Lower Duwamish Waterway Group

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

YEAR 1 MONITORING REPORT

Enhanced Natural Recovery/Activated Carbon Pilot Study

Lower Duwamish Waterway

FINAL

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ACRONYMS AND ABBREVIATIONS

AC	activated carbon
AOC	Administrative Order on Consent
AOC2	Second Amendment to the AOC
aRPD	apparent redox-potential discontinuity
ASTM	American Society for Testing and Materials
BC	black carbon
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C_{free}	freely dissolved concentrations
cm	centimeter(s)
DGPS	digital global positioning system
DQO	data quality objective
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
ENR+AC	enhanced natural recovery with activated carbon
EPA	U.S. Environmental Protection Agency
IDW	Inverse distance weighted
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
MTC	Materials Testing & Consulting, Inc.
ng/L	nanogram(s) per liter
PCB	polychlorinated biphenyl
ppt	part(s) per thousand
PRC	performance recovery compound
PSEP	Puget Sound Estuary Program
QAPP	quality assurance project plan
RPD	relative percent difference
SPI/PV	sediment profile imaging/plan view
SPME	solid-phase micro extraction
TOC	total organic carbon
TVS	total volatile solids
µg/kg dw	microgram(s) per kilogram dry weight

LDW ENR/AC PILOT STUDY – YEAR 1 MONITORING REPORT
Enhanced Natural Recovery/Activated Carbon Pilot Study
Lower Duwamish Waterway

1.0 INTRODUCTION

The Lower Duwamish Waterway Group (LDWG) is conducting a pilot study to evaluate the potential effectiveness of an innovative sediment technology in the Lower Duwamish Waterway (LDW). The study is designed to determine whether Enhanced Natural Recovery (ENR) material amended with activated carbon (AC) can be successfully applied to reduce the bioavailability of polychlorinated biphenyls (PCBs) in contaminated sediments in the LDW. The study will compare the effectiveness of ENR with added AC (ENR+AC) versus ENR without added AC in three study areas (called *plots*) in the LDW. The three plots are referred to as the Intertidal Plot, the Scour Plot, and the Subtidal Plot. Each plot comprises two subplots, one with ENR alone, and the other with ENR+AC.

This pilot study was specified under the Second Amendment (July 2014) to the Administrative Order on Consent (AOC) for Remedial Investigation/Feasibility Study for the Lower Duwamish Waterway, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No. 10-2001-0055, issued by the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology) on December 20, 2000. The Second Amendment to the AOC, which is referred to as AOC2, 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. In accordance with AOC2, Amec Foster Wheeler et al. (2016)[1] prepared a quality assurance project plan (QAPP) and supporting addenda. The work described herein was performed in accordance with the EPA and Ecology-approved QAPP (Amec Foster Wheeler et al., 2016a) and QAPP addenda (Amec Foster Wheeler et al., 2016b, 2017, and 2018a).

1.1 PROJECT GOALS

AOC2 identified the goals for the ENR/AC Pilot Study to help inform the data quality objectives (DQOs) and engineering design of the pilot study plots. Pilot study results will be used to assess and appropriately refine the technology assignment assumptions of ENR with respect to addition of AC including its potential for use in scour mitigation applications.

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

The goals of the pilot study, as stated in AOC2, are:

- Verify that ENR amended with AC (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 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 QAPP identified the following data quality objectives (DQOs) for the ENR/AC Pilot Study:

- DQO-1: Verify the Placement of the ENR and ENR+AC Materials – Determine whether the ENR and ENR+AC material can be placed in the subtidal, intertidal, and scour plots within the targeted specifications.
- DQO-2: Evaluate the Stability of ENR and ENR+AC Materials – Evaluate the stability of the ENR materials and the stability of the AC material in the ENR matrix in the scour plot.
- DQO-3: Assess Changes in Bioavailability in ENR+AC Compared to ENR Alone – For the purposes of the Pilot Study, changes in bioavailability are based on measurements of the bioavailable fraction of PCBs as represented by the porewater PCB concentrations.
- DQO-4: Assess the Potential Impacts of AC on Benthic Communities – To determine whether the use of AC could adversely affect the benthic communities in the LDW, a benthic survey will be conducted in Year 3.

This Year 1 Monitoring Report satisfies Task 5 of AOC2 which requires the Year 1 Monitoring Report to include construction completion details, baseline data, Year 0 data, and the Year 1 monitoring results. Construction details were reported in the Construction Report (Amec Foster Wheeler, 2018) and are summarized in this report.

1.2 Overall Approach

The ENR and ENR+AC material was placed on sediments in three 1-acre plots that represent different physical conditions: an intertidal plot, a scour plot, and a subtidal plot.

- **Intertidal Plot (River Mile 3.9)**

  The intertidal plot represents the intertidal area conditions in the LDW and is defined as sediments above -4 feet mean lower low water (MLLW).

- **Scour Plot (River Mile 0.1)**

  The scour plot represents subtidal areas of the LDW that may experience scour (e.g., berthing areas).

- **Subtidal Plot (River Mile 1.2)**

  The subtidal plot represents subtidal conditions in the LDW.

Figure 1-1 shows the plot locations in the LDW. Figures 1-2 through 1-4 show the locations of the ENR and ENR+AC subplots in each study area as well as pre-construction bathymetric conditions, for the three study areas. Each plot is approximately 1 acre in size and each of the three plots is divided into two subplots, each approximately ½ acre in size.

The ENR subplots were composed of 6- to 9-inch-thick layers of sand or gravelly sand (Subtidal Plot had only sand, the Intertidal and Scour Plots had gravelly sand). The ENR+AC subplots were composed of the same material and thicknesses used in the ENR subplots, but AC was added at 4% (by weight) of the AC mass to the mass of gravelly sand or sand. Details of the engineering design, including ENR material grain size and AC specifications are provided in the Narrative Design Report (Amec Foster Wheeler et al., 2015a), and the plans and specifications for the pilot study (Amec Foster Wheeler 2015b). The plot selection memorandum (Appendix A of the Narrative Design Report) provided sediment results for LDW contaminants of concern, a physical description of the plots, and the basis for selecting each of the plot areas. Construction occurred between December 1, 2016 and January 31, 2017. Results of the placement are provided in the Construction Report (Amec Foster Wheeler, 2018b).

To meet the project goals, the following five monitoring events were developed:

- Baseline monitoring conducted in 2016, prior to placement of the ENR and ENR+AC material (which occurred from December 2016 through January 2017). Baseline sediment and porewater samples were collected to determine the concentrations of PCBs in sediment and porewater within each plot prior to placement of the ENR and ENR+AC layers. In addition, the sand and gravelly sand from the aggregate supplier that was used for the ENR material, and the AC that was used in the ENR+AC material, were tested for contaminants during the Baseline monitoring event.

- Placement confirmation (Year 0) monitoring conducted in January and February 2017. Year 0 monitoring was used to document the thickness and evenness of the ENR and ENR+AC material and the distribution and content of the AC in the placed ENR+AC layer immediately after construction.
- Post-Placement Monitoring events at Year 1 (conducted from March to June 2018), Year 2 (scheduled for March to June 2019), and Year 3 (scheduled for March to June 2020). These events are intended to gather data on the stability and performance of the ENR+AC layer over time, relative to the ENR layer at adjacent subplots. Additional studies conducted in Year 3 will assess the potential effects of AC on the benthic communities.

2.0 SAMPLING AND ANALYSIS

The sampling locations, field activities, sample processing and compositing, and sample analyses conducted during the Baseline, Year 0, and Year 1 monitoring events are described below. Table 2-1 presents the field activity timeline for each monitoring event.

2.1 LOCATION DETERMINATION

Sample locations and Sediment Profile Imaging (SPI) image locations were recorded from the sampling vessel using a Differential Global Positioning System (DGPS). The DGPS was mounted to the winch of arm of the sampling vessel, directly over the receiver, so that the sampling vessel was positioned within 1 to 2 meters of each proposed sampling location. The intertidal plot was accessed on foot during lower tides in Year 1, for which GPS locations were determined using a handheld GPS system. Figures 1-2 through 1-4 show sampling locations within each plot for the Baseline, Year 0 and Year 1 monitoring events.

2.2 COMPOSITING SCHEME FOR SEDIMENT AND POREWATER

For each sampling event the compositing scheme used for sediment and porewater samples followed procedures outlined in the QAPP (Amec Foster Wheeler et al, 2016b). The sampling locations were selected by dividing the subplot into six grid cells, which were further divided into 24 location cells, numbered 1 through 24. Five discrete sediment and porewater samples were collected from each grid cell at location cells determined by a random number generator. These samples were identified as “A”, “B”, “C”, “D”, or “E” composites. Composite samples were created within each subplot from the five discrete sample groups (representing A, B, C, D, or E), which were composited together to form the A, B, C, D, and E composite samples. During the Baseline and Year 1 sampling events, sediment and porewater composites formed with the D and E sample groups were archived pending analyses of the A, B, and C sediment and porewater results. These archived D and E composites were not analyzed either because sufficient power was achieved with A, B, and C composites or because analysis of additional composites would not likely change the findings (USEPA, 2018). The D and E locations are shown in Appendix A figures and Tables A-1A through A-1C. These archived locations are not discussed in the sampling event details below. In Year 0 only A, B, and C composites were collected. Specific sampling events are described in further detail below.

2.3 Sediment Imagery

SPI and plan view (PV) imagery was collected in Baseline, Year 0, and Year 1. For the Baseline effort, the sample design was to collect and analyze three replicate SPI and PV (SPI/PV) images from 12 stations in each plot (6 stations per subplot); the subplots were divided into six grid cells and one station was identified for each grid cell. During Year 0 and Year 1 surveys, the sample design was to collect and analyze three replicate SPI/PV images from 24 stations within each plot (12 stations per subplot); two SPI/PV stations were sampled for each of the six grid cells in each subplot. Images were taken prior to sediment and porewater sampling to avoid short-term disturbance of the ENR and ENR+AC layers by the SPI camera prior to other sampling activities. The Year 0 SPI/PV results are available in the Construction Report. The Baseline and Year 1 SPI/PV data reports are provided as an appendix to this report. Section 3.1 summarizes the SPI/PV observations.

2.4 Porewater Salinity Sampling

Porewater salinity was calculated in surface sediment samples during the Baseline and Year 1 sampling events. Temperatures and conductivities were recorded during each sampling event, and salinities were calculated from those measurements. Measurements were made on board the sampling vessel or on shore using a conductivity meter (Myron L Ultrameter II 6P) rather than using an underwater conductivity meter as proposed in the QAPP. The use of an underwater conductivity meter was determined to be unfeasible because the conductivity probe would not function correctly if in direct contact with the substrate. During the Baseline event, salinity was calculated from measurements collected from 49 locations in the intertidal plot, 56 locations in the scour plot, and 9 locations in the subtidal plot. During the Year 1 event, salinity was calculated from measurements collected from 28 locations in the intertidal plot, 11 locations in the scour plot, and 8 locations in the subtidal plot.

2.5 Sediment and Porewater Sampling

Sediment and sediment porewater were sampled in the 0 to 10 centimeter (cm) surface sediment interval for each monitoring event. The porewater was sampled using either in-situ or ex-situ solid-phase micro extraction (SPME) exposures, depending on the plot.

2.5.1 Baseline Sediment and Porewater Sampling

Baseline sediment and porewater samples were collected between July 25 and September 9, 2016, for intertidal and scour plots. Subtidal sediment was collected for ex-situ SPME exposures and sediment analyses on November 16 through 18, 2016 (Table 2-1). Ex-situ SPME sampling was approved in QAPP Addendum 1 (Amec Foster Wheeler et al., 2016b) due to the high loss rates (e.g., > 90%) of in-situ SPME samplers during the Baseline event at the subtidal plot. The high loss rate was likely due to the fact that vessels transiting through this area appear to allow their anchor chains to drag on the bottom. The bottom substrate disturbance at the subtidal plot was documented in the Construction Quality Assurance Project Plan Addendum 1 (Amec Foster Wheeler et al., 2016c). The actual Baseline sampling locations for the intertidal, scour, and subtidal plots were within their respective target sampling areas and are shown on Figures 1-2, 1-3, and 1-4, respectively, and in Appendix A Table A-1A. The sample collection date, plot, subplot, treatment type, sample ID, grid cell, location cell, composite (A, B, C), and coordinates for the Baseline discrete samples are summarized in Appendix A Table A-2A.

2.5.1.1 Sediment Samples

During the Baseline event, sediment samples were collected by divers using hand cores at the intertidal and scour plots and by power grab at the subtidal plot. Sediment sample locations were collocated with SPME sampling locations. After collection and logging, the surface sediment grab samples (top 10 cm) were transferred to the Port Gamble Washington lab (EcoAnalysts Laboratory) where the samples were homogenized and composited in stainless steel bowls. Appendix A Table A-2A shows that SMPEs were either not usable or not recovered from two scour plot locations and from six intertidal plot locations; because sediment and SPME samples were collocated to represent the same locations, sediment samples were not collected from those locations where SPMEs could not recovered or analyzed.

2.5.1.2 Porewater Samples

For intertidal and scour plots, in-situ sediment-exposed SPMEs were deployed in the top 10 cm of the surface sediment and retrieved by divers. Station positioning was performed using temporary marker buoys and the vessel's DGPS, as described above and in the QAPP. The in-situ sediment-exposed SPME samplers (at intertidal and scour plot areas) were placed from July 25, 2016, to September 9, 2016; individual sampler exposure durations averaged 39 days (ranging from 32 to 45 days).

For the subtidal plot, sediment porewater was measured in the laboratory using ex-situ exposure methods as described in QAPP Addendum 1. Intact sediment cores were delivered to the

EcoAnalysts Laboratory where the SPMEs were deployed in the top 10 cm of the individual core samples that were labeled for inclusion within the A, B, or C composites. After exposure, the SPMEs were removed from the sediment samples, composited, and extracted following the methods used for the in-situ SPME samples. Samplers that were exposed ex-situ to sediment cores (from the subtidal plot areas) in the laboratory were placed from November 28, 2016, to January 18, 2017; individual sampler exposure durations were 51 days. Deviations in SPME deployment duration are discussed in Section 2.8 below.

2.5.2 Year 0 Sediment Sampling

Year 0 sediment samples were collected between January 12 and February 3, 2017 (Table 2-1). Year 0 sampling locations were determined as described above and in the QAPP; however, Baseline sampling locations were not excluded from the random selection of Year 0 sampling locations because ENR and ENR+AC material presented a new surface layer to be sampled. The Year 0 sampling locations for the intertidal, scour, and subtidal plots were within their respective target sampling areas and are shown on Figures 1-2, 1-3, and 1-4, respectively, and in Appendix A Table A-1B. The sample collection date, plot, subplot, treatment type, sample ID, grid cell, location cell, composite (A, B, C), and coordinates for the Year 0 discrete samples are summarized in Appendix A Table A-2B.

During the Year 0 event, sediment samples were collected using hand cores during low tide at the intertidal plot, by divers using hand cores at the scour plot, and using a power grab sampler at the subtidal plot. After collection and logging, the surface sediment grab samples (top 10 cm) were transferred to EcoAnalysts Laboratory where the samples were homogenized and composited in stainless-steel bowls. Samples were placed in 2-gallon buckets and transferred to Materials Testing & Consulting, Inc. (MTC). At MTC samples from the intertidal and scour plots were air dried and sieved with a 3/8" sieve and a #4 sieve prior to compositing to remove gravel from the samples prior to testing. All respective fractions were weighed and then the fractions that passed the #4 sieve were composited (6 grabs per composite) and placed in jars for testing. The subtidal samples were not air dried or sieved prior to compositing because the ENR material was composed of sand only (no gravel). In addition to the composite samples, 18 discrete samples from each of the three ENR+AC subplots were placed in jars for carbon analysis. Subsamples of the ENR+AC composites from all three plots were sieved with a #50 sieve at Alpha and the finer fraction was analyzed for total volatile solids (TVS) and total organic carbon (TOC). Discrete samples also were analyzed for TOC and TVS. The analyses are discussed in Section 2.6.1.

2.5.3 Year 1 Sediment and Porewater Sampling

Year 1 sediment samples were collected between April 30 and July 9, 2018 (Table 2-1). The Year 1 sampling locations for the intertidal, scour, and subtidal plots were within their respective target sampling areas and are shown on Figures 1-2, 1-3, and 1-4, respectively, and in Appendix A Table A-1C. The sample collection date, plot, subplot, treatment type, sample ID, grid cell, location cell, composite (A, B, C), and coordinates for the Year 1 discrete samples are summarized in Appendix A Table A-2C.

2.5.3.1 Sediment Samples

During the Year 1 event, sediment samples were collected in the same manner as for Year 0, except the samples were dried and composited at MTC. After samples were dried and composited, samples were sieved with a 3/8" sieve and a #4 sieve using the same procedure that was used during Year 0. As shown in Appendix A Table A-2C, SMPEs were either not usable or not recovered in seven scour plot locations and three intertidal plot locations. Sediment samples were not collected where SPMEs were not recovered so that sediment and SPME composites would represent matched locations in each subplot.

2.5.3.2 Porewater Samples

SPME samplers were exposed in situ and ex situ following the same procedures used in Baseline sampling, and as described in the QAPP and QAPP Addendum 1. The in-situ sediment-exposed SPME samplers (at intertidal and scour plot areas) were placed from May 14 to May 17, 2018 and were retrieved from June 24 to June 29, 2018; individual sampler exposure durations averaged 42 days (ranging from 41 to 44 days). Samplers that were exposed ex-situ in sediment cores (from the subtidal plot areas) were placed on May 3, 2018 and were retrieved June 30, 2018; individual sampler exposure durations were 58 days. Deviations are discussed further in Section 2.8 below.

2.6 SUMMARY OF LABORATORY ANALYSES

The analyses conducted on sediment and porewater samples during each of the monitoring events are summarized below and shown in Appendix A Tables A-3A through A-3C. The laboratory records, reports, electronic deliverables, and chain-of-custody forms are provided in Appendix B. The laboratory analyses and QA/QC procedures were performed in accordance with the QAPP in almost all cases; minor modifications are described below in Section 2.8 below.

2.6.1 Sediment Samples

Composited sediment samples from the A, B, and C locations collected during the Baseline sampling event were analyzed for:

- PCB congeners by EPA 1668C at Frontier Analytical Laboratory (Frontier)
- TOC by EPA Method 9060, Black Carbon by Gustafsson et al. (1997) Grain Size by ASTM Method D422 at Alpha Analytical Laboratory (Alpha)

In Year 0, sediment was analyzed for:

- TOC by EPA Method 9060 at ALS
- Grain size by ASTM Method D422 at Alpha
- Total volatile solids (TVS) by Standard Methods SM 2540E at Alpha

As discussed in QAPP Addendum 3, during Year 0, it was determined that the original black carbon analysis method yielded results that were biased low because of natural sourced AC and the combustion temperature used in the Gustafsson method. TOC also was initially biased low due to the small sample size used in the laboratory method. The following approaches were used to improve carbon analysis methods and to measure carbon at baseline, Year 0, and Year 1.

- TVS was analyzed in Year 0, as a surrogate for black carbon, to confirm that the percent AC levels in construction material were consistent with the percent AC indicated by weight tickets.[2] For Year 0, TOC and TVS represent the percent AC in the placed material,[3] as AC was the only carbon type in the placed material; thus, by definition, TOC and TVS measured only AC in the Year 0 samples.

Because conventional TOC and TVS methods cannot differentiate between black carbon (including AC), natural organic carbon, and inorganic carbonates (only TVS method measures carbonates), conventional TOC and TVS methods are not suitable for measuring AC in sediments after placement (i.e., at Years 1-3). The Gustafsson method used to measure black carbon (BC) could not measure and distinguish AC from natural organic carbon. Working with Dr. Upal Ghosh at the University of Maryland Baltimore Campus (UMBC), Dr. Ghosh tested the Grossman and Ghosh AC/BC method to demonstrate that this method could differentiate between natural organic material found in native sediment and the AC that was placed with the ENR material. The success of the Grossman and Ghosh method prompted the incorporation of the Grossman and Ghosh

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[2] The samples were collected from ENR+AC material coming down the conveyer belts prior to barge loading.
[3] Additional discussion on black carbon, TVS, and TOC measurements can be found in Section 2.1.3 of the Construction Report (Amec Foster Wheeler et al. 2018b).

method into the QAPP (QAPP Addendum 3); the Grossman and Ghosh method replaced the Gustafsson method and thereafter was used to measure AC/BC in Year 1 sediment samples.[4]

In Year 1, composited sediment from the A, B, and C locations were analyzed for the same analyses conducted during the Baseline sampling event, with a few modifications per QAPP Addendum 3:

- PCB congeners by EPA 1668C at Frontier
- AC/BC using the method developed by Ghosh et al. (Grossman and Ghosh, 2009) at UMBC
- TOC by EPA Method 9060 at ALS
- Grain size by Puget Sound Estuary Program (PSEP) at MTC

Grain size was measured at different laboratories using different methods for different events; during the Baseline and Year 0 events Alpha was used as the laboratory, and MTC was used as the laboratory during the Year 1 event. While there are some differences in the methods, results can be compared when the samples are reclassified as gravel, sand, and fines using the two sieve sizes that were used by both methods. Further explanation is provided in Appendix C.

2.6.2 Porewater Samples

Porewater PCB concentrations were determined based on PCBs measured in SPME fibers. Following sediment exposures, SPMEs were maintained cold (4 degrees C) until they could be processed. Processing consisted of compositing SPMEs (6 SPMEs per composite, assuming all SPMEs in the composite sample were recovered) into a vial, followed by addition of solvent (hexane) to extract the PCBs from the SPME. Composited SPME extracts for Baseline and Year 1 Monitoring events were analyzed for PCB Congeners by EPA Method 1668C. The passive sampling and C_{free} quantification methods were performed in accordance with the QAPP, and the reports detailing the PCB C_{free} calculations are provided in Appendix D (Sections A and B).

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[4] The Gustafsson method measures black carbon, and does not distinguish natural organic carbon and AC, while the Grossman and Ghosh method separates natural organic carbon from AC+BC through an acid digestion process but does not distinguish AC and BC. Thus, the Grossman and Ghosh method results represent AC+BC or AC/BC.

2.7 DATA VALIDATION

Analytical data received from Frontier, Alpha, ALS, and MTC were validated by Sayler Data Solutions, Inc. PCB congener data were subjected to Stage 4 validation. TOC, black carbon, grain size, and SMS constituents (for the ENR fill materials) data were subjected to Stage 2A validation. The data validation reports are provided in Appendix E.

The data were reviewed using guidance and quality control criteria documented in the analytical methods and the following project and guidance documents:

- Quality Assurance Project Plan – Enhanced Natural Recovery/Activated Carbon Pilot Study, Lower Duwamish Waterway (Amec Foster Wheeler et al., 2016)
- National Functional Guidelines for Inorganic Superfund Data Review (USEPA, 2014)
- National Functional Guidelines for High Resolution Superfund Methods Data Review (USEPA, 2016)
- National Functional Guidelines for Superfund Organic Methods Data Review (USEPA, 2014)

Data qualifiers were assigned during data validation if applicable control limits were not met, in accordance with EPA's data validation guidelines and the quality control requirements included in the referenced methods. The laboratory and data validation qualifiers and definitions are summarized in Table 2-2.

In addition to the review and assessment of the documentation identified above, data packages subjected to the Stage 4 validation included verification of reported concentrations for the field and quality control samples, verification of intermediate transcriptions, and review of instrument data such as mass spectra to verify analyte identification procedures.

The data validator performed a calculation verification check on the conversion of SPME extract concentrations to C_{free} concentrations using performance recovery compounds (PRCs).

2.7.1 Data Qualification

27,875 data points were reported. Of these, 183 (0.6%) were estimated (i.e., J/UJ qualified). No results were rejected. Completeness was 100%.

Results were estimated (i.e., J/UJ-qualified) for the following reasons:

- Matrix spike recovery outside of acceptance limits
- Precision (replicates) greater than acceptance limits
- Laboratory control sample recovery outside of acceptance limits
- Isotope dilution standard recovery outside of acceptance limits

2.7.2 C_{free} Calculation Review

In both the Baseline and Year 1 events, C_{free} concentrations and estimated detection limits (EDLs) or minimum level of quantitation (MLs) of each detected PCB were re-calculated by the validator following the procedure outlined in the C_{free} report and compared to reported values. Concentrations agreed within a reasonable variation for rounding differences. Calculated relative percent differences (RPDs) were between 0 and 5.

2.7.3 Usability

The bulk sediment and porewater data collected during the Baseline, Year 0, and Year 1 sampling events met the criteria set forth in the referenced quality assurance documents. Data validation resulted in 6.5% of results qualified as estimated. All results are acceptable for their intended use. The complete validated data set is provided as an EDD in Appendix B.

2.8 QAPP Deviations

All methods and procedures outlined in the QAPP and the applicable QAPP Addenda were followed in the collection and analysis of the samples, with the exceptions listed below. These changes did not affect the data quality and met the study objectives.

During the Baseline sampling event, the average duration of deployment was 39 days for the in-situ SPME samplers and 51 days for the ex-situ SPME samplers. During the Year 1 sampling event, the average deployment duration was 42 days for the in-situ SPME samplers and 58 days for the ex-situ SPME samplers; the QAPP proposed 28 days for in-situ deployments and 42 days for ex-situ. The extended deployment times allowed the SPMEs to further equilibrate and improved data quality. The extended deployment times were discussed with EPA and Ecology on August 23, 2017.

During the Baseline and Year 1 sampling events, porewater conductivity was measured on board the sampling vessel using a conductivity meter (Myron L Ultrameter II 6P) rather than using an underwater probe as proposed in the QAPP; during fieldwork it became clear that using an underwater probe was unfeasible. Measurements were collected prior to sediments being logged and composited.

The Year 1 porewater statistical power analysis was used to determine whether archived samples should be analyzed to meet the QAPP objective of being able to detect approximately 50% or greater decrease in porewater PCB concentrations from Baseline to Year 1. The QAPP noted that the power analysis should be based on Baseline samples. However, as anticipated in EPA's April 13, 2017 letter, the variance in Year 1 porewater sampling was lower than in the Baseline sampling, and so consistent with EPA's approval, Year 1 results were used to assess the results of the power analysis.

Section 3.2.4.2 of the QAPP stated that if salinities are uniform within a plot then the number of salinity measurements may be reduced for that plot in future events. The number of salinity measurements in the scour plot were reduced prior to the Year 1 monitoring event due to the uniform salinities observed during the Baseline sampling event. The reduction was approved by EPA via an email dated April 19, 2018.

3.0 RESULTS AND DISCUSSION

This section describes the results of the Baseline, Year 0, and Year 1 sampling events and makes comparisons between events as appropriate. All samples were collected from the 0 to 10 cm surface sediment horizon except as noted in Table A-1 in the individual C_{free} reports provided in Appendix D. The exceptions were SPMEs that had a portion of the top exposed above the sediment, as indicated in the "Length of Fiber Trimmed" columns in each of the Appendix A-1 tables in the individual C_{free} reports. In those cases, the protruding portion of the SPME was removed before processing.

3.1 SPI/PV, ENR Material Thicknesses, and Sediment Observations

This section reports results from SPI/PV, ENR material thicknesses, and field observations, for Baseline, Year 0, and Year 1 sampling events.

3.1.1 Baseline

This section presents Baseline sediment conditions based on SPI/PV data obtained during the Baseline sampling event (i.e., the native LDW sediments prior to ENR material placement). For the Baseline SPI and PV (SPI/PV) survey, a total of 36 stations were sampled. Three replicate SPI/PV images were collected from 12 stations in each plot (6 stations per subplot); the subplots were divided into six grid cells and one station was collected in each grid cell. More information can be found in the Baseline SPI/PV Data Report (Appendix F), including a discussion of the parameters measured from SPI/PV images and the underlying interpretive rationale.

Two key SPI parameters discussed in this section are the apparent redox-potential discontinuity (aRPD) depth and the infaunal successional stage. The aRPD depth is the depth of intensive biological mixing of particles and porewater by infaunal organisms. This near-surface aerobic layer is brown or olive in color and overlies reduced sediments that are generally dark gray or black. The depth of the aRPD is related to the types of infaunal organisms that inhabit an area. Benthic infaunal communities broadly follow a three-stage successional sequence after a disturbance of the seafloor. Stage 1 infauna typically are the first organisms to colonize a disturbed sediment surface and typically consist of small, tubicolous, surface-dwelling polychaetes and are associated with thin aRPD depths. Stage 2 organisms follow and are typically shallow-dwelling bivalves or tube-dwelling amphipods that bioturbate more deeply into the sediment column and are associated with transitional aRPD depths. Stage 3 are the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms that feed at depth and biogenically mix the sediment column to 10 cm or more, create distinctive feeding voids and oxidized burrows that are visible in SPI images and often extend below the depth of the aRPD.

The baseline SPI/PV survey of the intertidal plot showed that the base substrate was silt/clay throughout the area. In the intertidal plot, algal mats were sufficiently dense to impede SPI camera penetration at 7 of 37 sampling stations,[5] and disrupted the imaged sediment column such that aRPD depths could not be measured. Based on other 30 images collected from the intertidal plot, measured aRPD depths ranged from 0.8 to 4.6 centimeters (cm) with a mean aRPD across the plot of 2.2 cm. Eight of 12 stations had evidence of Stage 3 infauna, indicating the presence of head-down deposit feeders; two stations exhibited only Stage 2 assemblages, and two other stations had indeterminate successional stages due to interference from the algal mats.

SPI imagery showed that the base substrate at the scour plot was predominantly silt throughout the entire area with surficial veneers of sand and gravel at nine of 12 stations. The aRPDs measured from the scour plot ranged from 1 cm to 2.8 cm with a mean aRPD across the plot of 2 cm. Stage 3 infauna were observed at all sampling stations indicating the widespread presence of head-down deposit feeders and subsurface infauna.

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[5] An extra replicate image was collected at one station to ensure that three analyzable images were obtained and was subsequently analyzed.

SPI imagery showed that the base substrate at the subtidal plot was predominantly silt throughout the entire area with scattered surficial veneers of fine sand. The aRPDs measured from the subtidal plot ranged from 0.2 cm to 3 cm with a mean aRPD across the plot of 1.3 cm. Stage 3 infauna were observed at half of the sampling stations (6 of 12), with Stage 2 infauna at four stations, and Stage 1 infauna at two stations.

3.1.2 Year 0

The goal for placement of the ENR or ENR+AC layer was to place the material as uniformly as practicable while targeting a thickness of between 6 and 9 inches (15 and 23 cm) in 80% of stake/probe locations per subplot, and with a minimum thickness of 4 inches (10 cm) at 100% of stake/probe locations per subplot. The minimum thickness goal was achieved in all plots, though the material was thicker than the thickness goal in a few sample cores. The minimum thickness across all plots was 6 inches (15 cm), and the maximum was 18 inches (46 cm). The mean thickness of material across the 6 subplots ranged from 9.5 inches to 13.7 inches. More information can be found in the Construction Report (Amec Foster Wheeler et al., 2018b).

This section presents sediment conditions in Year 0 based on SPI/PV data obtained during the Year 0 sampling event. For the Year 0 SPI/PV survey, a total of 72 stations were sampled. Three replicate SPI/PV images were collected from 24 stations in each plot. Twelve stations were sampled in each subplot.

- The SPI/PV analysis found that the substrate at the intertidal ENR subplot was sandy gravel in all replicates from all stations except for one; at this location no ENR material was observed, indicating that a small area of the ENR subplot did not have ENR coverage.
- The intertidal ENR+AC subplot was sandy gravel in all replicates. The scour ENR and ENR+AC plots were sandy gravel in all replicates.
- The subtidal ENR and ENR+AC were predominantly coarse sand with scattered fine gravel, covered with a recently deposited fine-grained sediment.

More information can be found in the Construction Report (Amec Foster Wheeler et al., 2018b). No SPI aRPD data or infauna stages are discussed for Year 0 as the newly applied ENR and ENR+AC material had not been in place for a long enough time interval to allow appreciable development of aRPD features.

3.1.3 Year 1

Benthic physical and biological conditions observed in the Year 1 SPI/PV images for each study plot and observed during collection of sediment and SPMEs are summarized here. The complete Year 1 SPI/PV survey results are provided in Appendix F. As in Year 0, the survey design for the Year 1 SPI/PV survey consisted of a total of 72 stations. Three replicate SPI/PV images were collected from 24 stations in each plot with 12 stations sampled in each subplot.

3.1.3.1 Summary of SPI/PV Data Intertidal

Surface sediment textures ranged from predominately silt through sands and into gravels in both the ENR and ENR+AC subplots in the intertidal plot. This reflects the presence of the placed materials combined with inputs of ambient fine-grained sediments since construction. The placed materials extended below the depth of the SPI prism penetration at all stations; prism penetration averaged 5 to 6 cm in both subplots.

Benthic community recolonization is evident in both intertidal subplots. The Year 1 aRPD depths average about 2 cm across both subplots and are comparable to aRPD depths measured during Baseline. Evidence of high-order successional infauna (Stage 3) was observed in about one-half of the SPI images from both the ENR and ENR+AC plots, indicating on-going benthic infaunal recolonization of the plots. Stage 1 or Stage 2 assemblages were observed in a total of three and six SPI image replicates from the ENR and ENR+AC plots, respectively. These replicates were scattered throughout the subplots, i.e., they were not concentrated in a particular cell or cells.

Scour

At the scour plot, the mean SPI prism penetration depth averaged 9.3 cm for the ENR subplot and 7.8 cm for the ENR+AC subplot. The ENR subplot showed predominately fine-grained sediments (silts) mixed into the coarse-grained ENR material in the SPI images. Sands and gravel were evident in some of the PV images. The sediment texture in the subplot appears to reflect silts deposited and physically and/or biogenically mixed into the ENR material since Year 0.

Surface sediment textures in the ENR+AC subplot are more varied, ranging from gravel and sands only (ENR+AC material) at the downstream stations to predominately silt upstream. These observations suggest varying sediment accumulation/transport dynamics within the two subplots, some of which could be related to vessel traffic in the downstream portion of the ENR+AC subplot.

Where the silt deposit is present in the scour plot, the sediment matrix is a silt and sand mix pointing to some biogenic mixing of the ENR and ENR+AC material with ambient sediment.

Evidence of benthic infauna is widespread in the scour plot. Only one SPI replicate image from the ENR subplot exhibited a Stage 1 assemblage. Stage 3 infauna (subsurface deposit-feeders) were seen in 33 of the 36 replicates, indicating the re-establishment of the benthic infaunal community. The average aRPD depth of 1.9 cm compares closely to the mean aRPD depth of 2.0 cm observed during Baseline. In the ENR+AC subplot, Stage 3 infauna were evident in 23 of the 36 images (two images were Stage 1 only). The average aRPD depth for this subplot was 1.4 cm. The PV images from the scour plot, especially where silt is present, showed evidence of epifaunal biological activity in the form of widespread tracks and tubes.

Subtidal

At the subtidal plot, the mean SPI prism penetration depth averaged 5.4 cm for the ENR subplot and 7.4 cm for the ENR+AC subplot. Surface sediments in the SPI images from the subtidal ENR subplot show mixtures of ENR sands and ambient silts. Sand ripples and surface sandy lag deposits (i.e., residual coarse material remaining after fines are winnowed away) observed in some images point to anthropogenic disturbance. ENR material was present at all locations and was generally greater in thickness than prism penetration. At one location in upstream grid cell 6, the ENR layer could be measured and ranged from 3 to 13 cm in thickness.

In the ENR+AC subplot, images showed similar textures. In the two upstream cells 5 and 6, the ENR+AC material is no longer evident and appears to have been disturbed by barge chain dragging (Amec et al. 2016b), but downstream transport of the placed material due to other processes is a possibility. Very thin veneers of sand are observed overlying, highly reduced silt in these disturbed areas. Benthic community re-colonization is apparent at the subtidal plot, but it appears to represent a more dynamic and disturbed setting than the scour and intertidal plots. Evidence of Stage 3 infauna was observed in one-third of the SPI images from both subplots. Stage 1 and 2 assemblages were evident in five of the SPI replicates scattered throughout the ENR subplot. Twelve (one third) of the ENR+AC subplot replicates exhibited Stage 1 only, eight of these replicates are in the disturbed, upstream cells 5 and 6.

3.1.3.2 Summary of Field Observations

The presence of fine-grained sediment deposited on the ENR and ENR+AC material was recorded when retrieving the SPME samplers at each location. Fine-grained deposits were observed on all plots. Thicknesses were visually estimated at the SPME insertion locations by divers in the scour plot and were measured with a ruler by sampling personnel at low tide at the intertidal plot, and from the power grabs collected from the subtidal plot (for the ex-situ SPME deployment). Visual observations indicate that the fine-grained deposits are composed of particulate material transported to the plots and deposited via the existing LDW sediment transport regime. In contrast to the SPI images, which indicate mixing of ambient silt and ENR/ENR+AC materials at many stations, the field staff were unable to observe mixing processes between the silt and ENR or ENR+AC material in the intertidal and scour plots (i.e., from the diver or grab sample observations). The subtidal plot had prior evidence (during the Baseline sampling) of anchor chain dragging which may have mixed recently deposited sediment into the ENR and ENR+AC material.

Fine-grained deposit thicknesses are presented in Table 3-1 and in Figures 3-1 through 3-3 for the scour, intertidal, and subtidal plots, respectively. Average surficial deposit thicknesses for the six subplots ranged from 0.63 to 2.5 cm. Thickness varied among the three plots, likely due to differential sedimentation regimes in different parts of the LDW. More importantly, differences in surficial deposit layer thicknesses between the two subplots were evaluated, as large differences in thickness could influence the comparisons of the concentrations of PCBs in sediment and porewater between the ENR and ENR+AC treatments within each plot. There were statistically significant differences in deposit thickness between the ENR and ENR+AC subplots at the scour plot, but not the intertidal or subtidal plot:

- Mean fine-grained deposit thicknesses were 1.6 cm (ENR subplot) and 1 cm (ENR+AC subplot) for the intertidal subplots, and were not significantly different (t test, $p = 0.197$).
- Mean fine-grained deposit thicknesses were 2.5 cm (ENR subplot) and 1.5 cm (ENR+AC subplot) for the scour subplots, and were statistically different (t test, $p = 0.035$).
- Mean fine-grained deposit thicknesses were 0.63 cm (ENR subplot) and 1.7 cm (ENR+AC subplot) for the subtidal subplots, and were not significantly different (t test, $p = 0.145$).

The thicknesses of natural deposits on the ENR and ENR+AC material will continue to be estimated in the Year 2 and Year 3 monitoring events, in accordance with the QAPP.

Based on Year 1 substrate observations, an aRPD layer was observed during sediment/SPME sampling in some intertidal plot sampling locations, including apparent sulfide staining at the top of the ENR or ENR+AC layer. No debris was found in the intertidal plot, but filamentous algae were observed in several locations. The silt layer and algae in the intertidal plot suggest that it was not frequently disturbed over the one-year monitoring period.

An aRPD layer was not observed during sediment/SPME sampling in the scour or subtidal plots[6], although both had anthropogenic debris which was not present in the intertidal plot. The scour plot had diverse biota including barnacles, crabs and crab tracks, piddock clams, sea pens, an anemone, and a sea slug. It also had lumber, asphalt, concrete, metal debris, a beer can, a traffic cone, and some rubber hose deposited on the surface. The biota found, some of which are sensitive to disturbance, suggest that the scour plot was not highly disturbed over the one-year monitoring period.

The subtidal plot had very little evidence of biota based on substrate observations during sampling, only one sample had evidence of a large worm. The subtidal plot also had anthropogenic debris, including partially buried chunks of wood, wood and construction debris, plastic observed inside one core, large gravel, and metal. It is likely that the subtidal plot was experiencing disturbance from dragging anchor chains over the one-year monitoring period.

3.2 GRAIN SIZE DISTRIBUTION AND CARBON ANALYSES

This section reports results of the grain size and carbon analyses for the Baseline, Year 0, and Year 1 sampling events. Grain size data results for the general classifications of gravel, sand, and fines for all years are presented in Tables 3-2, A-5A, A-5B, and A-5D, and in Figures 3-4 through 3-7 for the intertidal, scour, and subtidal plots, respectively. Carbon analysis results for all years are presented in Tables 3-2, A-5A, A-5C, and A-5D and in Figures 3-8 and 3-9.

3.2.1 Baseline

Baseline grain sizes were at least 50% fines (silt plus clay) in all three plots; the Scour ENR plot and the Subtidal ENR+AC subplot sediment exceeded 75% fines (Tables 3-2 and A-5A).

Mean black carbon (BC) levels were between 0.092% and 0.36% in all plots using the Gustafsson et al. (1997) method (Figure 3-8 and Table 3-2). Mean TOC varied between 1.4% and 2.7% in all plots (Figure 3-9).

[6] Although aRPD depths were indeterminate in some of the Year 1 SPI images, the SPI camera captures a relatively, undisturbed view of the upper sediment column in profile and oxidized surface layers were evident and measured in the majority of SPI images from all plots as summarized above in Section 3.1.3.1 and detailed in Appendix F.

3.2.2 Years 0 and 1

3.2.2.1 Grain Size Distribution Years 0 and 1

The grain size of the sediment was compared between Year 0 and Year 1 (Figures 3-4 through 3-6). The percent fines increased between Year 0 and Year 1 in all plots, likely due to natural sedimentation (see Section 3.1.3 and Figures 3-1 through 3-3 and Table 3-2). Figure 3-7 shows only Year 1 plots, with ENR and ENR+AC together. The subtidal plot has higher percent fines compared to the intertidal and scour plots.

Intertidal Plot

In Year 0 in the intertidal plot, average percent fines, sand, and gravel were 0.33%, 33%, and 67%, respectively. In Year 1 in the intertidal plot, average percent fines, sand, and gravel were 2.7%, 42%, and 55%, respectively. The increase in percent fines from 0.33% (Year 0) to 2.7% (Year 1) is attributed to natural sediment deposition on the ENR and ENR+AC materials.

Scour Plot

In Year 0 in the scour plot, average percent fines, sand, and gravel were, 0.38%, 34%, and 66%, respectively. In Year 1 in the scour plot, average percent fines, sand, and gravel were 3.4%, 31%, and 65%, respectively. The increase in percent fines from 0.38% (Year 0) to 3.4% (Year 1) is attributed to natural sediment deposition on the ENR and ENR+AC materials.

Subtidal Plot

In Year 0 in the subtidal plot, average percent fines, sand, and gravel were 1.4%, 76%, and 23%, respectively. In Year 1 in the subtidal plot, average percent fines, sand, and gravel were 10%, 69%, and 21%, respectively. The increase in percent fines from 1.4% (Year 0) to 10% (Year 1) is attributed to natural sediment deposition on the ENR and ENR+AC materials.

3.2.2.2 Carbon Analysis Years 0 and 1

As discussed in Section 2.6.1, the Gustafsson et al. (1997) method did not work for samples containing naturally sourced (coconut) AC. Therefore, the amount of carbon present in the samples was compared using BC in Baseline (Gustafsson et al. [1997] method), TVS in Year 0, and AC/BC during Year 1 (Grossman and Ghosh method). The results are compared in Figure 3-8 and in Table 3-2. TOC was analyzed for all three sampling events and is compared in Figure 3-9 and Table 3-2.

- The ENR subplots had similar mean percentages of BC (Baseline) and AC/BC (Year 1); however, the mean percent TVS (Year 0) was consistently higher than either BC or AC/BC measured at Baseline and Year 0, respectively. This is likely an artifact of the change in methods and does not necessarily reflect much higher levels of AC/BC at Year 0.
- In the ENR+AC subplots, the percent BC at Baseline was comparable to the ENR subplots. At Year 0, the mean percent AC/BC increased substantially, from less than 0.5% at Baseline to between 2 and 3% at Year 0 based on composite samples that were collected during Year 0 monitoring. The average AC/BC of the 18 discrete samples (see Section 2.5.2) was similar to the average AC/BC of the composite samples; however, the values ranged from about 1 to 5%. The Year 0 data are presented in Appendix A-5C. This increase in AC/BC is attributed to the addition of AC in the ENR+AC layer. For all three subplots, the mean percent AC/BC levels decreased from Year 0 to Year 1, though the Year 1 AC/BC levels remained well above mean BC (Baseline).
- At Year 1, the mean percent AC/BC was lower in the subtidal ENR+AC subplot compared to the scour and intertidal ENR+AC subplots. This observation may be due to chain dragging that could have mixed underlying or deposited material into the ENR+AC material.

The TOC results are consistent with the BC and AC/BC results. In all three ENR subplots, mean TOC levels decreased from over 1 to close to zero between the Baseline and Year 0 events, due to the addition of the ENR material which is naturally low in TOC (Table 3-2). Between Year 0 and Year 1 in ENR subplots, mean TOC increased significantly (*t-test* $p < 0.001$; Figure 3-9) due to the natural deposition of fine-grained material on the surface of the plots.

Following the placement of ENR+AC layer (Year 0), TOC levels in ENR+AC subplots averaged 1.8%, and then remained relatively constant into Year 1 where they averaged 1.7% (Table 3-2 and Figure 3-9). The fact that TOC levels did not decrease in the ENR+AC subplots, as they did in the ENR subplots, is due to the presence of AC in the ENR+AC material.

3.3 BULK SEDIMENT PCB ANALYSES

This section presents the bulk sediment PCB Analyses for the Baseline and Year 1 sampling events; bulk sediment PCB concentrations were not measured in situ at Year 0. Total PCBs were calculated as the sum of detected congeners for each composite. The results were corrected to include the fraction of material removed from sieving. The geometric mean concentrations of the total PCBs in sediment are shown in Table 3-3. Baseline and Year 1 bulk sediment PCB concentrations are shown in Figures 3-10 through 3-12 for the intertidal, scour, and subtidal plots, respectively. Bulk-sediment PCB concentrations for all Year 1 Subplots are shown in Figure 3-13.

3.3.1 Baseline

In the Baseline data, among the three plots, the intertidal and subtidal plots had higher Total PCBs than the scour plot, in both ENR and ENR+AC subplots (Tables 3-3 and A-6A). The scour plot also exhibited much less variability among composite samples compared to the other two plots.

3.3.2 Year 0

In Year 0, sediment samples were not tested for PCBs. Instead, Year 0 PCB results represent PCB concentrations measured in the upland-sourced ENR material that was used to construct the plots, as reported in the Construction Report (Amec Foster Wheeler et al., 2018b). Total PCBs were 0.031 and 0.037 micrograms per kilogram dry weight (µg/kg dw) in the sand and gravelly sand material, respectively. PCB concentrations in the AC material were 0.035 µg/kg dw, before blending with the ENR material.

3.3.3 Year 1

Year 1 Bulk Sediment Total PCB concentrations ranged from 0.49 to 45.1 µg/kg dw across all plots (Tables 3-3 and A-6B). Year 1 and Baseline Total PCB concentrations were compared using an analysis of variance (ANOVA) to examine how plot, subplot, and year explained the variance in Total PCB concentrations.

- All six subplots have lower Total PCB concentrations in Year 1 when compared to the native sediments measured in Baseline (Figures 3-10 to 3-12 and Table 3-3); total PCBs in Year 1 were significantly lower than Baseline levels ($p < 0.001$). Total PCBs in Year 1 were lower due to the addition of ENR and ENR+AC materials without PCBs, which resulted in reduced PCB concentrations in the upper sediment column.

- Within Year 1 data, and within each plot, ENR subplots and ENR+AC subplots had comparable total PCB concentrations (Figure 3-13 and Table 3-3); subplots did not differ significantly ($p = 0.68$).

- Plots were significantly different from each other, which was expected as they had different baseline PCB levels ($p = 0.0067$).

To test whether differences in subplots in Year 1 were more pronounced than they were during Baseline sampling, further tests were conducted using only Year 1 data. An ANOVA was conducted with Total PCBs as the dependent variable, and plot and subplot as the independent variables. The ANOVA showed that ENR and ENR+AC subplots were not significantly different from each other (p = 0.18), but that the three plots were significantly different from each other (p = 0.0015); this last result was not surprising, because the Baseline PCB concentrations for the three plots differed. To confirm these results, a t-test and a Wilcoxon rank sum test was conducted in which total PCBs were compared between ENR and ENR+AC groups pooled from all plots. Neither of these tests found significant differences between the subplots (p = 0.36, and p = 0.49, respectively).

Additionally, Year 1 concentrations of sediment PCBs were compared using a t-test and a Wilcoxon Rank Sum test to compare differences in the concentration of PCBs in sediment between ENR and ENR+AC subplots at each plot. In all three plots, the ENR and ENR+AC subplots were not significantly different ($p > 0.05$).

3.4 SPME Porewater PCB Analyses

This section reports on the SPME results for the Baseline, Year 0, and Year 1 sampling events. Total PCB concentrations in porewater (C_{free} PCBs) were calculated from the SPME fiber extract analyses per the methods in the QAPP. C_{free} PCBs were calculated as the sum of detected congeners for each composite. The comparison of Baseline to Year 1 total C_{free} PCBs are presented in Figures 3-14 through 3-16, with all Year 1 Subplots in Figure 3-17. C_{free} concentrations were not measured at Year 0.

3.4.1 Baseline

Geometric mean baseline total C_{free} PCB concentrations ranged from 1.5 to 103 nanograms per liter (ng/L) across all three plots (Table 3-3). The subtidal plot had the highest geometric mean total C_{free} PCB (34 ng/L in ENR subplot and 103 ng/L in the ENR+AC subplot). The scour plot had the lowest geometric mean total C_{free} PCB (1.5 ng/L in ENR subplot and 8.5 ng/L in the ENR+AC subplot).

3.4.2 Year 1

Geometric mean Year-1 total C_{free} PCB concentrations ranged from 0.49 to 9.6 ng/L across all plots (Table 3-3). The subtidal plot had the highest mean total C_{free} PCB concentration (10.3 ng/L in the ENR subplot and 3.8 ng/L in the ENR+AC subplot). The intertidal plot had the lowest geometric mean total C_{free} PCB concentration (1.1 ng/L in the ENR subplot and 0.49 ng/L in the ENR+AC subplot).

At each plot, the mean total PCB C_{free} concentrations were compared between the ENR and ENR+AC subplots. At both the intertidal and scour plots, there were no statistically significant differences between the ENR and ENR+AC subplots ($p > 0.05$) (Figure 3-17). For the subtidal plot, the mean C_{free} value for the ENR+AC subplot was approximately 2.5 times lower than that of the ENR subplot ($p = 0.024$). Total C_{free} measured during the Baseline event was approximately 3 times higher in the ENR+AC subplot compared to that of the ENR subplot, indicating a higher proportional reduction in C_{free} in the subtidal ENR+AC subplot, compared to the ENR subplot.

3.4.3 Comparison of Porewater total PCB C_{free}: Baseline vs. Year 1

The total PCB C_{free} measured during the Baseline and Year 1 events are compared in intertidal, scour, and subtidal plots in Figures 3-14 through 3-16, respectively, and in Tables 3-3, A-7A, and A-7B. All six subplots have lower total C_{free} PCB concentrations in Year 1 when compared to Baseline (five of the six subplots indicated statistically lower geometric mean values in Year 1). The C_{free} data are discussed for each plot in the following subsections.

3.4.3.1 Intertidal Plot

In the intertidal plot, the geometric mean total PCB C_{free} concentration decreased from 31 ng/L (Baseline) to 1.1 ng/L (Year 1) in the ENR subplot, and decreased from 28 ng/L (Baseline) to 0.49 ng/L (Year 1) in the ENR+AC subplot (Figure 3-14). The mean C_{free} values decreased 96% and 98% compared to the Baseline in the ENR and ENR+AC subplots, respectively. A t-test was conducted to compare the Baseline and Year 1 C_{free} measurements in the two subplots. Results indicated that the C_{free} measurements between Baseline and Year 1 were statistically significant in both ENR and ENR+AC subplots ($p < 0.05$).

3.4.3.2 Scour Plot

In the scour plot, the mean total PCB C_{free} concentration decreased from 1.5 ng/L (Baseline) to 1.4 ng/L (Year 1) in the ENR subplot, and decreased from 8.5 ng/L (Baseline) to 0.89 ng/L (Year 1) in the ENR+AC subplot (Figure 3-15). The mean C_{free} values decreased 7% and 90% compared to the Baseline in the ENR and ENR+AC subplots, respectively. The small relative decrease in the C_{free} values in the ENR subplot (not statically significant) is likely because Baseline total PCB C_{free} concentrations were already low and comparable to C_{free} in the overlying LDW surface water. During pre-design studies conducted by the LDWG, Cf_{ree} total PCBs in surface water were measured at two locations in 2018 using polyethylene passive samplers deployed in LDW surface water, approximately 1 meter above the sediment-water interface (Windward, 2018). The average concentration at the South Park Bridge (approximately 0.5 miles downstream of the intertidal plot) and Sea-Freeze dock (approximately 0.75 miles upstream of the subtidal plot, 1.75 miles upstream of the scour plot) locations in 2018 were very similar, at 1.0 (SD=0.11) and 1.0 (SD=0.09) ng/L, respectively. C_{free} values at the ENR plot measured during LDW pre-design studies were very similar to the range of concentrations observed in the scour Baseline and Year 1 events. As concentrations in the upper layers of the ENR and ENR+AC material are likely influenced by surface water, the approximate 1 to 2 ng/L range may represent the lowest currently-achievable C_{free} within the sandy material layers applied in a pilot study. The ranges of C_{free} PCBs for the scour ENR and ENR+AC subplots in Year 1 (0.6 to 2.4 ng/L) overlap with the values observed in 2018 during pre-design studies (Windward, 2018), and there were no statistical differences between the three data groupings (ENR plot Year 1, South Park, and Sea Freeze; P = 0.28) indicating similar concentrations in overlying water and the porewater in the ENR and ENR+AC materials. Year 2 and 3 monitoring events are planned to include SPME measurements of C_{free} at the sediment-water interface, which may allow a further evaluation of the potential influence of surface water on porewater conditions.

Although C_{free} measurements in the Baseline and Year 1 were statistically different in the ENR+AC scour subplot ($p < 0.05$), these measurements were not statistically different in the Baseline and Year 1 in the ENR scour subplot. To exhibit a statistically significant difference between Year 1 and Baseline, C_{free} in Year 1 would have had to decrease by at least 56% compared to the Baseline (i.e., a concentration of 0.7 ng/L or lower).

3.4.3.3 Subtidal Plot

The mean total PCB C_{free} concentration in the subtidal plot decreased from 34 ng/L (Baseline) to 9.6 ng/L (Year 1) in the ENR subplot, and from 103 ng/L (Baseline) to 3.8 ng/L (Year 1) in the ENR+AC subplot (Figure 3-16). The mean C_{free} values decreased 72% and 96% compared to the Baseline in the ENR and ENR+AC subplots, respectively. C_{free} measurements comparing Baseline and Year 1 showed that differences in C_{free} concentrations were statistically significant ($p < 0.05$) in both ENR and ENR+AC subplots.

3.5 SALINITY

This section reports on the salinity results for the Baseline and Year 1 sampling events. The purpose of the salinity measurements was to determine if there was a potential for fresh groundwater discharge within the plots. Groundwater discharge (advective flow) could potentially affect the results of the SPME porewater analysis.

Baseline salinity varied widely across all plots (Figures 3-19 to 3-21 and Tables A-4A and A-4B)[7] . Salinity was by far the lowest in the intertidal plot (6.1 to 26 parts per thousand (ppt)), followed by the scour plot (22 to 29 ppt). The subtidal plot had the highest salinity (28 to 29 ppt).

Year 1 salinity varied across all plots (Figures 3-19 to 3-21). Salinity in the scour and subtidal plots were at marine levels. The porewater salinity measurements at the scour and subtidal plots indicate there is no fresh groundwater discharge at the plots since the salinities are representative of marine water. Any salinity variation at these plots may not be relevant to the pilot study questions because all measurements represent marine conditions. The intertidal plot was sampled on foot at low tide in Year 1, and by divers at high tide during the Baseline event. Prior to sampling, the water overlaying the intertidal plot in Year 1 was likely the freshwater lens, and in Baseline was likely the marine layer, which could explain why salinity in the intertidal plot in Year 1 was lower than Baseline. At the intertidal plot, salinities range from brackish to marine conditions and the lower intertidal salinities may be entirely due to the daily exposure to the fresh surface water lens, although discharge of fresh groundwater may also be a contributing mechanism.

4.0 MONITORING FINDINGS AT YEAR 1

This section presents an overview of the Year 1 monitoring event and findings for the ENR/AC Pilot Study. The discussion is organized by Data Quality Objective (DQO) from the QAPP. As described in the DQOs, the goal of this pilot study is to generate results that will be used to assess and appropriately refine the technology assignment assumptions of ENR with respect to addition of AC, including its potential for use in scour mitigation applications. These are preliminary findings representing one-year post-placement conditions that will be revisited in the Year 3 Monitoring Report based on monitoring in Years 2 and 3. Two more monitoring years will be completed and thus findings discussed here with respect to these DQOs may change overtime.

DQO 1 regarding the verification of placement of the ENR and ENR+AC material was addressed in the Construction Report and is summarized below. DQOs 2 and 3, which are related to Year 1 observations and evaluations are also discussed below. DQO 4 regarding the potential impacts to benthic communities will be assessed in Year 3, thus is not discussed below.

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[7] The number of salinity measurements was reduced for scour and subtidal plots following Baseline due to uniformity in the measurements in accordance with the QAPP and approval by EPA.

4.1 DQO-1 Outcome: Verify the Placement of the ENR and ENR+AC Materials

The construction report concluded that DQO-1 was successfully met. DQO-1 was designed to determine whether the ENR and ENR+AC material could be successfully delivered and placed in the intertidal, scour and subtidal plots within the targeted specifications in the LDW. The Construction Report concluded:

> *Based on the observations throughout the placement process and inspections performed after the placement in each plot was complete, it was confirmed that the ENR+AC material can be successfully applied in the LDW.*

4.2 DQO-2 Outcome at Year 1: Evaluate Stability of ENR and ENR+AC Materials

The stability of ENR and AC material under DQO 2 was originally intended to address the scour plot; however, the discussion below includes the intertidal and subtidal plots. Similar field parameters were measured among all three plots, providing an opportunity to evaluate stability in all three plots. These additional assessments may provide insight into whether the intertidal and subtidal ENR and ENR+AC subplots are functioning as designed to decrease PCB bioavailability.

Several lines of evidence indicate that the ENR material in each plot is stable and has not eroded from the plots in any appreciable manner.

- The ENR and ENR+AC material is present and generally stable. The Year 1 SPI/PV images reveal the presence ENR and ENR+AC material in all images from all subplots except for grid cells 5 and 6 of the ENR+AC subtidal subplot (Figure 1-4) where barge chain dragging likely affects the bottom substrate (Amec et al., 2016). It is not clear if the ENR material has been mixed in to the underlying native material and/or if it has been lost through other mechanisms.

- Stability of the ENR/ENR+AC materials is indicated by the presence of high-order infaunal successional stages in all three plots from the SPI images. Stage 3 infauna feeding voids were evident in 41% of the replicate images from the intertidal subplots, 78% of the replicate images from the scour subplots, and 33% of the replicate images from the subtidal subplots. While these estimates may be biased high as some apparent feeding pockets may be physically formed in the silty sand matrix by the movement of the SPI prism, these percentages are approaching the percentages observed in the Baseline SPI survey (54%, 88%, and 45%, respectively). Results from the Year 2 and 3 surveys may help to reduce this uncertainty.

- TOC and BC measurements demonstrate the presence of AC in the ENR+AC subplots. Furthermore, TOC remained low in ENR subplots when compared to ENR+AC subplots, suggesting that the ENR+AC materials (or the added AC) has not moved from one subplot to another.

- Fine-grained material deposition was observed in Year 1 across all of the plots, at varying thicknesses. This represents a line of evidence of stability of the placed material. SPI images also indicated that there has been some mixing of the newly deposited material into the ENR and ENR+AC material. Newly-deposited material thicknesses will continue to be measured in Year 2 and Year 3. Grain size analyses and TOC concentrations supported this observation, as indicated by increased percent fines in all six subplots between Year 0 and Year 1, and increased TOC in all three ENR subplots between Year 0 and Year 1.

- As shown in Table 3-2, AC/BC in the Intertidal and Scour ENR+AC subplots was approximately the same between Year 0 and Year 1. At the Subtidal plot AC/BC levels decreased between Year 0 and Year 1 potentially due to chain dragging that could have mixed underlying or deposited material into the ENR+AC material, or suspended the material into the water column where it was transported away from the subplot.

4.3 DQO-3 at Year 1: Changes in Bioavailability in ENR+AC Compared to ENR Alone

In Year 1, The ENR and ENR+AC treatments reduced C_{free} PCB concentrations in porewater by 72% to 98% in five of the six subplots compared to Baseline. The exception was the Scour ENR subplot, which exhibited low bulk-sediment and C_{free} PCB concentrations at Baseline. Given the low concentrations of PCBs in bulk sediment, the lack of differences in C_{free} PCB concentrations from the Baseline to Year 1 in the Scour ENR subplot was understandable. Nonetheless, the Scour ENR subplot will continue to be monitored to evaluate C_{free} PCBs through Years 2 and 3.

In Year 1, comparison of the ENR and ENR+AC subplots showed statistical differences in C_{free} concentrations between ENR+AC and ENR only in the subtidal plot, while the intertidal and scour plots did not show statistically significant differences (Figure 3-17).

5.0 FUTURE EVENTS – YEARS 2 AND 3

The pilot study plots will continue to be monitored in 2019 (Year 2) and 2020 (Year 3). Year 2 monitoring will be similar to Year 1 with the addition of horizontally-placed SPMEs to measure C_{free} PCB concentrations at the sediment-water interface. Year 3 monitoring scope will be similar to Year 1 and Year 2 monitoring, except for the addition of benthic invertebrate taxonomy and a laboratory bioaccumulation study to complete the assessment of DQOs 3 and 4.

The results of Year 2 and 3 monitoring will be presented and the DQOs will be evaluated in the Year 3 Monitoring Report, which is scheduled to be submitted to EPA and Ecology in December 2020.

6.0 REFERENCES

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TABLES

Table 2-1
Sampling Activity Timeline

Plot	Subplot	Baseline							
		Activity							
			Sediment Collection		SPME Deployment[2]		SPME Retrieval		
		SPI/PV Date	Start	Finish	Start	Finish	Start	Finish
Intertidal	ENR+AC	07/12/16 - 07/13/16	09/04/16	09/09/16	07/26/16	07/26/16	09/04/16	09/09/16
	ENR		09/04/16	09/09/16	07/25/16	07/26/16	09/04/16	09/09/16
Scour	ENR+AC	07/12/16	09/01/16	09/05/16	07/27/26	07/29/16	09/01/16	09/05/16
	ENR		08/29/16	09/01/16	07/26/16	07/29/16	08/29/16	09/01/16
Subtidal	ENR+AC	07/13/16	11/16/16	11/18/16	11/28/16	11/28/16	01/18/17	01/18/17
	ENR		11/17/18	11/18/16	11/28/16	11/28/16	01/18/17	01/18/17

Plot	Subplot	Construction				Year 0		
		Activity						
		Material Placement		Stake Measurement/ Observation		Year 0 SPI/PV Date	Year 0 Sediment Collection	
		Start	Finish	Start	Finish		Start	Finish
Intertidal	ENR+AC	12/01/16	12/15/16	12/13/16	12/27/16	01/11/17	01/12/17	01/13/17
	ENR	12/08/16	12/19/16					
Scour	ENR+AC	12/20/16	12/28/16	01/09/17	01/09/17	01/16/17	01/17/17	01/23/17
	ENR	12/29/16	01/06/17					
Subtidal	ENR+AC	01/09/17	01/19/17	01/30/17	01/31/17	02/01/17	02/02/17	02/03/17
	ENR	01/20/17	01/26/17					

Plot	Subplot	Year 1						
		Activity						
			Sediment Collection		SPME Deployment[1]		SPME Retrieval	
		SPI/PV Date	Start	Finish	Start	Finish	Start	Finish
Intertidal	ENR+AC	03/29/18 - 03/30/18	06/28/18	07/09/18	05/17/18	05/17/18	06/28/18	06/29/18
	ENR		06/28/18	07/09/18	05/16/18	05/17/18	06/29/18	06/29/18
Scour	ENR+AC	03/30/18	06/26/18	07/09/18	05/15/18	05/16/18	06/26/18	06/28/18
	ENR		06/24/18	07/09/18	05/14/18	05/15/18	06/24/18	06/26/18
Subtidal	ENR+AC	03/29/18	05/01/18	05/02/18	05/03/18	05/03/18	06/30/18	06/30/18
	ENR		04/30/18	05/01/18	05/03/18	05/03/18	06/30/18	06/30/18

Abbreviations:
ENR = Enhanced natural recovery
ENR+AC = Enhanced natural recovery amended with activated carbon
SPI/PV = sediment profile imaging/plan view
SPME = solid-phase micro extraction

Notes:
1. Subtidal SPMEs deployed ex situ in the laboratory.

Table 2-2
Data Qualifier Definitions

Qualifier	Definition	Description
C	Co-eluting congener	Concentration represents total concentration of all congeners that coelute with qualified congener.
CXXX	Co-elutes with the indicated congener	Analyte coelutes with another congener, see numbered congener for concentration.
J	Estimated	Analyte was detected, concentration is considered an estimate.
U	Non-detect	Analyte was not detected, concentration is the estimated detection limit.
L	Percent to steady state less than 20%	Percent to steady state less than 20%. Concentration is considered estimated.
UB	Background concentration exceeds detected concentration	The background concentration exceeded the detected concentration and no PCB free concentration was reported. These results should be considered not detected at the lowest available detection limit, the MDL.

Abbreviations:
MDL = Method detection limit
PCB = Polychlorinated biphenyl

Table 3-1
Year 1 Silt Layer Thicknesses Estimates[1]

Plot	Sublot	Silt Layer Thickness Range (cm)	Average Thickness of Silt Layer (cm)
Intertidal	ENR+AC	0.31-6.3	1.0
	ENR	0.63-6.3	1.6
Scour	ENR+AC	0-4.4	1.5
	ENR	0-5	2.5
Subtidal	ENR+AC	0-15	1.7
	ENR	0-5	0.63

Abbreviations:
cm = centimeter(s)
ENR = Enhanced natural recovery
ENR+AC = Enhanced natural recovery amended with activated carbon
SPME = solid-phase micro extraction

Notes:
1. Silt layer thicknesses are based on field measurements during SPME retrieval, not sediment profile imaging.
2. The low and high values of the silt layer thickness at each location were averaged to represent an average silt layer thickness at each location. These values were then averaged to obtain an average silt layer thickness for each subplot, which are presented in this table.

Table 3-2
Data Summary – Conventionals

Chemical	Plot	Subplot	Event	Average	Minimum	Maximum	Standard Deviation
Black Carbon (Baseline), Total Volatile Solids (Y0) and Activated Carbon/Black Carbon (Y1) (%)	Intertidal	ENR	Baseline	0.12	0.041	0.26	0.12
			Y0	0.51	0.49	0.55	0.035
			Y1	0.056	0.012	0.14	0.073
		ENR+AC	Baseline	0.092	0.057	0.11	0.031
			Y0	2.6	2.4	3.0	0.30
			Y1	2.1	1.6	2.8	0.61
	Scour	ENR	Baseline	0.20	0.14	0.30	0.087
			Y0	0.49	0.46	0.55	0.054
			Y1	0.19	0.088	0.33	0.13
		ENR+AC	Baseline	0.36	0.22	0.49	0.14
			Y0	2.4	1.6	2.9	0.75
			Y1	2.6	2.0	3.4	0.72
	Subtidal	ENR	Baseline	0.13	0.063	0.18	0.063
			Y0	1.1	1.0	1.1	0.058
			Y1	0.25	0.13	0.34	0.11
		ENR+AC	Baseline	0.11	0.046	0.16	0.057
			Y0	3.0	3.0	3.0	0
			Y1	1.1	0.93	1.2	0.14
Total Organic Carbon (%)	Intertidal	ENR	Baseline	1.4	1.3	1.4	0.058
			Y0	0.056	0.054	0.057	0.0016
			Y1	0.20	0.15	0.28	0.070
		ENR+AC	Baseline	1.5	1.5	1.6	0.058
			Y0	1.8	1.4	2.2	0.40
			Y1	1.9	1.6	2.5	0.50
	Scour	ENR	Baseline	2.7	2.6	2.8	0.10
			Y0	0.054	0.053	0.055	0.0015
			Y1	0.33	0.27	0.37	0.053
		ENR+AC	Baseline	2.1	1.9	2.2	0.17
			Y0	1.8	1.5	2.1	0.26
			Y1	1.4	0.38	2.0	0.86
	Subtidal	ENR	Baseline	1.8	1.7	2.1	0.23
			Y0	0.11	0.10	0.12	0.012
			Y1	0.40	0.38	0.42	0.021
		ENR+AC	Baseline	2.1	2.0	2.2	0.10
			Y0	1.8	1.61	1.9	0.16
			Y1	1.7	1.4	2	0.31

Table 3-2
Data Summary – Conventionals

Chemical	Plot	Subplot	Event	Average	Minimum	Maximum	Standard Deviation
Gravel (%)	Intertidal	ENR	Baseline	1.3	0.60	2.5	1.0
			Y0	66	63	71	4.5
			Y1	53	50	61	4.7
		ENR+AC	Baseline	1.3	0.90	1.6	0.35
			Y0	68	67	68	0.58
			Y1	60	57	64	3.6
	Scour	ENR	Baseline	1.4	0.60	2.3	0.86
			Y0	66	65	67	1.2
			Y1	67	65	71	3.4
		ENR+AC	Baseline	5.1	1.4	12	6.4
			Y0	66	64	67	1.9
			Y1	64	55	70	7.7
	Subtidal	ENR	Baseline	5.2	2.2	7.1	2.6
			Y0	23	22	24	1.2
			Y1	22	20	23	1.2
		ENR+AC	Baseline	1.5	0.30	3.3	1.6
			Y0	22	21	24	1.2
			Y1	20	15	24	4.5
Sand (%)	Intertidal	ENR	Baseline	46	43	48	2.9
			Y0	34	29	37	4.5
			Y1	44	36	48	5.0
		ENR+AC	Baseline	46	38	52	7.3
			Y0	32	32	33	0.55
			Y1	38	34	41	3.5
	Scour	ENR	Baseline	17	12	26	7.1
			Y0	34	33	35	1.3
			Y1	29	26	31	2.8
		ENR+AC	Baseline	34	29	41	6.6
			Y0	34	32	36	1.8
			Y1	33	28	41	6.9
	Subtidal	ENR	Baseline	30	27	32	2.6
			Y0	76	74	77	1.7
			Y1	72	70	75	2.3
		ENR+AC	Baseline	19	15	25	5.4
			Y0	76	75	78	1.7
			Y1	64	63	65	0.80

Table 3-2
Data Summary – Conventionals

Chemical	Plot	Subplot	Event	Average	Minimum	Maximum	Standard Deviation
Fines (%)	Intertidal	ENR	Baseline	52	50	56	3.4
			Y0	0.27	0.20	0.30	0.058
			Y1	3.1	2.5	4.1	0.63
		ENR+AC	Baseline	53	47	62	7.6
			Y0	0.40	0.30	0.50	0.10
			Y1	2.0	1.8	2.2	0.21
	Scour	ENR	Baseline	81	72	87	8.0
			Y0	0.30	0.30	0.30	0.0000000061
			Y1	4.1	3.3	4.8	0.76
		ENR+AC	Baseline	61	57	70	7.4
			Y0	0.47	0.40	0.50	0.058
			Y1	2.7	2.0	3.5	0.75
	Subtidal	ENR	Baseline	65	61	67	3.2
			Y0	1.3	0.90	2.0	0.59
			Y1	6.7	5.0	8.3	1.5
		ENR+AC	Baseline	79	72	84	7.0
			Y0	1.4	0.90	1.7	0.42
			Y1	16	12	20	4.2

Abbreviations:

ENR = Enhanced natural recovery

ENR+AC = Enhanced natural recovery amended with activated carbon

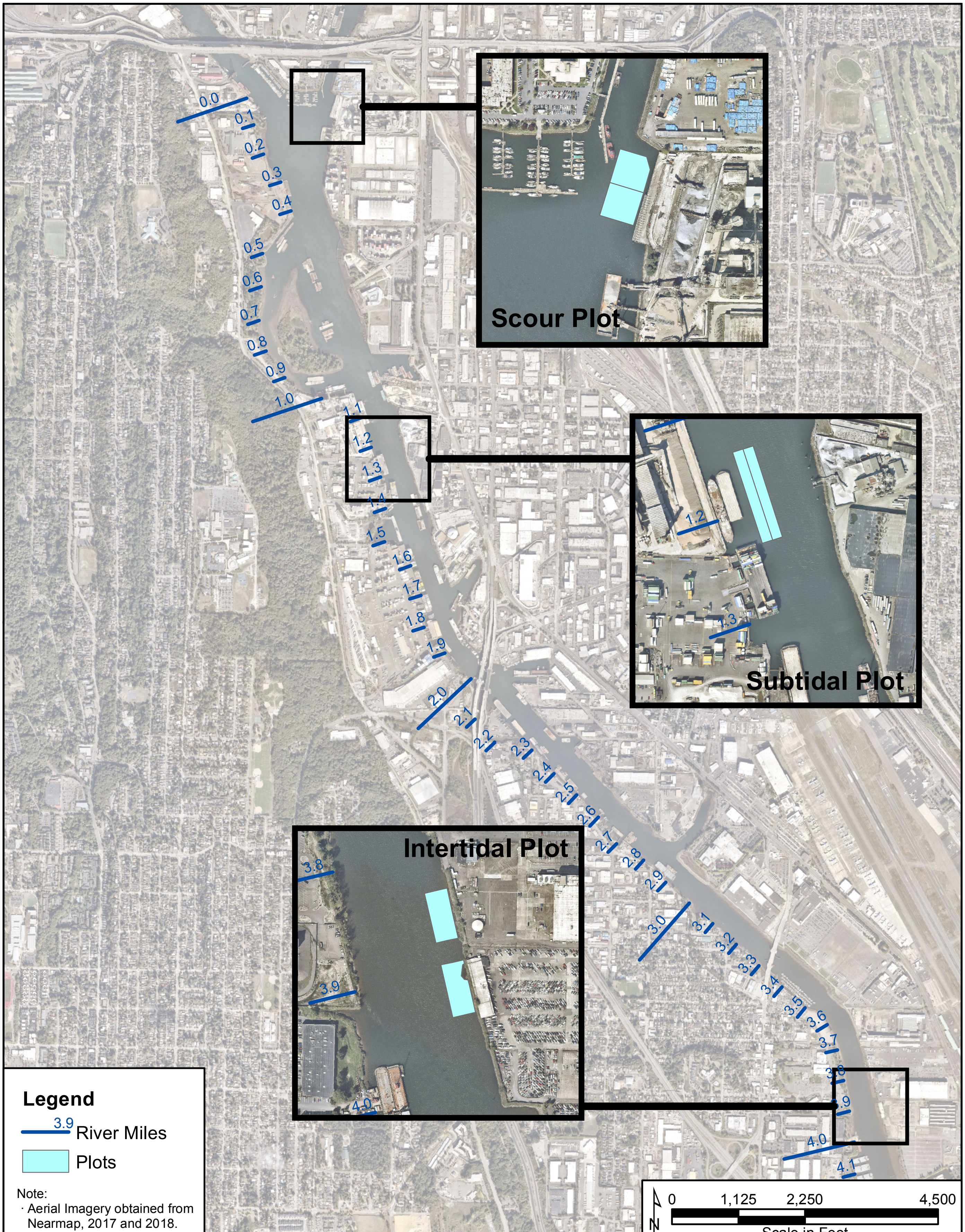
Table 3-3
Data Summary – Total PCBs

Chemical	Plot	Subplot	Event	Geometric Mean	Median	Minimum	Maximum	Standard Deviation
Sediment PCBs (Total Congeners, µg/kg dw)	Intertidal	ENR	Baseline	196	225	80.3	414	167
			Y1	4.96	4.52	3.24	8.32	2.64
		ENR+AC	Baseline	221	222	120	407	145
			Y1	3.30	3.37	2.56	4.16	0.8
	Scour	ENR	Baseline	29.4	26.6	17.5	54.7	19.4
			Y1	14.1	10.9	9.04	28.7	10.9
		ENR+AC	Baseline	22.6	21.7	19.2	27.6	4.31
			Y1	9.17	9.13	6.65	12.7	3.04
	Subtidal	ENR	Baseline	257	237	153	468	163
			Y1	45.1	45	26.8	76.3	25
		ENR+AC	Baseline	221	210	151	341	97.2
			Y1	39.4	40.6	31.1	48.5	8.71
C_{free} PCBs (Total Congeners, ng/L)	Intertidal	ENR	Baseline	30.8	25.4	15.0	75.0	32.1
			Y1	1.06	1.1	0.840	1.30	0.231
		ENR+AC	Baseline	27.7	28.9	18.0	41.0	11.5
			Y1	0.492	0.530	0.270	0.830	0.3
	Scour	ENR	Baseline	1.48	1.45	1.20	1.90	0.361
			Y1	1.42	1.20	1.00	2.40	0.757
		ENR+AC	Baseline	8.54	8.45	3.70	20.0	8.39
			Y1	0.886	0.94	0.570	1.30	0.365
	Subtidal	ENR	Baseline	34.1	30	26.0	51.0	13.4
			Y1	9.61	7.7	7.20	16.0	4.94
		ENR+AC	Baseline	103	97	76.0	150	38.1
			Y1	3.78	3.7	3.50	4.20	0.361

Abbreviations:
- dw = dry weight
- ENR = Enhanced natural recovery
- ENR+AC = Enhanced natural recovery amended with activated carbon
- ng/L = nanogram(s) per liter
- PCB = polychlorinated biphenyl
- µg/kg = microgram(s) per kilogram

Notes:
Measured in sediment and porewater samples from 0 to 10 centimeters.

FIGURES



Lower Duwamish Waterway Group
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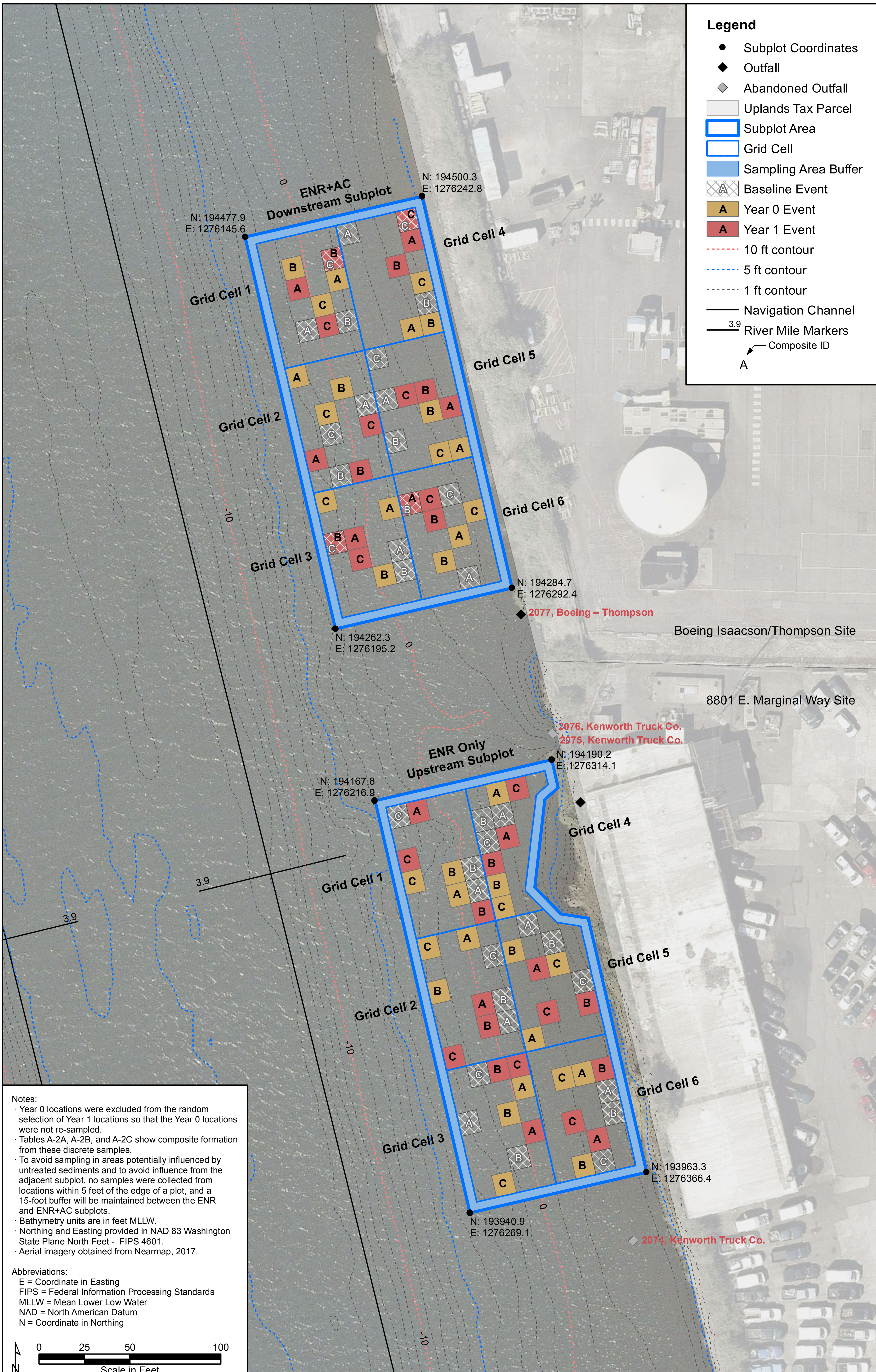
ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 1-1
Plot Locations in the
Lower Duwamish Waterway

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 1-1 Plot Locations in the Lower Duwamish Waterway.mxd
11/15/2018



Notes:
- Year 0 locations were excluded from the random selection of Year 1 locations so that the Year 0 locations were not re-sampled.
- Tables A-2A, A-2B, and A-2C show composite formation from these discrete samples.
- To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples were collected from locations within 5 feet of the edge of a plot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.
- Bathymetry units are in feet MLLW.
- Northing and Easting provided in NAD 83 Washington State Plane North Feet - FIPS 4601.
- Aerial imagery obtained from Nearmap, 2017.

Abbreviations:
E = Coordinate in Easting
FIPS = Federal Information Processing Standards
MLLW = Mean Lower Low Water
NAD = North American Datum
N = Coordinate in Northing

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

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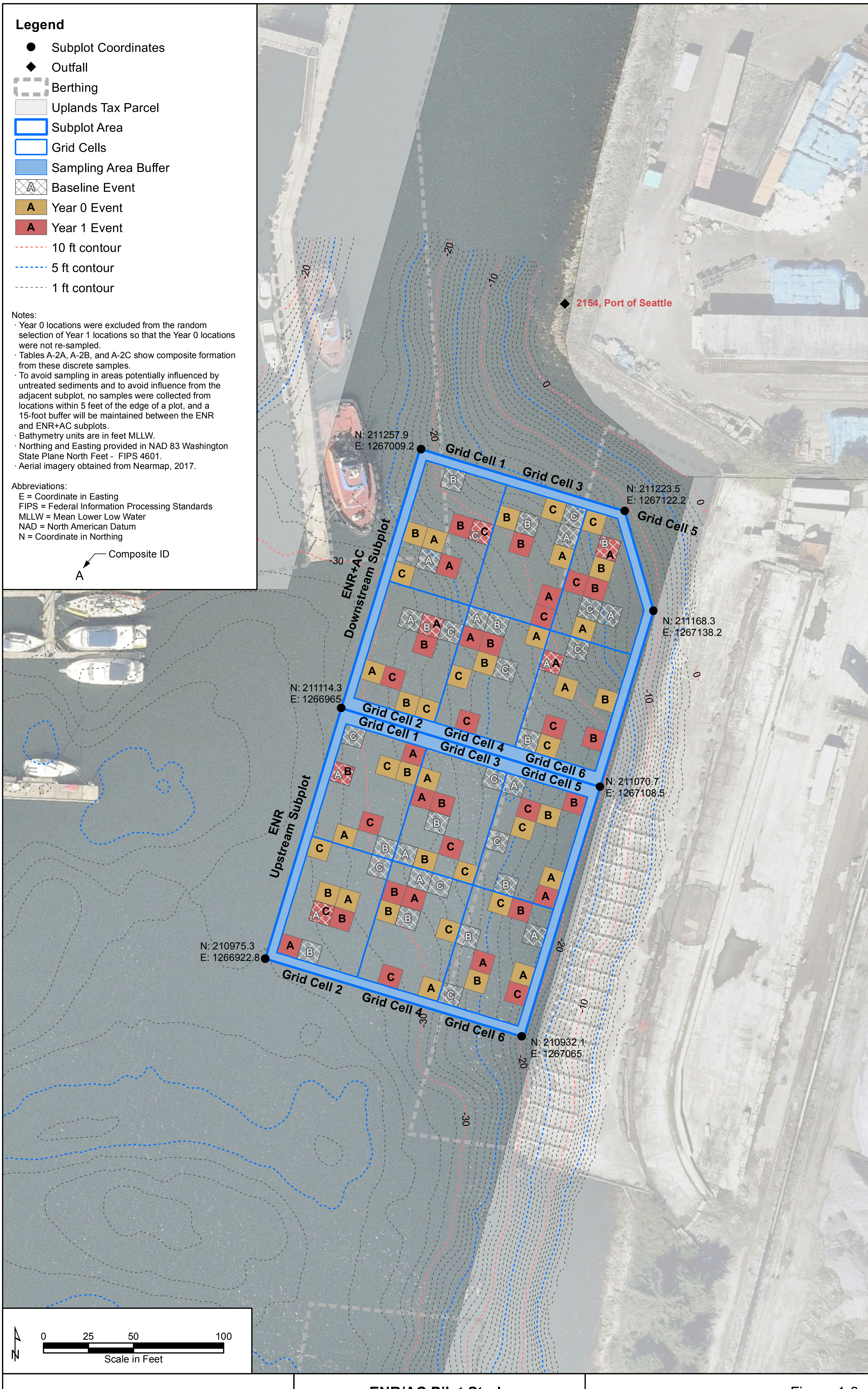
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 1-2
Intertidal Plot
Discrete Sample Locations

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 1-2 Intertidal Plot Discrete Sample Locations.mxd
11/6/2018



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ENR/AC Pilot Study
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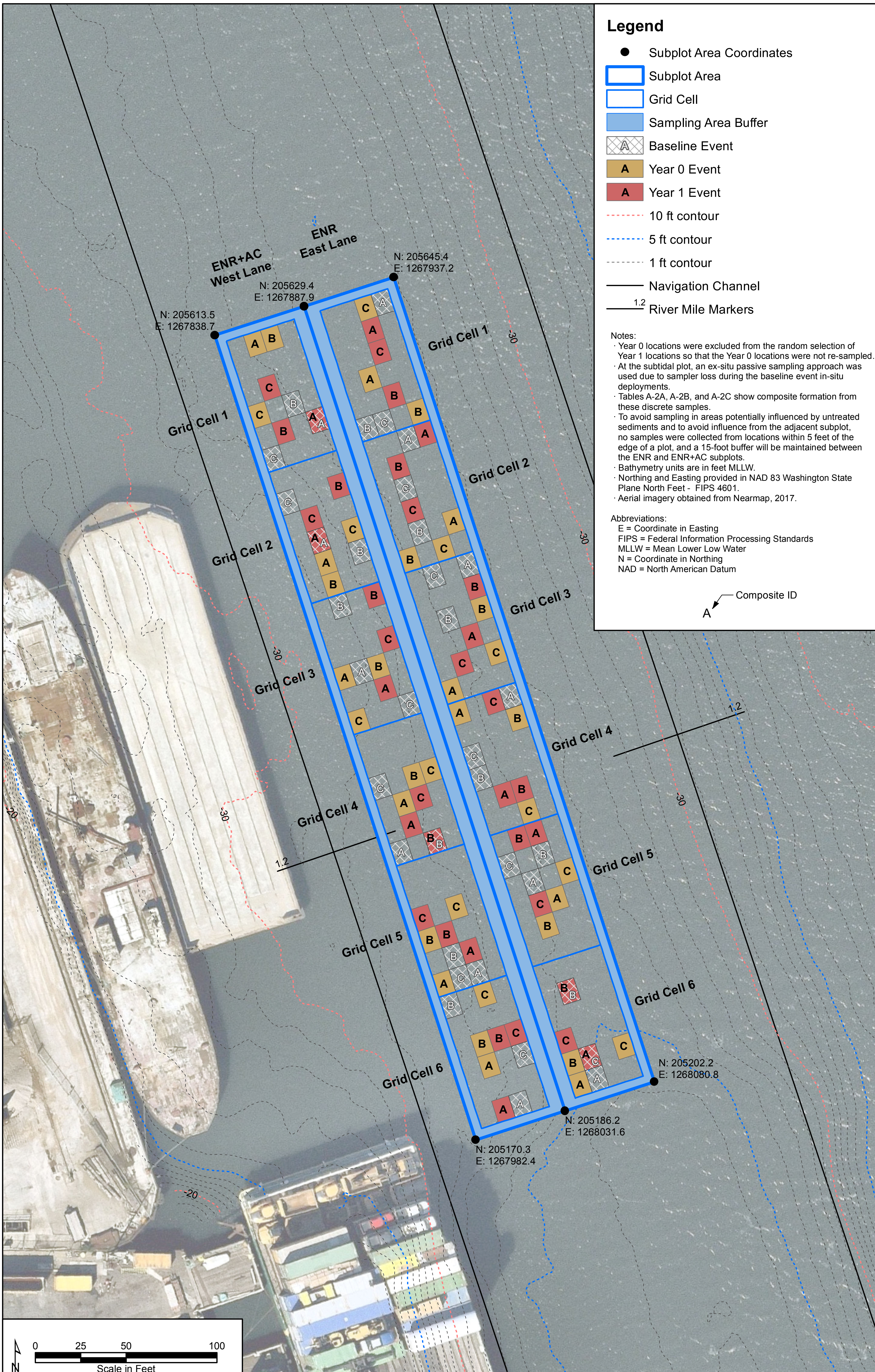
Lower Duwamish Waterway

Figure 1-3
Scour Plot
Discrete Sample Locations

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 1-3 Scour Plot Discrete Sample Locations.mxd
11/6/2018



Lower Duwamish Waterway Group
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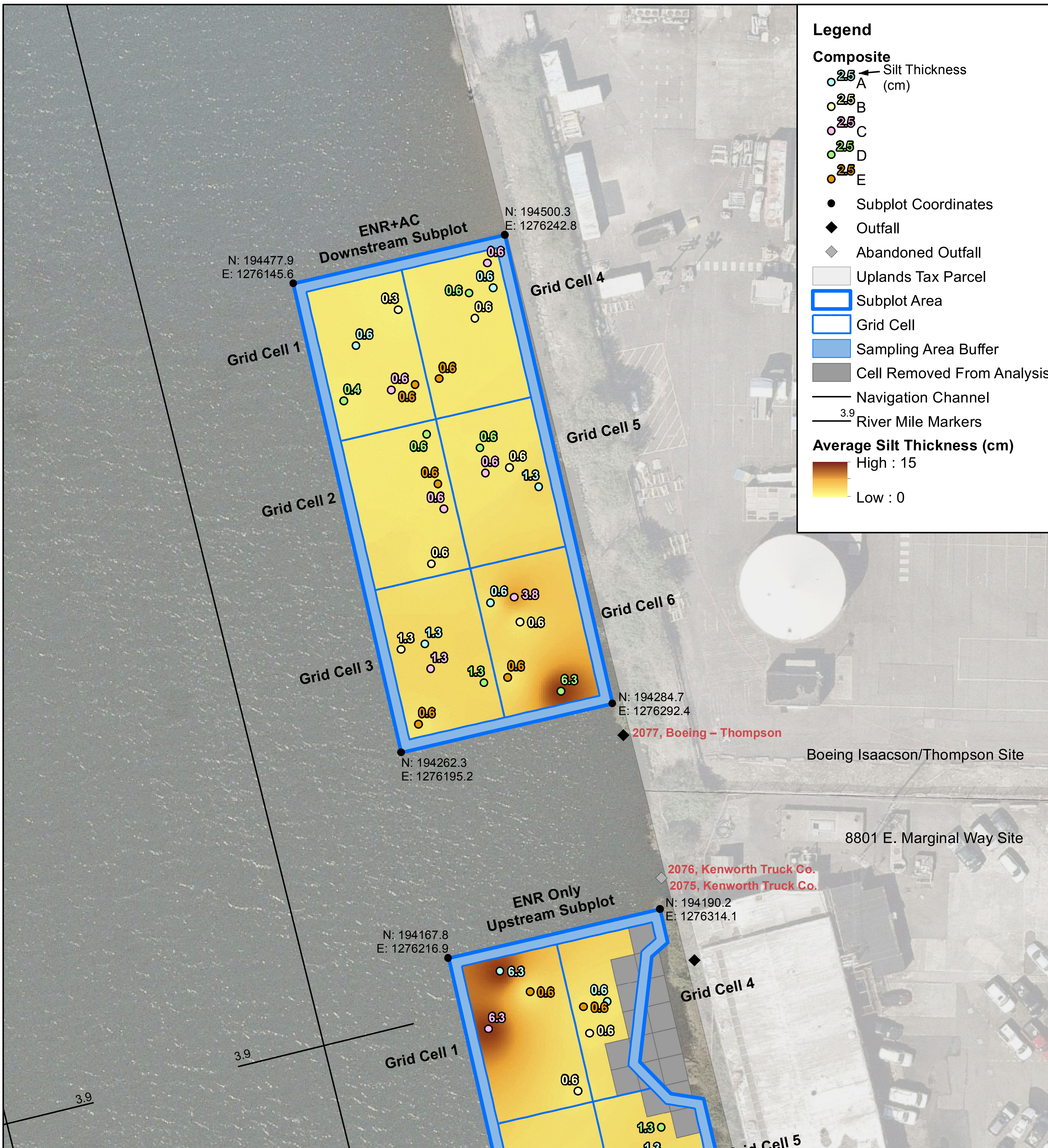
ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 1-4
Subtidal Plot
Discrete Sample Locations

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 1-4 Subtidal Plot Discrete Sample Locations.mxd
11/6/2018



Notes:
- Silt thickness was interpolated using IDW with a power of 2.
- The thickness of the silt layer deposited on top of the treatment layer (ENR or ENR+AC) was measured by field personnel when retrieving the SPME sampler at each location. The low and high range of the silt layer thickness measured at each sampling location are indicated in Table 3-1. The high and low ranges were averaged to represent an average silt layer thickness at each location.
- Some grid cells have fewer than 5 silt thickness measurements because sediment samples and silt thickness measurements were not collected when SPMEs were not recoverable.
- To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples were collected from locations within 5 feet of the edge of a plot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.
- Northing and Easting provided in NAD 83 Washington State Plane North Feet - FIPS 4601.
- Aerial imagery obtained from Nearmap, 2017.

Abbreviations:
E = Coordinate in Easting
ENR = Enhanced natural recovery
ENR+AC = Enhanced natural recovery amended with activated carbon
FIPS = Federal Information Processing Standards
IDW = Inverse distance weighted
N = Coordinate in Northing
NAD = North American Datum
SPME = Solid-phase microextraction

Lower Duwamish Waterway Group
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Lower Duwamish Waterway

Figure 3-1
Year 1 Intertidal Plot
Silt Deposition Thickness Using
IDW and Sample Measurements

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 3-1 Year 1 Intertidal Plot Silt Deposition Thickness Using IDW and Sample Measurements.mxd
11/15/2018

Legend

Composite

- 2.5 A ← Silt Thickness (cm)
- 2.5 B
- 2.5 C
- 2.5 D
- 2.5 E
- ● Subplot Coordinates
- ◆ Outfall

- Berthing
- Uplands Tax Parcel
- Subplot Area
- Grid Cells
- Sampling Area Buffer
- Cell Removed From Analysis

Average Silt Thickness (cm)

High : 15

Low : 0

Notes:

- Silt thickness was interpolated using Inverse Distance Weighting with a power of 2.
- The thickness of the silt layer deposited on top of the treatment layer (ENR or ENR+AC) was measured by a diver when retrieving the SPME sampler at each location. The low and high range of the silt layer thickness measured at each sampling location are indicated in Table 3-1. The high and low ranges were averaged to represent an average silt layer thickness at each location.
- Some grid cells have fewer than 5 silt thickness measurements because sediment samples and silt thickness measurements were not collected when SPMEs were not recoverable.
- To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples were collected from locations within 5 feet of the edge of a plot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.
- Northing and Easting provided in NAD 83 Washington State Plane North Feet - FIPS 4601.
- Aerial imagery obtained from Nearmap, 2017.

Abbreviations:

E = Coordinate in Easting
ENR = Enhanced natural recovery
ENR+AC = Enhanced natural recovery amended with activated carbon
FIPS = Federal Information Processing Standards
IDW = Inverse distance weighted
N = Coordinate in Northing
NAD = North American Datum
SPME = Solid-phase microextraction

Lower Duwamish Waterway Group
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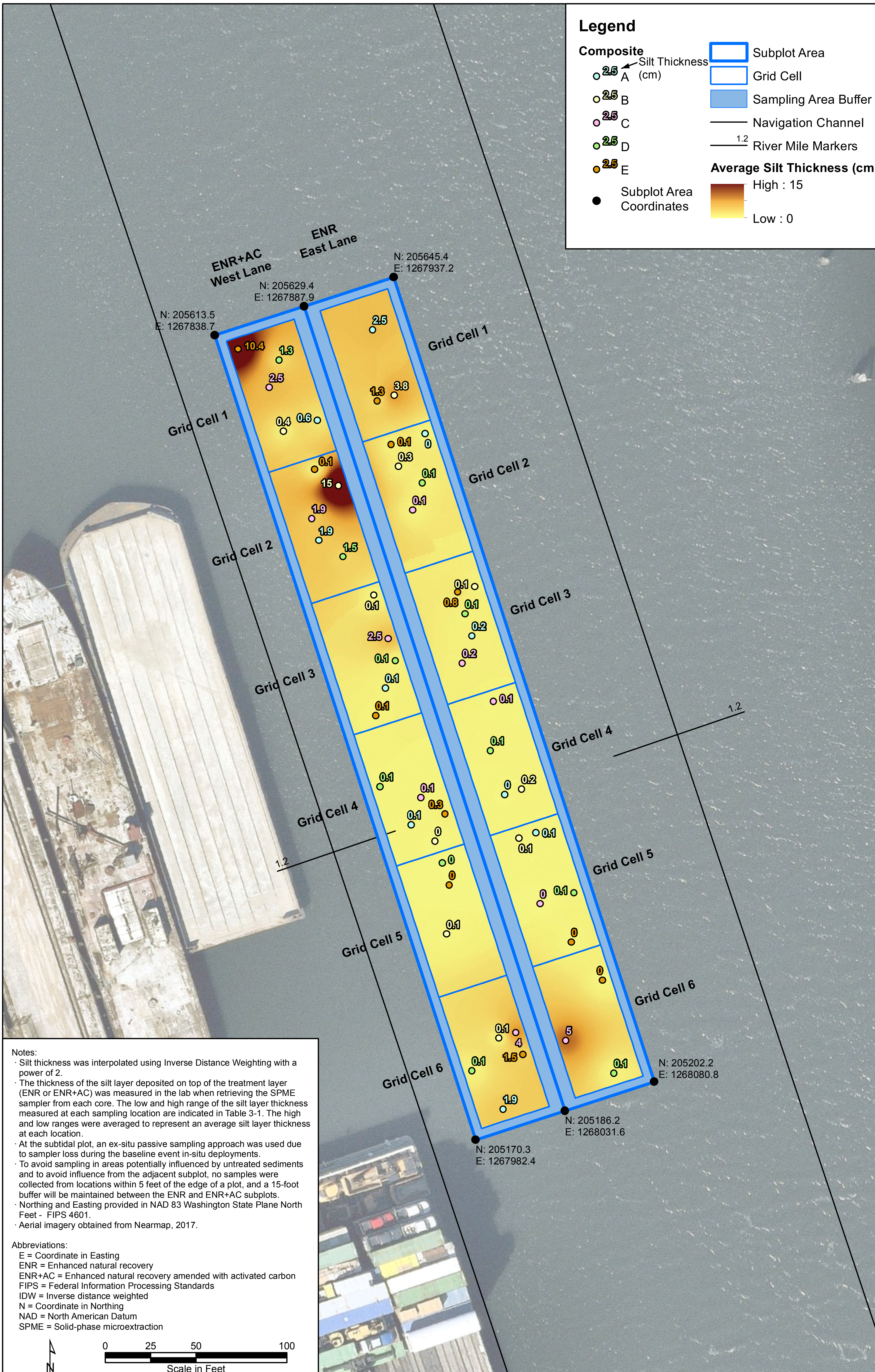
Lower Duwamish Waterway

Figure 3-2
Year 1 Scour Plot
Silt Deposition Thickness Using
IDW and Sample Measurements

I:\GIS\Projects\Wood-KC-ENR\MXD\Project Monitoring and Data Reports\Year 1 Figures\Monitoring Report\Figure 3-2 Year 1 Scour Plot Silt Deposition Thickness Using IDW and Sample Measurements.mxd
11/15/2018



Notes:
- Silt thickness was interpolated using Inverse Distance Weighting with a power of 2.
- The thickness of the silt layer deposited on top of the treatment layer (ENR or ENR+AC) was measured in the lab when retrieving the SPME sampler from each core. The low and high range of the silt layer thickness measured at each sampling location are indicated in Table 3-1. The high and low ranges were averaged to represent an average silt layer thickness at each location.
- At the subtidal plot, an ex-situ passive sampling approach was used due to sampler loss during the baseline event in-situ deployments.
- To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples were collected from locations within 5 feet of the edge of a plot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.
- Northing and Easting provided in NAD 83 Washington State Plane North Feet - FIPS 4601.
- Aerial imagery obtained from Nearmap, 2017.

Abbreviations:
E = Coordinate in Easting
ENR = Enhanced natural recovery
ENR+AC = Enhanced natural recovery amended with activated carbon
FIPS = Federal Information Processing Standards
IDW = Inverse distance weighted
N = Coordinate in Northing
NAD = North American Datum
SPME = Solid-phase microextraction

Lower Duwamish Waterway Group
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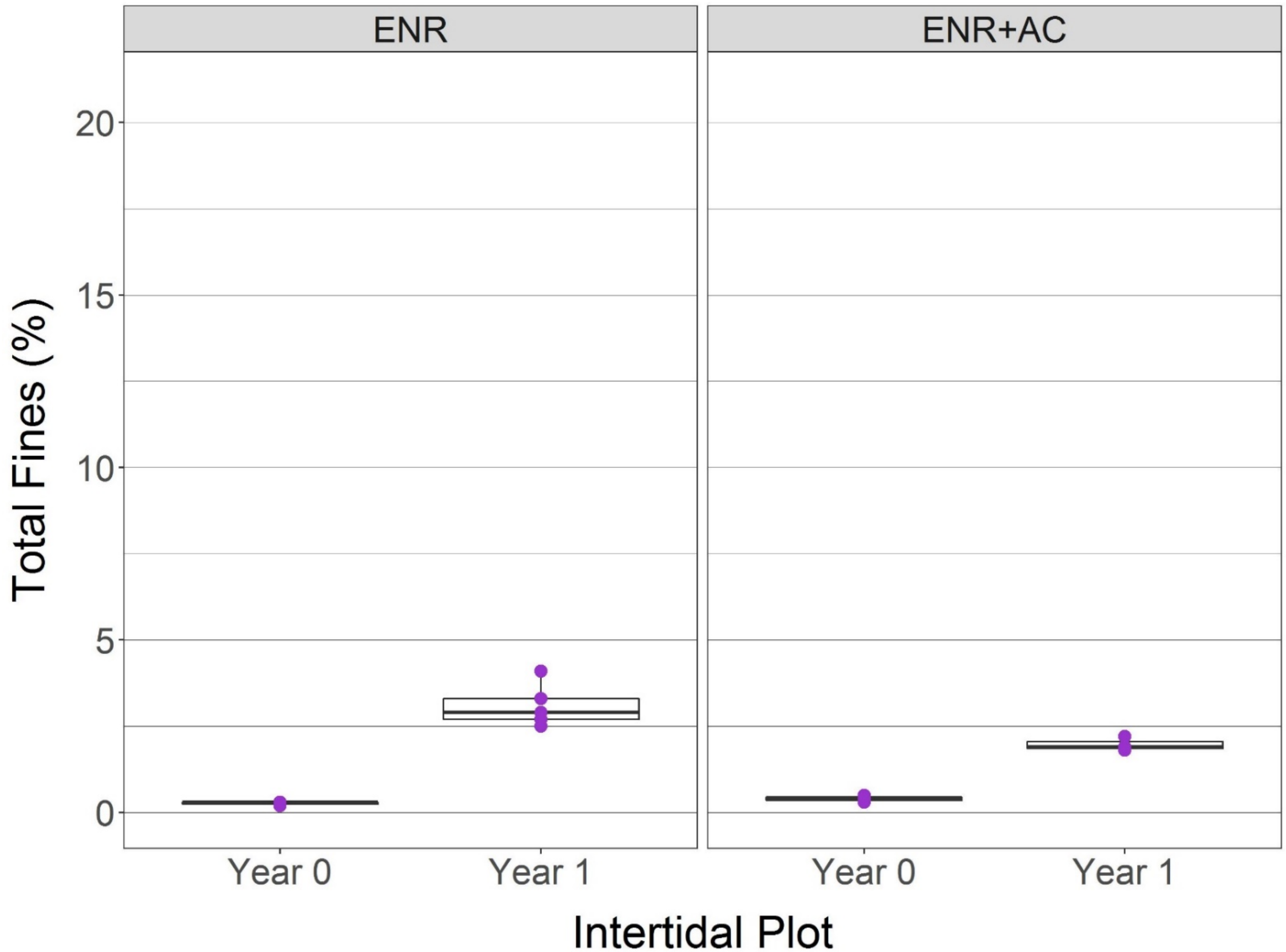
ENR/AC Pilot Study
Year 1 Data and Monitoring Report
Lower Duwamish Waterway

Figure 3-3
Year 1 Subtidal Plot
Silt Deposition Thickness Using
IDW and Sample Measurements

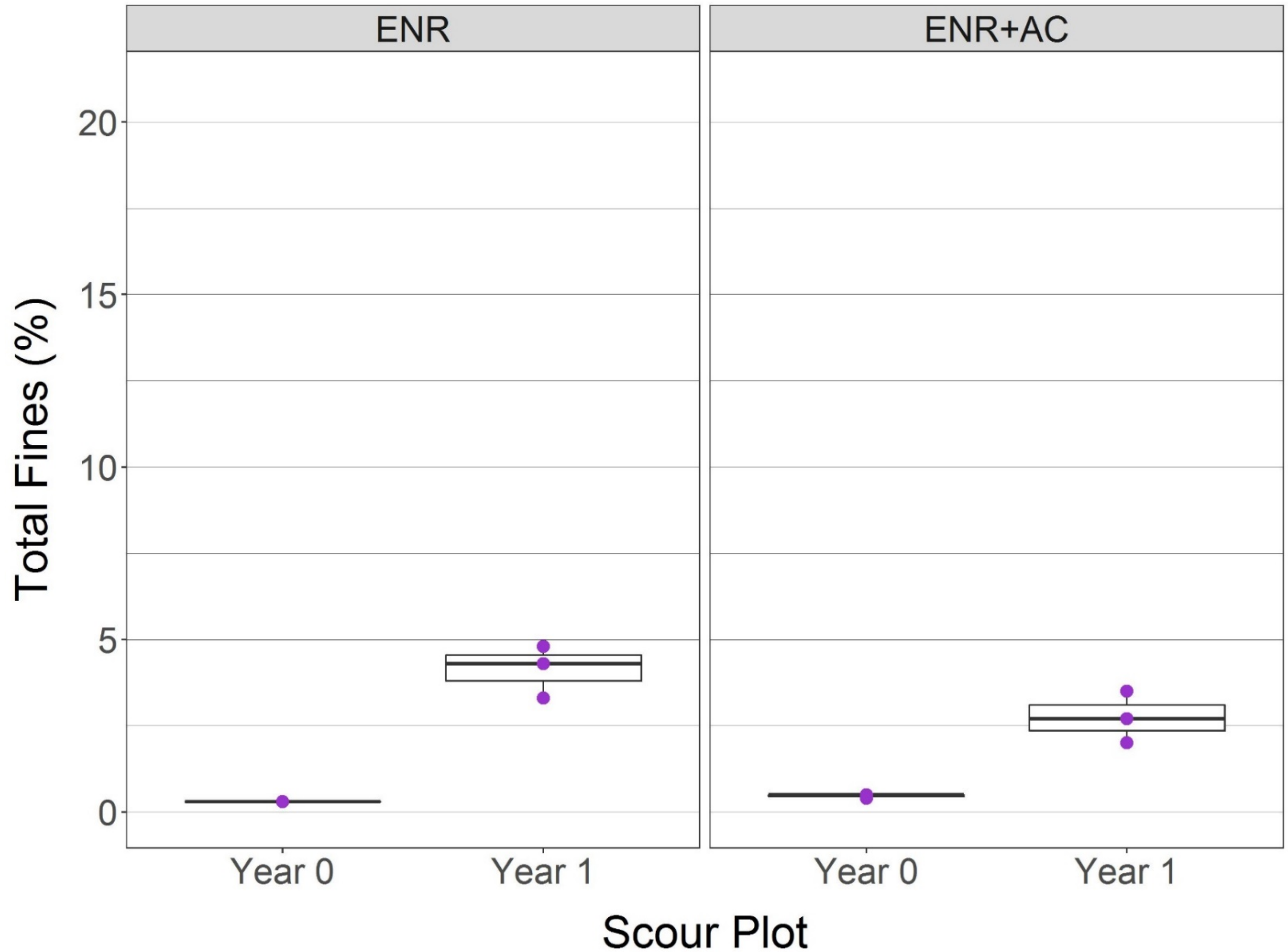


Boxes show first quartile, median, and third quartile. Dots show data points.

Mean Total Fines (%) for Baseline Event: ENR = 56%, ENR+AC = 57%

Baseline results not shown on figure for clarity.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-4 Intertidal Plot Percent Fines



Boxes show first quartile, median, and third quartile. Dots show data points.

Mean Total Fines (%) for Baseline Event: ENR = 83%, ENR+AC = 62%

Baseline results not shown on figure for clarity.

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

ENR/AC Pilot Study
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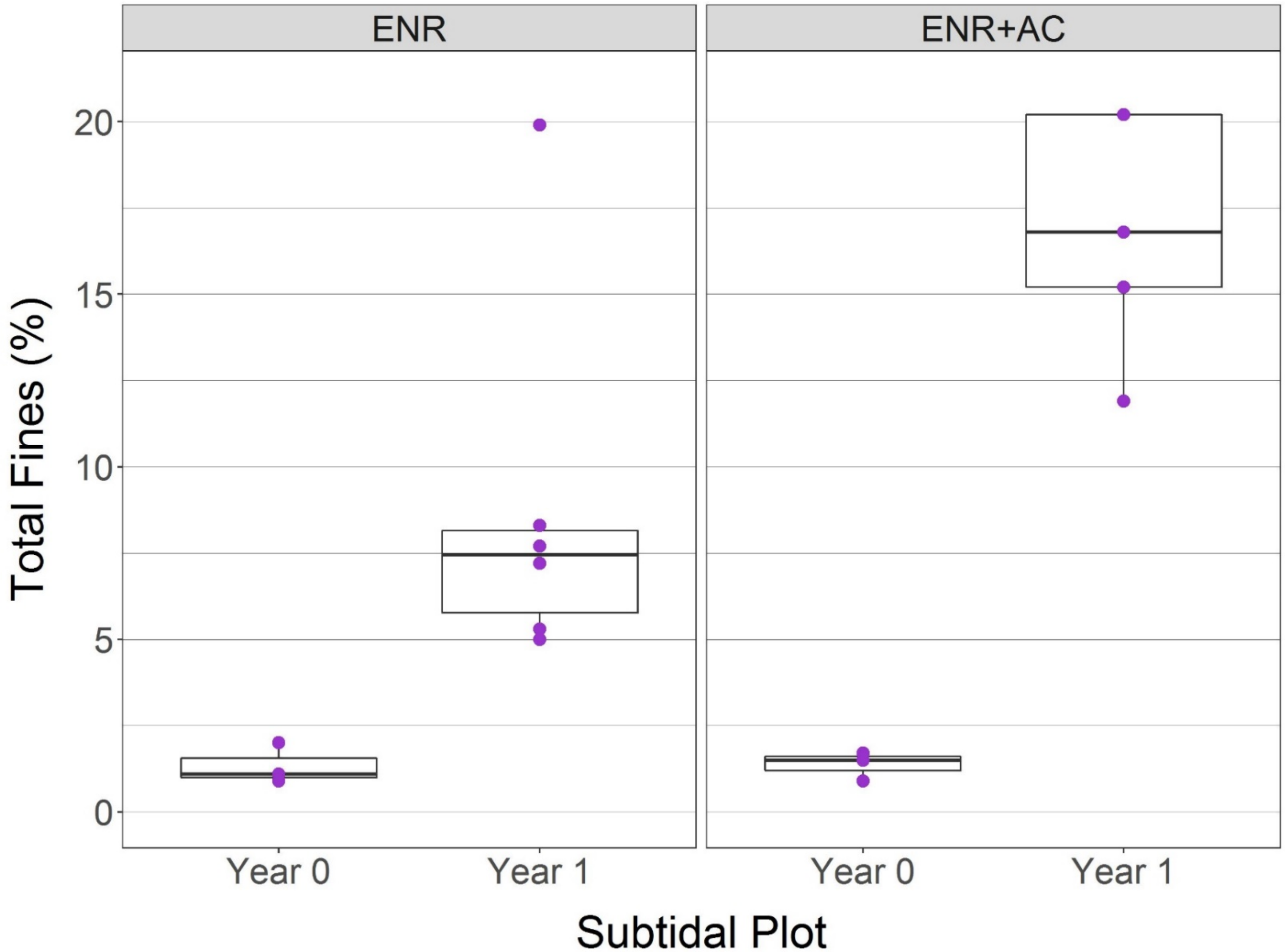
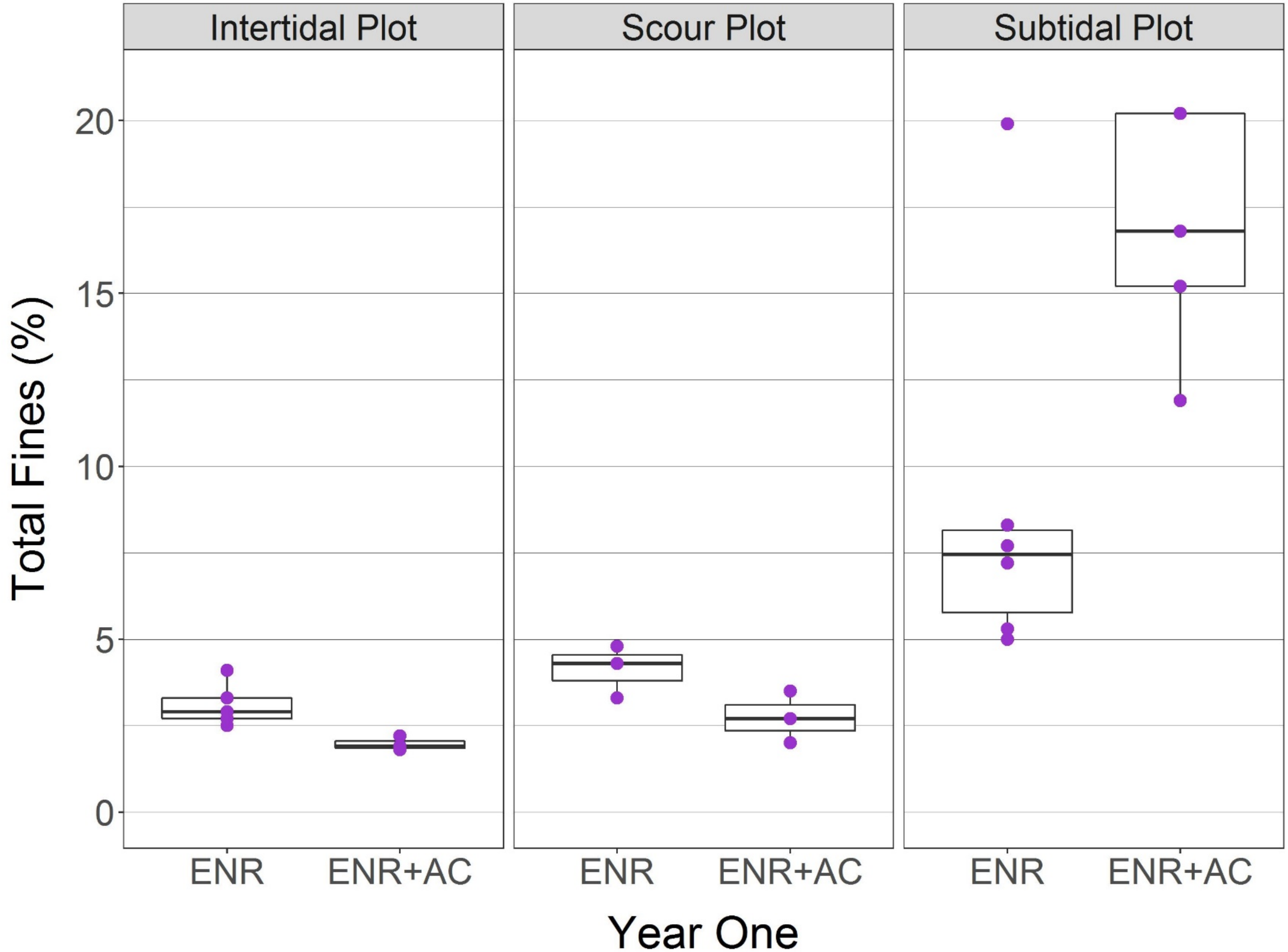
Lower Duwamish Waterway

Figure 3-5
Scour Plot Percent Fines



Boxes show first quartile, median, and third quartile. Dots show data points.
Mean Total Fines (%) for Baseline Event: ENR = 68%, ENR+AC = 83%
Baseline results not shown on figure for clarity.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-6 Subtidal Plot Percent Fines

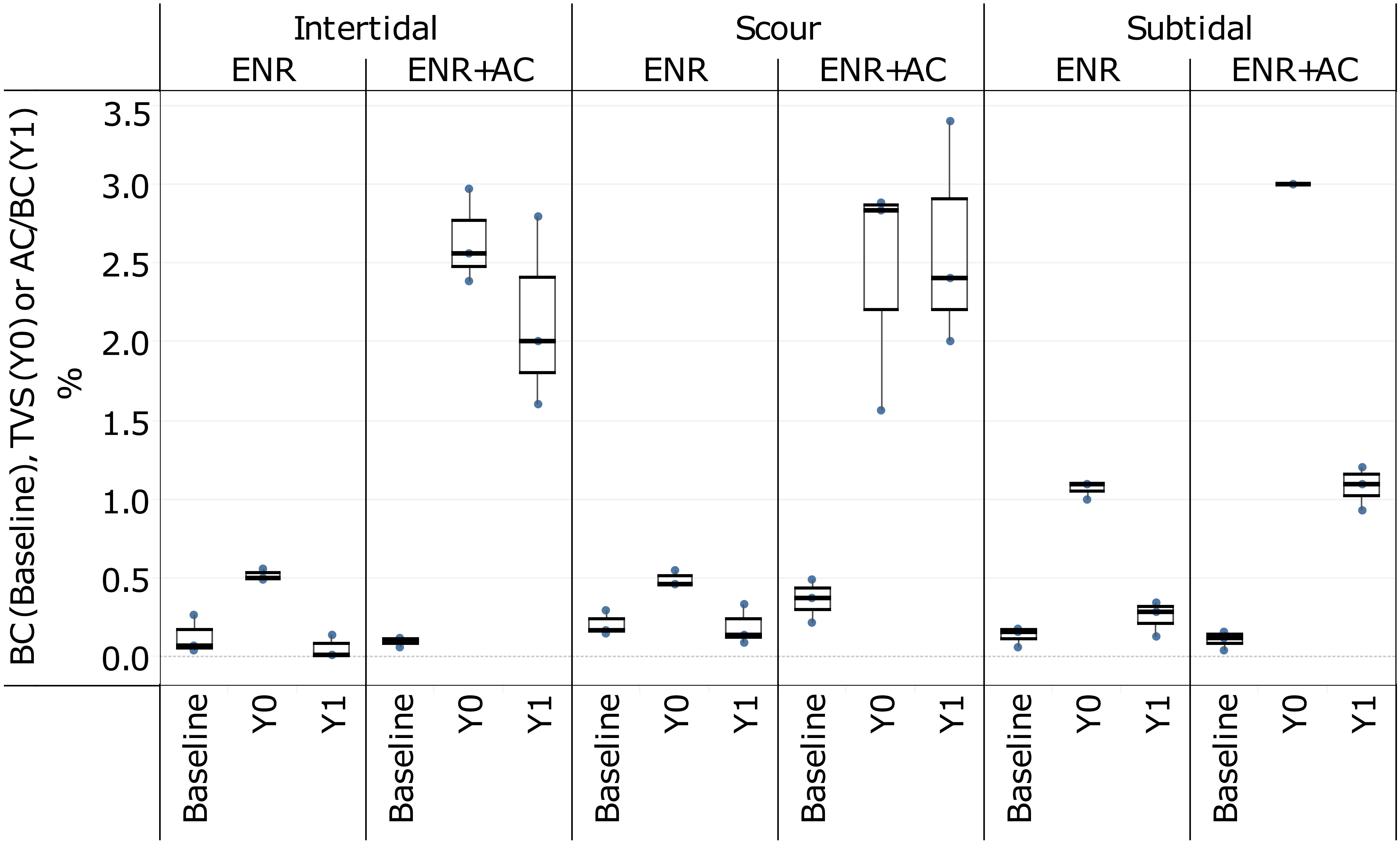


Boxes show first quartile, median, and third quartile. Dots show data points.

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

ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 3-7
Year 1 Grain Size



Boxes show first quartile, median, and third quartile. Dots show data points.

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

ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 3-8
Black Carbon (Baseline), Total Volatile Solids (Year 0), and Activated Carbon/Black Carbon (Year 1) Results

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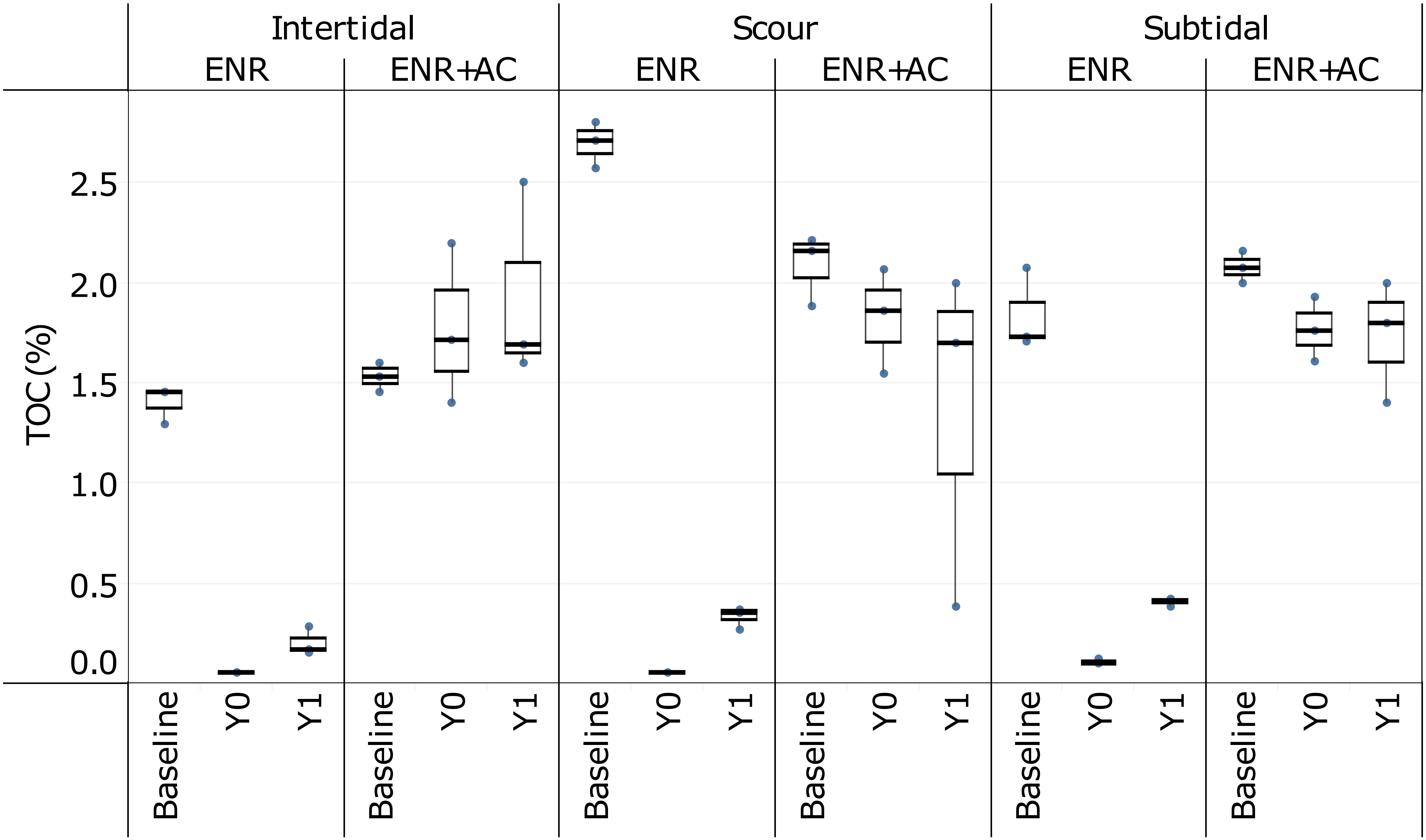
11/6/2018



Boxes show first quartile, median, and third quartile. Dots show data points.

Lower Duwamish Waterway Group
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Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 3-9
Total Organic Carbon Results

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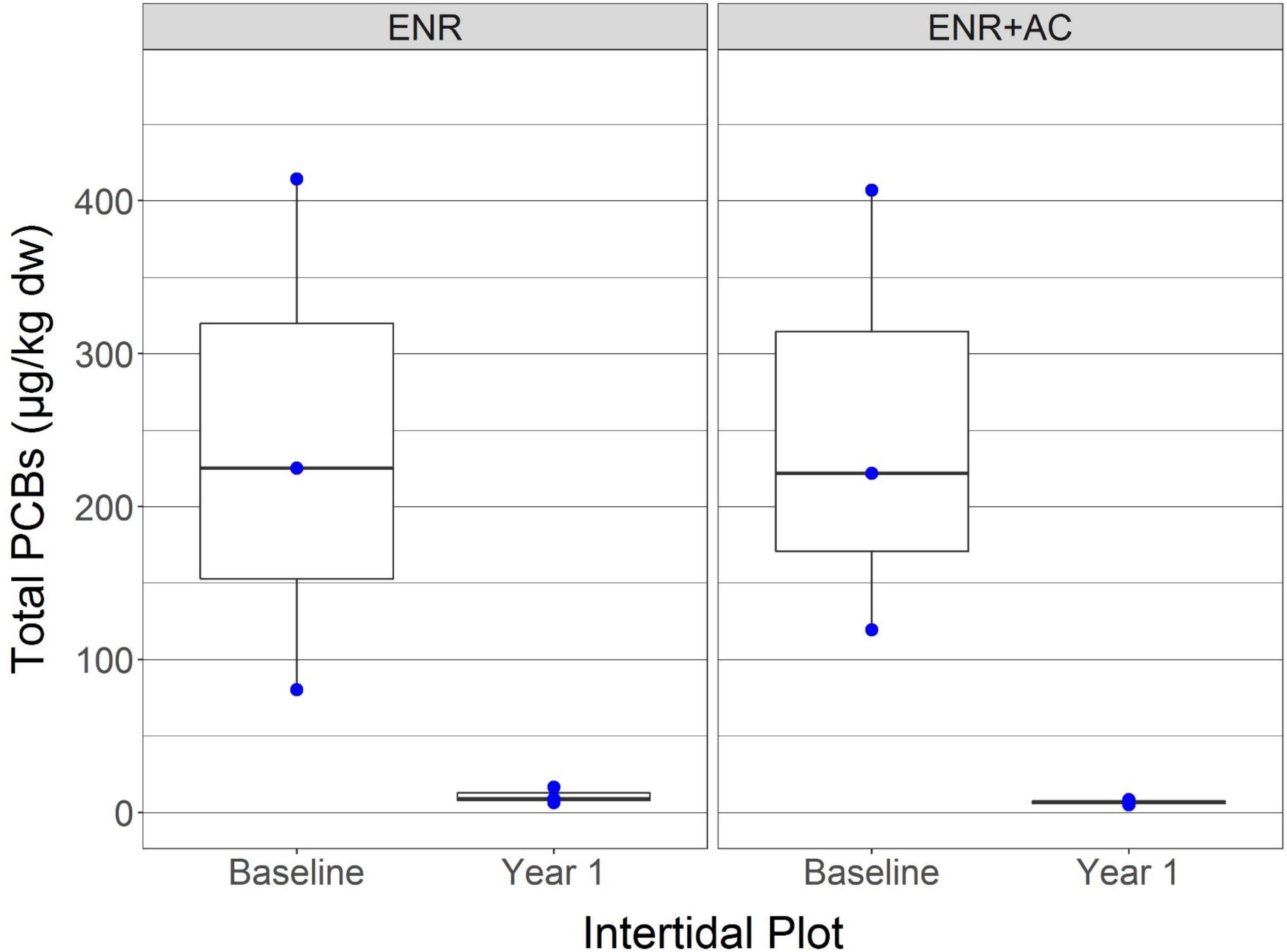
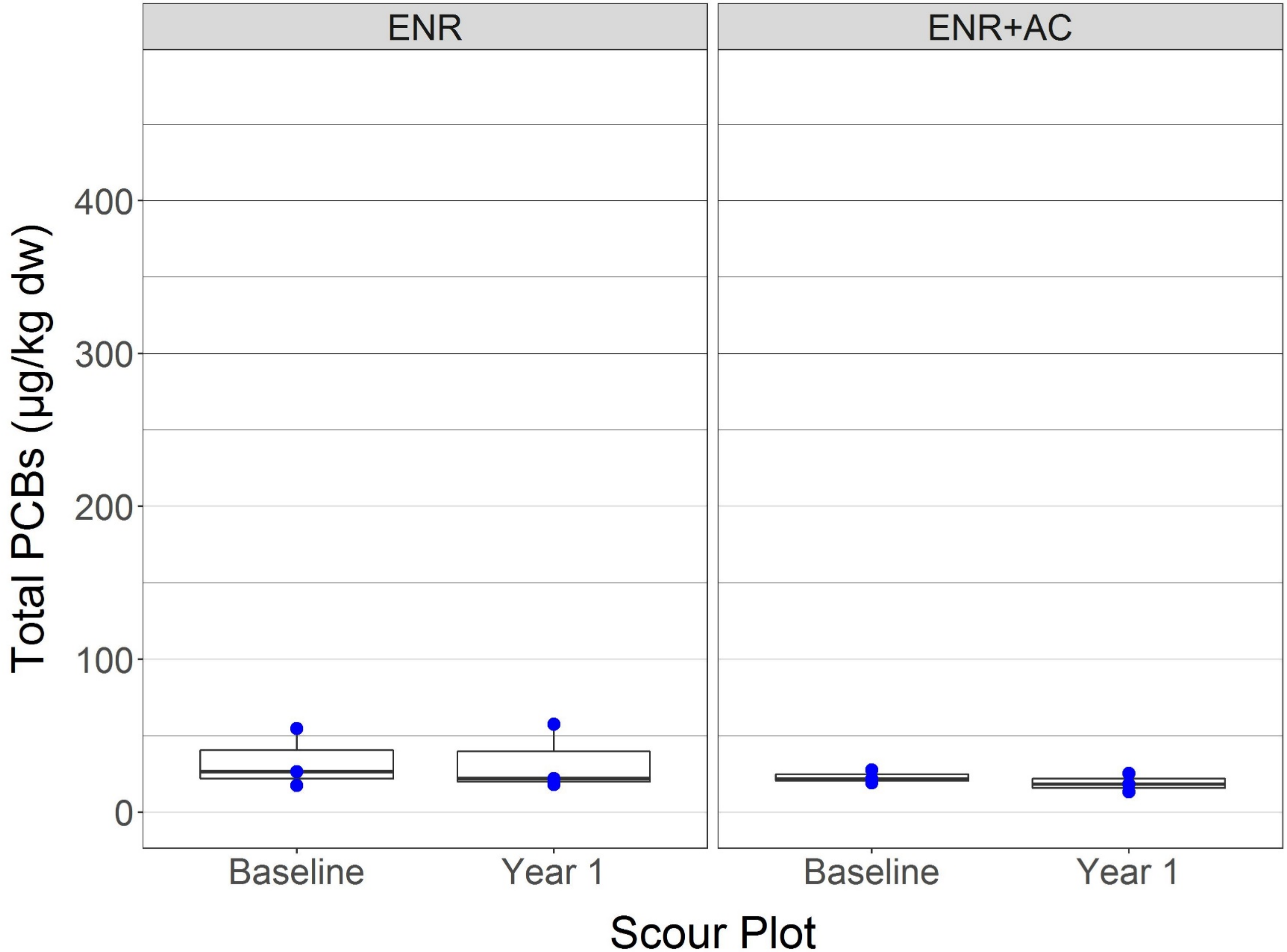
11/6/2018



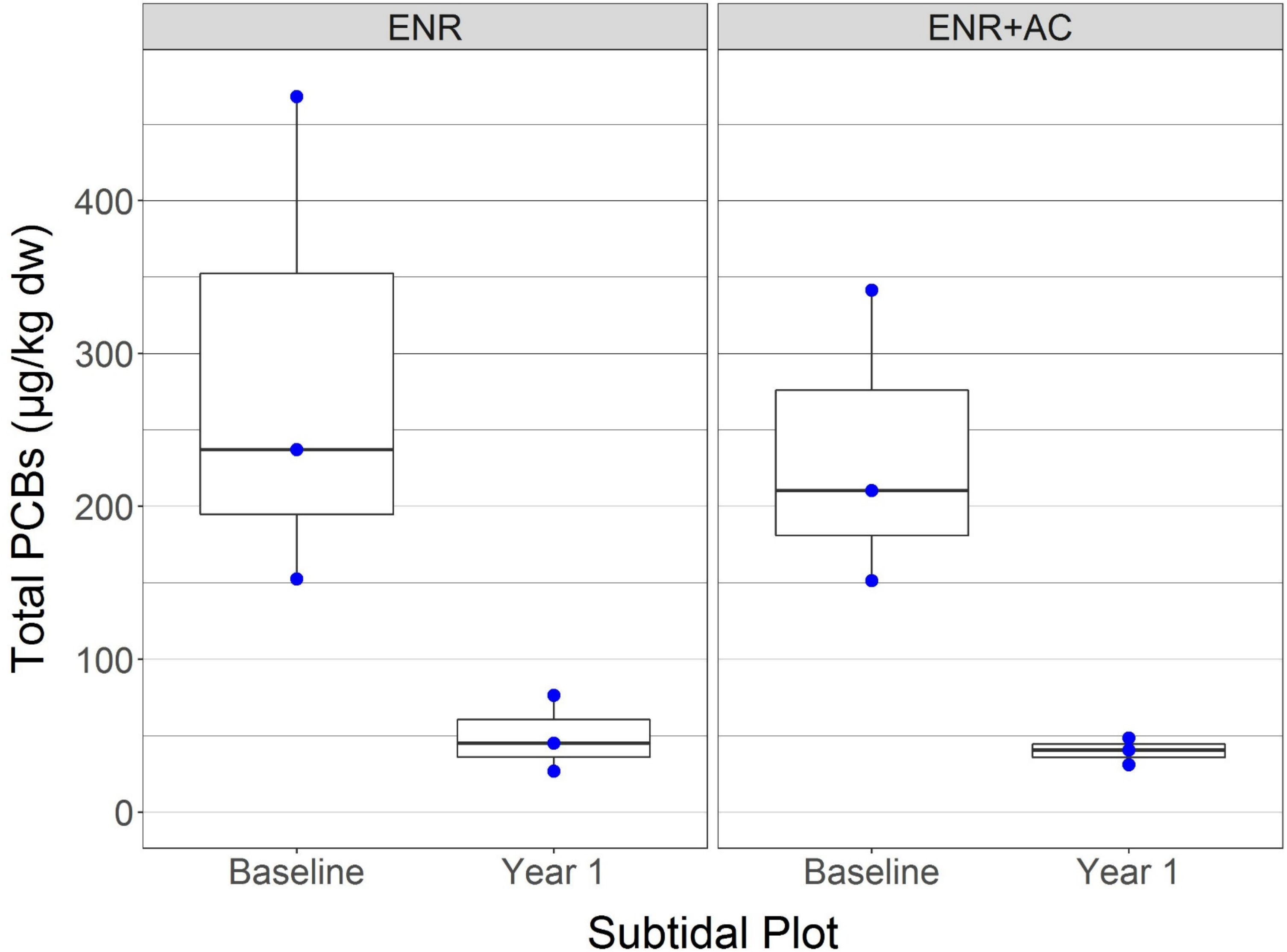
Boxes show first quartile, median, and third quartile. Dots show data points.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-10 Intertidal Plot Sediment PCB Concentrations



Boxes show first quartile, median, and third quartile. Dots show data points.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-11 Scour Plot Sediment PCB Concentrations

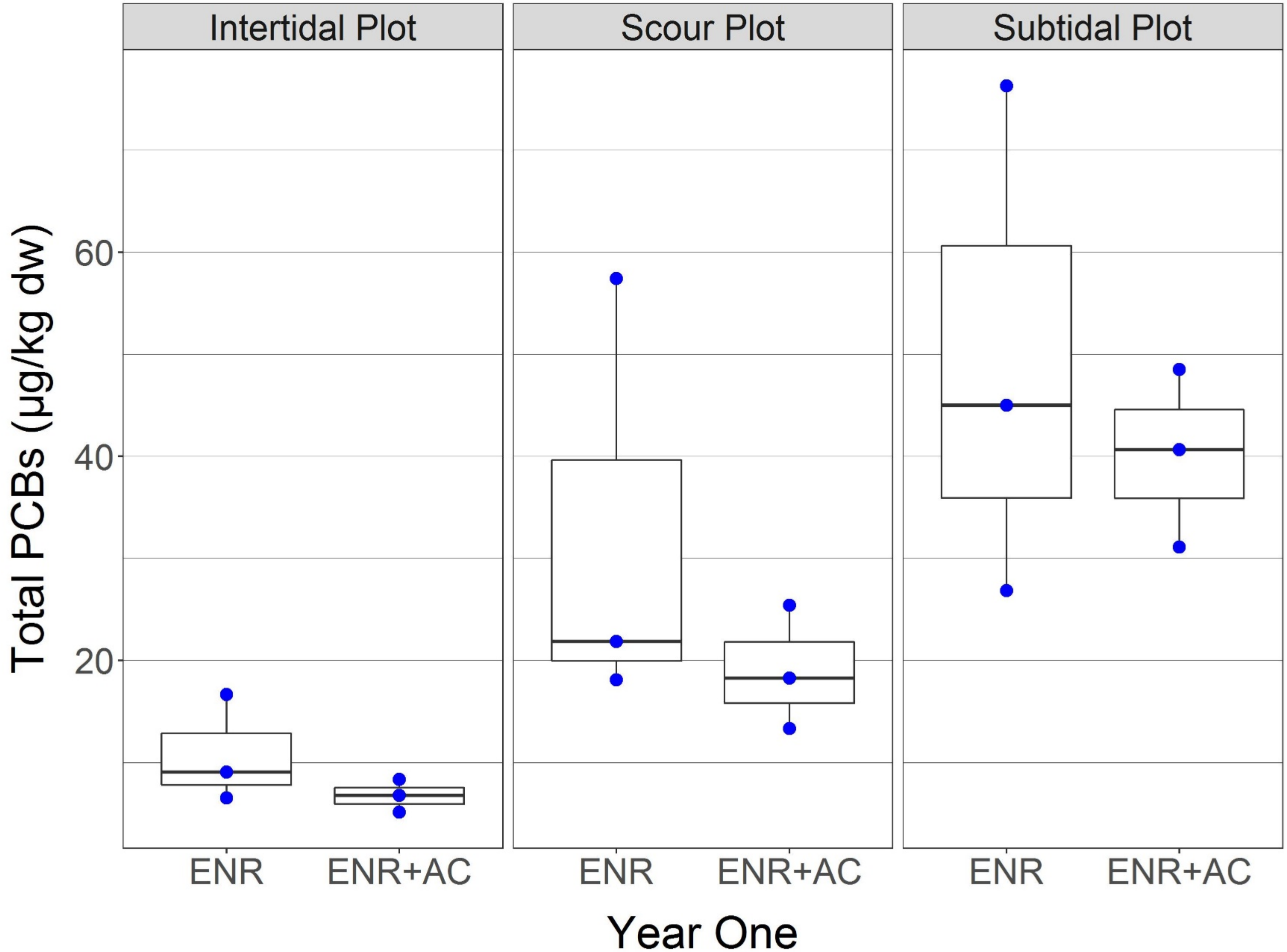


Boxes show first quartile, median, and third quartile. Dots show data points.

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

ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 3-12
Subtidal Plot Sediment PCB Concentrations



Boxes show first quartile, median, and third quartile. Dots show data points.

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

ENR/AC Pilot Study
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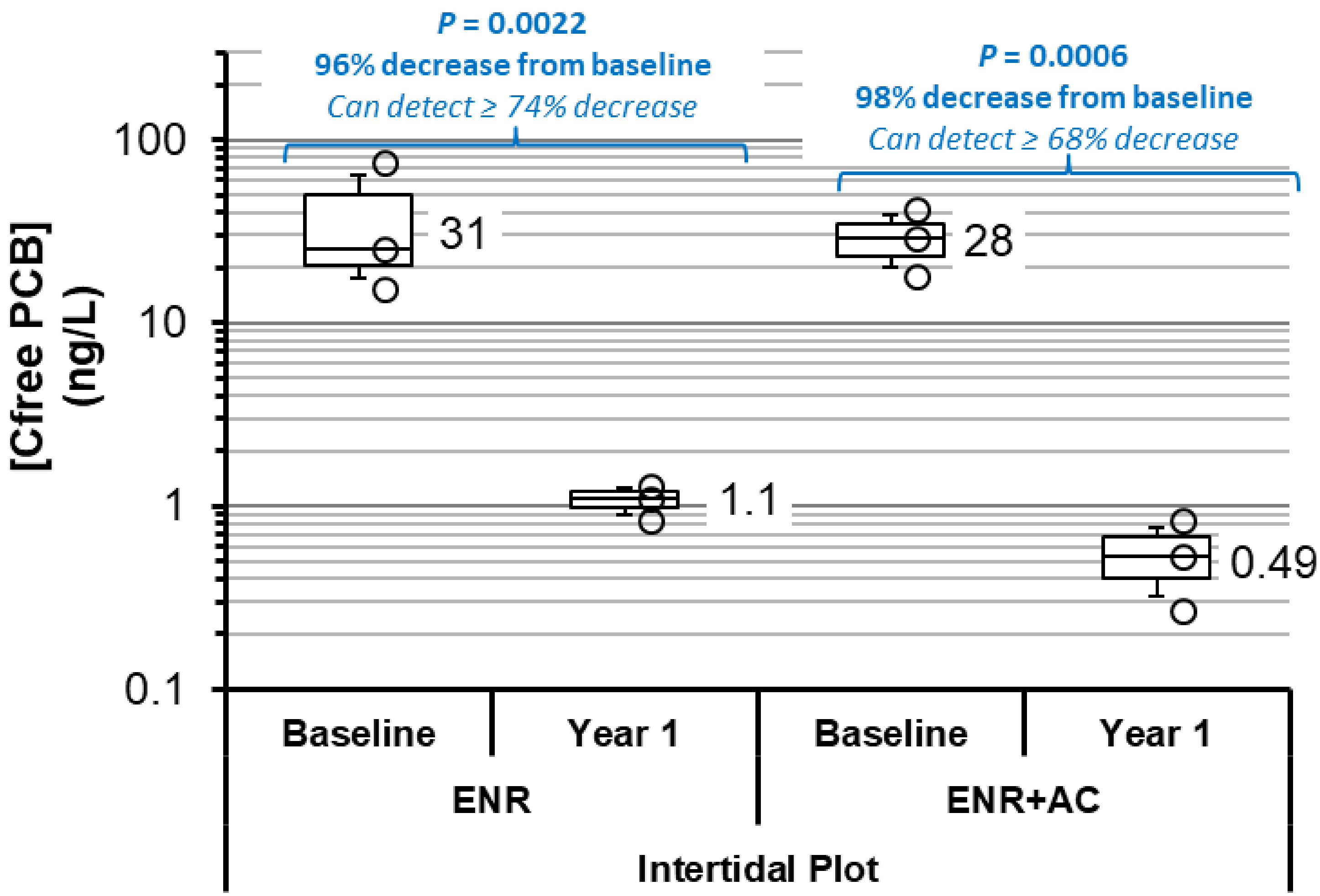
Lower Duwamish Waterway

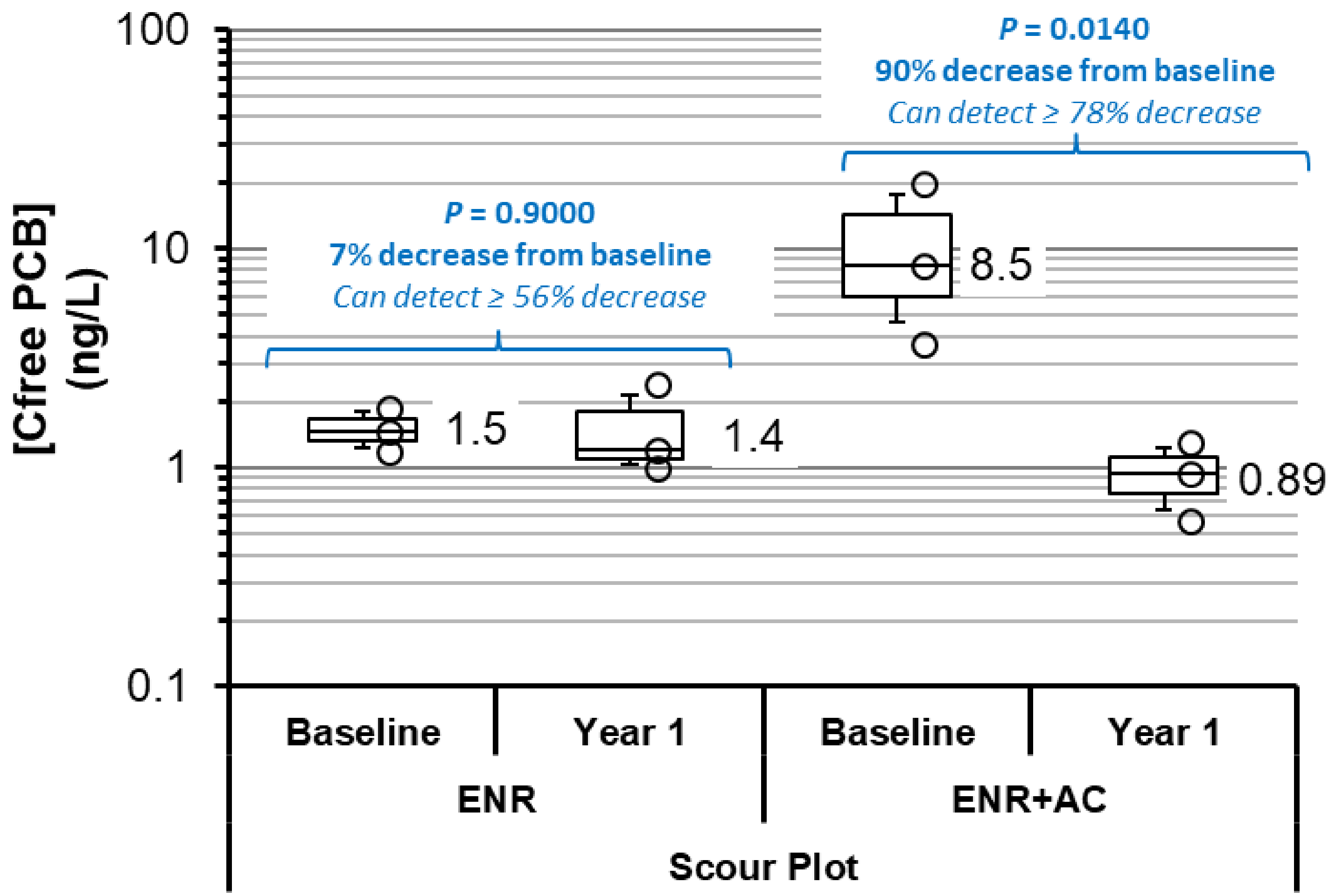
Figure 3-13
Year 1 Sediment PCB Concentrations



Key

Circles – Raw data; Boxes – 25th to 75th percentiles; Whiskers – 10th and 90th percentiles; Values – Geometric means

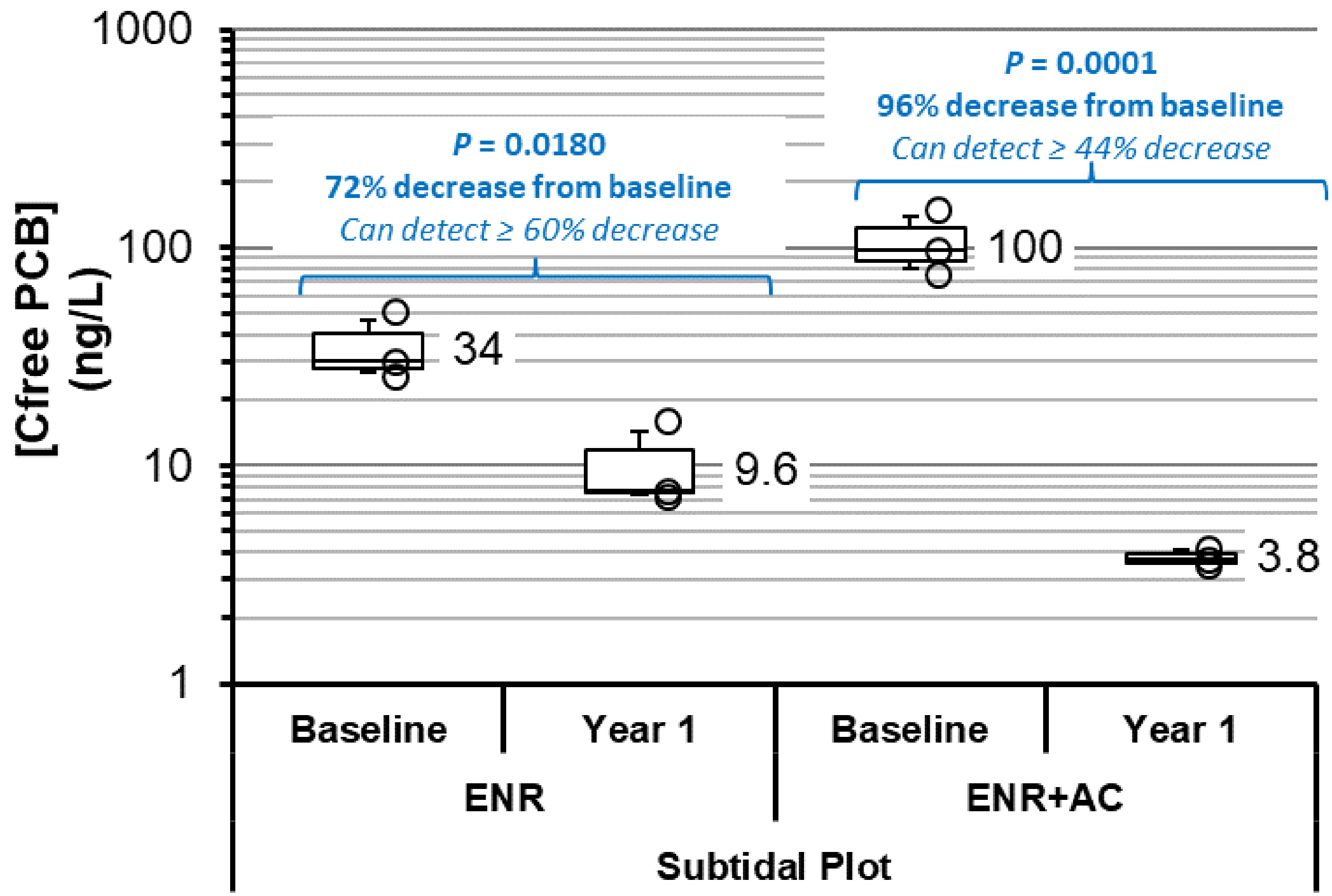
Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-14 Year 1 Intertidal Plot Sediment Porewater (Cfree) PCB Concentrations



Key

Circles – Raw data; Boxes – 25th to 75th percentiles; Whiskers – 10th and 90th percentiles; Values – Geometric means

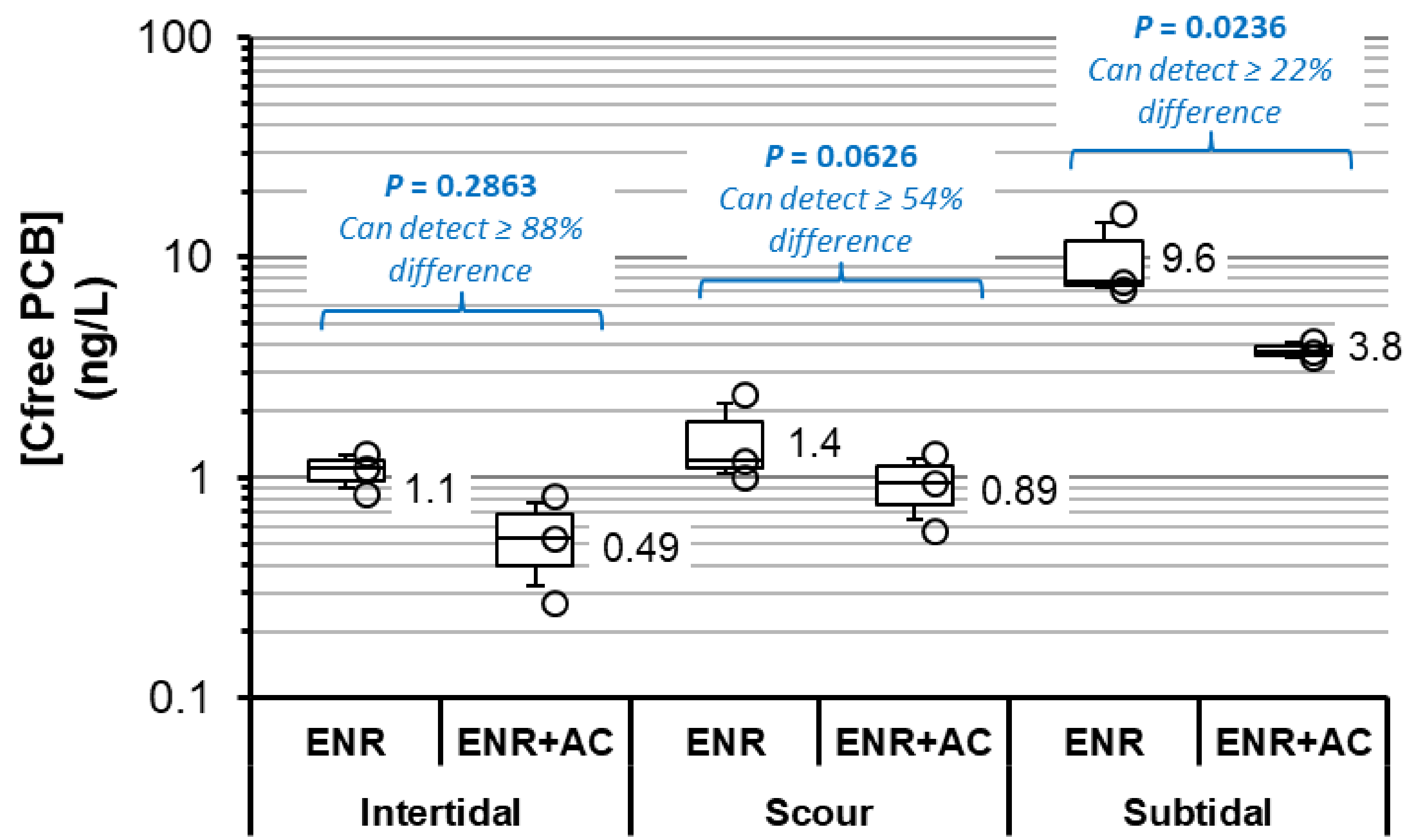
Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-15 Year 1 Scour Plot Sediment Porewater (Cfree) PCB Concentrations



Key

Circles – Raw data; Boxes – 25th to 75th percentiles; Whiskers – 10th and 90th percentiles; Values – Geometric means

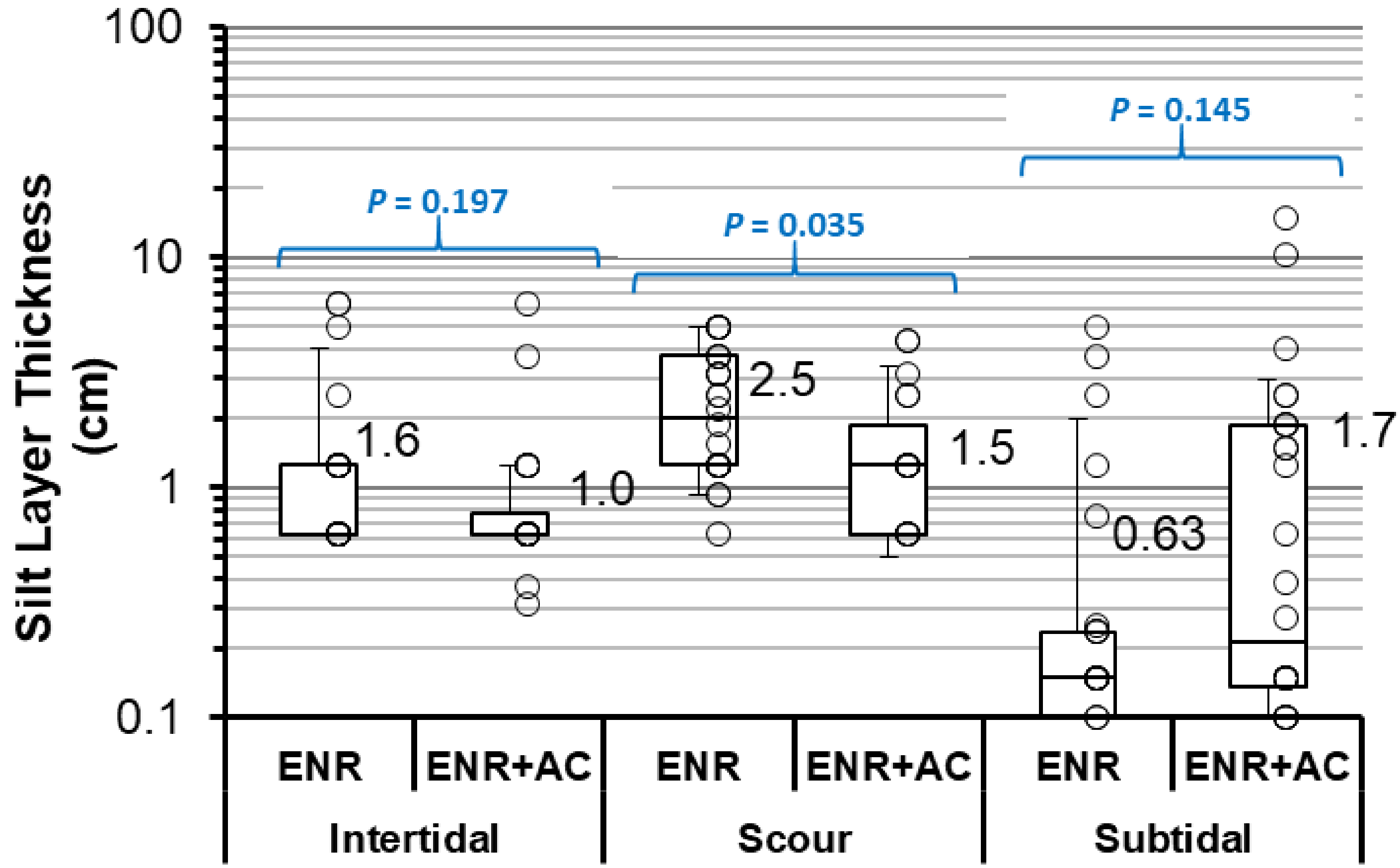
Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-16 Year 1 Subtidal Plot Sediment Porewater (Cfree) PCB Concentrations



Key

Circles – Raw data; Boxes – 25th to 75th percentiles; Whiskers – 10th and 90th percentiles; Values – Geometric means

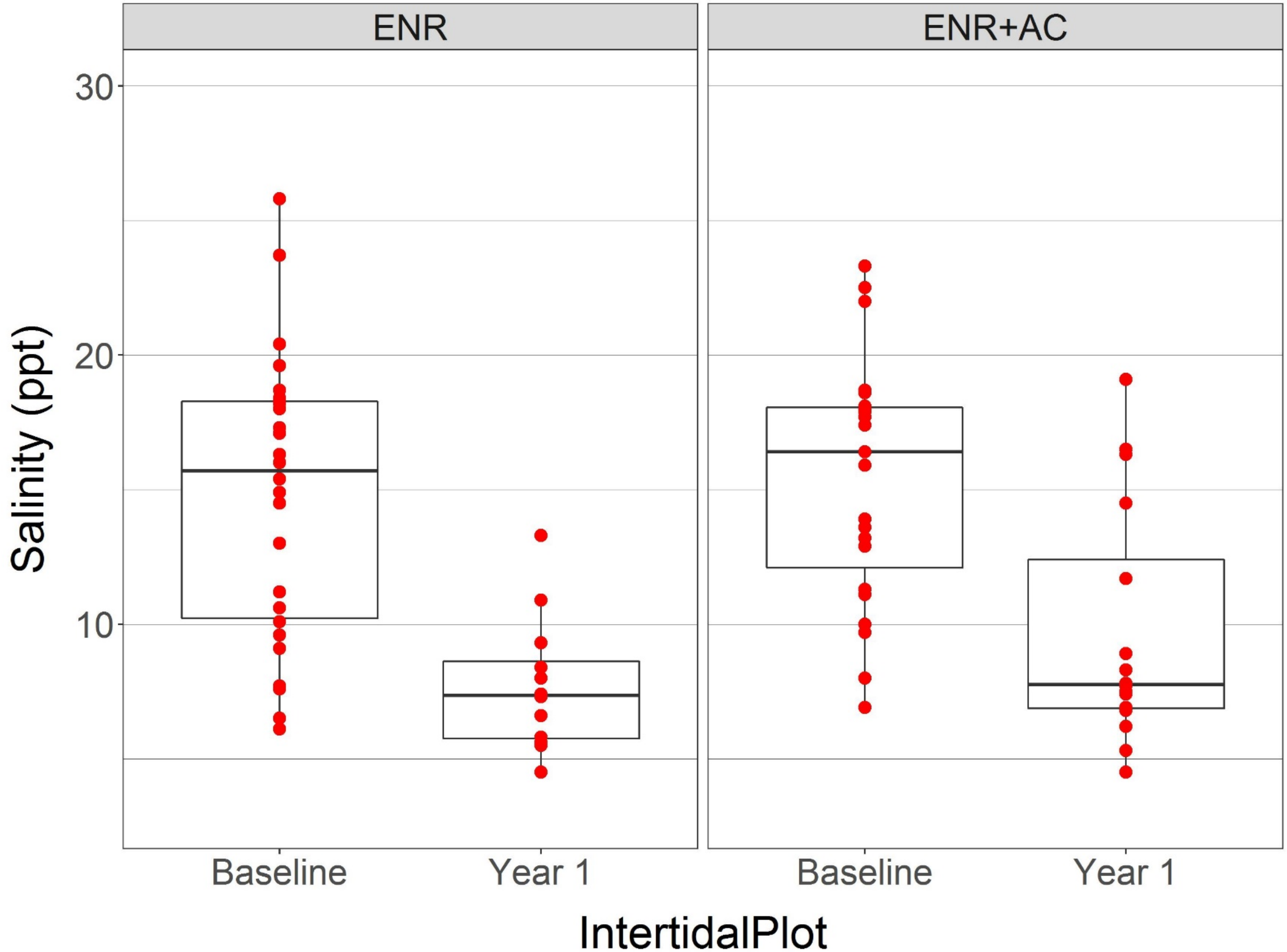
Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-17 Year 1 Sediment Porewater (Cfree) PCB Concentrations – All Plots



Key

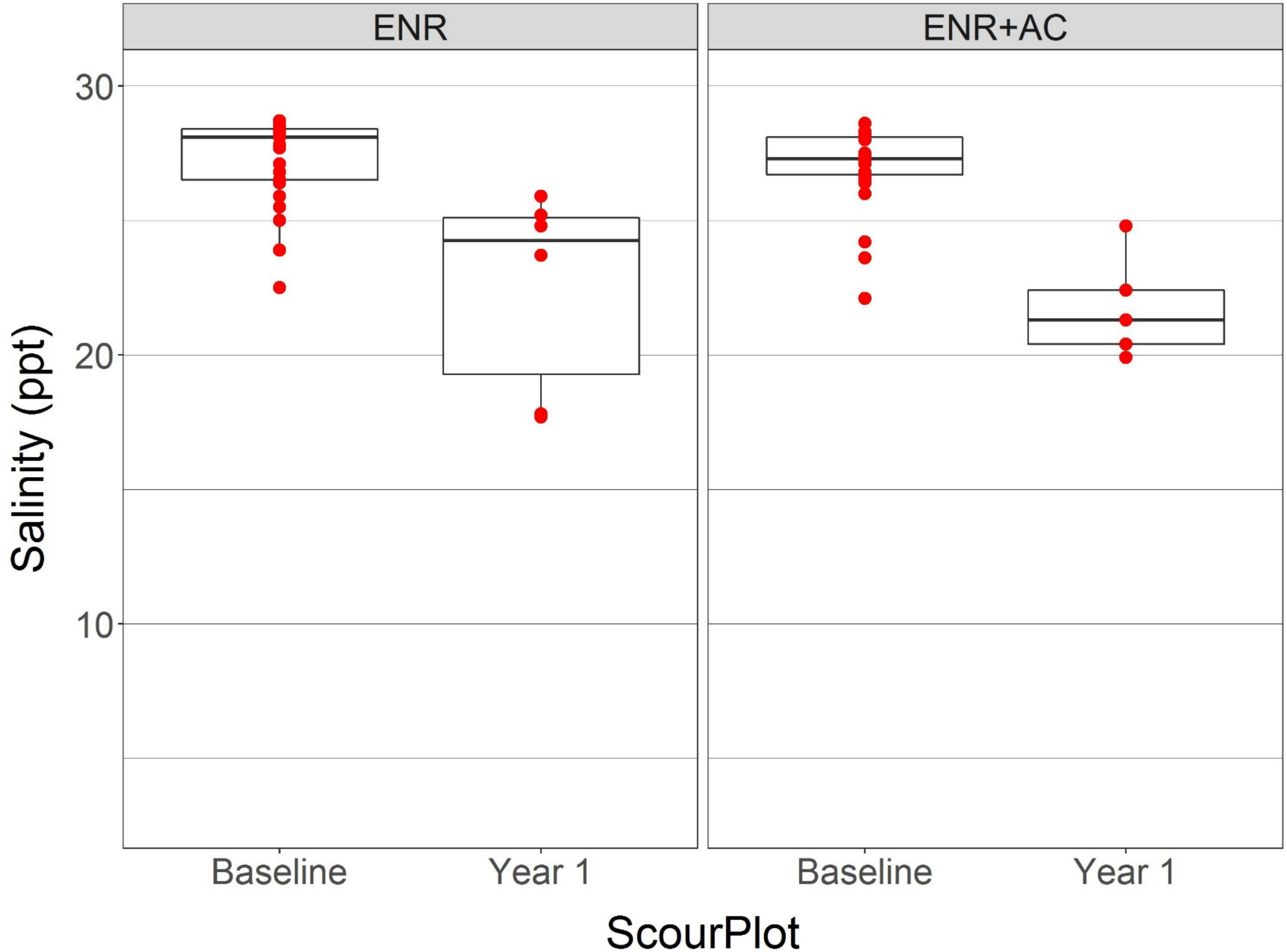
Circles – Raw data; Boxes – 25th to 75th percentiles; Whiskers – 10th and 90th percentiles; Values – Geometric means

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-18 Year 1 Silt Layer Thicknesses



Boxes show first quartile, median, and third quartile. Dots show data points.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-19 Intertidal Plot Salinity

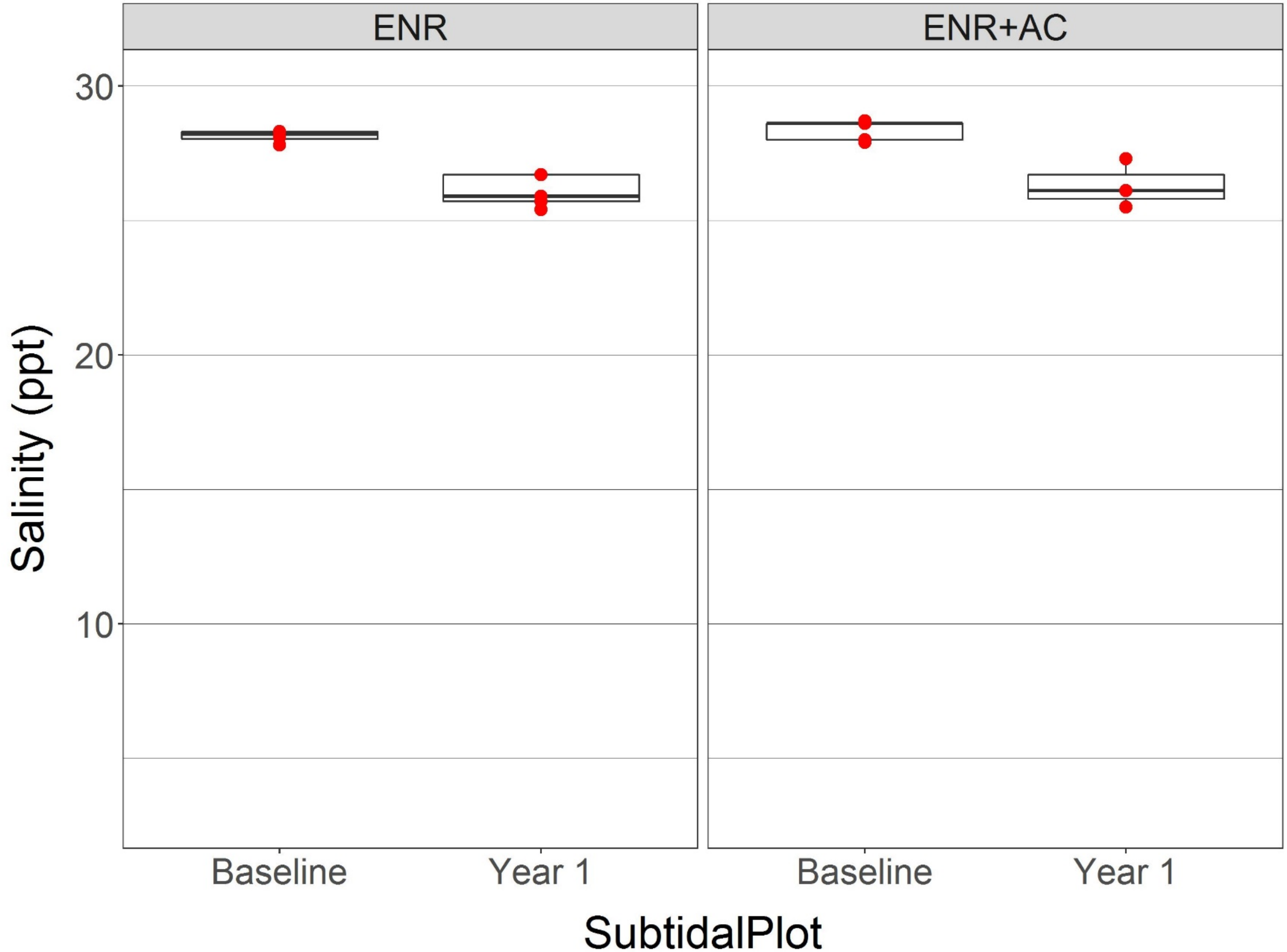


Boxes show first quartile, median, and third quartile. Dots show data points.

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

ENR/AC Pilot Study
Year 1 Monitoring Report
Lower Duwamish Waterway

Figure 3-20
Scour Plot Salinity



Boxes show first quartile, median, and third quartile. Dots show data points.

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Year 1 Monitoring Report** **Lower Duwamish Waterway**	Figure 3-21 Subtidal Plot Salinity