average mean penetration depth was 12.71 cm (n=36). Prism penetration showed a great deal of variation and this variation appeared to be related sediment types, i.e., surface sand layers at a subset of locations and variations in porosity across the plot.

The aRPD measured from the subtidal plot ranged from 0.24 cm to 3.02 cm with a mean aRPD across the plot of 1.26 cm. At 4 of the 36 replicates, aRPDs could not be measured due to sampling related disturbance.

Stage 3 infauna were observed at 6 of the 12 subplot plot stations (17 out of 38 replicates), Stage 2 or Stage 1 transitioning to Stage 2 assemblages (designated as 1 -> 2 in Table 3-4) were observed at 4 stations (11 and 4 out of 38 replicates respectively), and Stage 1 infauna only were observed at 2 stations (6 of 38 replicates). Stage 3 fauna were observed at half the subtidal plot stations and this plot had the highest proportion of lower level seres (Stages 1 and or 2) of any of the plots. This indicates higher levels of and/or more recent disturbance at the subtidal plots compared with the scour or intertidal plots at the time of the baseline survey.

4 DISCUSSION

The primary purpose of the baseline SPI/PV survey of the pilot areas was to document the sediment types and biological communities present prior to placement of the ENR and ENR+AC amendments at each of the pilot areas. The baseline survey achieved these goals. The range of sediment types and biological communities were documented at each plot in sufficient detail for comparison to post-placement surveys.

Throughout the intertidal plot, surface sediments were predominately silt/clay, but some images showed a thin veneer of fine sand at the sediment surface.

At the potential scour plot, the surface sediments were oftentimes fine to coarse sands along with fine gravels that overlay a silt/clay matrix. These coarser surficial particles were partially mixed with the underlying silts but were frequently free of detritus or recently deposited sediment. In the plan view images, many of the gravels appeared to be angular and possible pieces of debris (Figures 3-5 and 3-6). The absence or poor development of a fine-grained sediment coating or detrital mantling upon these gravels suggests that little or no sediment was being deposited on the surficial coarse-grained material. This can be due to one of two reasons, either the area is being sediment starved so that little or no new sediment is coming in, or that near bottom currents are sufficient to carry the fine-grained sediment and detritus away to be deposited elsewhere. Usually, the presence of coarse-grained sediment overlying fine-grained sediment is indicative of a lag deposit where finer-grained material is winnowed away leaving the coarser, heavier material behind (Figures 3-3, 3-5, and 3-6). Presumably, this occurs until the remaining material is in hydrodynamic equilibrium with the ambient forces. Based on these features, it appears that throughout the potential scour area there are periodic hydrodynamic forces exerted on the sediment column that result in coarser particles overlying and partially armoring the finer-grained subsurface substrate. Given that gravels are not ubiquitous across the potential scour plot, these forces appear to be patchy and may be related to instantaneous hydrodynamic forces (e.g. prop wash), steady state hydrodynamic forces (e.g., tides) or a combination of these two forces.

At the subtidal plot, the base substrate was silts and clays with minor amounts of surficial sands that were not typically present in either thickness or concentration to be considered a distinct layer (Figures 3-7 and 3-8). The aRPDs depths were generally shallower in the subtidal plot than in the scour and intertidal plots. In addition, the highest proportion of lower successional seres, Stages 1 and 1->2, were observed in the subtidal plot. When examining the SPI images from this area, much of the subsurface sediment is homogeneous and the aRPDs are shallow, with some being diffusional or only showing incipient bioturbation. There is also some laminar banding (Figure 3-7). Based on the features shown in the SPI images, it appears that the sediments have been physically disturbed with the upper portion of the sediment column being homogenized through either resuspension and subsequent deposition (e.g. prop wash) or through mechanical mixing (e.g. anchor drags, tow bridles). At many stations in the subtidal plot, aRPDs and benthic communities appear to be re-establishing themselves after a disturbance as evidenced by the shallow RPD (Figures 3-7 and 3-8) and higher proportion of lower infaunal successional seres measured from the area.

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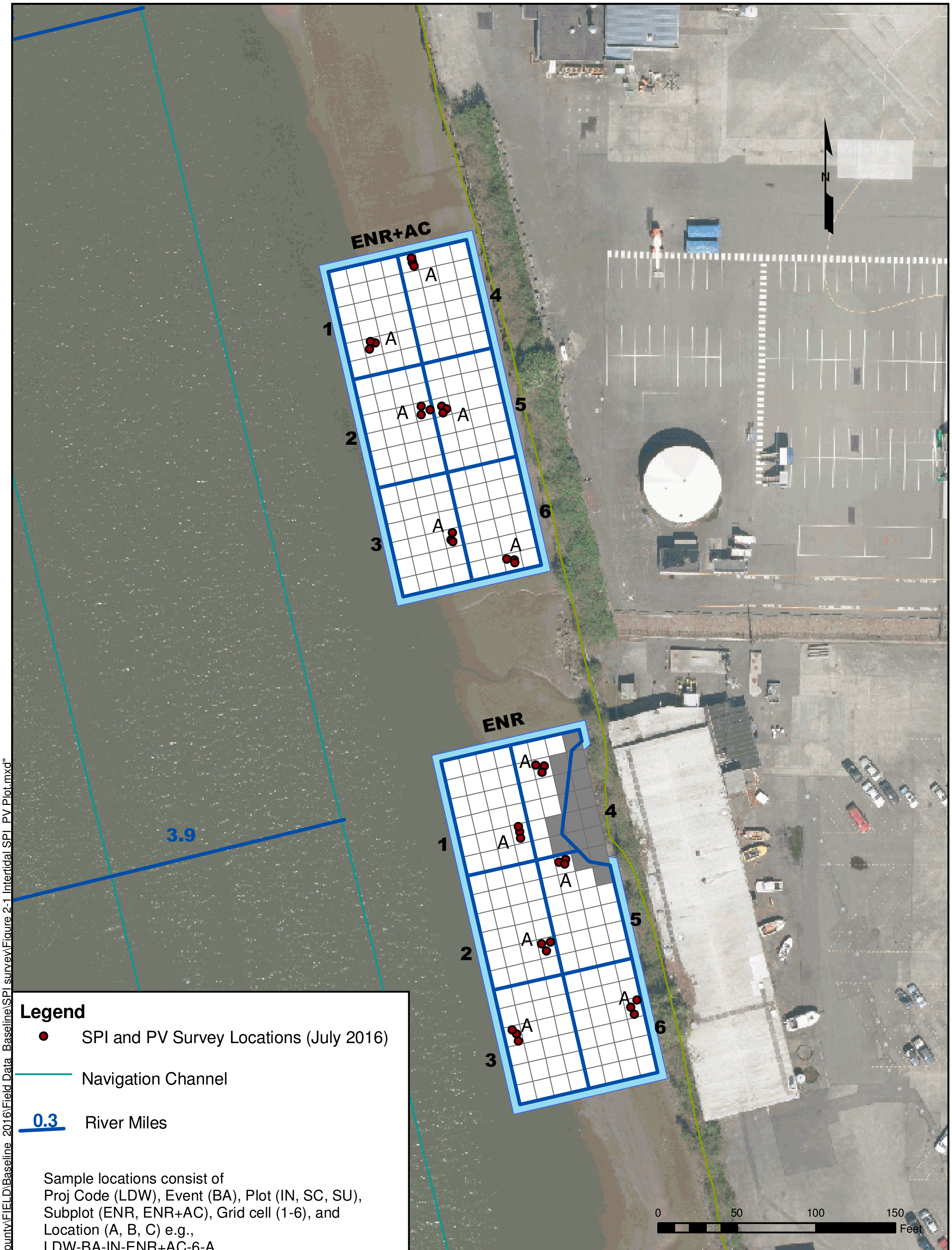
FIGURES

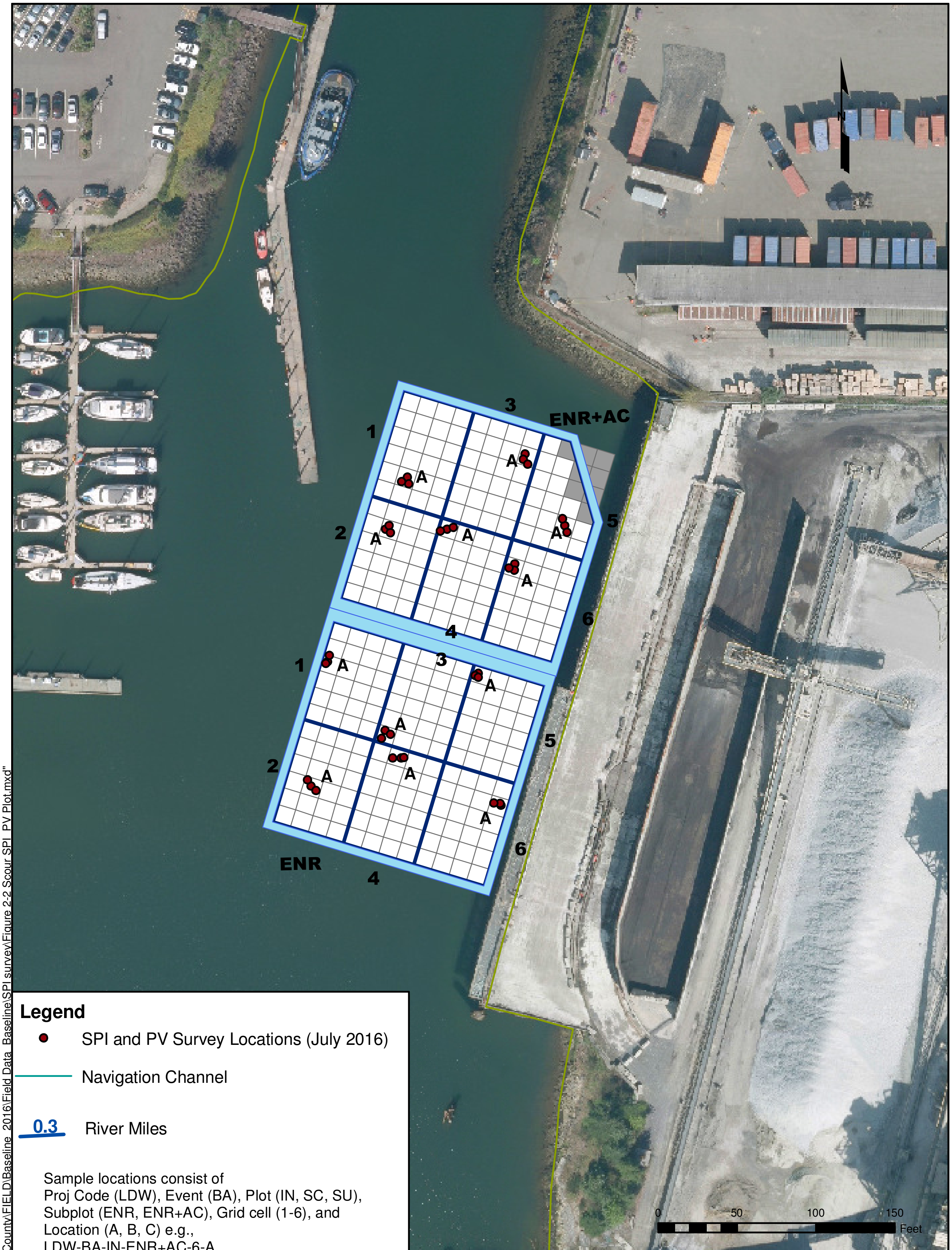


Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

ENR/AC Pilot Study
Baseline SPI Report

Figure 2-1
ENR/AC Pilot Study
Intertidal Plot

File path"P:\King County\FIELD\Baseline_2016\Field Data_Baseline\SPI survey\Figure 2-1 Intertidal SPI_PV Plot.mxd"



File path: "P:\King County\FIELD\Baseline_2016\Field Data_Baseline\SPI survey\Figure 2-2 Scour SPI_PV Plot.mxd"

Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

ENR/AC Pilot Study
Baseline SPI Report

Figure 2-2
ENR/AC Pilot Study
Scour Plot

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Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	ENR/AC Pilot Study Baseline SPI Report	Figure 2-3 ENR/AC Pilot Study Subtidal Plot

TABLES

Table 3-1. SPI Coordinates

Station/Replicate	Coordinates (SPCS WA N NAD 83 [survey feet])		Date	Time
	Northing	Easting		
LDW-BA-IN-ENR+AC-1-A-SPI-R1	194428.9	1276181.3	7/13/2016	13:17
LDW-BA-IN-ENR+AC-1-A-SPI-R2	194429.6	1276178.3	7/13/2016	13:19
LDW-BA-IN-ENR+AC-1-A-SPI-R3	194425.0	1276177.7	7/13/2016	13:21
LDW-BA-IN-ENR+AC-2-A-SPI-R1	194388.8	1276210.6	7/12/2016	17:08
LDW-BA-IN-ENR+AC-2-A-SPI-R2	194383.3	1276210.5	7/12/2016	17:11
LDW-BA-IN-ENR+AC-2-A-SPI-R3	194386.3	1276216.0	7/12/2016	17:12
LDW-BA-IN-ENR+AC-3-A-SPI-R1	194308.6	1276230.3	7/13/2016	13:27
LDW-BA-IN-ENR+AC-3-A-SPI-R2	194304.3	1276229.4	7/13/2016	13:28
LDW-BA-IN-ENR+AC-3-A-SPI-R3	194303.2	1276230.6	7/13/2016	13:30
LDW-BA-IN-ENR+AC-4-A-SPI-R1	194479.7	1276204.9	7/13/2016	13:35
LDW-BA-IN-ENR+AC-4-A-SPI-R2	194482.4	1276204.3	7/13/2016	13:38
LDW-BA-IN-ENR+AC-4-A-SPI-R3	194477.3	1276206.0	7/13/2016	13:39
LDW-BA-IN-ENR+AC-5-A-SPI-R1	194388.8	1276223.5	7/12/2016	16:55
LDW-BA-IN-ENR+AC-5-A-SPI-R2	194386.9	1276226.7	7/12/2016	16:57
LDW-BA-IN-ENR+AC-5-A-SPI-R3	194384.6	1276224.2	7/12/2016	16:59
LDW-BA-IN-ENR+AC-6-A-SPI-R1	194291.5	1276269.5	7/12/2016	16:45
LDW-BA-IN-ENR+AC-6-A-SPI-R2	194292.2	1276264.6	7/12/2016	16:46
LDW-BA-IN-ENR+AC-6-A-SPI-R3	194289.8	1276269.9	7/12/2016	16:47
LDW-BA-IN-ENR-1-A-SPI-R1	194119.4	1276272.8	7/13/2016	12:57
LDW-BA-IN-ENR-1-A-SPI-R2	194122.8	1276272.1	7/13/2016	12:58
LDW-BA-IN-ENR-1-A-SPI-R3	194115.5	1276273.5	7/13/2016	12:59
LDW-BA-IN-ENR-2-A-SPI-R1	194043.9	1276289.8	7/12/2016	16:08
LDW-BA-IN-ENR-2-A-SPI-R2	194048.4	1276286.7	7/12/2016	16:11
LDW-BA-IN-ENR-2-A-SPI-R3	194049.7	1276292.4	7/12/2016	16:14
LDW-BA-IN-ENR-3-A-SPI-R1	193991.4	1276270.9	7/13/2016	13:05
LDW-BA-IN-ENR-3-A-SPI-R2	193994.0	1276268.0	7/13/2016	13:07
LDW-BA-IN-ENR-3-A-SPI-R3	193986.8	1276272.2	7/13/2016	13:08
LDW-BA-IN-ENR-4-A-SPI-R1	194160.9	1276288.4	7/12/2016	16:25
LDW-BA-IN-ENR-4-A-SPI-R2	194161.4	1276283.2	7/12/2016	16:27
LDW-BA-IN-ENR-4-A-SPI-R3	194156.9	1276287.1	7/12/2016	16:29
LDW-BA-IN-ENR-5-A-SPI-R1	194101.9	1276302.0	7/12/2016	15:55
LDW-BA-IN-ENR-5-A-SPI-R2	194100.1	1276297.7	7/12/2016	15:57
LDW-BA-IN-ENR-5-A-SPI-R3	194099.0	1276301.6	7/12/2016	15:59
LDW-BA-IN-ENR-6-A-SPI-R1	194008.3	1276343.2	7/12/2016	15:27
LDW-BA-IN-ENR-6-A-SPI-R2	194014.1	1276342.1	7/12/2016	15:45
LDW-BA-IN-ENR-6-A-SPI-R3	194013.0	1276347.2	7/12/2016	15:47
LDW-BA-IN-ENR-6-A-SPI-R4	194003.9	1276345.6	7/12/2016	15:48
LDW-BA-SC-ENR+AC-1-A-SPI-R1	211196.7	1267014.5	7/12/2016	12:07
LDW-BA-SC-ENR+AC-1-A-SPI-R2	211192.4	1267015.4	7/12/2016	12:08
LDW-BA-SC-ENR+AC-1-A-SPI-R3	211193.7	1267010.9	7/12/2016	12:09

Table 3-1. SPI Coordinates (continued)

Station/Replicate	Coordinates (SPCS WA N NAD 83 [survey feet])		Date	Time
	Northing	Easting		
LDW-BA-SC-ENR+AC-2-A-SPI-R1	211163.8	1267000.7	7/12/2016	12:37
LDW-BA-SC-ENR+AC-2-A-SPI-R2	211166.1	1267003.0	7/12/2016	12:39
LDW-BA-SC-ENR+AC-2-A-SPI-R3	211161.6	1267003.8	7/12/2016	12:41
LDW-BA-SC-ENR+AC-3-A-SPI-R1	211211.3	1267089.2	7/12/2016	12:46
LDW-BA-SC-ENR+AC-3-A-SPI-R2	211207.9	1267087.9	7/12/2016	12:48
LDW-BA-SC-ENR+AC-3-A-SPI-R3	211204.9	1267090.7	7/12/2016	12:49
LDW-BA-SC-ENR+AC-4-A-SPI-R1	211163.9	1267039.6	7/12/2016	12:54
LDW-BA-SC-ENR+AC-4-A-SPI-R2	211162.7	1267035.4	7/12/2016	12:56
LDW-BA-SC-ENR+AC-4-A-SPI-R3	211164.9	1267043.5	7/12/2016	12:58
LDW-BA-SC-ENR+AC-5-A-SPI-R1	211166.0	1267114.2	7/12/2016	13:03
LDW-BA-SC-ENR+AC-5-A-SPI-R2	211170.4	1267112.8	7/12/2016	13:05
LDW-BA-SC-ENR+AC-5-A-SPI-R3	211161.9	1267115.8	7/12/2016	13:07
LDW-BA-SC-ENR+AC-6-A-SPI-R1	211141.8	1267082.5	7/12/2016	13:12
LDW-BA-SC-ENR+AC-6-A-SPI-R2	211137.8	1267082.2	7/12/2016	13:13
LDW-BA-SC-ENR+AC-6-A-SPI-R3	211139.1	1267079.0	7/12/2016	13:14
LDW-BA-SC-ENR-1-A-SPI-R1	211079.8	1266964.0	7/12/2016	13:25
LDW-BA-SC-ENR-1-A-SPI-R2	211083.7	1266964.9	7/12/2016	13:29
LDW-BA-SC-ENR-1-A-SPI-R3	211078.7	1266962.6	7/12/2016	13:13
LDW-BA-SC-ENR-2-A-SPI-R1	211001.0	1266953.3	7/12/2016	13:38
LDW-BA-SC-ENR-2-A-SPI-R2	210998.1	1266956.6	7/12/2016	13:40
LDW-BA-SC-ENR-2-A-SPI-R3	211004.9	1266951.2	7/12/2016	13:41
LDW-BA-SC-ENR-3-A-SPI-R1	211031.3	1266998.0	7/12/2016	13:48
LDW-BA-SC-ENR-3-A-SPI-R2	211036.3	1267000.4	7/12/2016	13:51
LDW-BA-SC-ENR-3-A-SPI-R3	211033.8	1267003.7	7/12/2016	13:52
LDW-BA-SC-ENR-4-A-SPI-R1	211018.7	1267010.4	7/12/2016	13:58
LDW-BA-SC-ENR-4-A-SPI-R2	211018.9	1267005.2	7/12/2016	13:59
LDW-BA-SC-ENR-4-A-SPI-R3	211019.0	1267012.3	7/12/2016	14:00
LDW-BA-SC-ENR-5-A-SPI-R1	211072.4	1267059.4	7/12/2016	14:11
LDW-BA-SC-ENR-5-A-SPI-R2	211071.2	1267057.5	7/12/2016	14:12
LDW-BA-SC-ENR-5-A-SPI-R3	211070.0	1267059.3	7/12/2016	14:14
LDW-BA-SC-ENR-6-A-SPI-R1	210988.8	1267073.8	7/12/2016	14:21
LDW-BA-SC-ENR-6-A-SPI-R2	210990.0	1267073.2	7/12/2016	14:22
LDW-BA-SC-ENR-6-A-SPI-R3	210990.2	1267069.4	7/12/2016	14:24
LDW-BA-SU-ENR+AC-1-A-SPI-R1	205564.2	1267896.2	7/13/2016	10:05
LDW-BA-SU-ENR+AC-1-A-SPI-R2	205567.7	1267897.9	7/13/2016	10:07
LDW-BA-SU-ENR+AC-1-A-SPI-R3	205571.6	1267895.7	7/13/2016	10:08
LDW-BA-SU-ENR+AC-2-A-SPI-R1	205501.2	1267895.6	7/13/2016	10:13
LDW-BA-SU-ENR+AC-2-A-SPI-R2	205501.7	1267897.0	7/13/2016	10:14
LDW-BA-SU-ENR+AC-2-A-SPI-R3	205495.8	1267897.3	7/13/2016	10:15
LDW-BA-SU-ENR+AC-2-A-SPI-R4	205496.5	1267897.5	7/13/2016	12:19

Table 3-1. SPI Coordinates (continued)

Station/Replicate	Coordinates (SPCS WA N NAD 83 [survey feet])		Date	Time
	Northing	Easting		
LDW-BA-SU-ENR+AC-3-A-SPI-R1	205425.4	1267922.7	7/13/2016	10:21
LDW-BA-SU-ENR+AC-3-A-SPI-R2	205429.9	1267920.8	7/13/2016	10:23
LDW-BA-SU-ENR+AC-3-A-SPI-R3	205429.1	1267918.7	7/13/2016	10:24
LDW-BA-SU-ENR+AC-3-A-SPI-R4	205428.0	1267919.4	7/13/2016	12:21
LDW-BA-SU-ENR+AC-4-A-SPI-R1	205324.7	1267939.6	7/13/2016	10:33
LDW-BA-SU-ENR+AC-4-A-SPI-R1	205325.2	1267942.6	7/13/2016	10:35
LDW-BA-SU-ENR+AC-4-A-SPI-R2	205330.5	1267941.7	7/13/2016	10:37
LDW-BA-SU-ENR+AC-5-A-SPI-R1	205264.6	1267986.5	7/13/2016	10:58
LDW-BA-SU-ENR+AC-5-A-SPI-R2	205261.2	1267986.1	7/13/2016	10:59
LDW-BA-SU-ENR+AC-5-A-SPI-R3	205262.9	1267983.0	7/13/2016	11:01
LDW-BA-SU-ENR+AC-6-A-SPI-R1	205189.0	1268008.9	7/13/2016	11:48
LDW-BA-SU-ENR+AC-6-A-SPI-R2	205192.5	1268010.3	7/13/2016	11:50
LDW-BA-SU-ENR+AC-6-A-SPI-R3	205193.8	1268007.9	7/13/2016	11:51
LDW-BA-SU-ENR-1-A-SPI-R1	205631.7	1267931.7	7/13/2016	8:35
LDW-BA-SU-ENR-1-A-SPI-R2	205636.4	1267931.5	7/13/2016	8:37
LDW-BA-SU-ENR-1-A-SPI-R3	205628.3	1267930.5	7/13/2016	8:39
LDW-BA-SU-ENR-2-A-SPI-R1	205554.9	1267944.1	7/13/2016	8:47
LDW-BA-SU-ENR-2-A-SPI-R2	205552.9	1267949.5	7/13/2016	8:48
LDW-BA-SU-ENR-2-A-SPI-R3	205558.9	1267943.5	7/13/2016	8:49
LDW-BA-SU-ENR-3-A-SPI-R1	205485.2	1267980.6	7/13/2016	8:59
LDW-BA-SU-ENR-3-A-SPI-R2	205489.5	1267980.7	7/13/2016	9:00
LDW-BA-SU-ENR-3-A-SPI-R3	205485.2	1267975.5	7/13/2016	9:02
LDW-BA-SU-ENR-4-A-SPI-R1	205412.4	1268000.3	7/13/2016	9:11
LDW-BA-SU-ENR-4-A-SPI-R2	205411.6	1268003.9	7/13/2016	9:26
LDW-BA-SU-ENR-4-A-SPI-R3	205414.6	1267998.9	7/13/2016	9:28
LDW-BA-SU-ENR-5-A-SPI-R1	205311.8	1268013.2	7/13/2016	9:37
LDW-BA-SU-ENR-5-A-SPI-R2	205307.4	1268014.7	7/13/2016	9:39
LDW-BA-SU-ENR-5-A-SPI-R3	205316.0	1268013.6	7/13/2016	9:41
LDW-BA-SU-ENR-6-A-SPI-R1	205202.4	1268048.5	7/13/2016	9:48
LDW-BA-SU-ENR-6-A-SPI-R2	205204.2	1268046.6	7/13/2016	9:51
LDW-BA-SU-ENR-6-A-SPI-R3	205201.4	1268046.7	7/13/2016	9:53

Table 3-2. SPI Results from the Intertidal Plot

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-IN-ENR+AC-1-A-SPI-R1	2.25	1.33	3.20	1.87	1.01	>4	>4	2	IND	0
LDW-BA-IN-ENR+AC-1-A-SPI-R2	3.09	2.47	4.32	1.85	IND	>4	>4	3	IND	0
LDW-BA-IN-ENR+AC-1-A-SPI-R3	2.18	1.85	2.69	0.84	IND	>4	>4	3	IND	0
LDW-BA-IN-ENR+AC-2-A-SPI-R1	9.61	9.08	10.04	0.95	2.11	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR+AC-2-A-SPI-R2	8.68	8.46	8.84	0.37	2.71	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR+AC-2-A-SPI-R3	11.43	11.20	11.94	0.74	1.99	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR+AC-3-A-SPI-R1	8.45	7.48	8.78	1.30	0.83	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR+AC-3-A-SPI-R2	10.50	10.04	10.84	0.81	2.04	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR+AC-3-A-SPI-R3	11.42	10.90	11.71	0.81	3.32	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-4-A-SPI-R1	9.05	8.78	9.43	0.65	2.01	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-4-A-SPI-R2	10.25	9.91	10.44	0.53	2.03	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-4-A-SPI-R3	10.05	9.66	10.74	1.08	1.58	>4	>4	2	2->3	0
LDW-BA-IN-ENR+AC-5-A-SPI-R1	12.42	12.00	12.85	0.85	1.82	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-5-A-SPI-R2	10.39	9.83	10.96	1.12	2.02	>4	>4	2	2->3	0
LDW-BA-IN-ENR+AC-5-A-SPI-R3	14.33	14.10	14.77	0.67	2.24	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-6-A-SPI-R1	11.70	11.31	12.03	0.72	1.51	>4	>4	2	1->2	0
LDW-BA-IN-ENR+AC-6-A-SPI-R2	9.17	8.80	9.46	0.66	1.46	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR+AC-6-A-SPI-R3	14.60	14.19	15.29	1.10	1.86	>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-1-A-SPI-R1	10.35	9.81	10.86	1.05	2.85	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-1-A-SPI-R2	10.02	9.55	10.38	0.84	2.46	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-1-A-SPI-R3	12.88	12.24	13.13	0.89	3.07	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-2-A-SPI-R1	10.17	9.86	10.56	0.69	2.27	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-2-A-SPI-R2	4.52	3.52	4.90	1.38	IND	>4	>4	3	IND	0
LDW-BA-IN-ENR-2-A-SPI-R3	13.53	12.31	14.04	1.73	IND	>4	>4	3	IND	0

Table 3-2. SPI Results from the Intertidal Plot (continued)

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-IN-ENR-3-A-SPI-R1	4.62	4.18	5.02	0.84	IND	>4	>4	3	IND	0
LDW-BA-IN-ENR-3-A-SPI-R2	6.51	5.52	7.31	1.79	4.64	>4	>4	3	IND	0
LDW-BA-IN-ENR-3-A-SPI-R3	13.96	13.67	14.23	0.56	2.44	>4	>4	3	IND	0
LDW-BA-IN-ENR-4-A-SPI-R1	10.83	10.58	11.12	0.53	2.51	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-4-A-SPI-R2	8.30	7.83	8.84	1.01	2.84	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-4-A-SPI-R3	10.99	10.57	11.62	1.05	2.69	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-5-A-SPI-R1	8.75	8.45	9.66	1.21	1.90	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-5-A-SPI-R2	11.71	11.41	12.21	0.81	2.63	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-5-A-SPI-R3	10.53	9.53	11.28	1.74	IND	3-2/>4	>4	2	1 on 3	0
LDW-BA-IN-ENR-6-A-SPI-R1A.jpg	9.95	9.37	10.90	1.53	IND	3-2/>4	>4	2	2->3	0
LDW-BA-IN-ENR-6-A-SPI-R2.jpg	10.69	10.47	10.92	0.45	1.53	3-2/>4	>4	2	IND	0
LDW-BA-IN-ENR-6-A-SPI-R3.jpg	10.18	9.98	10.41	0.43	1.46	3-2/>4	>4	2	2	0
LDW-BA-IN-ENR-6-A-SPI-R4.jpg	9.71	9.53	9.89	0.36	1.28	3-2/>4	>4	2	2	0
Mean	9.67	9.18	10.15	0.97	2.17					
Std Dev	3.08	3.16	3.00	0.43	0.76					
N	37.00	37.00	37.00	37.00	30.00					
Min	2.18	1.33	2.69	0.36	0.83					
Max	14.60	14.19	15.29	1.87	4.64					

Table 3-3. SPI Results from the Scour Plot

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-SC-ENR+AC-1-A-SPI-R1	8.60	7.97	9.16	1.18	1.27	1-0/>4	>4	-2	1 on 3	0
LDW-BA-SC-ENR+AC-1-A-SPI-R2	8.90	7.96	9.73	1.77	1.84	1-0/>4	>4	-1	2	0
LDW-BA-SC-ENR+AC-1-A-SPI-R3	12.91	12.42	13.26	0.84	1.79	1-0/>4	>4	-1	2	0
LDW-BA-SC-ENR+AC-2-A-SPI-R1	14.54	14.23	14.84	0.61	1.61	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-2-A-SPI-R2	14.42	14.17	15.05	0.88	1.96	4-3/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-2-A-SPI-R3	14.42	14.10	14.58	0.48	1.24	4-3/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-3-A-SPI-R1	15.38	14.92	15.90	0.97	1.21	3-2/>4	>4	0	1 on 3	0
LDW-BA-SC-ENR+AC-3-A-SPI-R2	16.14	15.64	16.81	1.17	1.72	3-2/>4	>4	0	1 on 3	0
LDW-BA-SC-ENR+AC-3-A-SPI-R3	14.21	13.89	14.62	0.73	1.00	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-4-A-SPI-R1	14.94	14.54	15.24	0.71	1.29	4-3/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-4-A-SPI-R2	15.82	15.38	16.22	0.84	1.64	4-3/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR+AC-4-A-SPI-R3	14.64	14.17	15.01	0.84	1.77	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR+AC-5-A-SPI-R1	15.47	14.43	17.30	2.88	1.38	3-2/>4	>4	-5	1 on 3	0
LDW-BA-SC-ENR+AC-5-A-SPI-R2	14.54	14.30	15.08	0.78	1.86	3-2/>4	>4	0	1 on 3	0
LDW-BA-SC-ENR+AC-5-A-SPI-R3	14.68	13.00	16.07	3.07	2.38	3-2/>4	>4	-2	1 on 3	0
LDW-BA-SC-ENR+AC-6-A-SPI-R1	0.29	0.09	1.84	1.75	IND	-5 - -6	>4	-6	IND	0
LDW-BA-SC-ENR+AC-6-A-SPI-R2	2.51	1.08	3.30	2.22	1.37	-6/3-2	>4	-6	1	0
LDW-BA-SC-ENR+AC-6-A-SPI-R3	7.08	6.01	8.00	1.99	1.90	3-2/>4	>4	0	1 on 3	0
LDW-BA-SC-ENR-1-A-SPI-R1	15.88	15.37	16.12	0.75	2.43	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-1-A-SPI-R2	14.20	13.84	14.82	0.98	1.99	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-1-A-SPI-R3	15.00	14.51	15.23	0.72	2.16	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-2-A-SPI-R1	15.37	14.97	15.54	0.58	2.46	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-2-A-SPI-R2	14.92	14.42	15.20	0.78	2.58	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-2-A-SPI-R3	15.43	15.08	16.04	0.95	2.31	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-3-A-SPI-R1	15.67	15.31	16.15	0.84	2.46	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-3-A-SPI-R2	14.39	13.70	14.88	1.18	2.80	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-3-A-SPI-R3	16.04	15.72	16.07	0.35	2.74	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-4-A-SPI-R1	16.42	16.15	16.61	0.46	2.45	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-4-A-SPI-R2	15.86	15.46	16.27	0.81	1.76	>4	>4	2	1 on 3	0

Table 3-3. SPI Results from the Scour Plot (continued)

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-SC-ENR-4-A-SPI-R3	15.88	15.34	16.41	1.07	2.82	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-5-A-SPI-R1	15.22	14.25	15.63	1.38	2.26	>4	>4	0	1 on 3	0
LDW-BA-SC-ENR-5-A-SPI-R2	15.58	15.17	15.83	0.66	2.46	>4	>4	2	1 on 3	0
LDW-BA-SC-ENR-5-A-SPI-R3	14.94	14.30	15.20	0.89	2.29	>4	>4	-4	1 on 3	0
LDW-BA-SC-ENR-6-A-SPI-R1	16.56	15.92	17.25	1.33	2.63	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-6-A-SPI-R2	15.89	15.40	17.45	2.05	2.76	3-2/>4	>4	1	1 on 3	0
LDW-BA-SC-ENR-6-A-SPI-R3	14.37	13.50	14.97	1.47	2.16	3-2/>4	>4	1	1 on 3	0
Mean	13.81	13.24	14.38	1.14	2.02					
Std Dev	3.71	3.82	3.57	0.64	0.52					
N	36.00	36.00	36.00	36.00	35.00					
Min	0.29	0.09	1.84	0.35	1.00					
Max	16.56	16.15	17.45	3.07	2.82					

Table 3-4. SPI Results from the Subtidal Plot

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-SU-ENR+AC-1-A-SPI-R1	13.41	12.26	14.17	1.90	IND	3-2/>4	>4	2	1->2	
LDW-BA-SU-ENR+AC-1-A-SPI-R2	14.77	13.95	15.25	1.30	1.37	3-2/>4	>4	2	1->2	0
LDW-BA-SU-ENR+AC-1-A-SPI-R3	15.26	14.88	15.90	1.02	2.75	3-2/>4	>4	2	1->2	0
LDW-BA-SU-ENR+AC-2-A-SPI-R1	21.61	21.63	21.63	0.00	2.34	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-2-A-SPI-R2	14.29	13.17	15.73	2.55	IND	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-2-A-SPI-R3	15.29	14.77	15.96	1.19	3.02	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-2-A-SPI-R4	13.26	11.18	14.51	3.33	2.92	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-3-A-SPI-R1	11.33	10.36	12.74	2.38	IND	3-2/>4	>4	2	2	0
LDW-BA-SU-ENR+AC-3-A-SPI-R2	13.07	12.42	14.08	1.66	1.97	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-3-A-SPI-R3	21.12	19.50	21.63	2.13	1.85	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-3-A-SPI-R4	15.79	15.21	16.18	0.97	IND	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-4-A-SPI-R1	17.47	16.42	18.19	1.77	0.93	>4	>4	2	1	0
LDW-BA-SU-ENR+AC-4-A-SPI-R2	16.31	14.58	17.09	2.51	0.46	>4	>4	2	1	0
LDW-BA-SU-ENR+AC-4-A-SPI-R3	13.13	10.06	14.95	4.89	0.24	>4	>4	2	1	0
LDW-BA-SU-ENR+AC-5-A-SPI-R1	8.98	8.62	9.14	0.52	0.89	>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-5-A-SPI-R2	10.02	9.72	10.53	0.81	0.60	>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-5-A-SPI-R3	10.25	9.95	10.76	0.81	1.18	>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-6-A-SPI-R1	13.48	12.29	14.16	1.88	1.06	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-6-A-SPI-R2	17.75	16.64	18.78	2.13	0.53	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR+AC-6-A-SPI-R3	14.95	14.36	16.06	1.70	0.66	3-2/>4	>4	2	1 on 3	0
LDW-BA-SU-ENR-1-A-SPI-R1	5.78	5.45	6.11	0.66	1.33	>4	>4	2	2	0
LDW-BA-SU-ENR-1-A-SPI-R2	10.38	8.83	11.82	3.00	0.91	>4	>4	2	2	0
LDW-BA-SU-ENR-1-A-SPI-R3	7.41	6.11	8.16	2.05	1.49	3-2/>4	>4	2	2	0
LDW-BA-SU-ENR-2-A-SPI-R1	10.89	10.41	11.16	0.75	1.39	>4	>4	2	2	0
LDW-BA-SU-ENR-2-A-SPI-R2	10.75	9.83	12.20	2.36	1.65	>4	>4	2	2	0
LDW-BA-SU-ENR-2-A-SPI-R3	12.98	11.71	15.05	3.35	1.48	>4	>4	2	2	0
LDW-BA-SU-ENR-3-A-SPI-R1	10.66	10.47	11.07	0.61	1.39	>4	>4	2	2	0
LDW-BA-SU-ENR-3-A-SPI-R2	10.50	9.75	10.82	1.07	1.07	>4	>4	2	2	0
LDW-BA-SU-ENR-3-A-SPI-R3	9.40	9.03	9.72	0.69	0.89	>4	>4	2	1 on 3	0

Table 3-4. SPI Results from the Subtidal Plot (continued)

Station/Replicate	Mean Penetration (cm)	Minimum Penetration (cm)	Maximum Penetration (cm)	Boundary Roughness (cm)	Apparent RPD (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Infaunal Successional Stage	Methane
LDW-BA-SU-ENR-4-A-SPI-R1	9.85	8.88	10.90	2.02	1.16	>4	>4	0	1	0
LDW-BA-SU-ENR-4-A-SPI-R2	9.80	9.37	10.27	0.89	1.75	>4	>4	0	1	0
LDW-BA-SU-ENR-4-A-SPI-R3	11.91	11.22	12.37	1.15	1.47	>4	>4	1	1	0
LDW-BA-SU-ENR-5-A-SPI-R1	10.71	9.11	11.48	2.36	0.50	>4	>4	1	1->2	0
LDW-BA-SU-ENR-5-A-SPI-R2	9.86	9.32	10.53	1.21	0.33	>4	>4	0	2	0
LDW-BA-SU-ENR-5-A-SPI-R3	9.73	9.37	9.98	0.61	0.68	>4	>4	0	2	0
LDW-BA-SU-ENR-6-A-SPI-R1	13.58	13.06	14.28	1.21	1.34	>4	>4	1	1 on 3	0
LDW-BA-SU-ENR-6-A-SPI-R2	12.76	12.11	13.41	1.30	0.72	>4	>4	0	1 on 3	0
LDW-BA-SU-ENR-6-A-SPI-R3	14.46	14.10	14.77	0.66	0.67	>4	>4	0	1 on 3	0
Mean	12.71	11.85	13.46	1.62	1.26					
Std Dev	3.40	3.36	3.44	0.99	0.71					
N	38.00	38.00	38.00	38.00	34.00					
Min	5.78	5.45	6.11	0.00	0.24					
Max	21.61	21.63	21.63	4.89	3.02					

YEAR 1

YEAR 1 SPI/PV DATA REPORT

Enhanced Natural Recovery/Activated Carbon Pilot Study
Lower Duwamish Waterway

Prepared for
Wood Environment & Infrastructure Solutions, Inc.

Prepared by

integral consulting inc.

1205 West Bay Drive NW
Olympia, WA 98502

December 4, 2018

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ACRONYMS AND ABBREVIATIONS

AC	activated carbon
aRPD	apparent redox potential discontinuity
BES	Browning Environmental Services
DGPS	digital global positioning system
ENR	enhanced natural recovery
ENR+AC	enhanced natural recovery amended with activated carbon
GAC	granular activated carbon
GUI	graphical use interface
Integral	Integral Consulting Inc.
LDW	Lower Duwamish Waterway
PCB	polychlorinated biphenyl
RSS	Research Support Services
SWI	sediment-water interface
SLR	single-lens reflex
SPI/PV	sediment profile imaging and plan view

1 INTRODUCTION

1.1 BACKGROUND

The Lower Duwamish Waterway Group is conducting a pilot study of an innovative sediment technology in the field to evaluate the potential effectiveness of the technology in the Lower Duwamish Waterway (LDW). The study will determine whether enhanced natural recovery (ENR) amended with activated carbon (AC) can be successfully used to decrease bioavailability of contaminants in sediment in the LDW. The study will compare the effectiveness of ENR amended with AC (ENR+AC) against that of ENR without added AC. This will be tested in three habitat types: the subtidal, the intertidal, and an area where vessel scour is possible. For the purposes of this project, ENR involves the placement of a thin layer of clean material over subtidal or intertidal sediments. ENR+AC involves the placement of a thin layer of clean material augmented with AC over subtidal or intertidal sediments.

This pilot study was specified under the Second Amendment (July 2014) to the Administrative Order on Consent (Order) for Remedial Investigation/Feasibility Study for the LDW, CERCLA Docket No. 10-2001-0055, issued on December 20, 2000.

The goals of the pilot study, as stated in the Order Amendment, are the following:

- Verify that ENR+AC can be successfully applied in the LDW by monitoring physical placement success (uniformity of coverage and percent of carbon in a placed layer).
- Evaluate performance of ENR+AC compared to ENR alone in locations with a range of polychlorinated biphenyl (PCB) concentrations.
- Assess potential impacts to the benthic community in ENR+AC compared to ENR alone.
- Assess changes in bioavailability in ENR+AC compared to ENR alone.
- Assess the stability of ENR and ENR+AC in scour areas (such as berthing areas).

The sediment profile imaging monitoring work described in this report was performed consistent with the *Quality Assurance Project Plan* (Amec et al. 2016a).

1.2 GOAL OF THE YEAR 1 SEDIMENT PROFILE IMAGING/PLAN VIEW SURVEY

This Year 1 sediment profile imaging/plan view (SPI/PV) survey is one of several methods used to address DQO-2: Evaluate the stability of ENR and ENR+AC materials in Years 1, 2 and 3 (Amec et al. 2016a). Specifically, the goal of the Year 1 SPI/PV survey of the pilot project is to collect information on the stability of the ENR and ENR+AC materials. Measurements collected during the SPI/PV survey to assess ENR and ENR+AC materials' stability are visual observations of physical sediment properties such as grain size, layering, and mixing that would indicate the presence of the ENR and ENR+AC materials with reference to baseline and Year 0 conditions. The extent of overlying sediment deposition on the ENR and ENR+AC materials was also assessed. By noting the presence and distribution of biota and biogenic structures in the SPI/PV images in comparison to previous surveys, the Year 1 SPI/PV results will also be used to assess the extent of benthic community recolonization of the ENR/AC subplots.

2 METHODS

2.1 FIELD COLLECTIONS

The Year 1 SPI/PV survey of the LDW pilot areas was conducted on March 29 and 30, 2018. The Subtidal plot was sampled on March 29, the Intertidal plot was sampled on March 29 and 30, and the Scour plot was sampled March 30.

The surveys were conducted aboard the R/V Carolyn Dow, owned and operated by Research Support Services (RSS) of Bainbridge Island, WA. All positioning and navigation during the survey was conducted by RSS using a digital global positioning system (DGPS). Scientists from Amec Foster Wheeler[1] provided oversight of navigation and positioning during the survey as well as record keeping. Scientists from Browning Environmental Services (BES) operated the sediment profile and plan view camera apparatus, kept field notes, and ensured successful image acquisition.

A total of 72 stations, 24 from each pilot plot, were occupied using the SPI/PV camera during the Year 1 monitoring event. At each station, the research vessel was piloted to the target location and the SPI/PV system was lowered to the sediment bed only when within 2 meters of the target location. A minimum of three replicate image sets were collected at each target location. Therefore, accounting for triplicate image sets, a total of 72 SPI/PV images were collected at each pilot plot. For all pilot plots, the 24 stations were apportioned such that 12 stations were occupied in the ENR-only subplot and 12 stations were occupied in the ENR+AC subplot. The 12 stations were collected from “A” and “B” cells during the Year 1 sampling event. The SPI/PV locations for each plot, including replicates, are shown in Figures 2-1, 2-2, and 2-3. The SPI/PV images are provided electronically in Exhibit 1 (provided as DVDs 1, 2, and 3).

Acquisition of high-resolution sediment profile images was accomplished using a Nikon D7100 digital single-lens reflex (SLR) camera with a 24.1-megapixel image sensor mounted inside an Ocean Imaging Model 3731 pressure housing system. Camera settings were f8, ISO 640, and 1/320 shutter speed. A total of 216 sediment profile images were selected for analysis (3 replicate images from each of 72 stations).

Plan view images were collected using a Nikon D7100 SLR camera with a 24.1-megapixel image sensor mounted inside an Ocean Imaging Model DSC2400 camera housing. For the baseline SPI/PV survey, a focal distance of 3 feet was utilized. However, based on the results of the baseline SPI/PV survey and higher turbidity levels expected in the Duwamish Waterway during

[1] Amec Foster Wheeler is now Wood Environment & Infrastructure Solutions, Inc.

spring run-off events, a shorter trigger wire of 2 feet was utilized to minimize the focal length through turbid water during Year 1. This decreased the effective area covered by the PV images but allowed increased clarity of the sediment bed features. In the subtidal and some intertidal areas, ambient turbidity prevented clear images from being collected. Also, turbidity clouds generated from the replicate point sampling often negatively affected the second and third replicate PV images collected at a target station. Throughout the survey, all images were downloaded in the field by BES to ensure successful image acquisition.

2.2 SEDIMENT PROFILE AND PLAN VIEW IMAGE ANALYSIS

Integral conducted the analysis and reporting of the Year 1 SPI/PV survey images. Integral used its integrated, MATLAB-based image analysis software (iSPI v1.1) to analyze the Year 1 SPI and PV images. The image files along with the metadata-containing Microsoft® Excel files generated during the field survey are imported directly into iSPI for analysis. A menu-structured graphical use interface (GUI) in iSPI allows the image analyst to measure and/or add descriptive comments for key imaged features (Figure 2-4). The draft data are stored in the system for review by a senior scientist. Following the QA check of all measured and descriptive parameters, the SPI/PV data set is compiled and identified as final; the data can then be evaluated and exported as desired.

The iSPI software facilitates and standardizes the measurement, storage, and QA review of data from SPI and PV images. However, the approach and underlying interpretive rationale used to identify and measure the suite of parameters and features observed in the images (e.g., grain size, aRPD depth, infaunal successional stage) is identical to the approach used for the Baseline and Year 0 surveys and the results can be compared across surveys. The overall image analysis approach and interpretive framework are detailed in the previous SPI/PV data reports for this project (e.g., Construction Report Attachment 5 [Amec et al. 2018), and are not repeated here.

Specific to the QAPP requirements for this study, the Year 1 SPI/PV image analysis included:

1) visually identifying ENR and ENR+AC layers in the SPI images, and if present, measuring the layer thickness if the SPI camera penetrated the ENR material
2) noting the presence and distribution of GAC in the images, if observed
3) noting and scoring (low, medium, high) the apparent surface roughness in each PV image
4) measuring the size and depth of all feeding voids observed in each SPI image.[2]

[2] Feeding voids are formed by subsurface deposit-feeding polychaetes and are indicative of higher order successional stage benthic infauna presence; examples of feeding voids can be seen in Figure 3-2 (image Y1-IN-ENR-1-A-R3).

3 RESULTS

The Year 1 SPI and PV survey image analysis results/observations are provided for each plot (Intertidal, Scour, and Subtidal) and subplot treatment (ENR and ENR+AC) in Tables 3-1 through 3-6. In each case, the SPI results are presented in the "a" table the PV results are in the "b" table.

The results for each plot and subplot treatment are summarized in the sections that follow.

3.1 INTERTIDAL PLOT

The sediment texture, e.g., the grain-size major mode, observed in the SPI images from the intertidal plot (both subplots) vary widely from predominately silt through fine, medium, coarse sands and into gravels, < -1 phi units, as indicated the Tables 3-1a and 3-2a. This apparently reflects the ENR materials placed there combined with inputs of ambient fine-grained sediments since construction.

3.1.1 Intertidal ENR Subplot

Evidence of the ENR material (i.e., sands and gravels) was observed in at least one SPI replicate from all twelve stations sampled in the intertidal ENR subplot. Figure 3-1 shows three SPI images which illustrate the range of textures and ENR material and ambient sediment mixtures observed in this subplot. Table 3-1a includes a column noting these textures. Table 3-1a also includes an ENR Layer Thickness column. In all cases where the ENR material was evident in an image, it extended to the bottom of the SPI prism window and so is noted as > P (greater than penetration) in the data tables. The average penetration depth (cm) for each image is also included in the tables. Images in which ENR material was not evident are indicated by an LNA (layer not apparent) in the table. It is likely that ENR material is present below the depth of camera penetration for the 10 of 36 images from this subplot when ENR was not apparent. The image from station Y1-IN-ENR-6-B in Figure 3-2 is an example of a SPI image when ENR is not evident. Figure 3-3 is a PV image from the same station and clearly shows the presence ENR gravel and sands on the sediment surface. PV images from all stations where the ENR material was not seen in all SPI replicates (stations IN-ENR 3-B, 4-B, 5-A, 5-B, 6-A, and 6-B, Table 3-1a) show the presence of coarse-grained material (sand and gravel) on the sediment surface (Table 3-1b). Finally, the SPI prism penetration depth for this subplot averaged 5.1 cm (Table 3-7). This is notably less than the baseline average depth of 9.7 cm and further points to the presence of coarse-grained ENR material throughout the area below the prism penetration depth where coarse-grained ENR material is not visible in the SPI image.

As shown in Figure 3-1, in many of the Year 1 SPI images there is visual evidence of mixing of ENR materials with ambient fine-grained sediments. This fine-grained sediment has been deposited at the site in the approximately 15 months between the Year 0 and Year 1 surveys. Some fines are also possibly being mixed upward from below the ENR layer. The mixing of ENR material and ambient sediments could be the due to both physical and biological disturbance factors. Image IN-ENR-1-A-SPI-R3 in Figure 3-2 shows several feeding voids more than 10 cm below the sediment-water interface (SWI) from infaunal deposit feeding polychaetes that move sediment particles over this depth range.

Features observed in the SPI images that indicate the presence of benthic infauna include oxidized surface sediments (aRPD), surface tube mats, worms at depth in the sediment column, and feeding voids formed by subsurface deposit feedings. Eighteen of the 36 replicate SPI images show evidence of high-order successional stage organisms (Stage 3), indicating the ENR material and ambient sediment mixture is being recolonized. The average aRPD depth for this subplot is 2.5 cm with a range of 1.1 to 3.5 cm. This is comparable to the aRPD depths measured during the baseline survey (Table 3-7). In contrast, the PV images show minimal evidence of epifauna in this intertidal plot. A thin brown algal film overlying a mixed gravel, sand, and silt bottom cover is present in many of the PV images (Tables 3-1a–b and Figure 3-3.).

3.1.2 Intertidal ENR+AC Subplot

The SPI/PV results from this subplot are similar to the intertidal ENR only subplot. Evidence of the ENR+AC layer (i.e., sands and gravels) greater than prism penetration was observed in all but two of the SPI images (Table 3-2a[3]). Both of those replicates were from Station 6-A and two of the three PV images from that location show widespread gravel (draped in silt) on the sediment surface. The SPI prism penetration depth for this subplot ranged from 2.3 to 9.0 cm with an average value of 5.6 cm, this compares to the baseline average of 9.7 cm (Table 3-7). As noted above, this points to the presence of coarse-grained ENR material just below the sediment surface throughout the area.

As at the intertidal ENR subplot, there is evidence of mixing of ENR materials with ambient fine-grained sediments at nearly all stations (Table 3-2a and Figure 3-4). While a single station, IN-ENR+AC-4-A, exhibits relatively silt-free ENR+AC material throughout the sediment profile (Figure 3-5), the other 11 locations sampled in this subplot show silts mixed with the ENR+AC material.

Fine to coarse sand-sized black particles, possibly GAC, are evident in some of the IN-ENR+AC images with sand and silt mixtures. However, black, sand-sized particles are also observed in some of the images from the IN-ENR subplot with sand and silt mixtures (Figure 3-6). This

[3] Only two, analyzable SPI images were obtained at Station LDW-Y1-IN-ENR+AC-1-A for a total of 35 SPI images from this subplot.

precludes drawing conclusions about whether the observed dark particles are GAC or natural, dark, lithic sands.

Evidence of benthic community presence and recolonization in the intertidal ENR+AC subplot is comparable to that observed for the intertidal ENR plot. The average aRPD depth for this subplot is 2.3 cm with a range from 0.4 to 3.6 cm, again this is comparable to mean aRPD depths of 2.2 cm (range of 0.8 to 4.6 cm) measured in the baseline survey (Table 3-7). About half of the SPI replicates (17 of 35) show evidence of stage 3 infauna and these subsurface deposit feeders are likely important contributors to the mixing of ENR+AC materials and the ambient and incoming sediments. As in the IN-ENR subplot, the PV images show minimal evidence of epifauna (Table 3-2b). Overall, the PV images from both subplots are similar, with surface boundary roughness values were either low or medium and brown algal mats and patches of green algae are widespread in both areas (Tables 3-1b and 3-2b).

3.2 SCOUR PLOT

The SPI/PV images from the scour plot show distinct differences in surface sediment textures between the two subplots. The upstream ENR subplot is predominately fine-grained, while surface textures in the downstream ENR+AC subplot range from gravel and sands at the downstream end, to sand and silt mixtures, and predominately fine-grained at the upstream end adjacent to the ENR subplot.

3.2.1 Scour ENR Subplot

Surface sediments captured in the SPI images from the scour ENR subplot are predominately fine-grained. While there are subfractions of sands and gravels in a number of images, the major mode evident in all replicates is either > 4 phi, silt or finer, or 4-3 phi, very fine sand, (Table 3-3a). Figure 3-7 shows three SPI images from this subplot that are predominately silt. Both image 1-A-SPI-R1 and 6-A-SPI-R1 show ENR sands within the silt matrix at depth. In 6-A-SPI-R1, gravel is also obvious within the silty surface matrix. In contrast, image 3-A-SPI-R2 shows a silt bottom with only a subtle indication of sand within the matrix at depth. This surface texture indicates a significant deposit of silt over the ENR material in the scour ENR subplot since the Year 0 survey.

Due to this predominance of fine-grained sediment in this subplot, which can visually obscure coarser material[4], ENR material is not apparent in 17 of the 36 scour ENR SPI replicates, this includes all replicates from Stations 3A, 3B, and 5B. However, review of the PV images from

[4] When the sediment matrix is a mixture of fine-grained (silts or finer) sediments and sands, the fines can visually dominate the field of view against the SPI prism window such that the fines fraction appears greater by area in the image than it actually is in the sediment column by volume.

these stations shows evidence of ENR material (gravel) at the sediment surface in at least one replicate. The mean SPI prism penetration depth for this subplot ranged from 0 to 13.5 cm with an average value of 9.3 cm (Table 3-7). This is deeper than the 5-6 cm penetration achieved in the intertidal plots and may reflect the deeper and/or more widespread overburden of silt deposited at the scour plot compared with the intertidal plot since the Year 0 survey.

The mixing of silt with the ENR materials is evident in all images from this subplot. Evidence of benthic infauna presence is also widespread in these images. Two of the images in Figure 3-7 show subsurface feeding voids and all three images show tubiculous polychaetes at the sediment surface and well-mixed, near-surface sediment layers. Stage 3 infauna are evident in 33 of the 36 replicates from this subplot, indicating the re-establishment of a subsurface benthic infaunal community in the subplot. The average aRPD depth for this subplot is 1.9 cm with a range from 1.1 to 3.2 cm, this compares closely to the mean aRPD depth of 2.0 cm and range of 1.0 to 2.8 cm measured in the baseline SPI survey (Table 3-7).

Consistent with the SPI benthic infauna observations, the PV images from the scour ENR subplot (Table 3-3b) show considerably more evidence of biological activity than those from the intertidal plots. This evidence is mostly in the form of widespread tracks and tubes, but some epifaunal organisms are also captured in the images (Figure 3-8). Reflecting the silt deposit covering the area, the reported surface roughness was low in all but four of the scour ENR PV images.

3.2.2 Scour ENR+AC Subplot

Surface sediments textures captured in the SPI images from the scour ENR+AC subplot are much more varied that those observed in the immediately adjacent ENR subplot (see Figure 2-2), ranging from gravel and sands only, to sand and silt mixtures, and to predominately silt (Figure 3-9). Two stations, 1-B and 3-B, at the northern end the subplot and furthest away from the scour ENR subplot, show cobble, gravel, and sand substrates with no significant fines subfraction. Conversely, the surface sediment at stations 4-A and 6-B, closest the ENR subplot are predominately silt. Other locations show a mix of coarse and fine-grained sediments.

ENR+AC material is evident to the bottom of the SPI images (greater than penetration (> P) in 33 of the 36 images from this subplot (Table 3-4a). Single replicate images from both station 6-A and 6-B lack evidence of ENR+AC material but the collocated PV images show some gravel at the surface suggest the material is buried and mixed with deposited silts.

The mean SPI prism penetration depth for this subplot ranged from 4.1 to 13.9 cm with an average value of 7.8 cm, less than the average of 9.3 cm at the adjoining ENR subplot, perhaps reflecting the thinner silt overburden (Table 3-7). As at other locations, where the silt is present, it is well mixed with the coarse-grained ENR+AC material (see the middle image in Figure 3-9 and left image in Figure 3-10).

Black particles, possibly GAC are subtly evident in many of the image with ENR+AC material and silt mixtures. In two images, black sand-sized, somewhat shiny particles are concentrated at different horizons. Figure 3-10 (left image) shows what may be a thin (1-3 mm), residual AC layer at the SWI station 6-A. The right image in Figure 3-10 from station 6-B shows black sand-sized particles throughout the profile, and concentrated black sands in the feeding voids that are approximately 10-13 cm below the SWI.

Evidence of subsurface deposit-feeding benthic infauna is present in 23 of the 36 images from this subplot, again indicating benthic infaunal recolonization of the area. The infaunal successional was indeterminate in the gravel and coarse-sand substrates in 11 of the 36 images. The average aRPD depth for this subplot is 1.4 cm with a range from 0.5 to 2.5 cm, this is somewhat lower than in the ENR subplot and in the baseline SPI survey for this area (Table 3-7). This may reflect somewhat higher physical disturbance here (and the related lack of silt deposition and/or accumulation) than in the adjacent subplot.

The PV image data from the scour ENR+AC subplot (Table 3-4b) also point to a more dynamic setting than the ENR subplot. Surface roughness was scored as medium in most of the images reflecting relative lack of silt cover in some areas. The presence/detection of surface tracks, tubes, and burrows was also reduced compared with the adjacent siltier setting.

3.3 SUBTIDAL PLOT

For the most part, the SPI/PV images from the subtidal plot show surface sediments are mixtures of ENR materials and silt. The ENR+AC material is not evident in grid cells 5 and 6 in the ENR+AC subplot (Figure 2-3) and has reportedly been disturbed by barge chain dragging (Amec et al. 2016b).

3.3.1 Subtidal ENR Subplot

Surface sediments captured in the SPI images from the subtidal ENR subplot are predominately mixtures of ENR sands and silts (Table 3-5a). The SPI data set consists of 33 images, no SPI images were obtained at station 2-A. Figure 3-11 shows the range of textures observed from stations 1-A through 5-B. The observed sand and silt mixtures over the entire profile notably contrasts with the predominately silt substrate observed in this subplot during the baseline survey, so it is inferred that this surface texture represents ambient silts mixed into the ENR material. This mixed silt and ENR material matrix exceeds prism penetration at all survey locations, except for station 6-A. The ENR layer thickness was less than penetration in two of the three replicates at station 6-A (Figure 3-12) equaling about 3 cm and 13 cm in those images.

The prism penetration depths for this subplot were relatively shallow, as illustrated in Figure 3-11, ranging from 3.4 to 13.4 cm with an average value of 5.4 cm (Table 3-7). This is comparable to the penetration depths obtained in the intertidal plot, and less than the baseline average of

12.7 cm. This reduced penetration relative to the baseline survey further supports the inference that ENR material is present throughout the subplot. The image from station 1-B in Figure 3-11 shows a sand ripple indicating bottom shear stresses are occasionally high in this deeper channel setting. Many of the images from this subplot also show sand lag deposits at the sediment-water interface over sand and silt bottom (Table 3-5a), further pointing to periodic disturbance winnowing away the fines (i.e., from natural bottom currents or prop wash, or other anthropogenic activities, such the barge chain dragging described in the Construction Quality Assurance Project Plan Addendum 1 [Amec et al. 2016b]).

Except at stations 5-B, 6-A, and 6-B where the ENR layer appears intact and overlies the ambient silt bottom, mixed silt and sand (presumably ENR material) surface textures are present throughout this subplot (Figure 3-11 and Table 3-5a). This may be the result of both physical and biological factors. While many images were classified as indeterminate for infaunal successional stage due to limited penetration, both surface and subsurface infauna were observed, with stage 3 organisms, i.e., subsurface bioturbators, noted in 11 of the 33 images. The average aRPD depth for this subplot was 2.6 cm with a range from 1.7 to 4.3 cm, this compares to a mean aRPD depth of 1.3 cm and range of 0.2 to 3.0 cm measured in the baseline SPI survey (Table 3-7). The PV images also show evidence of infauna and epifauna presence at this subplot, with surface worm tubes and epibenthic tracks detected in 20 and 14 of the 36 PV images, respectively, and epifaunal organisms noted in 11 of the images (Table 3-5b).

3.3.2 Subtidal ENR+AC Subplot

The three SPI images in Figure 3-13 show the range of surface sediment textures observed in the subtidal ENR+AC, from all silt, through silt and sand mixture, to all sand and gravel. The ENR+AC layer exceeds prism penetration stations 1-B, 2-A, 3-A, 3-B, 4-A, and 4-B (Table 3-6a). At stations 1-A and 2-B, thin (~1–2 cm) sand layers are present over silty sand mixtures which likely represents the ENR material mixed with ambient sediments, but this cannot be concluded with certainty. At most of the SPI replicates from stations 5-A, 5-B, 6-A, and 6-B, evidence of the ENR+AC material is limited to a very thin (<1 cm) sand layers at the sediment surface (Figure 3-14 and Table 3-6a). At stations 5-A (left image in Figure 3-14) and 5-B, and replicate 6-A-R2, sediments immediately below the surface sand veneer appear to be highly, reduced (i.e. dark gray to black) muds. This suggests a relatively recent physical disturbance/scour of the ENR+AC material in these grid cells.

While fine to coarse sand-sized, dark particles, possibly GAC, are evident in some of SU-ENR+AC images, a similar density and distribution of black, sand-sized particles are observed in some of the images from the SU-ENR. As for the intertidal plot, this precludes drawing conclusions about whether the observed dark particles in the subtidal plot are GAC or natural, dark, lithic sands.

The prism penetration depths for this subplot range from 1.9 to 19.9 cm with an average value of 7.4 cm, which is deeper than penetration achieved in the subtidal ENR plot and may reflect a reduced ENR+AC layer thickness at some locations (Table 3-7). Surface lag deposits of sand and some bedforms are observed in multiple SPI image from cells one through four suggesting disturbance from high bottom shear stress and chain dragging as in the adjacent subtidal ENR subplot.

Comparable to the subtidal ENR subplot, evidence of higher-order successional infauna were observed in a third of the SPI images (12 of 36). The average aRPD depth for the subplot was 1.3 cm with a range from 0.0 to 3.8 cm (Table 3-7), this average is lower than the adjacent ENR subplot average and appears to be is due very thin aRPDs measured in recent, physically disturbed surface sediments in grid cells 5 and 6 (Table 3-6a). The PV image data is provided in Table 3-6b and is comparable to the results from the subtidal ENR plot. In addition to some evidence of infauna and epifauna in this subplot (Table 3-6b), wood and leaf debris is present in many of the PV images from this channel setting (Figure 3-15).

4 DISCUSSION

The objectives of the Year 1 SPI/PV survey were to document the presence and appearance of the ENR and ENR+AC material layers, including the distribution of GAC (if discernable) measure specific SPI/PV parameters (e.g., penetration and aRPD depths, feeding voids) in the images, and assess evidence of benthic community recolonization in each study subplot. The ENR and ENR+AC materials were readily identifiable in the SPI and PV images due to their coarse-grained nature relative the finer-grained ambient sediments. In most instances, the ENR or ENR+AC layers exceeded SPI prism penetration depths so layer thicknesses could not be determined.

4.1 INTERTIDAL PLOT

ENR material was observed or inferred to be present at all locations sampled in the intertidal plot. Where evident as a sand and gravel layer, it exceeded the depth of prism penetration, which averaged only 5-6 cm in this plot. In most images, ambient silt deposited since the Year 0 survey was mixed into the ENR material. Some images showed only ENR material with no or minimal silt subfractions. In the few images where the silt deposits overlay and was not mixed into the ENR material, silt deposit layers ranged from about 3 to 7 cm thick (Tables 3-1a and 3-2a).

Significant benthic community recolonization was evident at both intertidal subplots. The measured aRPD depths were comparable between the ENR and ENR+AC subplots (averaging 2.5 and 2.3 cm, respectively). Evidence of high-order (stage 3) successional assemblages was noted in about 1/2 of the images in both the ENR subplot and ENR+AC subplot. While burrows and the actual organisms themselves are occasionally captured in SPI images, the most common feature revealing the presence of stage 3 subsurface deposit feeders is their feeding pockets or voids.

When voids were present in SPI images[5], the image analyst tags each feeding void with a polygon that approximately traces the structure's boundary. The iSPI software can then generate a list of the number, size, and depth distribution of all feeding voids observed in the images. As specified in the QAPP (Amec et al. 2016a), voids were grouped into the following sediment depth categories: 0-2cm, 2-5 cm, 5-10 cm, and > 10cm. The bottom or deepest portion of the void determined the depth bin into which it was placed. Table 4-1 shows these data for each subplot. The intertidal plot shows comparable overall void numbers and size between the two subplots.

[5] Good examples of feeding voids can be seen in image Y1-IN-ENR-1-A-R3 included in Figure 3-2.

4.2 SCOUR PLOT

The scour ENR subplot, which is upstream of the ENR+AC subplot, shows a significant deposit of silt over the ENR material. Consequently, an ENR layer was not evident in nearly half of the SPI images and the surface texture throughout this subplot, as identified visually from the SPI images, was predominately silt. The limited SPI penetration depths, sand subfractions within the silt matrix, and the presence of silt-covered gravel in many of the PV images provide evidence that the ENR sediments were present throughout subplot underlying the silt deposit.

While the upstream portion of the scour ENR+AC subplot showed a silt deposit as in the ENR subplot, the area furthest away from the ENR subplot (downstream), showed cobble, gravel, and sand substrates with no significant fines subfraction. This suggests different sediment accumulation/transport dynamics between the two areas since the year 0 survey and could be related to vessel traffic in that northern portion of the subplot. Stations 1B and 3B in Figure 2-2 show no/minimal silt accumulation.

The scour subplots show significant evidence of benthic community re-establishment since the ENR material placement, especially in the ENR subplot. Stage 3 infauna were evident in 33 of the 36 ENR images and 23 of the 36 the ENR+AC images. The PV images from the scour plot also show evidence of widespread surface/epifaunal biological activity. The relatively high abundance of subsurface deposit feeder feeding voids in the scour plot is shown in the Table 4-1. The number and relatively large size of feeding voids in the ENR versus the ENR+AC subplot may reflect greater silt accumulation and/or lower disturbance frequency in the ENR subplot.

4.3 SUBTIDAL PLOT

ENR material was present at all locations in the subtidal ENR subplot. It was evident as sand with a significant subfraction of silt mixed in. The ENR layer thickness was generally greater than the prism penetration. At one location where the sand and gravel ENR layer could be measured, it ranged from 3 to 13 cm in thickness.

At the subtidal ENR+AC subplot, the ENR+AC material appears to have been disturbed by barge chain dragging (Amec et al. 2016b) from the locations surveyed in grid cell 5 and perhaps in grid cell 6. Thin veneers of sand are observed overlying, highly reduced silt in these images.

Benthic community re-colonization is also apparent at the subtidal plot, but it appears to be more representative of a more dynamic and disturbed channel environment. Table 4-1 shows the both number and size of voids in the subtidal plots are markedly fewer and smaller than in both the scour and intertidal areas.

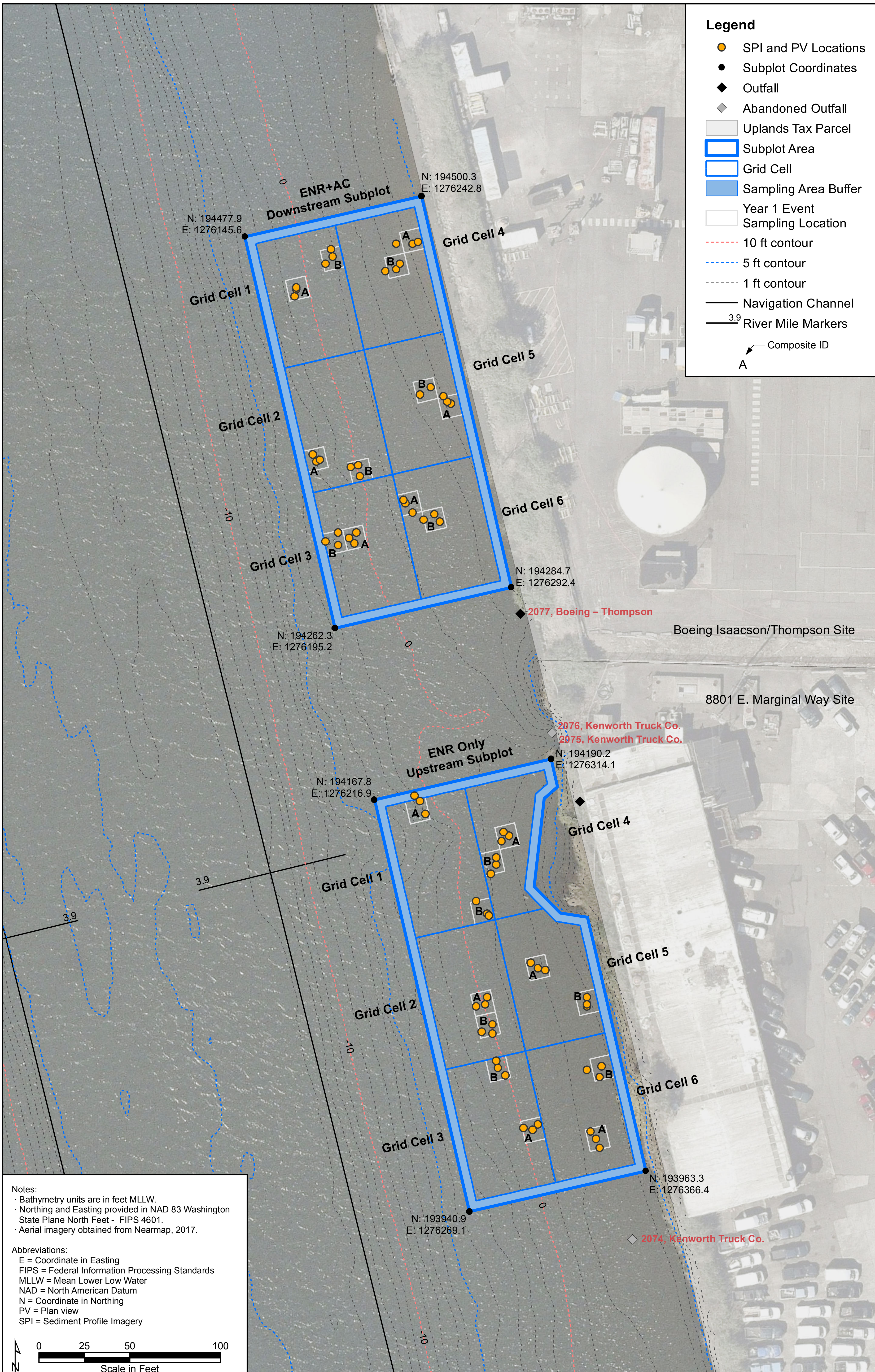
5 REFERENCES

Amec Foster Wheeler; Dalton, Olmsted & Fuglevand, Inc.; Ramboll Environ; Floyd|Snider; and Geosyntec Consultants. 2016a. Quality Assurance Project Plan, Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway. Lower Duwamish Waterway Group, Seattle, WA. February 22.

Amec Foster Wheeler; Dalton, Olmsted & Fuglevand, Inc.; Ramboll Environ; Floyd|Snider; and Geosyntec Consultants. 2016b. Construction Quality Assurance Project Plan (CQAPP) Addendum 1, Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway, ENR Layer Thickness Measurement during Construction at the Subtidal Plot and Grade Stakes at Test, Intertidal, and Scour Plots. Lower Duwamish Waterway Group, Seattle, WA. November 23.

Amec Foster Wheeler; Dalton, Olmsted & Fuglevand, Inc.; Ramboll Environ; Floyd|Snider; and Geosyntec Consultants. 2018. Quality Assurance Project Plan Construction Report, Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway, Lower Duwamish Waterway. Lower Duwamish Waterway Group, Seattle, WA. June.

FIGURES



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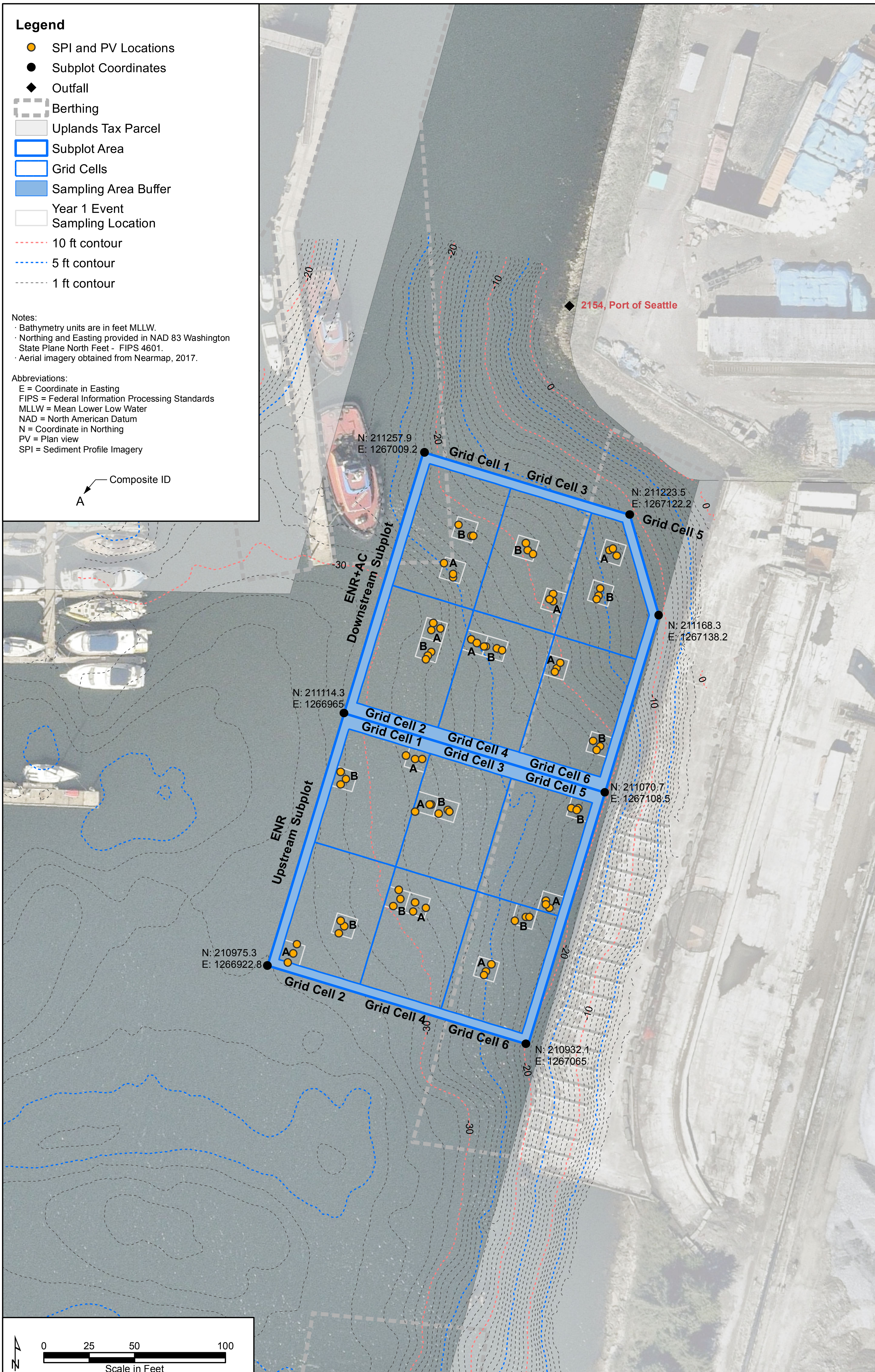
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 2-1
ENR/AC Pilot Study
Intertidal Plot

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\ENR AC Draft Year 1 Monitoring Report\Figure 2-1 ENR AC Pilot Study Intertidal Plot.mxd
11/26/2018



Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Draft** **Year 1 Monitoring Report** Lower Duwamish Waterway	Figure 2-2 ENR/AC Pilot Study Scour Plot

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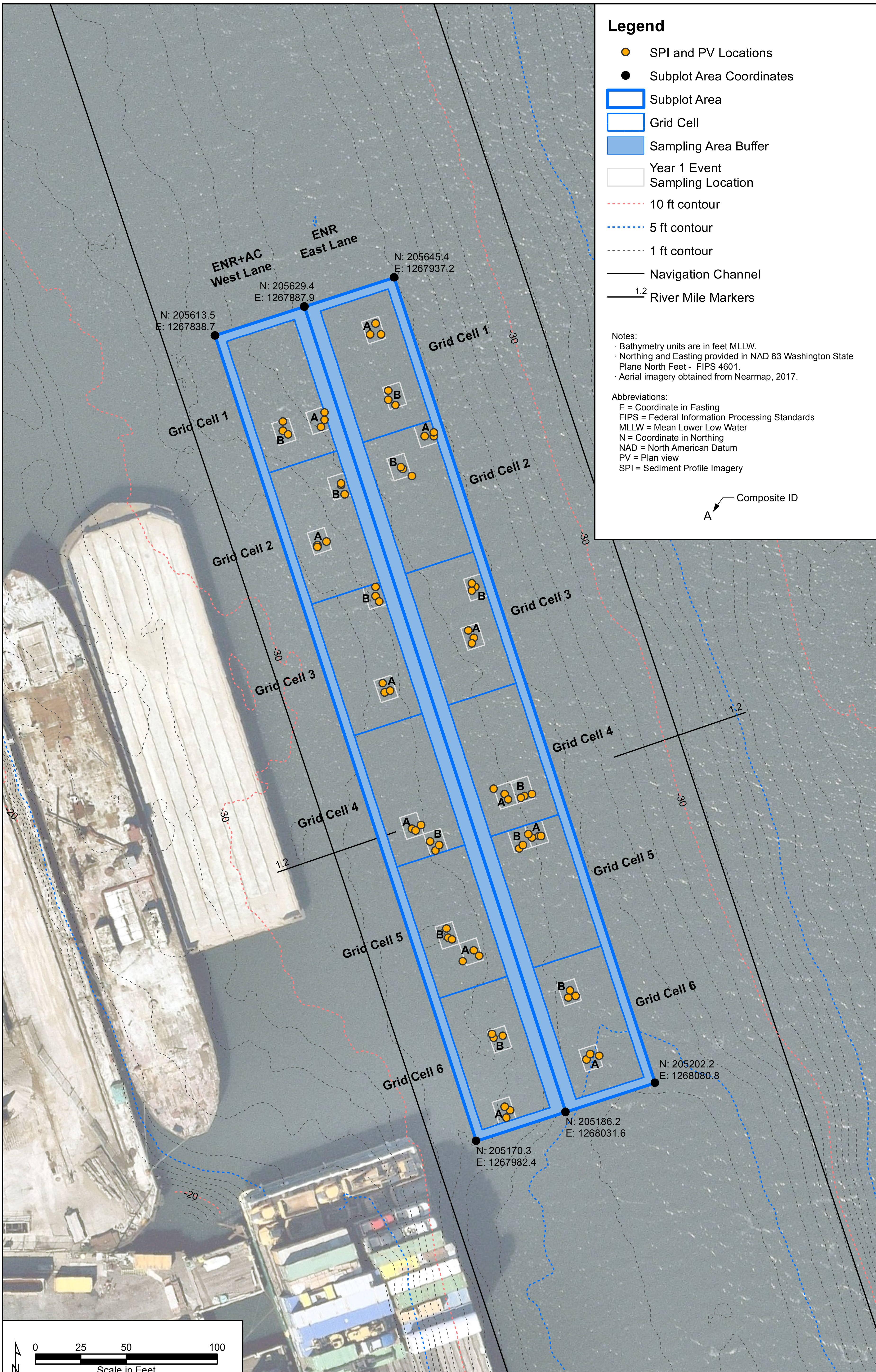

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Figure 2-3
ENR/AC Pilot Study
Subtidal Plot

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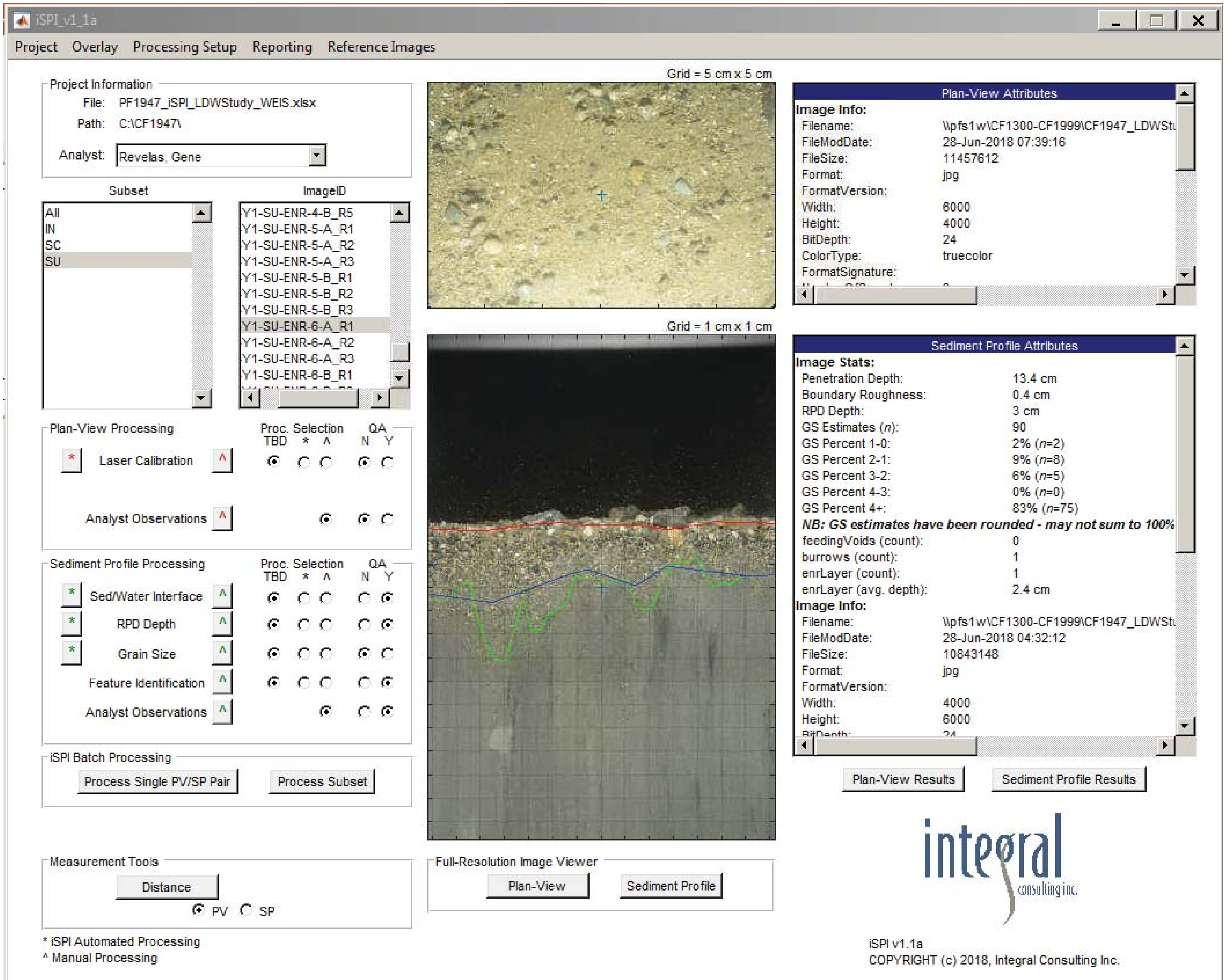

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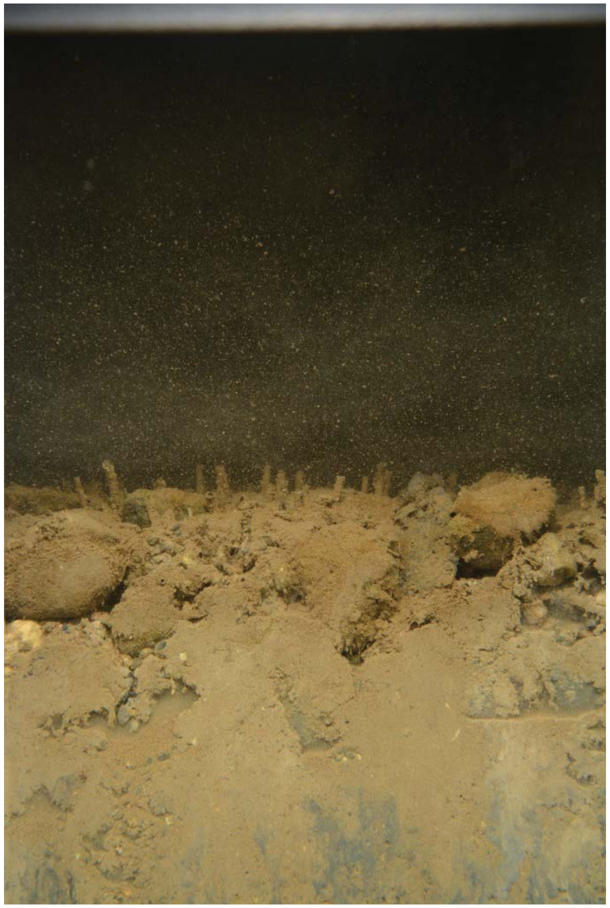
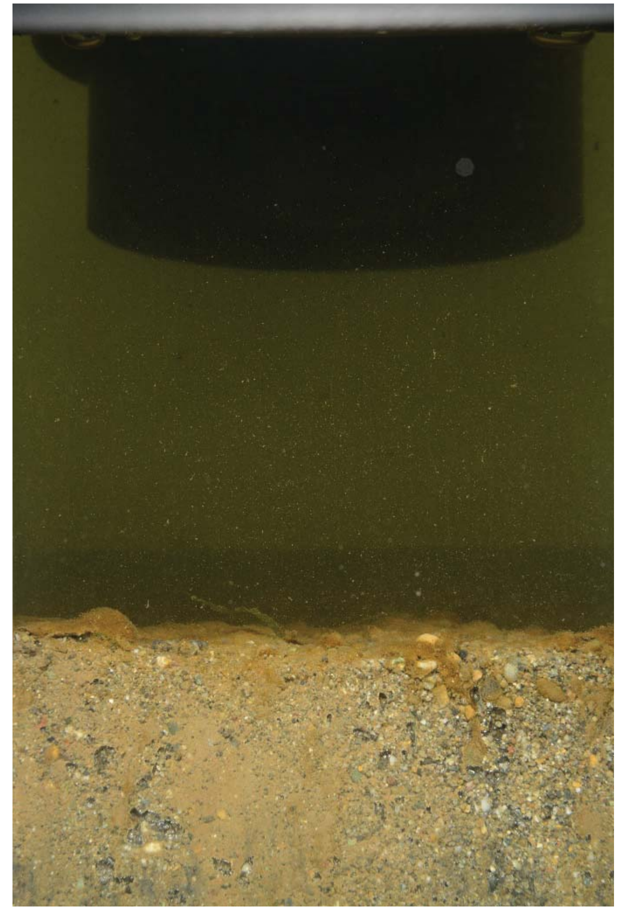
Figure 2-4.
iSPI v1.1a SPI/PV Image Analysis User Interface
ENR/AC Pilot Study Lower Duwamish Waterway



Y1 -IN-ENR-1-A-SPI-R2

Y1-IN-ENR-2-A-SPI-R2



Y1-IN-ENR-4-A-SPI-R1

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Figure 3-1.
Three SPI images from IN-ENR showing a cobble and silt (left), fine/medium sand and silt (middle), and coarse sand and silt mixtures (right). Width of each image = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-IN-ENR-1-A-SPI-R3

Y1-IN-ENR-6-B-SPI-R2

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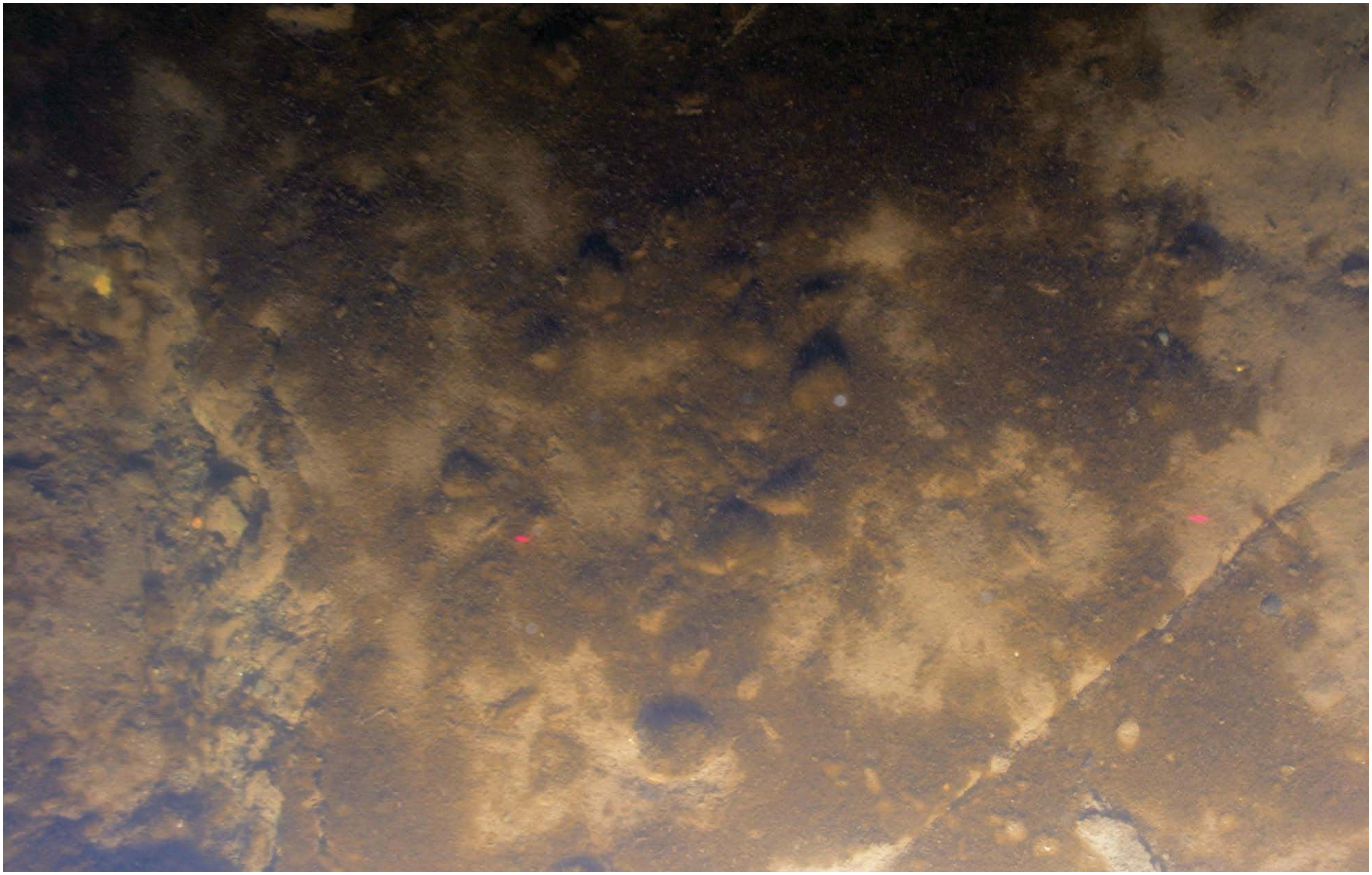
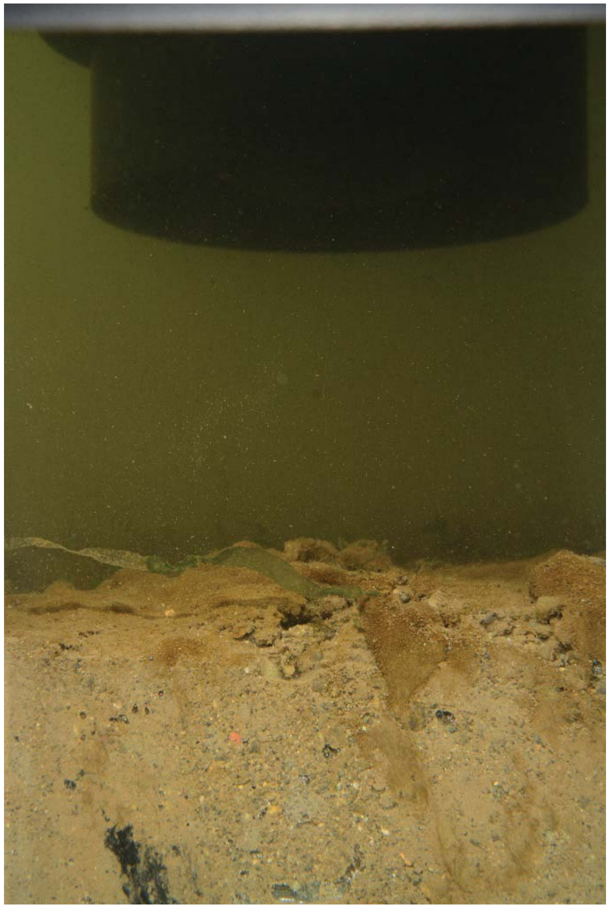
Figure 3-2.
Image 1-A-R3 (left) shows 6 cm of silt over an ENR sand and silt mix. Image 6-B-R2 shows 6 cm of silt with no evidence of ENR material. Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway



Y1-IN-ENR-6-B-PV-R4

Figure 3-3.
Plan view image from IN-ENR-6-B showing ENR gravels at a station where ENR material was not evident in all SPI replicates (see Figure 3-2). Scale: red laser dots are 26 cm apart.
ENR/AC Pilot Study Lower Duwamish Waterway



Y1-IN-ENR+AC-1-B-SPI-R3

Y1-IN-ENR+AC-2-B-SPI-R1

Y1-IN-ENR+AC-6-A-SPI-R3

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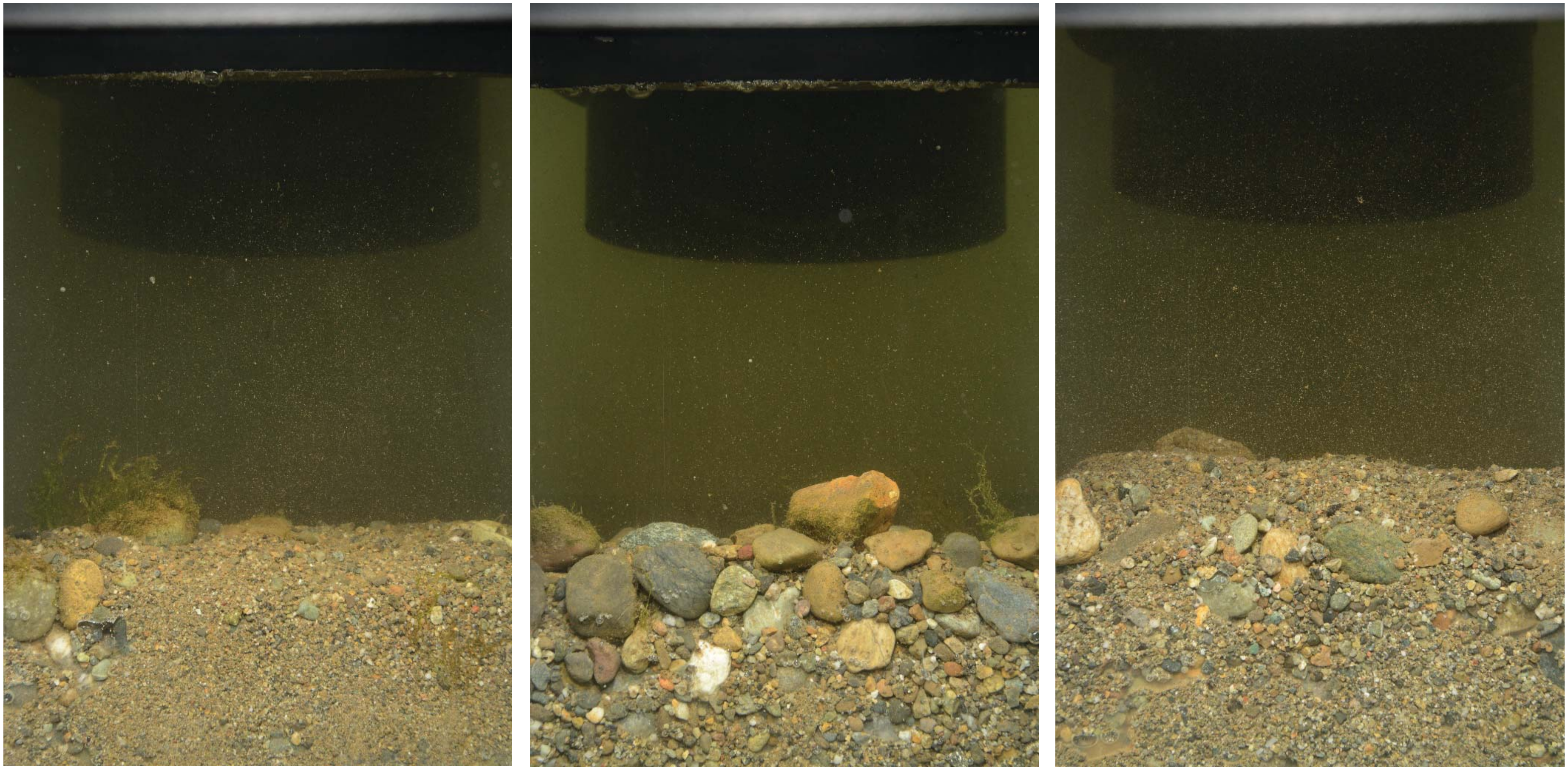
Figure 3-4.
Three SPI images from IN-ENR+AC showing a coarse sand and silt (left), gravel, sand, and silt (middle), and medium sand and silt mixtures (right). Image width = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway



Y1-IN-ENR+AC-4-A-SPI-R1

Y1-IN-ENR+AC-4-A-SPI-R2

Y1-IN-ENR+AC-4-A-SPI-R3

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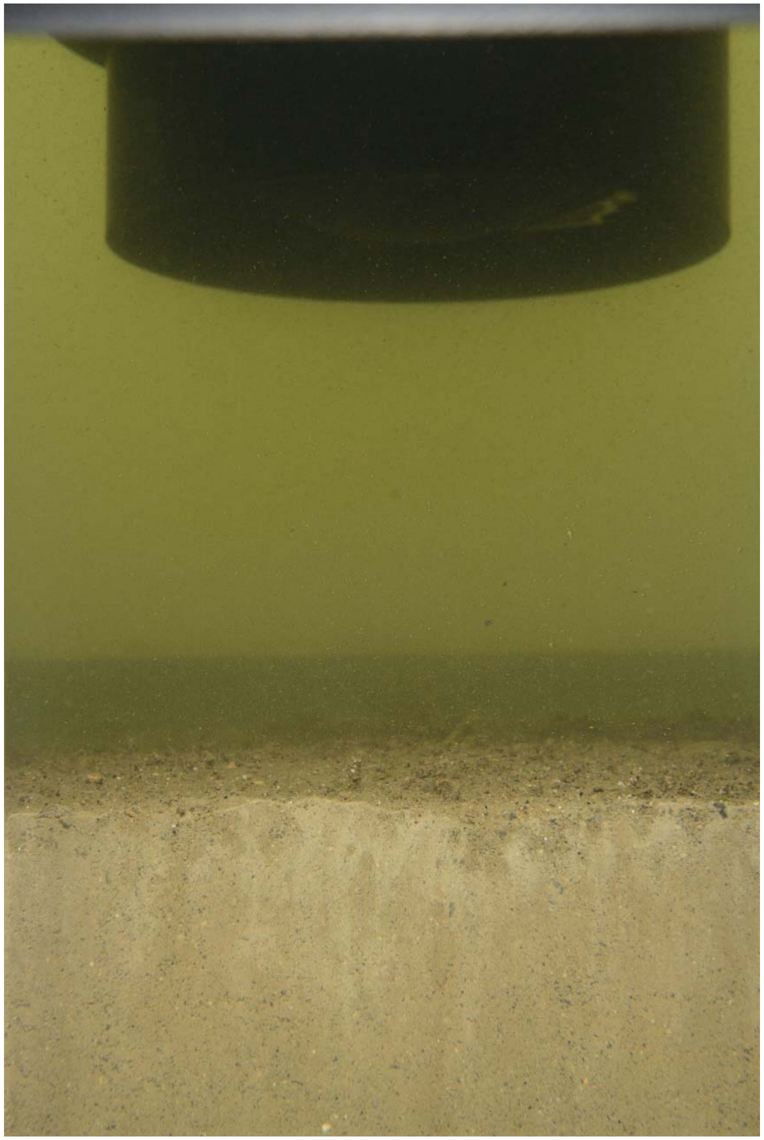
Figure 3-5.
Three SPI images from IN-ENR+AC-4-A showing ENR+AC material with minimal inputs or mixing with ambient fine-grained sediments. Width of each image = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-IN-ENR-2-A-SPI-R2



Y1-IN-ENR+AC-2-B-SPI-R3

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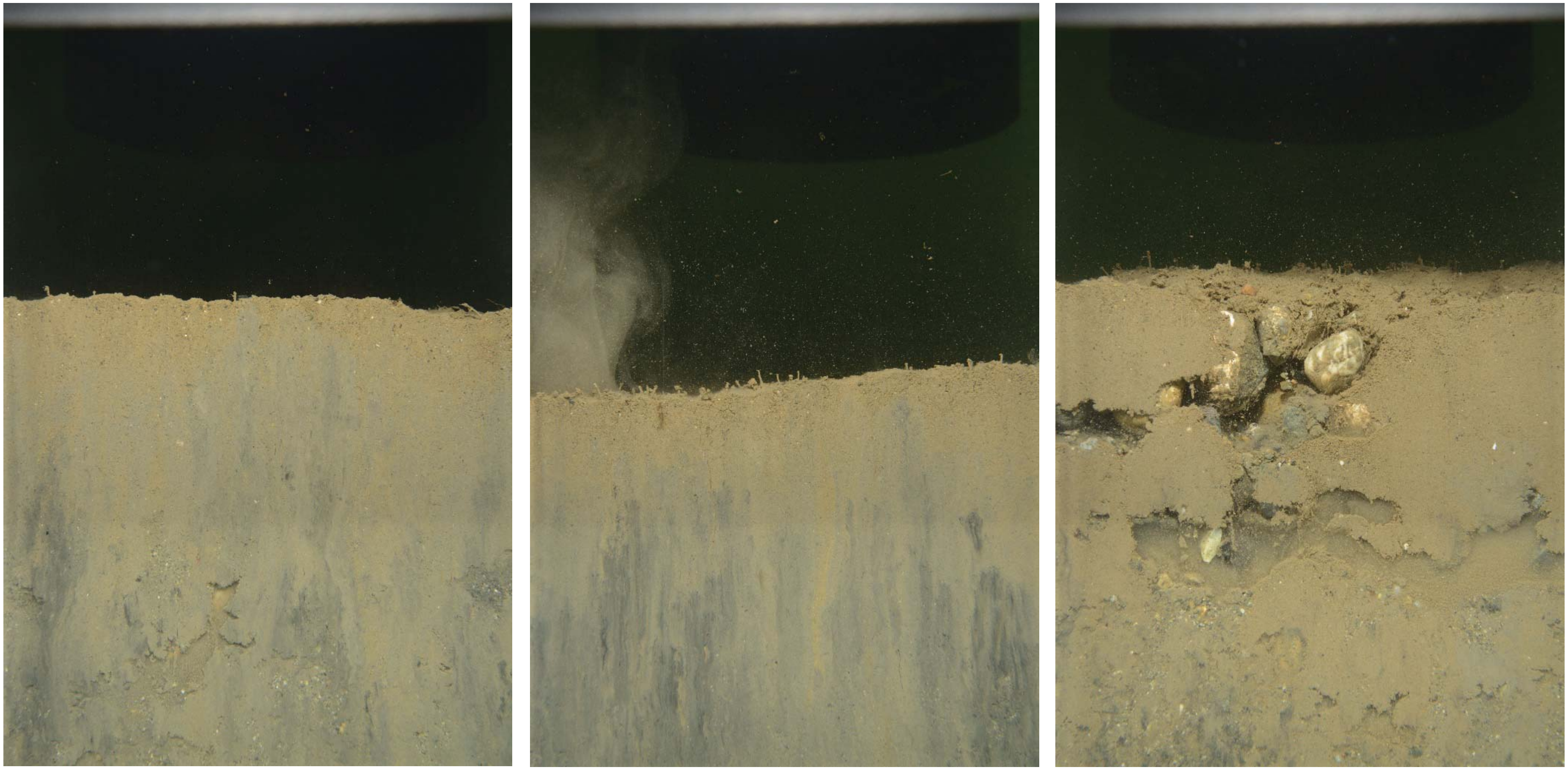
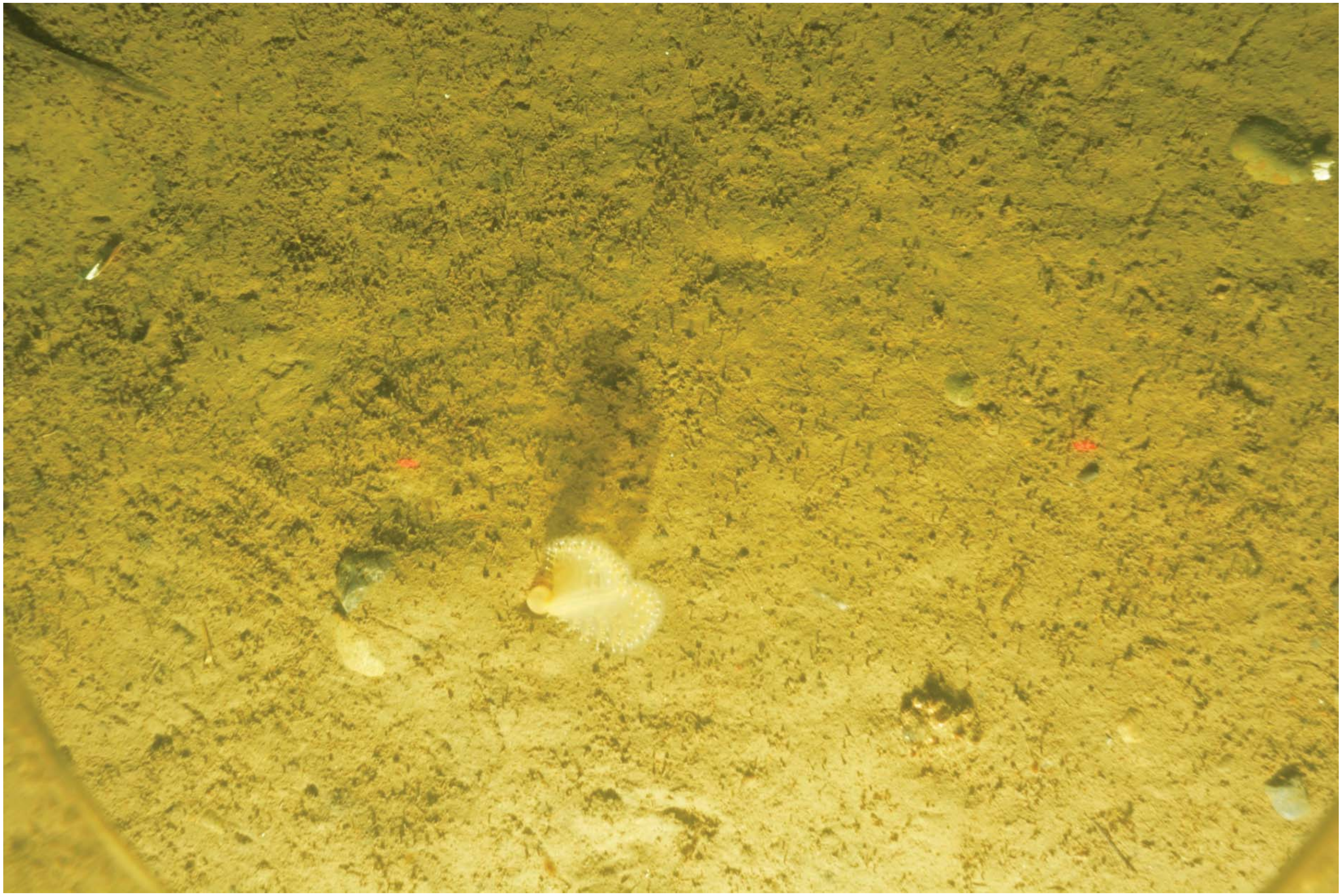
Figure 3-6.
Both images, ENR 2A-R3 and ENR+AC 2B-R3 show sand and silt mixtures with black, sand-sized particles throughout the profile. Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway



Y1-SC-ENR-1-A-SPI-R1 | Y1-SC-ENR-3-A-SPI-R2 | Y1-SC-ENR-6-A-SPI-R1

Figure 3-7.
Three SPI images from the SC-ENR subplot showing the predominately fine-grained texture at this site. Width of each image = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway



Y1-SC-ENR-2-A-PV-R1

integral consulting inc.

Figure 3-8.
Plan view image of the SC-ENR subplot showing widespread surface worm tubes, tracks, and a sea pen, as well as some ENR gravel. Scale: the red laser dots are 26 cm apart.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SC-ENR+AC-3-B-SPI-R1 | Y1-SC-ENR+AC-5-A-SPI-R3 | Y1-SC-ENR+AC-6-B-SPI-R1

integral consulting inc.

Figure 3-9.
Three SPI images from SC-ENR+AC showing the range of textures observed from left to right: gravels and sand, sand and silt, and silt. Width of each image = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SC-ENR+AC-6-A-SPI-R3

Y1-SC-ENR+AC-6-B-SPI-R3

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Figure 3-10.
Images from SC-ENR+AC showing black, sand-sized particles at the sediment surface (left) and in subsurface feeding voids (right). Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR-1-B-SPI-R4

Y1-SU-ENR-4-A-SPI-R3

Y1-SU-ENR-5-B-SPI-R3

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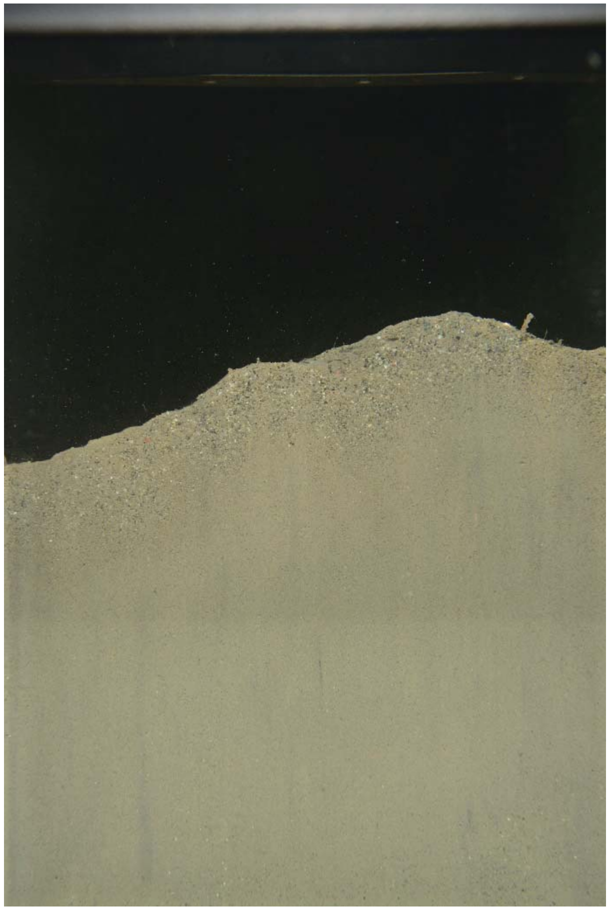
Figure 3-11.
Three SPI images from SU-ENR showing the range of textures observed from left: silt and medium sand mix, silt and coarse sand, and mostly sand. Image width = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR-6-A-SPI-R1

Y1-SU-ENR-6-A-SPI-R2

Figure 3-12.
Images from SU-ENR-6-A showing thin ENR material over ambient sediment. ENR layers are 2–3 cm (left) and 8–13 cm (right) thick. Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR+AC-5-A-SPI-R3



Y1-SU-ENR+AC-2-A-SPI-R3

Y1-SU-ENR+AC-4-A-SPI-R3

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Figure 3-13.
Three SPI images from SU-ENR+AC showing the range of textures observed from left: silt, sand and silt mix, and sand and gravel. Image width = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR+AC-5-A-SPI-R1

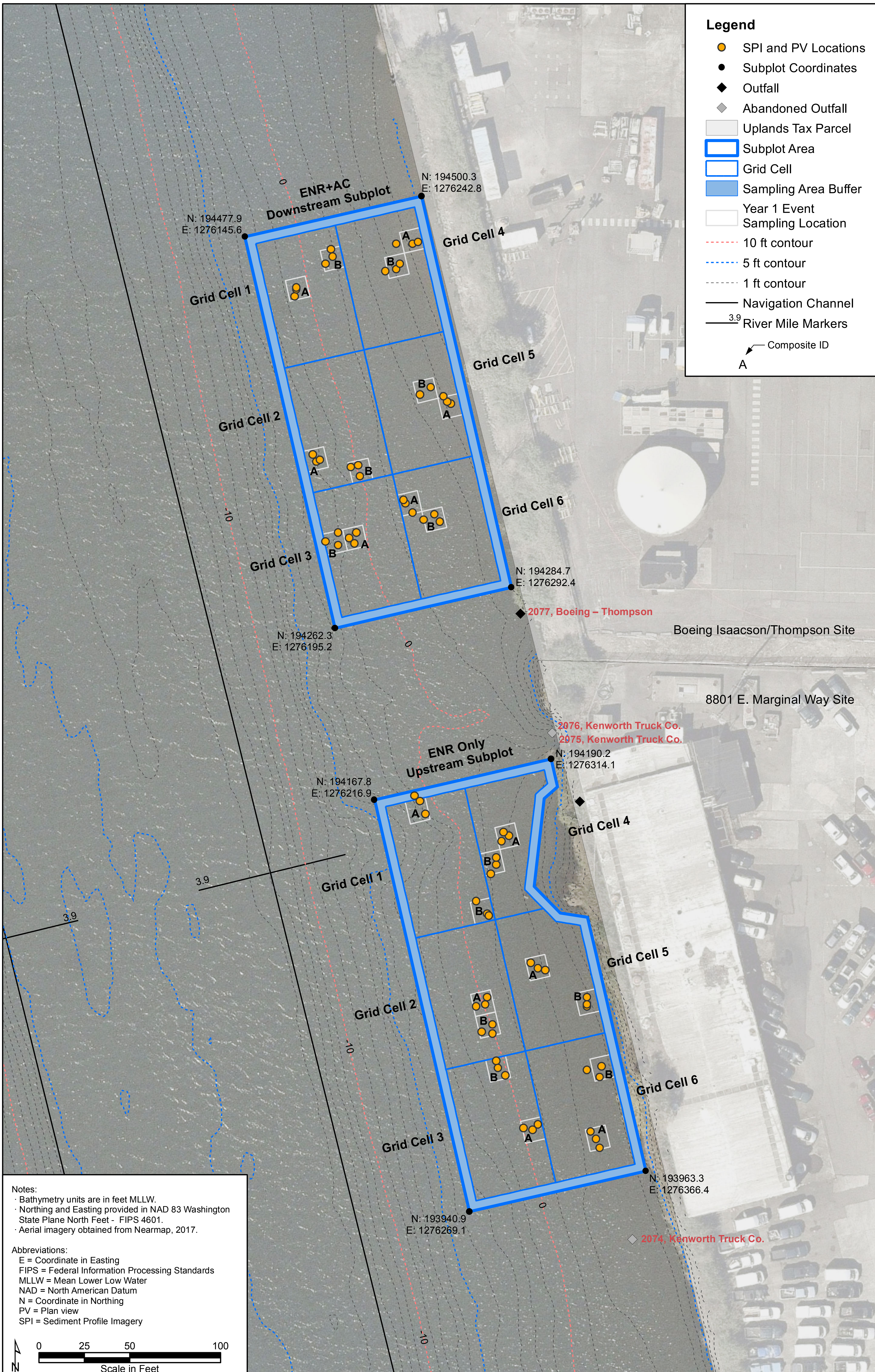
Y1-SU-ENR+AC-6-B-SPI-R2

Figure 3-14.
Images from SU-ENR+AC showing very thin (<1 cm) ENR+AC material over ambient sediment at Stations 5-A and 6-A. Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR+AC-3-A-PV-R3

Figure 3-15.
Plan view image from the SU-ENR+AC subplot showing coarse-grained bottom with patchy silt deposits and some leaf and wood debris. Scale: red laser dots are 26 cm apart.
ENR/AC Pilot Study Lower Duwamish Waterway

FIGURES



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ENR/AC Draft
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 2-1
ENR/AC Pilot Study
Intertidal Plot

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\ENR AC Draft Year 1 Monitoring Report\Figure 2-1 ENR AC Pilot Study Intertidal Plot.mxd
11/26/2018

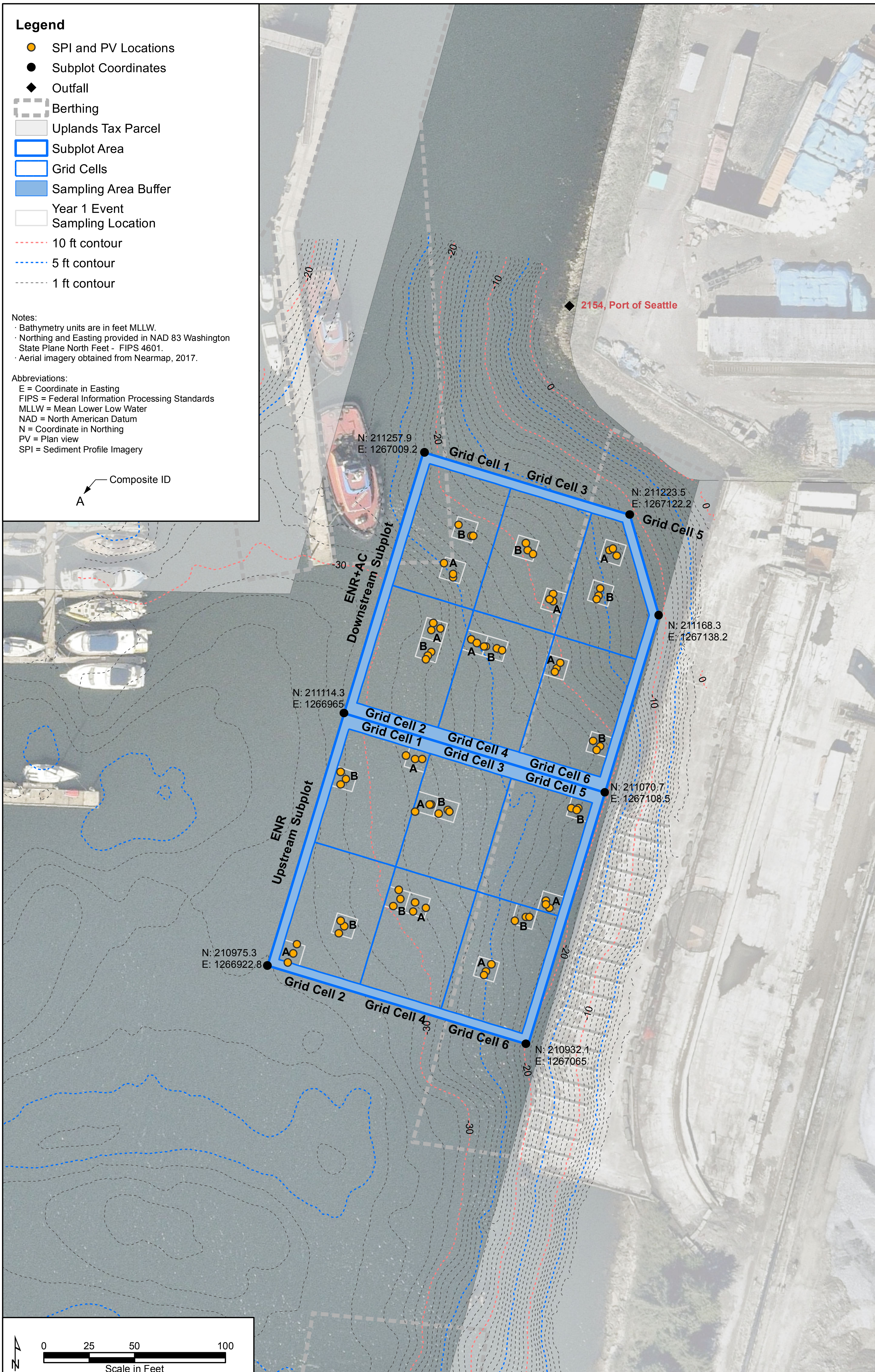

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Figure 2-2
ENR/AC Pilot Study
Scour Plot

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\ENR AC Draft Year 1 Monitoring Report\Figure 2-2 ENR AC Pilot Study Scour Plot.mxd
11/26/2018

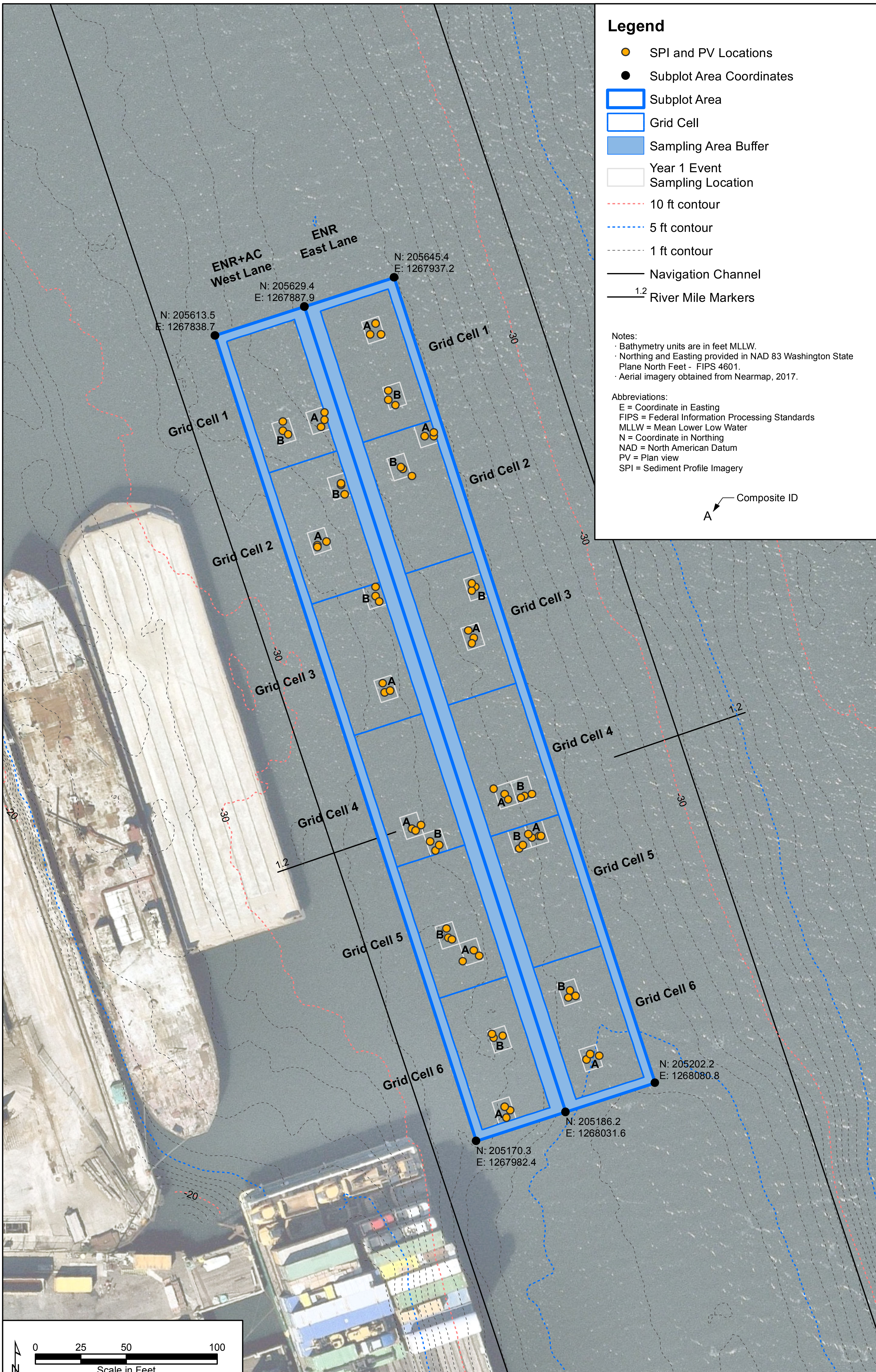

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Figure 2-3
ENR/AC Pilot Study
Subtidal Plot

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\ENR AC Draft Year 1 Monitoring Report\Figure 2-3 ENR AC Pilot Study Subtidal Plot.mxd
11/26/2018

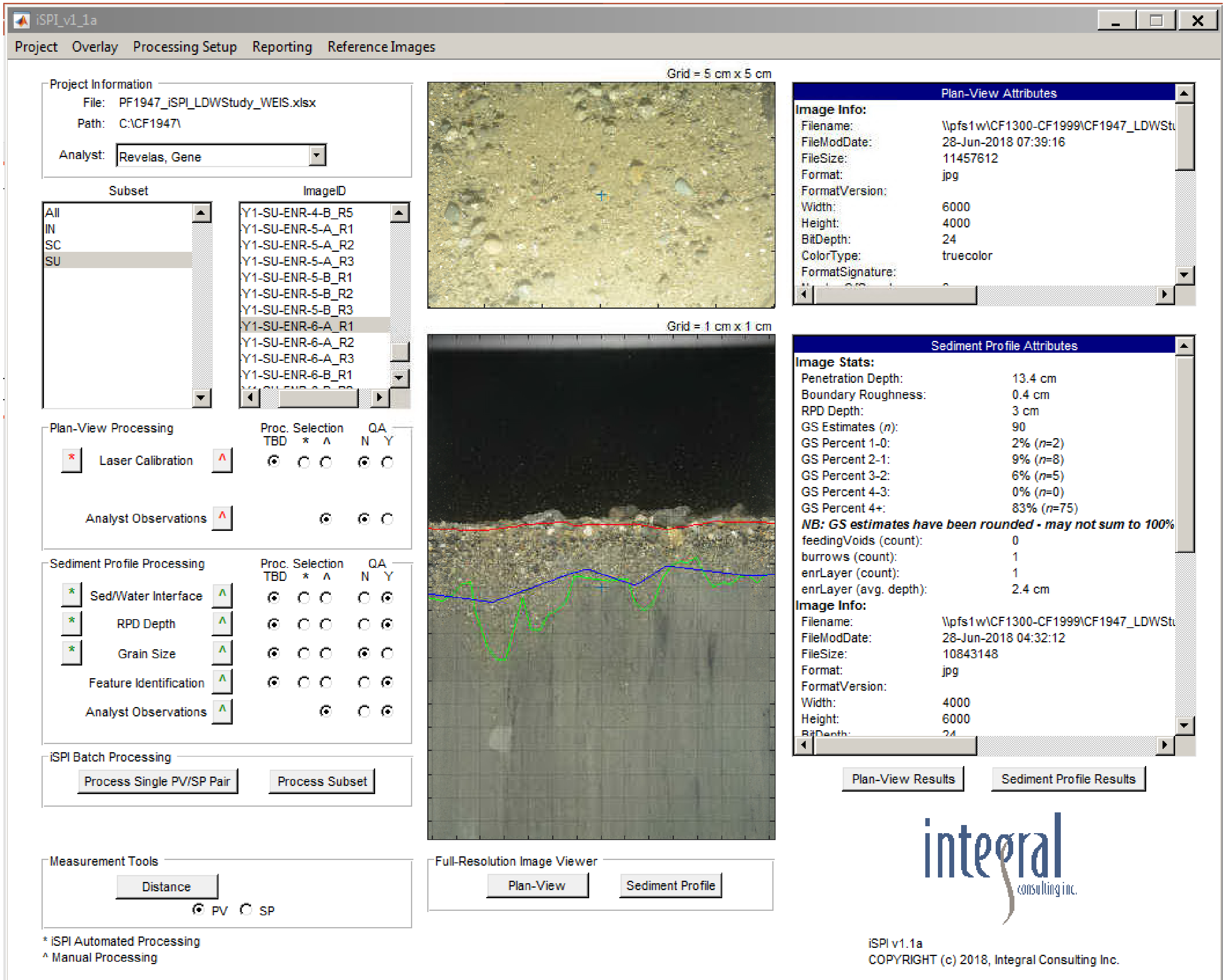

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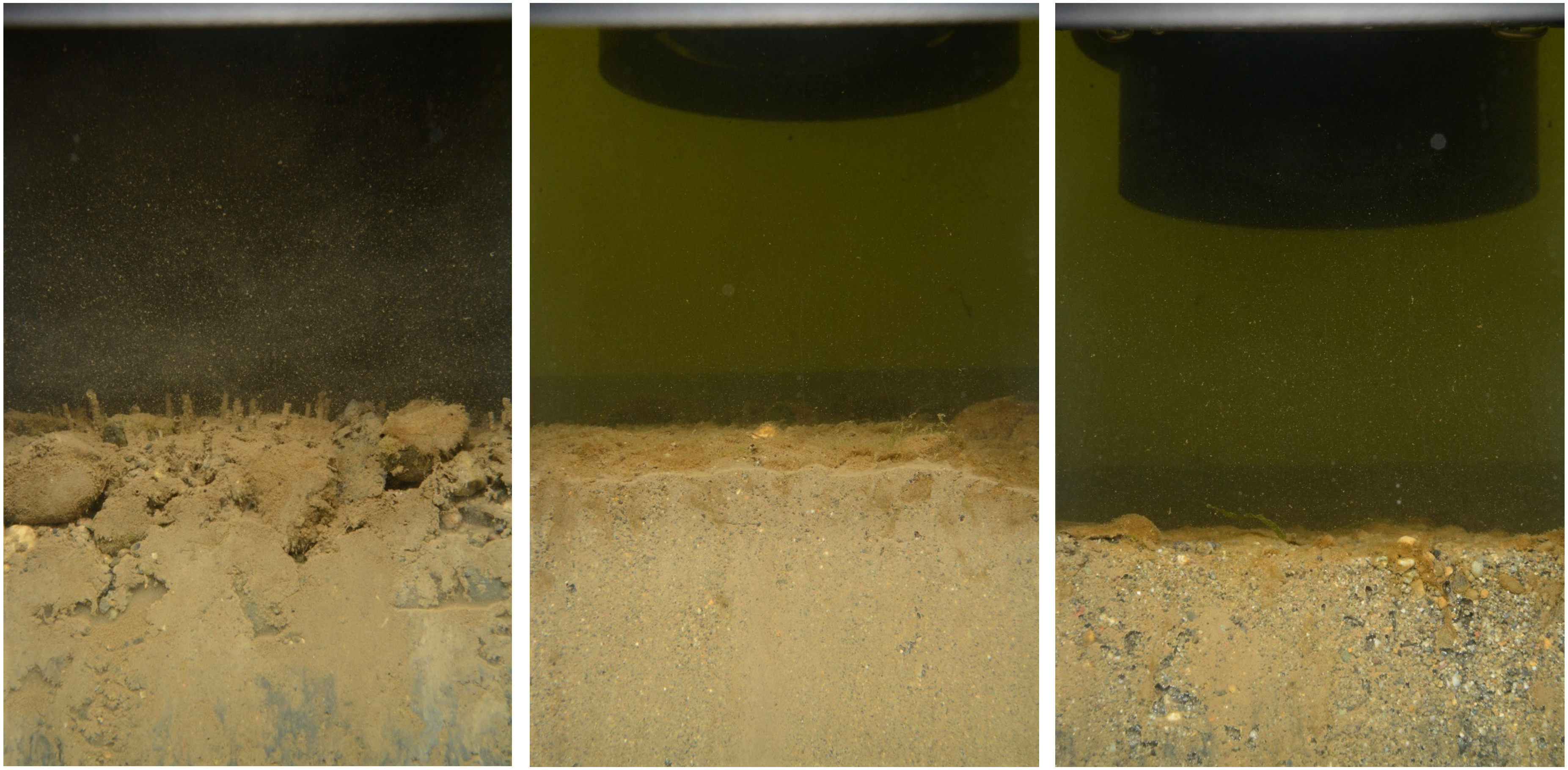
Figure 2-4.
iSPI v1.1a SPI/PV Image Analysis User Interface
ENR/AC Pilot Study Lower Duwamish Waterway



Y1 -IN-ENR-1-A-SPI-R2 | Y1-IN-ENR-2-A-SPI-R2 | Y1-IN-ENR-4-A-SPI-R1

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Figure 3-1.
Three SPI images from IN-ENR showing a cobble and silt (left), fine/medium sand and silt (middle), and coarse sand and silt mixtures (right). Width of each image = 14.42 cm.
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Y1-IN-ENR-1-A-SPI-R3

Y1-IN-ENR-6-B-SPI-R2

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Figure 3-2.
Image 1-A-R3 (left) shows 6 cm of silt over an ENR sand and silt mix. Image 6-B-R2 shows 6 cm of silt with no evidence of ENR material. Width of SPI images = 14.42 cm.
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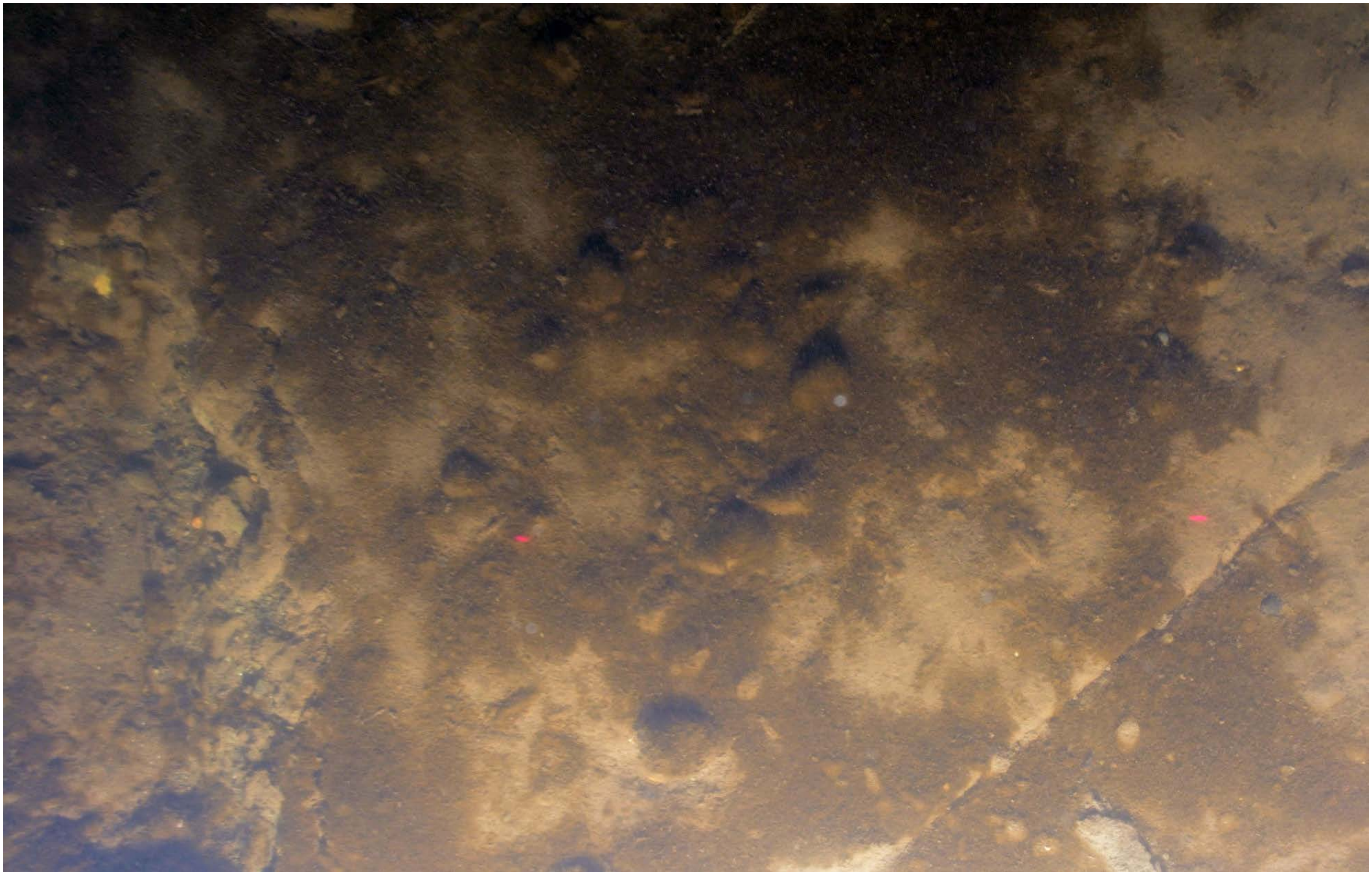

Y1-IN-ENR-6-B-PV-R4

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Figure 3-3.
Plan view image from IN-ENR-6-B showing ENR gravels at a station where ENR material was not evident in all SPI replicates (see Figure 3-2). Scale: red laser dots are 26 cm apart.
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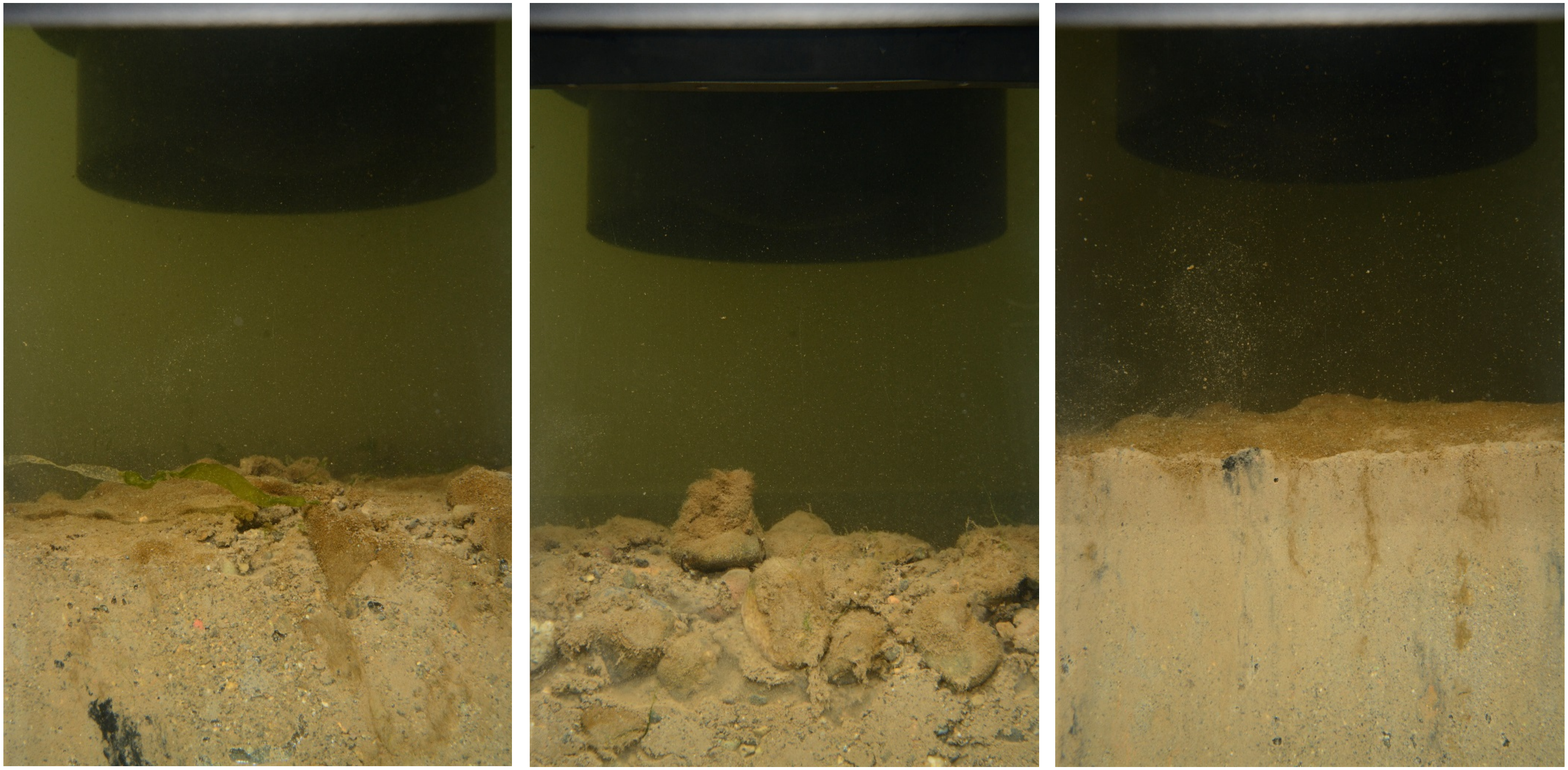

Y1-IN-ENR+AC-1-B-SPI-R3

Y1-IN-ENR+AC-2-B-SPI-R1

Y1-IN-ENR+AC-6-A-SPI-R3

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Figure 3-4.
Three SPI images from IN-ENR+AC showing a coarse sand and silt (left), gravel, sand, and silt (middle), and medium sand and silt mixtures (right). Image width = 14.42 cm.
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Y1-IN-ENR+AC-4-A-SPI-R1

Y1-IN-ENR+AC-4-A-SPI-R2

Y1-IN-ENR+AC-4-A-SPI-R3

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Figure 3-5.
Three SPI images from IN-ENR+AC-4-A showing ENR+AC material with minimal inputs or mixing with ambient fine-grained sediments. Width of each image = 14.42 cm.
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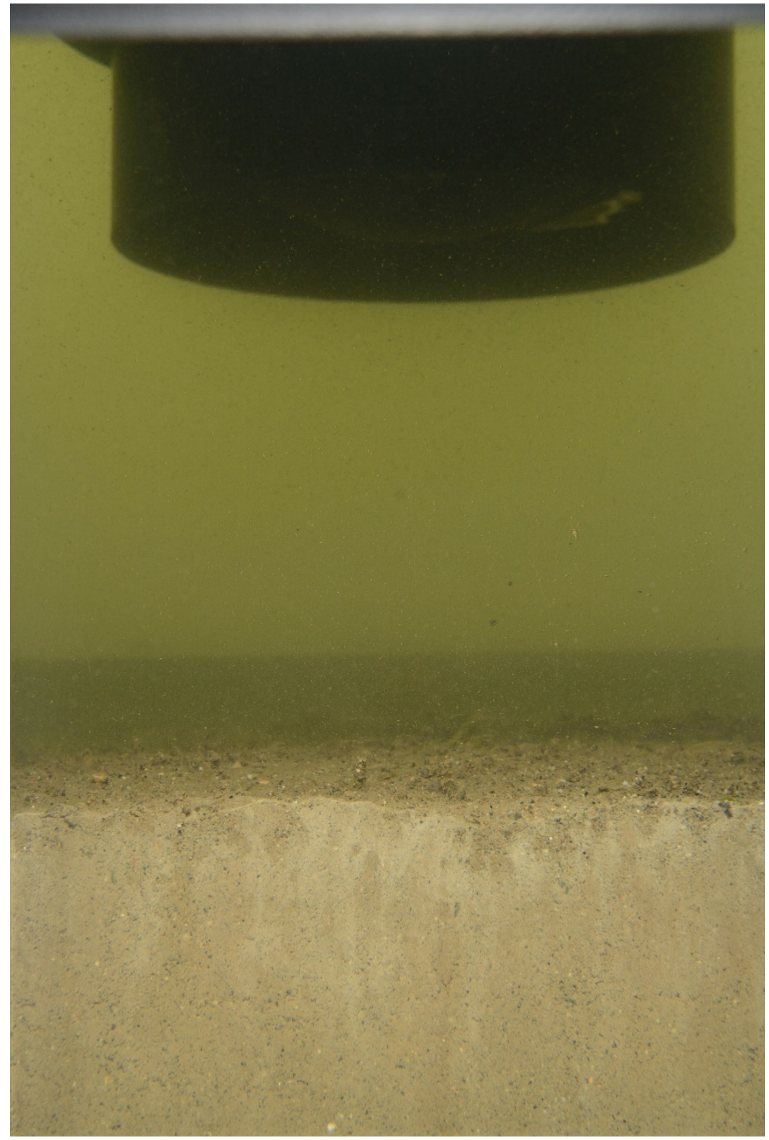
Y1-IN-ENR-2-A-SPI-R2



Y1-IN-ENR+AC-2-B-SPI-R3

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Figure 3-6.
Both images, ENR 2A-R3 and ENR+AC 2B-R3 show sand and silt mixtures with black, sand-sized particles throughout the profile. Width of SPI images = 14.42 cm.
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Y1-SC-ENR-1-A-SPI-R1

Y1-SC-ENR-3-A-SPI-R2

Y1-SC-ENR-6-A-SPI-R1

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Figure 3-7.
Three SPI images from the SC-ENR subplot showing the predominately fine-grained texture at this site. Width of each image = 14.42 cm.
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Y1-SC-ENR-2-A-PV-R1

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Figure 3-8.
Plan view image of the SC-ENR subplot showing widespread surface worm tubes, tracks, and a sea pen, as well as some ENR gravel. Scale: the red laser dots are 26 cm apart.
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Y1-SC-ENR+AC-3-B-SPI-R1

Y1-SC-ENR+AC-5-A-SPI-R3

Y1-SC-ENR+AC-6-B-SPI-R1

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Figure 3-9.
Three SPI images from SC-ENR+AC showing the range of textures observed from left to right: gravels and sand, sand and silt, and silt. Width of each image = 14.42 cm.
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Y1-SC-ENR+AC-6-A-SPI-R3

Y1-SC-ENR+AC-6-B-SPI-R3

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Figure 3-10.
Images from SC-ENR+AC showing black, sand-sized particles at the sediment surface (left) and in subsurface feeding voids (right). Width of SPI images = 14.42 cm.
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Y1-SU-ENR-1-B-SPI-R4

Y1-SU-ENR-4-A-SPI-R3

Y1-SU-ENR-5-B-SPI-R3

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Figure 3-11.
Three SPI images from SU-ENR showing the range of textures observed from left: silt and medium sand mix, silt and coarse sand, and mostly sand. Image width = 14.42 cm.
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Y1-SU-ENR-6-A-SPI-R1

Y1-SU-ENR-6-A-SPI-R2

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Figure 3-12.
Images from SU-ENR-6-A showing thin ENR material over ambient sediment. ENR layers are 2–3 cm (left) and 8–13 cm (right) thick. Width of SPI images = 14.42 cm.
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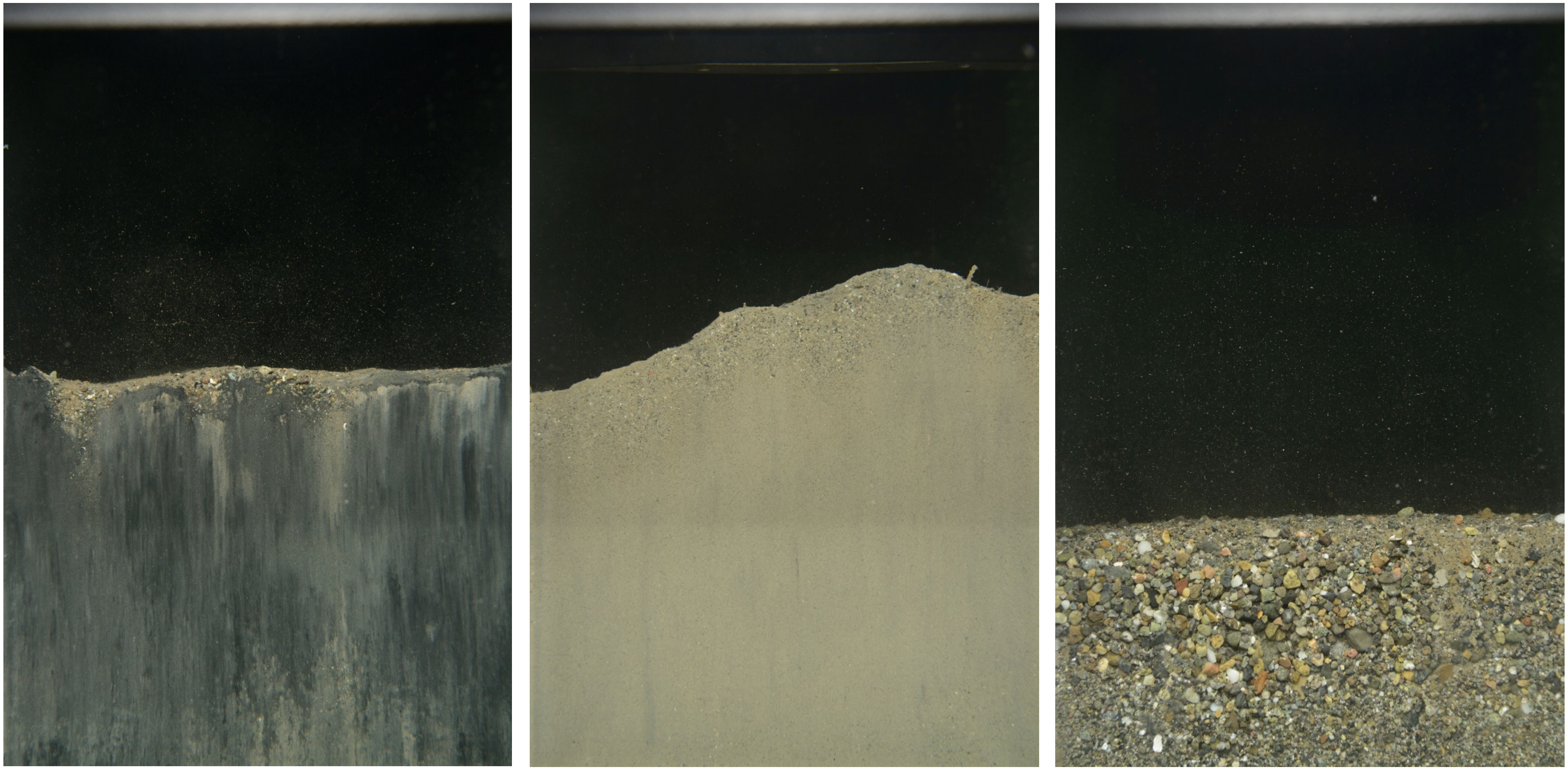

Y1-SU-ENR+AC-5-A-SPI-R3

Y1-SU-ENR+AC-2-A-SPI-R3

Y1-SU-ENR+AC-4-A-SPI-R3

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Figure 3-13.
Three SPI images from SU-ENR+AC showing the range of textures observed from left: silt, sand and silt mix, and sand and gravel. Image width = 14.42 cm.
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Y1-SU-ENR+AC-5-A-SPI-R1

Y1-SU-ENR+AC-6-B-SPI-R2

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Figure 3-14.
Images from SU-ENR+AC showing very thin (<1 cm) ENR+AC material over ambient sediment at Stations 5-A and 6-A. Width of SPI images = 14.42 cm.
ENR/AC Pilot Study Lower Duwamish Waterway

Y1-SU-ENR+AC-3-A-PV-R3

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DRAFT

Figure 3-15.
Plan view image from the SU-ENR+AC subplot showing coarse-grained bottom with patchy silt deposits and some leaf and wood debris. Scale: red laser dots are 26 cm apart.
ENR/AC Pilot Study Lower Duwamish Waterway

TABLES

Table 3-1a. Year 1 Intertidal ENR Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-IN-ENR-1-A	R1	3/29/2018	9.9	5.3	>P	Cobble, gravel, sand and silt mix; large worm tube mat	1.6	2	>4	<-1	>4	N	1 on 3
LDW-Y1-IN-ENR-1-A	R2			6.6	>P	Cobble, gravel, sand and silt mix; large worm tube mat	2.1	2.5	>4	-4	>4	N	1 on 3
LDW-Y1-IN-ENR-1-A	R3			14.3	>P	6 cm silt over sand and silt mix	0.7	1.3	3-2	-2	>4	N	1 on 3
LDW-Y1-IN-ENR-1-B	R1	3/29/2018	7.3	3.3	>P	Brown algae covered gravel, coarse sand, and silt; eelgrass detritus	0.8	Ind	2-1	-2	>4	N	Ind
LDW-Y1-IN-ENR-1-B	R2			4.5	>P	Brown algae covered gravel, coarse sand, and silt; eelgrass detritus	2	2.3	>4/3-2	-1	>4	Y	1 on 3
LDW-Y1-IN-ENR-1-B	R3			3.8	>P	Brown algae covered gravel, coarse sand, and silt; eelgrass detritus	1.1	2.1	3-2	-2	>4	Y	Ind
LDW-Y1-IN-ENR-2-A	R1	3/29/2018	7.4	4.8	>P	Brown algae covered sand and silt mix	0.5	1.5	2-1	-2	>4	Y	Ind
LDW-Y1-IN-ENR-2-A	R2			8.2	>P	Brown algae covered sand and silt mix	1	2.9	3-2	0	>4	Y	1
LDW-Y1-IN-ENR-2-A	R3			3	>P	Brown algae covered sand and silt mix	1	1.1	>4	-4	>4	N	1 on 3
LDW-Y1-IN-ENR-2-B	R1	3/29/2018	7.4	3.9	>P	Brown algae covered gravel, coarse sand, and silt mix	1	Ind	>4	-4	>4	Y	Ind
LDW-Y1-IN-ENR-2-B	R2			2.8	>P	Brown algae covered gravel, coarse sand, and silt mix	3.1	Ind	2-1	<-4	>4	N	Ind
LDW-Y1-IN-ENR-2-B	R3			3.2	>P	Brown algae covered gravel, coarse sand, and silt mix	3.2	Ind	0-(-)1	-5	>4	N	Ind
LDW-Y1-IN-ENR-3-A	R1	3/29/2018	8.7	4.5	>P	Brown algae covered gravel, coarse sand, and silt mix	1.2	2.2	2-1	<-1	>4	Y	Ind
LDW-Y1-IN-ENR-3-A	R2			3.4	>P	Brown algae covered gravel, coarse sand, and silt mix	1.6	Ind	-1-(-2)	-5	>4	N	Ind
LDW-Y1-IN-ENR-3-A	R3			4.9	>P	Well-sorted medium sand and silt mix; sand assumed to be ENR material	1.2	2.6	3-2 and >4	0	>4	Y	1 on 3
LDW-Y1-IN-ENR-3-B	R1	3/29/2018	7.8	5	>P	Brown algae covered coarse sand, sand, and silt mix	2.3	Ind	3-2	-4	>4	N	Ind
LDW-Y1-IN-ENR-3-B	R2			2.8	>P	Brown algae covered gravel, sand, and mostly silt mix	2.3	2.2	>4	<-4	>4	N	Ind
LDW-Y1-IN-ENR-3-B	R3			9.7	LNA	Silt, highly reduced sediment below 4 cm	0.4	3.5	3-2/>4	0	>4	N	1 on 3
LDW-Y1-IN-ENR-4-A	R1	3/29/2018	6.7	5.8	>P	Brown algae covered gravel, sand, and silt mix	0.7	3.5	2-1	-4	>4	Y	Ind
LDW-Y1-IN-ENR-4-A	R2			3	>P	Brown algae covered sand and silt mix; wood debris	2	Ind	>4	-3	>4	Y	Ind
LDW-Y1-IN-ENR-4-A	R3			4.4	>P	Brown algae covered gravel, sand, and silt mix	1	Ind	2-1	-4	>4	Y	1 on 3
LDW-Y1-IN-ENR-4-B	R1	3/29/2018	7.5	4.4	LNA	Brown algae covered sand and silt mix	0.9	2.4	>4	-1	>4	N	1 on 3
LDW-Y1-IN-ENR-4-B	R2			5.2	>P	Brown algae covered gravel, coarse sand, and silt mix	2.4	2.2	>4 and 3-2	-4	>4	Y	2->3

Table 3-1a. Year 1 Intertidal ENR Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-IN-ENR-4-B	R3			3.6	>P	Brown algae covered gravel, coarse sand, and silt mix	2.2	Ind	3-2	-3	>4	N	Ind
LDW-Y1-IN-ENR-5-A	R1	3/29/2018	6.7	5.7	LNA	Brown algae covered silt	1	3.1	>4 and 3-2	2-1	>4	Y	1 on 3
LDW-Y1-IN-ENR-5-A	R2			4	>P	Brown algae covered sand and silt mix; wood debris	1.3	2.6	>4 and 3-2	-3	>4	Y	Ind
LDW-Y1-IN-ENR-5-A	R3			4.5	LNA	Brown algae covered silt	0.6	3.3	3-2	2-1	>4	Y	1 on 3
LDW-Y1-IN-ENR-5-B	R1	3/29/2018	6.3	6.4	>P	Brown algae covered 4 cm silt layer blending into sand and silt mix	1	3.3	>4/3-2	-2	>4	Y	1 on 3
LDW-Y1-IN-ENR-5-B	R2			6.6	LNA	Brown algae covered silt, highly reduced below 3 cm, possible some sand in matrix	0.7	2.9	>4	<-1	>4	Y	1
LDW-Y1-IN-ENR-5-B	R3			7.6	LNA	Silt, highly reduced below 3 cm, wood on surface	0.5	1.9	>4	<-1	>4	N	1 on 3
LDW-Y1-IN-ENR-6-A	R1	3/29/2018	6.6	4.1	LNA	Brown algae covered silt, possibly some sand in matrix, some reduced sediment at depth	0.7	2.3	>4	2	>4	N	1
LDW-Y1-IN-ENR-6-A	R2			3.9	LNA	Brown algae covered silt, possibly some sand in matrix	1.5	3.1	3-2	-1	>4	Y	1 on 3
LDW-Y1-IN-ENR-6-A	R3			4.2	>P	Brown algae covered cobble, gravel, coarse sand, and silt mix	2.1	Ind	-3-(-)4	-5	>4	N	Ind
LDW-Y1-IN-ENR-6-B	R1	3/29/2018	6.5	4.4	LNA	Brown algae covered silt, possibly some sand in matrix	0.5	3.1	3-2	1	>4	Y	1 on 3
LDW-Y1-IN-ENR-6-B	R2			6.6	LNA	Brown algae covered silt, possibly some sand in matrix	0.5	2	>4	-4	>4	N	1 on 3
LDW-Y1-IN-ENR-6-B	R3			4.7	>P	Brown algae covered gravel, sand, and silt mix	0.7	2.2	>4 and 3-2	<-4	>4	Y	1 on 3

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	36	36	26
Average	5.1	1.3	2.5
Median	4.5	1	2.4
Minimum	2.8	0.4	1.1
Maximum	14.3	3.2	3.5

Notes:

AC = activated carbon
aRPD = apparent redox potential discontinuity
ENR = enhanced natural recovery
Ind = indeterminate
LNA = layer not apparent
P = penetration
SPI = sediment profile imaging

Table 3-1b. Year 1 Intertidal ENR Pilot Subplot PV Results

Station	Replicate	Sediment Type	Bedforms	*Lebensspuren* Burrows	*Lebensspuren* Tubes	*Lebensspuren* Tracks	*Lebensspuren* Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-IN-ENR-1-A	R1	Sand and silt and some gravel	N	Y	Y	N	M	N	NA	N	Sticks	L	N	L	Some algae.
LDW-Y1-IN-ENR-1-A	R2	Sand and silt with some gravel	N	Y	Y	N	M	N	NA	N	Stick	L	N	L	Algae present.
LDW-Y1-IN-ENR-1-A	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable, due to turbidity in the water column.
LDW-Y1-IN-ENR-1-B	R1	Sand	N	N	Y	N	L	N	NA	N	NA	N	N	L	Algae and silt covering substrate.
LDW-Y1-IN-ENR-1-B	R2	Sand and silt	N	N	Y	N	L	N	NA	N	NA	N	N	L	Image partially obscured from turbidity in water column. Few algae and fecal casts.
LDW-Y1-IN-ENR-1-B	R3	Sand and silt	N	N	N	N	N	N	NA	N	NA	N	N	L	Algae and silt covering the substrate.
LDW-Y1-IN-ENR-2-A	R1	Sand and silt	N	N	N	N	N	N	NA	N	Stick	L	N	L	Algae and silt covering substrate.
LDW-Y1-IN-ENR-2-A	R2	Sand and silt with gravel	N	N	N	N	N	N	NA	N	NA	N	N	L	Silt and algae covering substrate
LDW-Y1-IN-ENR-2-A	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Algae and silt covering substrate.
LDW-Y1-IN-ENR-2-B	R1	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	L	One laser visible. Algae and silt covering substrate.
LDW-Y1-IN-ENR-2-B	R2	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	One laser visible. Algae and silt covering substrate.
LDW-Y1-IN-ENR-2-B	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	One laser visible. Algae covering majority of substrate.
LDW-Y1-IN-ENR-3-A	R4	Sand	Y	Y	Y	N	L	N	NA	N	Leaf	L	N	L	Evidence of scouring in portion of image.
LDW-Y1-IN-ENR-3-A	R5	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable, too turbid.
LDW-Y1-IN-ENR-3-A	R6	Sand and gravel	N	N	N	N	N	N	NA	N	Sticks	L	N	L	Linear lines are an artifact from the SPI frame. Some algae present.
LDW-Y1-IN-ENR-3-B	R4	Gravel and sand	N	Y	Y	N	L	N	NA	N	Sticks	L	N	M	Light film of silt covering substrate, few algae.
LDW-Y1-IN-ENR-3-B	R5	Gravel and sand	N	N	N	N	N	N	NA	N	Sticks	L	N	M	Linear lines are an artifact from the SPI frame. Algae and some silt covering substrate.
LDW-Y1-IN-ENR-3-B	R6	Sand and silt with gravel	N	Y	Y	N	L	N	NA	N	Sticks and leaves	L	N	L	Some algae and silt covering substrate.
LDW-Y1-IN-ENR-4-A	R4	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	A thin film of algae and silt covering substrate.
LDW-Y1-IN-ENR-4-A	R5	Sand and gravel	N	N	N	N	N	N	NA	N	Stick	L	N	L	Linear line is an artifact from the SPI frame. Light film of silt and algae covering portion of substrate.
LDW-Y1-IN-ENR-4-A	R6	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	Silt and algae lightly covering substrate.
LDW-Y1-IN-ENR-4-B	R4	Gravel and sand	N	N	N	N	N	N	NA	N	Leaf	L	N	M	Thin film of algae and silt covering substrate.
LDW-Y1-IN-ENR-4-B	R5	Gravel and sand	N	N	N	N	N	N	NA	N	Sticks	L	N	M	A thin film of algae and silt covering substrate.
LDW-Y1-IN-ENR-4-B	R6	Sand and gravel	Y	N	N	N	N	N	NA	N	Sticks	L	N	H	Thin film of silt and algae covering a portion of the substrate.
LDW-Y1-IN-ENR-5-A	R4	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable, due to turbidity. Imprint from SPI frame visible.
LDW-Y1-IN-ENR-5-A	R5	Sand, silt, and gravel	N	N	Y	N	L	N	NA	N	NA	N	N	L	Thin film of algae and silt covering substrate.
LDW-Y1-IN-ENR-5-A	R6	Sand, silt, and gravel	N	N	Y	Y	L	Y	Fish (2)	N		N	N	L	Thin film of algae and silt covering substrate.
LDW-Y1-IN-ENR-5-B	R4	Sand, silt, and gravel	N	Y	Y	Y	L	N	NA	N	NA	N	N	L	Thin film of algae cover substrate. Indentation from SPI prism.
LDW-Y1-IN-ENR-5-B	R5	Silt and sand with gravel	N	N	N	Y	L	N	NA	N	Leaf and sticks	L	N	L	Thin film of algae. Few gravel pieces.
LDW-Y1-IN-ENR-5-B	R6	Sand, silt, and gravel	N	N	Y	N	L	N	NA	N	NA	N	N	L	Imprint is an artifact from the SPI frame.
LDW-Y1-IN-ENR-6-A	R4	Sand, silt, and gravel	N	Y	Y	Y	L	N	NA	N	Stick	L	N	M	Thin film of algae and silt covering a portion of the substrate.
LDW-Y1-IN-ENR-6-A	R5	Sand, silt, and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Algae and silt covering substrate.
LDW-Y1-IN-ENR-6-A	R6	Sand, silt, and gravel	N	Y	Y	N	L	N	NA	N	Sticks	L	N	L	Thin film of algae and silt covering substrate. Some gravel.
LDW-Y1-IN-ENR-6-B	R4	Sand, silt, and gravel	N	N	Y	N	L	N	NA	Y	NA	N	N	L	Linear lines and angular mud clasts are an artifact from the SPI frame.
LDW-Y1-IN-ENR-6-B	R5	Gravel and sand	N	N	N	N	N	N	NA	N	Wood	L	N	M	Patchy distribution of algae and silt.
LDW-Y1-IN-ENR-6-B	R6	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Linear lines are an artifact from the SPI frame. Image partially obscured by turbidity in water column.

Notes:

Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-2a. Year 1 Intertidal ENR+AC Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-IN-ENR+AC-1-A	R2	3/30/2018	3.3	5.7	>P	Sand and silt mix	0.9	1.5	>4	1	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-1-A	R3			4.6	>P	Gravel, sand and silt mix	4.4	Ind	3-2	-4	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-1-B	R1	3/30/2018	2.6	3.9	>P	Algae covered cobble, gravel and coarse sand	2.2	Ind	<-1	-6	>4	N	Ind
LDW-Y1-IN-ENR+AC-1-B	R2			4.1	>P	Algae covered cobble, gravel, coarse sand, and silt	1.8	2.7	>4	-6	>4	Y	3
LDW-Y1-IN-ENR+AC-1-B	R3			6	>P	Algae covered gravel, coarse sand, and silt; eelgrass detritus	1.6	2.3	3-2	-4	>4	Y	1
LDW-Y1-IN-ENR+AC-2-A	R1	3/30/2018	5.9	7.3	>P	Cobble, gravel, sand and silt mix; large worm tubes at surface	1.6	3.1	>4	-4	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-2-A	R2			2.3	>P	Sand and silt mix; large worm tubes at surface	1.5	1.5	3-2	-4	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-2-A	R3			4.7	>P	Gravel, sand and silt mix; large worm tubes at surface	2	2.1	2-1	<-1	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-2-B	R1	3/30/2018	3.5	5.7	>P	Cobble, gravel, sand and silt mix	1.2	Ind	-4-(-)5	-6	>4	N	Ind
LDW-Y1-IN-ENR+AC-2-B	R2			4.5	>P	Cobble, gravel, sand and silt mix	1.7	2.1	3-2	-5	>4	N	Ind
LDW-Y1-IN-ENR+AC-2-B	R3			6.4	>P	Sand and silt mix; surface worm tubes	0.6	1.2	3-2	-1	>4	N	1
LDW-Y1-IN-ENR+AC-3-A	R1	3/30/2018	4.6	6.7	>P	Sand and silt mix; surface worm tubes	1	1.6	3-2 & >4	0	>4	Y	1
LDW-Y1-IN-ENR+AC-3-A	R2			5.7	>P	Sand and silt mix	1.7	1.6	3-2	-4	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-3-A	R3			6.1	>P	Gravel, sand and silt mix; large worm tubes at surface, eelgrass	1.1	3.6	3-2	-2	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-3-B	R1	3/30/2018	5.7	7.9	>P	4 cm silt layer over sand and silt mix	0.5	3.2	4-3	0	>4	N	2
LDW-Y1-IN-ENR+AC-3-B	R2			6.7	>P	Sand and silt mix; surface worm tubes	0.6	2.1	3-2 and >4	0	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-3-B	R3			5.2	>P	Sand and silt mix; surface worm tubes	0.7	1.9	>4	-1	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-4-A	R1	3/30/2018	2.6	4.8	>P	Cobble, gravel, and sand, no silt	1.5	Ind	2-1	<-4	3	N	Ind
LDW-Y1-IN-ENR+AC-4-A	R2			5.6	>P	Graded, cobble, gravel, and sand with depth, no silt	1.2	Ind	2-(-)3	-5	3	N	Ind
LDW-Y1-IN-ENR+AC-4-A	R3			6.2	>P	Cobble, gravel, and sand, no silt	2	Ind	0-(-)1	<-4	3	N	Ind
LDW-Y1-IN-ENR+AC-4-B	R1	3/30/2018	3.5	5.8	>P	Cobble, gravel, sand and silt mix	1	Ind	2-1	-5	>4	N	Ind
LDW-Y1-IN-ENR+AC-4-B	R2			5.4	>P	Cobble, gravel, sand and silt mix	2	Ind	3-2	-3	>4	Y	Ind
LDW-Y1-IN-ENR+AC-4-B	R3			5.6	>P	Cobble, gravel, sand and silt mix	0.9	Ind	2-1	-5	>4	Y	Ind

Table 3-2a. Year 1 Intertidal ENR+AC Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-IN-ENR+AC-5-A	R1	3/30/2018	2.0	3.8	>P	Cobble, gravel, sand and silt mix; green algae	1.6	Ind	3-2	<-4	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-5-A	R2			8.2	>P	Cobble, gravel, sand and silt mix; green algae	0.5	Ind	2-1	-3	>4	N	Ind
LDW-Y1-IN-ENR+AC-5-A	R3			5.5	>P	Cobble, gravel, sand and silt mix; green algae	1.1	2.7	2-1	-6	>4	Y	Ind
LDW-Y1-IN-ENR+AC-5-B	R1	3/30/2018	3.0	4.3	>P	Cobble, gravel, sand and mostly silt mix; brown algae surface cover	0.6	2	3-2	-3	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-5-B	R2			3.8	>P	Cobble, gravel, sand and mostly silt mix; brown algae surface cover	1.3	2.2	3-2	-4	>4	Y	1
LDW-Y1-IN-ENR+AC-5-B	R3			4.5	>P	Cobble, gravel, sand and mostly silt mix; brown algae surface cover	1.1	2.2	3-2	-3 - -4	>4	Y	1 on 3
LDW-Y1-IN-ENR+AC-6-A	R1	3/30/2018	2.7	7.2	LNA	7 cm of silt, no ENR material evident, surface worm tubes	0.6	3.2	>4	0	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-6-A	R2			6	LNA	6 cm of silt, silt-covered cobbles on surface	1.5	2.9	>4	0	>4	N	1 on 3
LDW-Y1-IN-ENR+AC-6-A	R3			9	>P	3 cm of silt over sand and silt mix; brown algal mat	0.8	3.6	>4	-1	>4	Y	1 on 3
LDW-Y1-IN-ENR+AC-6-B	R1	3/30/2018	2.9	6.8	>P	Sand and silt mix; brown algae	0.5	0.4	3-2	0	>4	Y	1 on 3
LDW-Y1-IN-ENR+AC-6-B	R2			5.6	>P	Cobble, sand and mostly silt mix; brown algae surface cover	1.3	Ind	>4	<-4	>4	Y	1 on 3
LDW-Y1-IN-ENR+AC-6-B	R3			5.7	>P	Sand and silt mix; brown algae or detritus on surface	0.6	2.5	3-2	0	>4	Y	1

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	35	35	23
Average	5.6	1.3	2.3
Median	5.7	1.2	2.2
Minimum	2.3	0.5	0.4
Maximum	9	4.4	3.6

Notes:
- AC = activated carbon
- aRPD = apparent redox potential discontinuity
- ENR = enhanced natural recovery
- Ind = indeterminate
- LNA = layer not apparent
- P = penetration
- SPI = sediment profile imaging

Table 3-2b. Year 1 Intertidal ENR+AC Pilot Subplot PV Results

				Lebensspuren											
Station	Replicate	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-IN-ENR+AC-1-A	R1	Sand and silt	N	Y	Y	N	H	N	NA	N	NA	N	N	L	High concentration of tubes and burrows. Few pieces of algae. Unable to locate second laser dot.
LDW-Y1-IN-ENR+AC-1-A	R2	Sand	N	Y	Y	N	H	N	NA	N	NA	N	N	L	One laser visible. Few pieces of algae. Few shell fragments.
LDW-Y1-IN-ENR+AC-1-A	R3	Sand and gravel	Y	Y	Y	N	H	N	NA	N	Wood	L	N	M	Few shell fragments. Few algae.
LDW-Y1-IN-ENR+AC-1-B	R1	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	One laser visible. Algal mat covering substrate. Few algae.
LDW-Y1-IN-ENR+AC-1-B	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to turbidity in water column.
LDW-Y1-IN-ENR+AC-1-B	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	L	One laser visible. Algae covering surface. Linear line is an artifact from the SPI frame.
LDW-Y1-IN-ENR+AC-2-A	R1	Sand and silt	N	Y	Y	N	H	N	NA	N	NA	N	N	L	Few shell fragments.
LDW-Y1-IN-ENR+AC-2-A	R2	Sand and silt	N	Y	Y	Y	H	N	NA	N	NA	N	N	L	Few shell fragments, high concentration of tubes.
LDW-Y1-IN-ENR+AC-2-A	R3	Sand and silt	N	Y	Y	N	H	N	NA	N	Leaf	L	N	L	Few shell fragments.
LDW-Y1-IN-ENR+AC-2-B	R1	Sand and gravel	N	N	Y	N	N	N	NA	N	NA	N	N	M	Algae covering larger rocks. Shell fragments.
LDW-Y1-IN-ENR+AC-2-B	R2	Sand and silt	N	N	Y	N	H	N	NA	N	Sticks	L	N	L	High concentration of tubes.
LDW-Y1-IN-ENR+AC-2-B	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to turbidity in water column.
LDW-Y1-IN-ENR+AC-3-A	R1	Sand and silt	Y	Y	Y	Y	H	N	NA	N	Stick	L	N	L	
LDW-Y1-IN-ENR+AC-3-A	R2	Sand and silt	N	Y	Y	N	H	N	NA	N	NA	N	N	L	Few shell fragments, and few cobble.
LDW-Y1-IN-ENR+AC-3-A	R3	Sand and silt	N	Y	Y	N	M	N	NA	N	Sticks	L	N	M	Algae and few shell fragments.
LDW-Y1-IN-ENR+AC-3-B	R1	Sand and silt	Y	N	Y	N	H	N	NA	N	Stick	L	N	L	Few shell fragments, few algae.
LDW-Y1-IN-ENR+AC-3-B	R2	Sand and silt	N	N	Y	N	H	N	NA	N	NA	N	N	L	High concentration of tubes. Some algae.
LDW-Y1-IN-ENR+AC-3-B	R3	Sand and silt	N	N	Y	N	M	N	NA	N	NA	N	N	L	Evidence of initial formation of sand waves. Few cobble.
LDW-Y1-IN-ENR+AC-4-A	R1	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Few algae, few cobble.
LDW-Y1-IN-ENR+AC-4-A	R2	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	Few algae.
LDW-Y1-IN-ENR+AC-4-A	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	One laser visible. Some algae.
LDW-Y1-IN-ENR+AC-4-B	R1	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Some algae covering larger rocks.
LDW-Y1-IN-ENR+AC-4-B	R2	Sand and silt	N	N	Y	N	N	N	NA	N	NA	N	N	L	One laser visible. Algae covering substrate.
LDW-Y1-IN-ENR+AC-4-B	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	L	One laser visible. Algae and light silt covering substrate.
LDW-Y1-IN-ENR+AC-5-A	R1	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Some algae. Silt covering substrate.
LDW-Y1-IN-ENR+AC-5-A	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to turbidity in water column.
LDW-Y1-IN-ENR+AC-5-A	R3	Sand and gravel	N	N	Y	N	L	N	NA	N	NA	N	N	L	Linear line in surface is an artifact from the SPI frame, from previous replicate. Silt and few algae.
LDW-Y1-IN-ENR+AC-5-B	R1	Sand and gravel	N	N	Y	N	L	N	NA	N	NA	N	N	M	Silt and algae covering substrate.
LDW-Y1-IN-ENR+AC-5-B	R2	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Silt and algae covering substrate.
LDW-Y1-IN-ENR+AC-5-B	R3	Sand and silt	N	N	N	N	N	N	NA	N	NA	N	N	L	Silt and algae covering substrate.
LDW-Y1-IN-ENR+AC-6-A	R1	Sand and silt	N	N	Y	N	M	N	NA	N	Stick	L	N	L	Algae present.
LDW-Y1-IN-ENR+AC-6-A	R2	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	Silt and algae covering substrate.
LDW-Y1-IN-ENR+AC-6-A	R3	Sand and silt	N	Y	Y	Y	L	N	NA	N	NA	N	N	L	Some gravel on edge of image. Silt and algae present.
LDW-Y1-IN-ENR+AC-6-B	R1	Sand and silt	N	Y	Y	Y	L	N	NA	N	NA	N	N	L	Some algae, few gravel.
LDW-Y1-IN-ENR+AC-6-B	R2	Gravel and sand	N	N	N	N	N	N	NA	N	Sticks	L	N	M	Algae and silt covering substrate.
LDW-Y1-IN-ENR+AC-6-B	R3	Sand and gravel	N	N	Y	N	L	N	NA	N	Sticks	L	N	M	Thin film of algae and silt.

Notes:
Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-3a. Year 1 Scour ENR Pilot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SC-ENR-1-A	R1	3/30/2018	29.9	13.2	>P	Silt over ENR Layer	0.5	1.3	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-1-A	R2			13.5	>P	Silt over ENR Layer	1.3	3.2	>4	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-1-A	R3			10.3	>P	Silt over ENR Layer	0.9	2.2	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-1-B	R1	3/30/2018	32.5	7.4	LNA	Wood	0.5	1.8	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-1-B	R2			8.2	LNA		1.1	1.9	>4	-1	>4	N	1 on 3
LDW-Y1-SC-ENR-1-B	R3			6.4	1-2 cm	Some sand and cobble	5.6	1.6	4-3	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-2-A	R1	3/30/2018	34.4	9.5	LNA		0.7	1.3	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-2-A	R2			10	LNA		1.1	2	>4	<-4	4	N	1 on 3
LDW-Y1-SC-ENR-2-A	R3			7.4	surface only	Cobbles on surface	1.4	1.6	>4	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-2-B	R1	3/30/2018	32.7	7.9	>P	PVC debris	2	2.8	4-3	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-2-B	R2			10.6	1 cm		2.7	2	>4	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-2-B	R3			7.5	>P	Silt over ENR Layer	0.9	1.4	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-3-A	R1	3/30/2018	29.2	9.8	LNA		1.2	1.4	>4	-1	>4	N	1 on 3
LDW-Y1-SC-ENR-3-A	R2			11	LNA	Sand subfraction	1.1	2.5	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-3-A	R3			8.8	LNA	Sand subfraction	2.2	1.1	4-3	0	>4	N	1
LDW-Y1-SC-ENR-3-B	R1	3/30/2018	28.5	9.5	LNA	Sand in feeding void	1.7	2.3	4-3	0	>4	N	1 on 3
LDW-Y1-SC-ENR-3-B	R2			9.8	LNA		1.3	1.1	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-3-B	R3			10.9	LNA		0.9	1.3	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-4-A	R1	3/30/2018	30.8	10.9	>P	Sand subfraction	0.5	2.1	4-3	0	>4	N	1 on 3
LDW-Y1-SC-ENR-4-A	R2			12.5	>P	Sand subfraction	0.4	2.3	>4	-1	>4	N	1 on 3
LDW-Y1-SC-ENR-4-A	R3			12.3	LNA	Sand subfraction	1.4	1.7	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-4-B	R1	3/30/2018	31.4	10.6	>P	Cobble	0.8	3.1	>4	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-4-B	R2			10.2	>P	Sand in voids	1	1.9	>4	<-1	>4	N	1 on 3

Table 3-3a. Year 1 Scour ENR Pilot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SC-ENR-4-B	R3			11	LNA		0.8	3	4-3	0	>4	Y	1 on 3
LDW-Y1-SC-ENR-5-A	R1	3/30/2018	23.6	8.9	>P	Sand and silt mix	1.9	2.5	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-5-A	R2			7.1	>P	Sand at depth	1.4	2.2	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-5-A	R3			7.4	>P	Sand in voids	1.5	3.1	>4	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-5-B	R1	3/30/2018	23.1	10.4	LNA		1.1	1.6	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-5-B	R2			8.6	LNA		0.7	1.4	4-3	-1	>4	N	1 on 3
LDW-Y1-SC-ENR-5-B	R3			11.6	LNA		2	1.4	4-3	-0.5	>4	N	1 on 3
LDW-Y1-SC-ENR-6-A	R1	3/30/2018	26.5	13.1	>P	Silt and ENR layer mix	1.7	Ind	>4/3-2	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR-6-A	R2			9.1	LNA		0.5	1.2	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR-6-A	R3			11.4	>P	Sand in void	1.2	1.5	>4	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR-6-B	R1	3/30/2018	24.7	0.8	LNA	Minimal penetration	1.8	Ind	>4	<-4	>4	N	Ind
LDW-Y1-SC-ENR-6-B	R2			8	>P	Sand and silt mix	0.7	1.7	4-3	<-2	>4	N	1 on 3
LDW-Y1-SC-ENR-6-B	R3			0	--	No penetration, not analyzable	--	--	--	--	--	--	--

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	36	35	33
Average	9.3	1.3	1.9
Median	9.8	1.1	1.8
Minimum	0	0.4	1.1
Maximum	13.5	5.6	3.2

Notes:
- -- = not analyzed
- AC = activated carbon
- aRPD = apparent redox potential discontinuity
- ENR = enhanced natural recovery
- Ind = indeterminate
- LNA = layer not apparent
- P = penetration
- SPI = sediment profile imaging

Table 3-3b. Year 1 Scour ENR Pilot PV Results

				Lebensspuren											
Station	Replicate	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-SC-ENR-1-A	R1	Silt and sand	N	N	Y	Y	M	N	NA	N	Leaf	L	N	L	Few gravels.
LDW-Y1-SC-ENR-1-A	R2	Silt and sand	N	N	Y	Y	H	Y	Crab (1)	N	Wood	L	N	L	
LDW-Y1-SC-ENR-1-A	R3	Silt and sand	N	Y	Y	Y	L	N	NA	Y	Wood and leaves	L	N	L	Imprint is from SPI frame.
LDW-Y1-SC-ENR-1-B	R1	Silt, few gravel	N	Y	Y	Y	H	Y	Tunicate (1)	N	NA	N	N	L	
LDW-Y1-SC-ENR-1-B	R2	Silt, few gravel	N	Y	Y	Y	H	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-1-B	R3	Sand and gravel with silt	N	N	Y	Y	L	N	NA	N	NA	N	N	L	Surface disturbed, unknown origin.
LDW-Y1-SC-ENR-2-A	R1	Silt, trace gravel	N	N	Y	Y	H	Y	Sea Pen (1)	N	wood	L	N	L	
LDW-Y1-SC-ENR-2-A	R2	Silt, few gravel	N	N	Y	Y	M	Y	Barnacle (1)	N	Wood	L	N	L	Image partially obscured by suspended sediment.
LDW-Y1-SC-ENR-2-A	R3	Silt, few gravel	N	N	Y	Y	M	Y	Barnacle (4)	N	Wood	L	N	M	
LDW-Y1-SC-ENR-2-B	R1	Sand and silt with gravel	N	N	Y	Y	M	Y	Bivalve siphon (1)	N	N	N	N	L	
LDW-Y1-SC-ENR-2-B	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-2-B	R3	Sand and gravel with silt	N	N	Y	Y	L	N	NA	N	NA	N	N	M	
LDW-Y1-SC-ENR-3-A	R1	Silt	N	N	Y	Y	M	N	NA	N	Wood	L	N	L	
LDW-Y1-SC-ENR-3-A	R2	Silt	N	N	Y	Y	M	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-3-A	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-3-B	R1	Silt, trace gravel	N	N	Y	Y	H	Y	Crab (1)	N	Wood and leaves	L	N	L	
LDW-Y1-SC-ENR-3-B	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-3-B	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-4-A	R1	Silt	N	N	Y	Y	H	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-4-A	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-4-A	R3	Silt	N	N	Y	Y	M	N	NA	N	NA	N	N	L	Image partially obscured due to suspended sediment.
LDW-Y1-SC-ENR-4-B	R1	Silt and few gravel	N	N	Y	Y	M	N	NA	N	Vegetation	L	N	L	
LDW-Y1-SC-ENR-4-B	R2	Silt	N	N	Y	Y	M	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-4-B	R3	Silt, trace gravel	N	N	Y	Y	H	N	NA	N	Vegetation	L	N	L	
LDW-Y1-SC-ENR-5-A	R1	Silt and gravel	N	N	Y	Y	M	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-5-A	R2	Silt and few gravel	N	N	Y	Y	M	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-5-A	R3	Sand and silt, few gravel	N	N	Y	N	L	N	NA	N	NA	N	N	L	Linear lines are an artifact from the SPI frame.
LDW-Y1-SC-ENR-5-B	R1	Silt and few gravel	N	N	Y	Y	M	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR-5-B	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-5-B	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-6-A	R1	Silt and gravel	N	N	Y	Y	M	Y	Barnacles (4)	N	NA	N	N	M	
LDW-Y1-SC-ENR-6-A	R2	Silt, few gravel	N	N	Y	Y	H	Y	Barnacles (2)	N	NA	N	N	L	
LDW-Y1-SC-ENR-6-A	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable due to suspended sediment.
LDW-Y1-SC-ENR-6-B	R2	Silt and gravel	N	N	Y	Y	M	N	NA	N	Decayed vegetation	L	N	L	
LDW-Y1-SC-ENR-6-B	R3	Wood and silt	N	N	N	N	L	N	NA	N	Wood	H	N	H	Large log.
LDW-Y1-SC-ENR-6-B	R4	Silt, few gravel	N	N	Y	Y	H	N	NA	N	NA	N	N	L	Few algae present.

Notes:

Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-4a. Year 1 Scour ENR+AC SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SC-ENR+AC-1-A	R1	3/30/2018	27.4	7.2	>P	Cobbles over silt	1.4	Ind	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-1-A	R2			5.2	>P	Cobbles over silt	1.8	3.5	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-1-A	R3			6.2	>P	Sand and silt mix	2.5	1.9	3-2	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-1-B	R1	3/30/2018	23.8	4.4	>P	Gravel and cobbles	2	Ind	<-1	<-1	>4	N	Ind
LDW-Y1-SC-ENR+AC-1-B	R2			4.7	>P	Gravel and cobbles	1.7	Ind	<-1	<-1	>4	N	Ind
LDW-Y1-SC-ENR+AC-1-B	R3			4.1	>P	Gravel and cobbles	2.1	Ind	<-1	<-1	>4	N	Ind
LDW-Y1-SC-ENR+AC-2-A	R1	3/30/2018	31.0	8.5	>P	Silt over ENR Layer	0.6	2.2	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-2-A	R2			7.2	>P	Sand and silt mix	1.5	2	3-2	< -2	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-2-A	R3			9.4	>P	Silt over ENR Layer, wood debris	0.9	2	4-3	-1	>4	N	3
LDW-Y1-SC-ENR+AC-2-B	R1	3/30/2018	30.6	7.3	>P	Sand and silt mix	1	1.8	>4	-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-2-B	R2			7.1	>P	Cobbles, sand, and silt	1.6	Ind	3-2	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-2-B	R3			5.2	LNA	Surface debris	0.9	1.5	3-2	0	-4	N	1 on 3
LDW-Y1-SC-ENR+AC-3-A	R1	3/30/2018	21.7	7.2	>P	Gravel, cobbles over sand	1.5	Ind	<-1 / 2-1	<-1	>4	N	Ind
LDW-Y1-SC-ENR+AC-3-A	R2			8.7	>P	Cobbles over silty sand	1	Ind	<-1 / 1-0	<-1	>4	N	Ind
LDW-Y1-SC-ENR+AC-3-A	R3			7.1	>P	Gravel and cobbles	1.1	Ind	<-1	<-4	>4	N	Ind
LDW-Y1-SC-ENR+AC-3-B	R1	3/30/2018	22.5	7.3	>P	Gravel and cobbles	1.1	Ind	< -1	<-4	>4	N	Ind
LDW-Y1-SC-ENR+AC-3-B	R2			6.8	>P	Gravel and cobbles	1.5	Ind	<-4	<-4	>4	N	Ind
LDW-Y1-SC-ENR+AC-3-B	R3			5.9	>P	Gravel, cobbles over sand	1.1	Ind	<-1 / 2-1	<-1	4-3	N	Ind
LDW-Y1-SC-ENR+AC-4-A	R1	3/30/2018	27.3	9.4	>P	Sand and silt mix	2.3	3	3-2	-1	>4	N	1
LDW-Y1-SC-ENR+AC-4-A	R2			9.2	>P	Sand and silt mix	1	4.3	3-2	-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-4-A	R3			10.3	>P	Sand and silt mix	0.7	2.8	4-3	-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-4-B	R1	3/30/2018	27.0	8.1	>P	Sand and silt mix, many dark particles	0.8	4.7	3-2	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-4-B	R2			9.3	>P	Sand and silt mix	1.1	2.7	3-2	0	>4	N	1 on 3

Table 3-4a. Year 1 Scour ENR+AC SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SC-ENR+AC-1-A	R1	3/30/2018	27.4	7.2	>P	Cobbles over silt	1.4	Ind	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-4-B	R3			9.8	>P	Sand and silt mix	2.3	2.4	3-2	-1	>4	N	1
LDW-Y1-SC-ENR+AC-5-A	R1	3/30/2018	19.7	6.2	>P	Gravel, sand, and silt mix	1.9	Ind	2-1	<-2	>4	N	Ind
LDW-Y1-SC-ENR+AC-5-A	R2			6.6	>P	Gravel, sand, and silt mix	1.6	4.6	2-1	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-5-A	R3			5.7	>P	Gravel, sand, and silt mix	0.5	Ind	2-1	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-5-B	R1	3/30/2018	19.9	6.9	>P	Gravel, sand, and silt mix	0.7	Ind	3-2	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-5-B	R2			4.9	>P	Gravel, sand, and silt mix	1.7	3.6	2-1	<-4	>4	N	Ind
LDW-Y1-SC-ENR+AC-5-B	R3			5.9	>P	Gravel, sand, and silt mix	1.6	Ind	3-2	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-A	R1	3/30/2018	25.1	7.8	LNA	1-2 cm sand, cobble over silt	2.5	3.1	4-3/>4	<-4	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-A	R2			13.9	>P	Sand and silt mix	1.3	4.7	4-3	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-A	R3			9.5	>P	Sand and silt mix, dark particle layer at surface	1.2	4.5	3-2	<-1	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-B	R1	3/30/2018	23.2	10.7	LNA	Silt with sand trace	0.6	2.1	>4	0	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-B	R2			12.2	>P	Sand and silt mix	0.9	1.8	4-3	0	>4	N	1 on 3
LDW-Y1-SC-ENR+AC-6-B	R3			13.9	>P	Sand and silt mix, dark particles in voids	0.6	2.7	>4	-1	>4	N	1 on 3

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	36	36	21
Average	7.8	1.4	2.9
Median	7.2	1.25	2.7
Minimum	4.1	0.5	1.5
Maximum	13.9	2.5	4.7

Notes:
- AC = activated carbon
- aRPD = apparent redox potential discontinuity
- ENR = enhanced natural recovery
- Ind = indeterminate
- LNA = layer not apparent
- P = penetration
- SPI = sediment profile imaging

Table 3-4b. Year 1 Scour ENR+AC PV Results

				Lebensspuren											
Station	Replicate	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-SC-ENR+AC-1-A	R1	Silt and gravel	N	N	Y	Y	L	Y	Sea pen (2), barnacles (3)	N	NA	N	N	M	Few shell fragments.
LDW-Y1-SC-ENR+AC-1-A	R2	Silt and gravel	N	N	Y	Y	L	N	NA	N	NA	N	N	M	Fine silt covering sand and gravel. Few shell fragments.
LDW-Y1-SC-ENR+AC-1-A	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image too blurred by suspended sediments to analyze.
LDW-Y1-SC-ENR+AC-1-B	R	Sand and gravel	N	N	N	N	N	Y	Barnacle (1)	N	NA	N	N	M	Sand and gravel with some shell fragments.
LDW-Y1-SC-ENR+AC-1-B	R1	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	Few algae and shell fragments.
LDW-Y1-SC-ENR+AC-1-B	R3	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	Image blurred by suspended sediments.
LDW-Y1-SC-ENR+AC-2-A	R1	Silt with gravel	N	N	Y	Y	H	Y	Unidentified organism	N	NA	N	N	L	Few gravel.
LDW-Y1-SC-ENR+AC-2-A	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable, due to suspended sediment.
LDW-Y1-SC-ENR+AC-2-A	R3	Silt and wood	N	N	N	N	N	N	NA	N	Wood and vegetation	M	N	M	Image partially obscured from suspended sediment.
LDW-Y1-SC-ENR+AC-2-B	R1	--	--	--	--	--	--	--	--	--	--	--	--	--	Image obscured by suspended sediment.
LDW-Y1-SC-ENR+AC-2-B	R2	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	M	One laser visible. Image partially obscured by suspended sediment. Some silt and algae.
LDW-Y1-SC-ENR+AC-2-B	R3	Silt and gravel	N	N	N	N	N	N	NA	N	NA		N	M	No lasers visible. Image partially obscured by suspended sediment.
LDW-Y1-SC-ENR+AC-3-A	R1	Gravel and sand	N	N	N	N	N	N	NA	N	NA	N	N	M	No lasers visible, close up view of bottom.
LDW-Y1-SC-ENR+AC-3-A	R2	Gravel and sand	N	N	Y	N	L	Y	Barnacles and unidentified organism (1)	N	NA	N	N	M	Recent deposit of silt, not from SPI frame.
LDW-Y1-SC-ENR+AC-3-A	R3	Gravel and sand	N	N	N	N	N	Y	Barnacles	N	Wood	L	N	M	Shell fragments.
LDW-Y1-SC-ENR+AC-3-A	RNG	Sand and gravel	N	N	N	N	N	Y	Barnacles	N	NA	N	N	M	
LDW-Y1-SC-ENR+AC-3-B	R1	Gravel and sand	N	N	N	N	L	Y	Tunicate (1) and barnacles	N	NA	N	N	M	
LDW-Y1-SC-ENR+AC-3-B	R2	Gravel and sand	N	N	N	N	N	N	NA	N	Wood	L	N	M	
LDW-Y1-SC-ENR+AC-3-B	R3	Sand and gravel	N	N	N	N	N	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR+AC-4-A	R1	Silt	N	N	Y	Y	L	Y	Sea pen (1)	N	Wood and leaves	L	N	L	Film of algae on surface.
LDW-Y1-SC-ENR+AC-4-A	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Not analyzable due to suspended sediment.
LDW-Y1-SC-ENR+AC-4-A	R3	Silt	N	N	N	N	N	Y	Barnacles (6)	N	NA	N	N	L	Image partially obscured due to suspended sediment.
LDW-Y1-SC-ENR+AC-4-B	R1	Sand and gravel with silt	N	N		Y	L	Y	Barnacles (7)	N	Leaves	L	N	M	
LDW-Y1-SC-ENR+AC-4-B	R2	Sand and gravel with silt	N	N	Y	Y	L	Y	Barnacles (15)	N	Wood	L	N	M	Shell fragments.
LDW-Y1-SC-ENR+AC-4-B	R3	Sand and gravel with silt	N	N	Y	Y	L	N	NA	N	Wood	L	N	L	
LDW-Y1-SC-ENR+AC-5-A	R1	Sand and gravel with silt	N	N	Y	Y	L	Y	Barnacles	N	Wood	L	N	M	
LDW-Y1-SC-ENR+AC-5-A	R2	Sand and gravel with silt	N	N	Y	N	L	N	NA	N	NA	N	N	M	Some algae.
LDW-Y1-SC-ENR+AC-5-A	R3	Sand and gravel with silt	N	N	N	N	N	N	NA	N	Leaf	L	N	M	Linear lines are an artifact from the SPI frame.
LDW-Y1-SC-ENR+AC-5-B	R1	Sand and gravel	N	N	Y	Y	L	N	NA	N	NA	N	N	L	
LDW-Y1-SC-ENR+AC-5-B	R2	Gravel and sand with silt	N	N	Y	N	L	N	NA	N	NA	N	N	M	
LDW-Y1-SC-ENR+AC-5-B	R3	Gravel and sand with silt	N	N	N	N	N	N	NA	N	NA	N	N	M	Algae.
LDW-Y1-SC-ENR+AC-6-A	R1	Sand and silt with gravel	N	Y	Y	Y	M	Y	Barnacles (&), gastropod (1)	N	NA	N	N	L	Shell fragments.
LDW-Y1-SC-ENR+AC-6-A	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR+AC-6-A	R3	Sand with silt, trace gravel	N	N	Y	Y	M	Y	Barnacles (3)	N	NA	N	N	L	Few shell fragments.
LDW-Y1-SC-ENR+AC-6-B	R1	Silt and sand	N	N	Y	Y	M	N	NA	N	Leaf and wood	L	N	L	
LDW-Y1-SC-ENR+AC-6-B	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.
LDW-Y1-SC-ENR+AC-6-B	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	Image not analyzable due to suspended sediment.

Notes:
Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-5a. Year 1 Subtidal ENR Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SU-ENR-1-A	R1	3/29/2018	38.5	5.6	>P	Sand and silt mix	1.2	4.3	3-2	0	>4	N	1 on 3
LDW-Y1-SU-ENR-1-A	R2			5.5	>P	Sand and silt mix	0.4	2.6	4-3	0	>4	N	2
LDW-Y1-SU-ENR-1-A	R3			3.6	>P	Sand and silt mix, wood	2.1	1.8	3-2	<-1	>4	N	Ind
LDW-Y1-SU-ENR-1-B	R1	3/29/2018	37.7	5.3	>P	Sand and silt mix	0.2	2.4	4-3	0	>4	N	Ind
LDW-Y1-SU-ENR-1-B	R2			4.2	>P	Sand and silt mix	2.1	2.1	3-2	1	>4	N	Ind
LDW-Y1-SU-ENR-1-B	R4			4.6	>P	Sand and silt mix, bedform	2	2.4	3-2	-1	>4	N	Ind
LDW-Y1-SU-ENR-2-B	R1	3/29/2018	38.0	4.4	>P	Sand and silt mix	0.9	2	3-2	0	>4	N	1 on 3
LDW-Y1-SU-ENR-2-B	R2			3	>P	Sand and silt mix, wood	2.2	Ind	2-1	0	>4	N	Ind
LDW-Y1-SU-ENR-2-B	R3			5.3	>P	Sand and silt mix	1.7	3.2	3-2	-1	>4	N	1 on 3
LDW-Y1-SU-ENR-3-A	R1	3/29/2018	38.1	3.7	>P	Sand and silt mix, sand lag deposit at surface	0.9	2.2	4-3	-1	>4	N	Ind
LDW-Y1-SU-ENR-3-A	R2			4.7	>P	Sand and silt mix, sand lag deposit at surface	0.7	2.4	3-2	-1	>4	N	1 on 3
LDW-Y1-SU-ENR-3-A	R3			3.6	>P	Sand and silt mix	0.9	2	4-3	-1	>4	N	1 on 3
LDW-Y1-SU-ENR-3-B	R1	3/29/2018	37.3	6	>P	Sand and silt mix	0.6	3.1	3 to 2	-1	>4	N	2
LDW-Y1-SU-ENR-3-B	R2			4.2	>P	Sand and silt mix	2	1.7	3-2	0	>4	N	1
LDW-Y1-SU-ENR-3-B	R3			4	>P	Sand and silt mix, sand lag deposit at surface	1.3	2.4	3-2	-1	>4	N	1 on 3
LDW-Y1-SU-ENR-4-A	R1	3/29/2018	37.5	4.2	>P	Coarse sand and silt mix	1	2.5	3-2	-2	>4	N	1 on 3
LDW-Y1-SU-ENR-4-A	R2			5.3	>P	Coarse sand and silt mix	1.6	Ind	2-1	-3	>4	N	1 on 3
LDW-Y1-SU-ENR-4-A	R3			8.3	>P	Coarse sand and silt mix	0.8	Ind	3-2	-2	>4	N	1 on 3
LDW-Y1-SU-ENR-4-B	R1	3/29/2018	38.0	3.7	>P	Sand and silt mix, sand lag deposit at surface	1	Ind	3-2	-1	>4	N	1 on 3
LDW-Y1-SU-ENR-4-B	R2			5.6	>P	Sand and silt mix, sand lag deposit at surface	0.5	3.3	3-2	0	>4	N	Ind
LDW-Y1-SU-ENR-4-B	R3			4.6	>P	Sand and silt mix, sand lag deposit at surface	0.7	2.3	3-2	-1	>4	N	Ind
LDW-Y1-SU-ENR-5-A	R1	3/29/2018	39.4	3	>P	Sand and silt mix, sand lag deposit at surface	2.1	Ind	2-1	-1	>4	N	Ind
LDW-Y1-SU-ENR-5-A	R2			7.2	>P	Sand and silt mix, sand lag deposit at surface, wood	0.5	3.1	4-3	1-0	>4	N	2

Table 3-5a. Year 1 Subtidal ENR Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SU-ENR-5-A	R3			7.2	>P	Sand and silt mix, sand lag deposit at surface, wood	4.5	3	3-2	-1	>4	N	2
LDW-Y1-SU-ENR-5-B	R1	3/29/2018	38.5	3.4	>P	Coarse to medium sand	1.2	Ind	0-1	-3	>4	N	Ind
LDW-Y1-SU-ENR-5-B	R2			4.2	>P	Coarse to medium sand, wood	1.2	Ind	2-1	-2	>4	N	Ind
LDW-Y1-SU-ENR-5-B	R3			5.1	>P	Coarse to medium sand	1.1	Ind	1-0	<-1	>4	N	Ind
LDW-Y1-SU-ENR-6-A	R1	3/29/2018	41.7	13.4	3 cm ENR layer	Gravel and sand over silt	0.4	3	2-1/>4	-5	>4	N	1 on 3
LDW-Y1-SU-ENR-6-A	R2			12.8	8 to >13 cm ENR layer	Coarse sand over silt	0.9	Ind	1-0/>4	-2	>4	Y	Ind
LDW-Y1-SU-ENR-6-A	R3			4.7	>P	Coarse to medium sand	1	Ind	2-1	-3	>4	N	Ind
LDW-Y1-SU-ENR-6-B	R1	3/29/2018	39.1	6.5	>P	Graded gravel to medium sand with depth	1.6	Ind	2-1	-5	>4	N	Ind
LDW-Y1-SU-ENR-6-B	R2			4.1	>P	Graded gravel to medium sand with depth	1.3	Ind	2-1	-3	4	N	Ind
LDW-Y1-SU-ENR-6-B	R3			5.6	>P	Graded gravel to medium sand with depth	1.7	Ind	2-1	-2	3	N	Ind

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	33	33	20
Average	5.4	1.3	2.6
Median	4.7	1.1	2.4
Minimum	3	0.2	1.7
Maximum	13.4	4.5	4.3

Notes:
- AC = activated carbon
- aRPD = apparent redox potential discontinuity
- ENR = enhanced natural recovery
- Ind = indeterminate
- LNA = layer not apparent
- P = penetration
- SPI = sediment profile imaging

Table 3-5b. Year 1 Subtidal ENR Pilot Subplot PV Results

				Lebensspuren											
Station	Replicate	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-SU-ENR-1-A	R1	Sand and silt	N	N	Y	Y	L	N	NA	N	Leaves, wood	L	N	L	Few shell fragments; some evidence of epifaunal activity.
LDW-Y1-SU-ENR-1-A	R2	Sand and silt	N	N	Y	Y	L	N	NA	N	Wood, leaves	L	N	L	Some evidence of epifaunal activity.
LDW-Y1-SU-ENR-1-A	R3	Sand and silt	N	N	N	N	N	Y	Barnacles (3)	N	Wood, leaves	M	N	M	Unable to locate second laser dot; image blurry due to suspended sediments.
LDW-Y1-SU-ENR-1-B	R1	Sand with silt	N	N	Y	Y	L	Y	Unidentified organism	N	Wood	L	N	L	Few shell fragments; some signs of epifaunal activity.
LDW-Y1-SU-ENR-1-B	R2	Sand and silt	N	N	Y	Y	L	N	NA	N	NA	N	N	L	Unable to locate second laser dot; few shell fragments. Image partially obscured by suspended sediment.
LDW-Y1-SU-ENR-1-B	R3	Sand and silt	Y	N	N	Y	N	N	NA	N	Wood	L	N	L	Few sand waves; image blurred by suspended sediments.
LDW-Y1-SU-ENR-2-A	R1	Sand with silt	Y	N	Y	Y	L	N	NA	N	Wood, leaves	L	N	L	Some evidence of epifaunal activity; few shell fragments and soft deposits.
LDW-Y1-SU-ENR-2-A	R2	Sand and silt	Y	N	N	N	N	N	NA	N	Wood, leaves	L	N	L	Sand waves and soft deposits present with accumulated woody debris. Image blurred by suspended sediments.
LDW-Y1-SU-ENR-2-A	R3	Sand with wood and silt	Y	N	Y	Y	L	N	NA	N	Wood, leaves	L	N	M	Sand waves with depositional areas of woody and leafy debris.
LDW-Y1-SU-ENR-2-B	R1	Sand and silt	N	Y	Y	Y	M	Y	Gastropod (1)	N	Wood	L	N	L	Evidence of epifaunal activity; few shell fragments.
LDW-Y1-SU-ENR-2-B	R2	Sand	Y	N	N	Y	L	N	NA	N	Wood, leaves	M	N	M	Defined sand waves with woody detrital deposits . Image partially obscured by suspended sediment.
LDW-Y1-SU-ENR-2-B	R3	Sand and silt	N	N	Y	Y	L	N	NA	N	Leaves, wood	L	N	L	Few shell fragments and soft deposits.
LDW-Y1-SU-ENR-3-A	R1	Sand and gravel	N	N	Y	Y	L	N	NA	N	Wood	L	N	L	Large depositional depression with pebbles, shell fragments, and woody debris present.
LDW-Y1-SU-ENR-3-A	R2	Sand and gravel	N	N	Y	N	L	N	NA	N	NA	N	N	L	Few gravel and shell fragments.
LDW-Y1-SU-ENR-3-A	R3	Sand with silt	N	N	Y	N	L	Y	Worms	N	NA	N	N	L	Some soft deposits, shell fragments.
LDW-Y1-SU-ENR-3-B	R1	Sand	N	N	Y	N	N	Y	Encrusting epizoans (2)	N	Wood	L	N	L	Some shell fragments; few soft depositional areas.
LDW-Y1-SU-ENR-3-B	R2	Sand	N	N	Y	N	L	N	NA	N	NA	N	N	L	Some shell fragments and gravel.
LDW-Y1-SU-ENR-3-B	R3	Sand with silt	N	N	Y	N	L	N	NA	N	Wood	L	N	L	Disturbance from SPI frame visible; few shell fragments and pebbles.
LDW-Y1-SU-ENR-4-A	R1	Sand	N	N	Y	N	N	Y	Encrusting epizoans (1)	N	Wood	L	N	M	Some cobble and woody debris in depositional pockets; shell fragments throughout.
LDW-Y1-SU-ENR-4-A	R2	Sand with silt	N	N	N	N	N	N	NA	N	Wood	M	N	M	Some woody debris and shell fragments.
LDW-Y1-SU-ENR-4-A	R3	Sand with silt	N	N	N	N	N	Y	Bivalves (2)	N	Wood, leaves	M	N	L	Woody and leafy debris with shell fragments in depositional areas; few cobble.
LDW-Y1-SU-ENR-4-B	R1	Sand	N	N	Y	N	N	N	NA	N	Wood, leaves	L	N	L	Few soft sediment deposits, few cobble, some shell fragments, few algae.
LDW-Y1-SU-ENR-4-B	R2	Sand	N	N	Y	N	L	N	NA	N	Wood	L	N	L	Sediment disturbance from SPI frame visible. Few shell fragments.
LDW-Y1-SU-ENR-4-B	R3	Sand	N	N	Y	N	N	Y	Gastropod (1)	N	Wood	L	N	L	Disturbance from SPI camera visible. Few shell fragments; few soft sediment deposits.
LDW-Y1-SU-ENR-5-A	R1	Sand with silt	N	N	N	N	N	N	N	NA	Wood, leaves	M	N	M	Few cobble, few pebbles, few shell fragments; few areas of soft sediment deposits.
LDW-Y1-SU-ENR-5-A	R2	Sand and wood	N	N	N	N	N	N	NA	N	Wood, leaves, reeds	H	N	M	High density of woody debris; few shell fragments and pebbles.
LDW-Y1-SU-ENR-5-A	R3	Sand and wood	N	N	N	N	N	N	NA	N	Wood, leaves, reeds	H	N	M	High density of woody debris.
LDW-Y1-SU-ENR-5-B	R1	Sand and few gravel	N	N	Y	N	L	Y	Barnacles (3), sea pen (1)	N	Wood	L	N	L	Few gravel and shell fragments; some soft sediment deposits.
LDW-Y1-SU-ENR-5-B	R2	Sand	N	N	N	Y	L	Y	Barnacle (1)	N	Wood, leaves	M	N	L	Few shell fragments; few pebbles.
LDW-Y1-SU-ENR-5-B	R3	Sand	N	N	Y	N	L	N	NA	N	Wood	L	N	L	Few shell fragments, few cobble. Linear line is an artifact from the SPI frame.
LDW-Y1-SU-ENR-6-A	R1	Sand and gravel	N	N	N	N	N	N	NA	N	Wood, leaves	L	N	L	Some shell fragments and silt.
LDW-Y1-SU-ENR-6-A	R2	Sand and gravel	N	N	N	Y	L	N	NA	N	NA	N	N	L	Some shell fragments and cobble.
LDW-Y1-SU-ENR-6-A	R3	Sand and gravel	N	N	N	N	N	N	NA	N	Leaf	L	N	L	Shell fragments and few soft sediment deposits.
LDW-Y1-SU-ENR-6-B	R1	Sand and gravel	N	N	N	Y	L	N	NA	N	Wood	L	N	L	Few shell fragments and cobble.
LDW-Y1-SU-ENR-6-B	R2	Sand	N	N	N	N	N	N	NA	N	Wood	L	N	L	Imprint from SPI frame visible. Few small shell fragments and gravel.
LDW-Y1-SU-ENR-6-B	R3	Sand and gravel	N	N	N	N	N	Y	Barnacles (10+)	N	NA	N	N	L	Few algae, some shell fragments. SPI frame imprint visible.

Notes:
Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-6a. Year 1 Subtidal ENR+AC Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SU-ENR+AC-1-A	R1	3/29/2018	38.7	4.8	>P	Sand and silt mix, sand lag deposit	1.6	2.1	4-3	1	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-1-A	R2			14.1	>P?	2 cm sand over silt	1.8	Ind	>4	>-1	>4	N	1
LDW-Y1-SU-ENR+AC-1-A	R3			8.9	>P?	2 cm sand over silt, sediment-water interface disturbed by camera drop	1.5	Ind	>4	0	>4	N	1
LDW-Y1-SU-ENR+AC-1-B	R1	3/29/2018	38.5	4.9	>P	Sand and silt mix, sand lag deposit	1.9	1.8	4-3	-2	4	N	1 on 3
LDW-Y1-SU-ENR+AC-1-B	R2			6.2	>P	Sand and silt mix	0.8	1.5	4-3	0	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-1-B	R3			4.4	>P	Sand and silt mix, sand lag deposit	3.2	1.8	3-2	0	>4	N	Ind
LDW-Y1-SU-ENR+AC-2-A	R1	3/29/2018	37.3	7.6	>P	Sand and silt mix	1.1	3.2	3 to 2	1 to 0	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-2-A	R2			6.8	>P	Sand and silt mix	0.5	2.1	4 to 3	0	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-2-A	R3			12.8	>P?	2 cm sand layer over sandy silt	3.6	2.6	>4	0	>4	N	1
LDW-Y1-SU-ENR+AC-2-B	R1	3/29/2018	37.3	10.6	>P?	2 cm sand layer over sandy silt	3.9	3.8	>4	1 to 0	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-2-B	R2			12.7	>P?	2 cm sand layer over sandy silt	1.9	2.4	4 to 3	0	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-2-B	R3			10.5	>P?	2 cm sand layer over sandy silt	4.2	Ind	>4	-1	>4	N	1
LDW-Y1-SU-ENR+AC-3-A	R1	3/29/2018	37.2	4.2	>P	Coarse to medium sand	0.4	Ind	1-0	<-1	>4	N	Ind
LDW-Y1-SU-ENR+AC-3-A	R2			3.8	>P	Coarse to medium sand	2	Ind	1-0	<-4	>4	N	Ind
LDW-Y1-SU-ENR+AC-3-A	R3			5.5	>P	Coarse to medium sand	3.7	Ind	1-0	<-4	>4	N	Ind
LDW-Y1-SU-ENR+AC-3-B	R1	3/29/2018	39.0	4.5	>P	Sand and silt mix, sand lag deposit at surface	3.2	1.3	3 to 2	<-4	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-3-B	R2			3.3	>P	Sand and silt mix, sand lag deposit at surface	1.8	1.5	3 to 2	-1	>4	N	Ind
LDW-Y1-SU-ENR+AC-3-B	R3			3.5	>P	Sand and silt mix, sand lag deposit at surface	1.1	Ind	2-1/3-2	0	>4	N	Ind
LDW-Y1-SU-ENR+AC-4-A	R1	3/29/2018	41.4	3.4	>P	Gravel to medium sand with depth	1.8	Ind	2 to 1	-1	>4	N	Ind
LDW-Y1-SU-ENR+AC-4-A	R2			5.2	>P	Medium sand	1.7	Ind	2 to 1	< -1	>4	N	Ind
LDW-Y1-SU-ENR+AC-4-A	R3			5.6	>P	Graded gravel to medium sand with depth	1	Ind	0 to -1	< -4	>4	N	Ind
LDW-Y1-SU-ENR+AC-4-B	R1	3/29/2018	41.0	5.6	>P	Gravel to medium sand	2.5	Ind	0 to -1	< -1	>4	N	Ind
LDW-Y1-SU-ENR+AC-4-B	R2			1.9	>P	Gravel to medium sand	1	Ind	2-1	-1	>4	N	Ind

Table 3-6a. Year 1 Subtidal ENR+AC Pilot Subplot SPI Results

Station	Replicate	Image Date	Water Depth (ft)	Penetration Depth (cm)	ENR+AC Layer Thickness	Texture and Other Observations	Surface Boundary Roughness (cm)	RPD Depth (cm)	Grain Size Major Mode (phi units)	Grain Size Maximum (phi units)	Grain Size Minimum (phi units)	Methane	Successional Stage
LDW-Y1-SU-ENR+AC-4-B	R3			5.5	>P	Gravel to very fine sand, bedform	4.7	Ind	2 to 1	-3	>4	N	Ind
LDW-Y1-SU-ENR+AC-5-A	R1	3/29/2018	43.2	12.4	<1 cm	Thin sand cover over reduced mud	0.7	0.3	>4	-1	>4	N	1
LDW-Y1-SU-ENR+AC-5-A	R2			19.9	<1 cm	Thin sand cover over reduced mud	2.8	Ind	>4	0	>4	N	1
LDW-Y1-SU-ENR+AC-5-A	R3			11	<1 cm	Thin sand cover over reduced mud	1.4	0.4	>4	-1	>4	N	1
LDW-Y1-SU-ENR+AC-5-B	R1	3/29/2018	41.8	9.3	<1 cm	Thin sand cover over reduced mud	1.3	0.2	>4	0	>4	N	1
LDW-Y1-SU-ENR+AC-5-B	R2			7.5	<1 cm	Thin sand cover over reduced mud	1.6	0.1	>4	-2	>4	N	1
LDW-Y1-SU-ENR+AC-5-B	R3			5.9	<1 cm	Thin sand cover over reduced mud	1.9	0	>4	0	>4	N	1
LDW-Y1-SU-ENR+AC-6-A	R2	3/29/2018	43.8	5.5	>P	Patchy sand in silt, redcued sediments	1.2	0.6	>4	-3	>4	Y	1
LDW-Y1-SU-ENR+AC-6-A	R3			7.7	< 1 cm	Surface sand over silt	1.5	0.5	>4	-2	>4	N	2->3
LDW-Y1-SU-ENR+AC-6-A	R4			5.8	>P	Surface sand over silt	0.5	0.7	>4	-3	>4	N	2->3
LDW-Y1-SU-ENR+AC-6-B	R2	3/29/2018	42.1	12.1	< 1 cm	Surface sand over silt	2.6	0.5	>4	-1	>4	N	1
LDW-Y1-SU-ENR+AC-6B	R4			6.8	LNA	Silt	1.8	0.3	>4	-1	>4	N	1 on 3
LDW-Y1-SU-ENR+AC-6B	R5			6	<1 cm	Surface sand over silt	3.3	0.7	>4	-3	>4	N	1 on 3

Summary Statistics for Some Numerical Parameters

	Penetration Depth (cm)	Surface Boundary Roughness (cm)	RPD Depth (cm)
N	36	36	22
Average	7.4	2.0	1.3
Median	6.0	1.8	1.0
Minimum	1.9	0.4	0.0
Maximum	19.9	4.7	3.8

Notes:
AC = activated carbon
aRPD = apparent redox potential discontinuity
ENR = enhanced natural recovery
Ind = indeterminate
LNA = layer not apparent
P = penetration
SPI = sediment profile imaging

Table 3-6b. Year 1 Subtidal ENR+AC Pilot Subplot PV Results

				Lebensspuren											
Station	Replicate	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Total Abundance	Epifauna	Epifauna Type (Count)	Mud Clasts	Debris Type	Debris Cover	*Beggiatoa*	Surface Boundary Roughness (cm)	Comments
LDW-Y1-SU-ENR+AC-1-A	R1	Sand and silt	Y	Y	Y	Y	L	Y	Isopod (1)	N	Wood	L	N	M	Few shell fragments, few algae.
LDW-Y1-SU-ENR+AC-1-A	R2	Sand with silt	Y	N	Y	N	L	N	NA	N	Wood, leaves	L	N	M	Few shell fragments and pebbles.
LDW-Y1-SU-ENR+AC-1-A	R3	Sand and silt	Y	N	N	N	N	N	NA	N	Wood	L	N	M	Image blurred due to suspended sediments.
LDW-Y1-SU-ENR+AC-1-B	R1	Sand	N	Y	Y	Y	L	N	NA	N	Wood	L	N	L	Few shell fragments, few gravel.
LDW-Y1-SU-ENR+AC-1-B	R2	Sand	N	N	N	N	N	N	NA	N	Wood	L	N	L	Image blurred due to suspended sediments.
LDW-Y1-SU-ENR+AC-1-B	R3	Sand	N	N	Y	Y	L	N	NA	N	Wood, leaves	L	N	L	Few algae, few shell fragments, few pebbles .
LDW-Y1-SU-ENR+AC-2-A	R1	Sand with some silt overlay	N	N	N	N	N	N	NA	N	NA	N	N	L	Few shell fragment and pebbles.
LDW-Y1-SU-ENR+AC-2-A	R2	Sand	N	N	N	N	N	N	NA	N	Wood	L	N	L	Image blurred due to suspended sediment; few shell fragments.
LDW-Y1-SU-ENR+AC-2-A	R3	Sand with silt	N	N	Y	Y	L	Y	Worm (1)	N	NA	N	N	L	Few shell fragments, few cobble, few algae, shrimp carcass.
LDW-Y1-SU-ENR+AC-2-B	R1	Sand	N	N	Y	Y	L	N	NA	N	Wood	L	N	L	Few shell fragments, few pebbles, few algae.
LDW-Y1-SU-ENR+AC-2-B	R2	Sand with silt	N	N	Y	N	L	N	NA	N	Wood	L	N	L	Few shell fragments, few pebbles. Linear lines are an artifact from the SPI frame.
LDW-Y1-SU-ENR+AC-2-B	R3	Sand	N	Y	Y	N	L	Y	Barnacles (10+), crab (1)	Y	Wood, leaves	L	N	L	Some small pebbles and shell fragments. Bottom likely disturbed by SPI frame.
LDW-Y1-SU-ENR+AC-3-A	R1	Sand with gravel	N	N	Y	N	L	N	NA	N	Wood	L	N	L	Few cobble and shell fragments.
LDW-Y1-SU-ENR+AC-3-A	R2	Sand with gravel	N	N	N	N	N	Y	Barnacles (8)	N	NA	N	N	L	Few cobble and shell fragments.
LDW-Y1-SU-ENR+AC-3-A	R3	Sand with gravel	N	Y	N	N	N	N	NA	N	Wood, leaves	L	N	L	Few algae and shell fragments.
LDW-Y1-SU-ENR+AC-3-B	R1	Sand	Y	Y	Y	N	L	N	NA	N	NA	N	N	L	Some shell fragments and pebbles.
LDW-Y1-SU-ENR+AC-3-B	R2	Sand	N	N	Y	N	L	N	NA	N	NA	N	N	L	Bottom disturbance likely due to SPI frame.
LDW-Y1-SU-ENR+AC-3-B	R3	Sand	N	N	N	N	N	N	NA	N	Leaves	L	N	L	Some pebbles and shell fragments. Image blurred due to suspended sediment.
LDW-Y1-SU-ENR+AC-4-A	R1	Sand	Y	N	N	N	N	Y	Barnacles (4)	N	NA	N	N	L	Shell fragments and pebbles, some silt.
LDW-Y1-SU-ENR+AC-4-A	R2	Sand	N	N	N	N	N	N	NA	N	NA	N	N	L	Few algae; few pebbles and shell fragments.
LDW-Y1-SU-ENR+AC-4-A	R3	Sand and gravel	N	N	N	N	N	N	NA	N	Wood	L	N	L	Some shell fragments and cobble.
LDW-Y1-SU-ENR+AC-4-B	R1	Sand and gravel	N	N	N	N	N	N	NA	Y	NA	N	N	L	Many shell fragments; some silt overlay.
LDW-Y1-SU-ENR+AC-4-B	R2	Sand with gravel	N	N	N	N	N	N	NA	Y	Wood	L	N	M	Few shell fragments; Mud clasts are an artifact from the SPI frame.
LDW-Y1-SU-ENR+AC-4-B	R3	Sand and gravel	Y	N	N	N	N	N	NA	N	NA	N	N	M	Few shell fragments and gravel.
LDW-Y1-SU-ENR+AC-5-A	R1	Sand and silt	Y	N	Y	Y	L	N	NA	N	Leaves	L	N	L	Few shell fragments and cobble.
LDW-Y1-SU-ENR+AC-5-A	R2	Sand and silt	Y	N	Y	N	L	N	NA	Y	Wood	L	N	M	Bottom appears highly disturbed. Few shell fragments and pebbles.
LDW-Y1-SU-ENR+AC-5-A	R3	Sand and silt	Y	Y	Y	N	L	N	NA	N	Wood	L	N	L	Few cobble and shell fragments.
LDW-Y1-SU-ENR+AC-5-B	R1	Sand and silt	N	N	Y	N	N	N	NA	Y	NA	N	N	M	Area appears to be recently disturbed; few shell fragments.
LDW-Y1-SU-ENR+AC-5-B	R2	Sand and silt	N	N	N	N	N	N	NA	N	NA	N	N	M	Image blurred by suspended sediment.
LDW-Y1-SU-ENR+AC-5-B	R3	Sand	Y	Y	N	Y	L	N	NA	N	Wood	L	N	L	Few shell fragments.
LDW-Y1-SU-ENR+AC-6-A	R1	Sand and gravel	Y	N	Y	N	L	Y	Sponges (2)	N	NA	N	N	L	Orange and red sponge colo.
LDW-Y1-SU-ENR+AC-6-A	R2	Sand	N	N	Y	N	L	Y	Barnacles (5)	N	NA	N	N	L	SPI frame imprint visible on sediment bottom. Some shell fragments and pebbles.
LDW-Y1-SU-ENR+AC-6-A	R3	Sand and silt	N	N	Y	N	N	N	NA	Y	NA	N	N	L	Algae abundant; few pebbles. SPI frame imprint visible.
LDW-Y1-SU-ENR+AC-6-B	R1	Sand and gravel	Y	N	N	N	N	Y	Barnacle (1)	N	NA	N	N	M	Some cobble; few shell fragments.
LDW-Y1-SU-ENR+AC-6-B	R2	Sand and silt	Y	N	Y	N	N	N	NA	N	Wood	L	N	L	Few gravel, few shell fragments.
LDW-Y1-SU-ENR+AC-6-B	R3	Sand and cobble	N	N	N	N	N	Y	Encrusting sponges	N	Wood	L	N	M	Cobble; some shell fragments; few algae.

Notes:
Lebensspuren = biologically formed sedimentary structures
-- = not analyzed
H = high
M = medium
L = low
T = trace
N = no
SPI = sediment profile imaging
Y = yes

Table 3-7. Prism Penetration and aRPD Depth Summary Statistics from the Baseline, Year 0, and Year 1 SPI Surveys

Prism Penetration Depths (cm)											
Baseline—Both Subplots				Year 0				Year 1			
Intertidal				**Intertidal—ENR**				**Intertidal—ENR**			
N	min	mean	max	N	min	mean	max	N	min	mean	max
37	2.9	9.7	14.6	36	5.4	7.4	12.6	36	2.8	5.1	14.3
				Intertidal—ENR+AC				**Intertidal—ENR+AC**			
				36	5.6	8.0	10.8	35	2.3	5.6	9.0
Scour				**Scour—ENR**				**Scour—ENR**			
36	0.29	13.8	16.6	36	6.2	9.9	16.4	36	0	9.3	13.5
				Scour—ENR+AC				**Scour—ENR+AC**			
				36	6.5	9.9	19.1	36	4.1	7.8	13.9
Subtidal				**Subtidal—ENR**				**Subtidal—ENR**			
36	5.8	12.7	21.6	36	6.1	10.5	16.00	33	3	5.4	13.4
				Subtidal—ENR+AC				**Subtidal—ENR**			
				36	6.6	10.8	20.4	36	1.9	7.4	19.9

aRPD Depths (cm)											
Baseline—Both Subplots				Year 0				Year 1			
Intertidal				**Intertidal—ENR**				**Intertidal—ENR**			
N	min	mean	max	N	min	mean	max	N	min	mean	max
30	0.8	2.2	4.6	0		all indeterminate		26	1.1	2.5	3.5
				Intertidal—ENR+AC				**Intertidal—ENR+AC**			
				2	3.3		4.3	23	0.4	2.3	3.6
Scour				**Scour—ENR**				**Scour—ENR**			
35	1.0	2.0	2.8	0		all indeterminate		33	1.1	1.9	3.2
				Scour—ENR+AC				**Scour—ENR+AC**			
				4	0.5	0.8	1.25	21	0.5	1.4	2.5
Subtidal				**Subtidal—ENR**				**Subtidal—ENR**			
34	0.2	1.3	3.00	18	0.2	1.5	2.00	20	1.7	2.6	4.3
				Subtidal—ENR+AC				**Subtidal—ENR+AC**			
				23	0.3	1.4	3	22	0	1.3	3.8

Notes:
AC = activated carbon
aRPD = apparent redox potential discontinuity
ENR = enhanced natural recovery
N = sample number
SPI = sediment profile imaging

Table 4-1. Number, Distribution, and Size of Feeding Voids Observed in Year 1 SPI Images

	Intertidal Plot			
	ENR		ENR+AC	
Sediment Depth (cm)	No. of Voids	Average Void Area (cm)	No. of Voids	Average Void Area (cm)
0–2	0	NA	1	0.22
2–5	15	3.39	15	2.28
5–10	3	0.48	13	2.12
>10	2	2.32	0	NA
Total or Mean Area	**20**	**2.06**	**29**	**1.54**

	Scour Plot			
	ENR		ENR+AC	
Sediment Depth (cm)	No. of Voids	Average Void Area (cm)	No. of Voids	Average Void Area (cm)
0–2	0	NA	0	NA
2–5	7	0.32	3	1.08
5–10	108	2.95	32	1.60
>10	47	5.47	20	3.27
Total or Mean Area	**162**	**2.92**	**55**	**1.98**

	Subtidal Plot			
	ENR		ENR+AC	
Sediment Depth (cm)	No. of Voids	Average Void Area (cm)	No. of Voids	Average Void Area (cm)
0–2	NA	NA	NA	NA
2–5	5	0.67	2	0.14
5–10	1	0.20	10	1.44
>10	0	NA	0	NA
Total or Mean Area	**6**	**0.43**	**12.00**	**0.79**

Notes:
AC = activated carbon
ENR = enhanced natural recovery
NA = not applicable