LONG TERM MONITORING PROGRAM
YEAR 2 IMPLEMENTATION REPORT
STUDY AREA 7 SEDIMENT REMEDY
JERSEY CITY, NEW JERSEY

Submitted to:

Honeywell
Morristown, New Jersey

Submitted by:

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1.0 INTRODUCTION

As required by the Consent Order on Sediment Remediation and Financial Assurances (Consent Order) entered by the U.S. District Court (District of New Jersey) on May 28, 2008 in the matter of *Interfaith Community Organization et al vs. Honeywell International et al, and Riverkeeper, Inc., et al vs. Honeywell International et al* (Civil Action Nos. 95-2097 and 06-0022), Honeywell conducted sediment remediation in the Hackensack River in the vicinity of Study Area (SA) 7 (Site) along Route 440 in Jersey City, New Jersey. The Consent Order, as amended in September 2013, set forth the following specific components of dredging, capping, and monitored natural recovery (MNR) for the Sediment Remedy and the requirements for a long-term monitoring program (LTMP):

- Dredging and subsequent capping in a 0.5-acre area adjacent to the SA-7 bulkhead. Sediments were dredged to a depth of 2 feet (ft) and then capped with 18 inches of sand and armoring.

- Capping of surface sediments (i.e., between depths of 0 to 1 ft) with total chromium concentrations greater than 370 parts per million (ppm) to achieve a 1 ft layer of natural sediments and/or cap material with a concentration of less than 370 ppm total chromium.

    - A six-inch cap placed over a total of 19 acres

    - A twelve-inch cap placed over a total of 18 acres

- MNR over 33 acres where sediments less than 1 ft below the sediment surface are below 370 ppm total chromium but sediments deeper than 1 ft exceed 370 ppm.

- Long-term monitoring to assess the on-going effectiveness of the sediment remedy. Long-term monitoring will be performed in accordance with a Long-Term Monitoring Plan (LTMP; Cornerstone/ENVIRON 2012) for a period of approximately 15 to 25 years following implementation of the remedy.

All parties have agreed to defer capping of three areas (Areas 16, 22, and 28) to a future date pending work to be performed adjacent to these areas which could result in disturbance to the cap integrity. These areas will be added to the monitoring program once they are completed.

The LTMP was developed as part of the *100% Design for Study Area 7* (100% Design; Cornerstone/ENVIRON 2012). The LTMP defined the scope and methods to be implemented to satisfy the requirements of the Consent Order. The monitoring tasks and events outlined in the LTMP are based on the following objectives, as specified in Paragraph 29 of the Consent Order:

- Provide monitoring to ensure that the integrity of the caps is maintained.

- In areas of MNR, confirm either that i) deposition of additional sediments is continuing, or ii) the contemporaneous bathymetry of the river bottom shows an increase or less than a four-inch decrease in the measured elevation of the river bottom.

- Collect data regarding the nature of the benthic community in remediated sediments after the implementation of the remedy.

The LTMP provides for the following monitoring events:

a. "First-Five Year Monitoring Activities" will take place in Years 1, 2, and 5.

b. "Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

   i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation, as recorded at Newark Airport;

   ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

   iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

c. "Five-Year Interval Monitoring Activities" will take place at 5-year intervals after Year 5 until either the objectives of the particular monitoring activity have been achieved and maintained for a period of 15 years and through at least two High Energy Events or the remedy has been in place for 25 years and met the objectives, whichever is shorter. According to the Consent Order, if after 25 years any of the objectives has not been met or if any of the objectives is close to being violated, monitoring will continue in 5-year intervals until it is clear that the objectives have been met.

The specific monitoring scope and methods to be performed for the first five years of the monitoring program are defined in the *First Five Year Implementation Plan* ("Implementation Plan"; ENVIRON 2014b), which was revised in 2015 as detailed below. The scope and methods defined in the Implementation Plan account for the post-remediation "as-built" conditions as reported in the *SA-7 Sediment Remedy Documentation and Remedial Action Summary Report* (ENVIRON 2014a) and clarification of objectives of certain monitoring elements. However, the tools and the schedule may be modified in the future to reflect new information or to adjust to changed field conditions.

The results of the Year 1 baseline monitoring were reported in the *Long Term Monitoring Program, Year 1 Implementation Report* ("Year 1 Implementation Report"; ENVIRON 2015). On April 17, 2015, following plaintiffs' review of the Year 1 Implementation Report, Honeywell proposed reducing or eliminating certain monitoring activities required by the Implementation Plan in Year 2, with the understanding that any required monitoring eliminated in Year 2 would be performed in Year 5 of the LTMP. On May 5, 2015, plaintiffs and Honeywell agreed to reduce monitoring as follows:

a. <u>Biological Monitoring in Capped Areas</u> – Year 2 requirement eliminated.

b. <u>Sediment Cap Thickness Verification</u> – Year 2 requirement eliminated.

c. Pore Water Sampling in Capped Areas for Hexavalent Chromium – Honeywell will stop pore water sampling at Locations 6A and 13D. However, Honeywell will continue performing pore water sampling at Locations 1A, 8A, 13A, 13B, 13C, and 18B.

These changes were reflected in the June 11, 2015 Revised Implementation Plan (ENVIRON 2015), which was approved by the plaintiffs on June 24, 2015. The elements of the long term monitoring program, reflecting the changes made to the scope of Year 2 monitoring, are summarized on **Tables 1** and **2**.

In conformance with the Revised Implementation Plan, the monitoring activities for **Year 2** of the long-term monitoring program were conducted from September to November 2015, and included the following:

- Hydraulic and Hydrodynamic Evaluation
- Bathymetric Survey
- Visual Cap Inspection
- Pore Water Sampling
- Sediment Profile Imaging (SPI)

As detailed in the remainder of this report, the second year monitoring program demonstrated that the remediation area remains stable relative to constructed conditions. In addition, the planned methods of verification were successfully implemented such that no changes in procedures are necessary. Therefore, no action is necessary.

Table 1: Summary of Long Term Monitoring of the Capped Areas

Monitoring Elements for Capped Areas	YEAR							LTMP Section Reference
	1	2	5	6 to 15	20	25	HEV	
Hydraulic and Hydrodynamic Evaluation								
Routine Monitoring and Analysis	X	X	X					4.1.1
Severe Event Monitoring and Analysis	X	X	X	X			Note 1	4.1.1
Bathymetry	X	X	X	X	X	X	Note 2	4.1.2
Cap Integrity Monitoring	X		X				Note 3	4.1.3
Pore Water Sampling	X	X	X	Note 4, 5				4.2.1
Surface Sediment Sampling			X	Note 5				4.2.2
Sediment Trap Sampling	Note 6							4.2.3
Biological Monitoring	X		X	Note 5				4.3

HEV: Following all High Energy Events

Note 1: After 15 years, high-event assessments will be discontinued if the monitoring objectives have been achieved and maintained for 15 years and through at least two high energy events.

Note 2: Bathymetric surveys will be conducted following up to two high-energy events (if not encountered in the first five years). No additional surveys will be performed if bathymetric surveys show no negative impacts on overall cap integrity (i.e., cap maintains coverage of target areas) for a period of 15 years and through two high-energy events, or a total period of 25 years, whichever is shorter.

Note 3: After Year 5, routine sediment cap thickness monitoring will be discontinued unless data collected during the first five years of monitoring indicate that additional monitoring is warranted. Monitoring will still be conducted following a high-energy event if two such events did not occur within the first five years. Monitoring may also be performed after Year 5 if the bathymetry survey identifies an area of potential erosion warranting further assessment (see Section 4.1.2).

Note 4: The first year of pore water sampling is limited to those areas of potential intermediate groundwater plume upwelling identified in the 2007 *Final Groundwater Investigation Report, Honeywell Study Area 7 Site*; this corresponds to portions of Cap Areas 1, 6, 8, 13, and 18. In Year 2, sampling will be performed in Areas 1, 8, 13 and 18.

Note 5: After Year 5, sampling will be discontinued, unless the data collected during the first five years of monitoring indicate further monitoring is warranted.

Note 6: If surface sediment sampling of capped areas results in the detection of total chromium concentrations greater than 370 ppm, sediment trap sampling units may be deployed in those areas to further assess site conditions and to evaluate potential contaminant sources.

Table 2: Summary of Long Term Monitoring of the MNR Areas

Monitoring Elements for MNR Areas	YEAR							LTMP Section Reference
	1	2	5	6 to 15	20	25	HEV	
Hydraulic and Hydrodynamic Evaluation								
Routine Monitoring and Analysis	X	X	X					5.1
Severe Event Monitoring and Analysis	X	X	X	X			Note 1	5.1
Bathymetry	X	X	X	X	X	X	Note 2	5.2
Sediment Profile Imaging	X	X	X				Note 3	5.3
Sediment Core Sampling	Note 4							5.2, 7.2

HEV: Following all High Energy Events

Note 1: After 15 years, severe event assessments will be discontinued if the monitoring objectives have been achieved and maintained for 15 years and through at least two high energy events.

Note 2: Bathymetric surveys will be conducted following up to two high-energy events (if not encountered in the first five years). Following at least two high energy events, bathymetry surveys will be conducted only in MNR areas where erosion may have resulted in more than a 4-inch decrease in the elevation of the sediment surface, based on the results of the hydrodynamic evaluation.

Note 3: Following high energy events, SPI surveys will be performed in MNR areas where erosion may have resulted in more than a four-inch decrease in surface sediment elevations based on the hydrodynamic evaluation and measured observations.

Note 4: In the event that a bathymetric survey identifies an Erosional Area as defined in the LTMP, sampling of top 12-inches sediment for total chromium in Erosion Areas is required to confirm that concentrations in top 12-inches remain below 370 ppm.

2.0 SCOPE OF WORK AND YEAR 2 RESULTS

The scope of work for Year 2 of the long-term monitoring program (LTMP) included the following tasks:

- Hydraulic and Hydrodynamic Evaluation
- Bathymetric Survey
- Visual Cap Inspection
- Pore Water Sampling
- Sediment Profile Imaging (SPI)

As discussed in Section 1.0, the requirements for sediment cap thickness verification and biological sampling were eliminated for Year 2 based on the results of the Year 1 monitoring event. The approach and results for each of these tasks is summarized in the following sections. Photographs of the monitoring implementation are provided in **Appendix A.**

2.1 Hydraulic and Hydrodynamic Evaluation

Records of river stage elevations and weather events in Year 2 of the LTMP (November 2014 through September 2015) were obtained to identify “high energy events” that would warrant additional inspection of the cap and MNR areas. Monitoring of hydraulic conditions near SA-7 included review of surface water elevations from the Battery Park gauge and wind and precipitation records from Newark Airport weather station as reported by the following sources:

- Rainfall recorded at Newark Airport: http://www.wunderground.com/history/
- Tide levels at Battery Park: http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750
- Wind conditions as recorded at Newark Airport: http://www.wunderground.com/history/

The monitoring data for Year 2 of the LTMP indicate that no high energy events occurred during this monitoring period. Monthly summaries generated from the monitoring data for Year 2 are provided in **Appendix B**.

2.2 Bathymetric Survey

A baseline Year 1 high-resolution multibeam bathymetric survey was conducted in September 2014 (refer to **Drawing 1** in **Appendix C**). The Year 2 survey was conducted by Aqua Survey, Inc. (ASI) on September 17 and 18, 2015. The survey was conducted over the 70-acre remedy area (refer to **Figures 1** and **2**) using a survey boat, R2 Sonic 2022 multibeam sonar, and RTK-DGPS precision positioning equipment. The bathymetry for the remedy area is provided on **Drawing 2** in **Appendix C**.

The results of this survey were compared with the results of the baseline bathymetric survey completed in Year 1 to identify any evidence of erosion of cap materials or native sediments in the MNR areas. In accordance with the 100% Design Report and the Implementation Plan, a cut-fill analysis was performed to estimate the differences between the bed elevations established by the two surveys over ¼-acre subareas. As shown in **Drawing 3** in **Appendix C**, separate grids of ¼-acre subareas were used to assess the sediment cap areas and the MNR areas independently. All of the sediment cap subareas showed net accumulation of sediment (i.e., net fill) and only one of the 141 MNR subareas (subarea 72 MNR) showed a net decrease in the bed elevation (i.e., net cut). In this MNR subarea, the average elevation difference (2.9 inches) was less than the 4 inch threshold established in the 100% Design for classifying an area as an "Erosional Area," and subject to more detailed survey and/or direct inspection. As the measured net bed elevation reduction is less than 4 inches, no action is required at this time in this subarea.

2.3 Cap Thickness Verification

As discussed in Section 1.0, the requirement for sediment cap thickness verification was eliminated for Year 2 based on the results of the Year 1 monitoring event. Therefore, measurements of sediment cap thickness at the designated monitoring points (refer to **Figures 1** and **2**) were not completed in Year 2. Sediment cap thickness verification will be performed in Year 5 in accordance with the requirements of the Revised Implementation Plan (ENVIRON, 2015).

It is noted, however, that during the implementation of the long-term monitoring activities conducted on September 30, 2015, accessible intertidal cap areas exposed at low tide were visually inspected to check the general condition of the sediment cap. Visual inspection indicated the presence of heron, crabs, snails, small fish, developing egg sacks, and some vegetative growth in areas where significant sediment redeposition has occurred. The most significant sediment deposition was evident in Cap Areas 6 and 13, where several inches of fine grained sediment have accumulated. Overall, the field inspectors observed the sediment caps to be in good condition.

One small area (approximately 3 by 5 feet) showing signs of material loss was observed along the shoreline of Cap Area 13, at the discharge point for an 18-inch stormwater PVC pipe from the adjacent DeFeo property. As shown in the photographs included in **Appendix A**, the area exhibited a scour hole-like depression, approximately 2 feet deep. No signs of material displacement were observed. On October 23, 2015, Ramboll Environ completed repairs at this location, which consisted of the following:

- Lining the depression with a woven geotextile fabric.
- Placing a large boulder (approximately 2 by 2 by 1.5 feet) and loose 3.5 to 6 inch rocks from the adjacent shoreline within the depression and over the geotextile.
- Placing ¼-inch stone in the depression.
- Covering the filled area with surplus 2.5-inch armor stone obtained from surrounding areas.

Photos of the completed repairs are included in **Appendix A**.

2.4 Sediment Profile Imaging (SPI)

The Sediment Profile Imaging (SPI) survey was completed on November 2, 2015 by Germano & Associates, Inc., Bellevue, WA and INSPIRE Environmental LLC, Newport, RI to evaluate surface sediment deposition and sediment bed stability in MNR areas. The SPI survey was conducted at 10 designated locations distributed across the SA7 MNR areas, as shown on **Figures 1** and **2**. A minimum of three replicate SPI images were collected at each station.

Sediment profile images were collected using a digital sediment-profile imaging camera system (Ocean Imaging Systems, Pocasset, MA) deployed from ASI's research vessel. The camera prism was mounted on an assembly that moves up and down within a stainless steel frame by allowing tension or slack on the winch wire. As the camera was lowered, tension on the winch wire kept the prism in the up position. Once the camera frame touched the bottom, slack on the winch wire allowed the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) was controlled by an adjustable passive hydraulic piston, which minimized the disturbance of the sediment-water interface. The camera was able to obtain images of up to 20 cm (approximately 8 inches) in the upper sediment column.

The SPI study collected the following data used to characterize surface sediment conditions in the MNR area:

1. Sediment grain size (major mode and range in phi sizes)
2. Camera prism penetration depth (cm)
3. Surface boundary roughness (cm)
4. Bottom kinetics and depositional layers (cm)
5. Apparent redox potential discontinuity (RPD) depth (cm)
6. Presence of subsurface methane
7. Infaunal successional stages
8. Biological mixing depth (cm)

The survey results are reported in **Appendix D** (note – the location numbering used in the SPI Report provided in Appendix D corresponds to the locations shown on **Figures 1** and **2**; i.e., Station 1 is the same as SPI-1, Station 2 is the same as SPI-2, etc.). The findings of the SPI are generally similar to the SPI results reported in the Sediment Remedial Alternatives Analysis Report (ENVIRON 2006) and the Year 1 Implementation Report. Specifically, the prevalence of Stage 3 infaunal community assemblages at the majority of stations and well-developed RPD indicate that "successful infaunal recolonization had occurred at the majority of locations by the time of the Year 1 monitoring event." The Year 2 monitoring showed similar results. The Year 2 monitoring were compared to the Year 1 results. **Appendix D** describes the process used to confirm that Year 2 stations were close enough to Year 1 stations to support these comparisons over time. As described in **Appendix D**, some general characteristics of the area remained constant (e.g., sediment grain size and deposition patterns) and in some stations (e.g., SPI-2) the benthic successional stage was observed to increase from an initial community of polychaete assemblages to a mature community of deep-dwelling, head-down deposit feeders. The comparison between the Year 1 and Year 2 survey results for apparent RPD depth, successional stage rank, methane presence/absence, and sediment grain-size major mode showed significant changes at only three stations (SPI-7, SPI-6, and SPI-3), summarized as follows:

- SPI-7
  - Location having the lowest apparent RPD depth in both Year 1 and Year 2;
  - The successional stage decreased from Stage 2 to Stage 1→2, which reflects a decrease in the quality of the infaunal community;
  - Methane appeared in Year 2 (absent in Year 1); and

- Slightly coarser material was noted in Year 2 compared to Year 1 (4 to 3 phi in Year 1 vs. 3 to 2 phi in Year 2)

While the SPI results at SPI-7 indicate relatively poor results in both years, this station is located near a storm water discharge outlet, and these results may reflect the influence of storm water discharges.

- SPI-6
  - Maximum apparent RPD depth was observed in Year 2 and was improved compared to Year 1 (increased 0.6 cm); and,
  - Successional stage was Stage 3 or equivalent in all replicates in both years, which indicates a change toward community maturity (i.e., improved conditions);
  - Methane was absent in Year 2 (present in Year 1).

- SPI-3
  - Maximum apparent RPD depth was observed in Year 1 and the greatest decline in apparent RPD was seen in Year 2 (decreased 1.4 cm);
  - Successional stage was Stage 3 or equivalent in 5 out of 6 replicates across both years, which indicates an overall trend toward a mature community (i.e., improved conditions); and,
  - Methane was absent in Year 2 (present in Year 1).

As presented in **Appendix D,** the Year 2 stations were close enough to Year 1 stations to support these comparisons over time; as indicated in **Appendix D**, among the comparisons made between Year 1 and Year 2, Station SPI-6 and SPI-3 had the greatest uncertainties because sample distances ranged from approximately 32 feet (SPI-6) to 99 feet (SPI-3). Therefore, the comparison of Year 1 to Year 2 findings as summarized above may reflect spatial variability rather than changes over time. Nevertheless, given the relatively low level of changes observed within the stations even for SPI-6 and SPI-3, the apparent RPD results do not indicate a negative trend.

Generally, the SPI data indicate the presence of a robust infaunal benthic community throughout the area. Evidence of mature, deposit-feeding assemblages was found at all stations except one (location SPI-7 located between cap areas 5 and 6). The infaunal community at SPI-7 may reflect impact of the storm sewer discharges (i.e., mature deep dwelling species were not observed), although, the sediment at SPI-7 was observed to have healthy oxidized conditions and the infaunal community shows evidence of recovery (i.e., the presence of shallow-dwelling deposit feeders are present).

There was no evidence of excessive organic loading or associated sediment contamination resulting in toxicity at the population level at any of the surveyed locations. These findings support a conclusion that the sediments within the monitoring area show the presence of an established sediment dwelling benthic community that is typical of the estuarine environment, and not indicative of locations subject to surface sediment erosion.

2.5 Pore Water Sampling

In conformance with the Revised Implementation Plan, pore water sampling from the capped areas was conducted in Year 2 for those areas of potential intermediate groundwater plume upwelling identified in the 2007 *Final Groundwater Investigation Report Honeywell Study Area 7 Site*; this corresponds to portions of Cap Areas 1, 8, 13, and 18. Therefore, a total of 6 pore water samples were collected on September 28 and 29, 2015 at Locations 1A, 8A, 13A, 13B, 13C, and 18B (refer to **Figures 1** and **2**). A Trimble SPS855 unit was used to navigate to and record pore water sampling locations in the intertidal areas. A vessel equipped with a Trimble SPS855 unit was used to navigate to and record pore water sampling locations in the subtidal areas. A Solinist® Drive Point Profiler was then pushed through the cap armor and filter layers (if present) and used to collect the pore water samples from the underlying sand layer of the cap. Samples were submitted to Accutest (a New Jersey certified laboratory) for hexavalent chromium analysis.

As presented on **Table 3**, hexavalent chromium was not detected in any of the pore water samples. In addition, the MDLs were reviewed and confirmed to be below both the acute and chronic saline water quality criteria.

2.6 Biological Sampling

As discussed in Section 1.0, the requirement for biological sampling was eliminated for Year 2 based on the results of the Year 1 monitoring event. Therefore, biological sampling at the designated monitoring points (refer to **Figures 1** and **2**) were not completed in Year 2. Biological sampling will be performed in Year 5 in accordance with the requirements of the Revised Implementation Plan (ENVIRON, 2015).

2.7 Summary

This monitoring report presents the results of the second long-term monitoring event conducted for the SA7 sediment remediation program, and includes assessment of capped, MNR, and reference areas. As documented in this report:

- During the period of monitoring activities, no high energy events were observed. Monitoring will continue to be performed on a continuous basis to identify any high energy events that would trigger additional assessment. The results of this monitoring will be included in the Year 5 monitoring report.
- A comparison between the baseline and Year 2 bathymetric surveys has been completed. In general, the results indicate a net deposition of sediment across both the sediment cap areas and the MNR areas. The comparison of the Year 2 survey with the baseline survey identified only one of the 141 MNR subareas (up to ¼-acre in size) with a loss in bed elevation (2.5 inches); however, the loss is less than 4-inches threshold for identifying an Erosional Area, and therefore does not require further evaluation at this time. The bathymetric survey will be repeated in Year 5 and the results compared to the Year 1 baseline survey to identify areas of potential erosion in both capped and MNR areas.
- While no cap thickness inspections were performed in Year 2, visual inspection of the intertidal cap areas confirmed that, with the exception of one small area along the shoreline, the armoring of the caps remains in-place with no evidence of erosion of cap materials. The small area near a stormwater outfall located along the shoreline evidencing material loss has been repaired. Cap thickness verification will be performed

in Year 5 at the “even” numbered monitoring plates. During this event the repaired area will be visually inspected.

- The SPI survey in MNR areas indicates an established sediment dwelling benthic community that is typical of the estuarine environment. There were no indications of surface sediment erosion. The SPI survey will be repeated at the same locations in Year 5 to assess changes that may be indicative of erosion of native sediments.
- Hexavalent chromium was not detected in any of the pore water samples. Pore water sampling will be repeated at the same locations in Year 5 to assess changes that may be indicative of upwelling of hexavalent chromium through the cap.
- As per the Revised Implementation Plan (ENVIRON, 2015) biological sampling was not completed in Year 2. Biological sampling will be performed in Year 5 at the “even” numbered monitoring plates.

In summary, the second year monitoring program demonstrated that the remediation area remains stable relative to constructed conditions. In addition, the planned methods of verification were successfully implemented such that no changes in procedures are necessary.

3.0 REFERENCES

Cornerstone Engineering Group, LLC and ENVIRON International Corporation. 2012. *100% Design Report, Study Area 7 Sediment Remediation, Jersey City, New Jersey*.

ENVIRON International Corporation (ENVIRON). 2006. *Sediment Remedial Alternatives Analysis Report, Study Area 7, Jersey City, New Jersey*.

ENVIRON International Corporation (ENVIRON). 2014a. *SA-7 Sediment Remedy Documentation and Remedial Action Summary Report, Study Area 7 Sediment Remedy, Jersey City, New Jersey*.

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ENVIRON International Corporation (ENVIRON). 2015. *Long Term Monitoring Program, Year 1 Implementation Report, Study Area 7 Sediment Remedy, Jersey City, New Jersey*.

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TABLES

TABLE 3
Summary of Porewater Sampling Results
Study Area 7 Sediment Remedy
Jersey City, NJ

Location Field Sample ID Lab Sample ID Sample Date Comments	NJDEP Salt Water Aquatic Acute Values	NJDEP Salt Water Aquatic Chronic Values	1A Porewater 1A-20150928 JC4862-1 9/28/2015	8A Porewater 8A-20150928 JC4862-2 9/28/2015	13A Porewater 13A-20150929 JC4981-1 9/29/2015	13B Porewater 13B-20150929 JC4981-2 9/29/2015	13B DUP-20150929 JC4981-4 9/29/2015 Field Duplicate	13C Porewater 13C-20150929 JC4981-3 9/29/2015	18B Porewater 18B-20150928 JC4862-3 9/28/2015
INORG									
Chromium VI	1100	50	U (5.5)	U (5.6)	U (5.8)	U (5.8)	U (5.8)	U (5.8)	U (5.6)

Notes:

1 All concentrations are presented in ug/L (ppb).

2 None of the concentrations exceed the published criteria.

Abbreviations:

U -- Not Detected.

( ) -- Detection Limit.

FIGURES

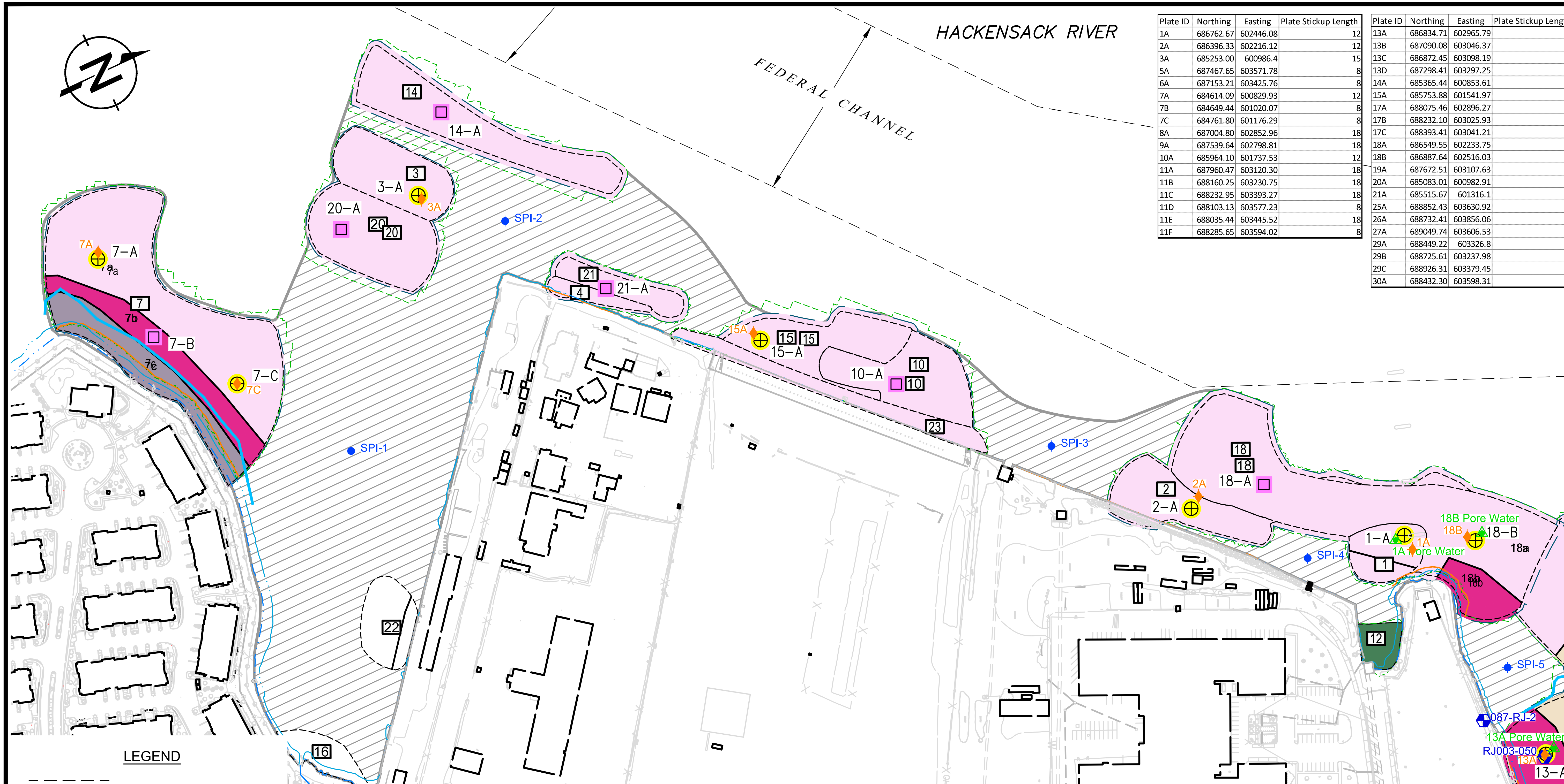


Plate ID	Northing	Easting	Plate Stickup Length
1A	686762.67	602446.08	12
2A	686396.33	602216.12	12
3A	685253.00	600986.4	15
5A	687467.65	603571.78	8
6A	687153.21	603425.76	8
7A	684614.09	600829.93	12
7B	684649.44	601020.07	8
7C	684761.80	601176.29	8
8A	687004.80	602852.96	18
9A	687539.64	602798.81	18
10A	685964.10	601737.53	12
11A	687960.47	603120.30	18
11B	688160.25	603230.75	18
11C	688232.95	603393.27	18
11D	688103.13	603577.23	8
11E	688035.44	603445.52	18
11F	688285.65	603594.02	8

Plate ID	Northing	Easting	Plate Stickup Length
13A	686834.71	602965.79	15
13B	687090.08	603046.37	15
13C	686872.45	603098.19	15
13D	687298.41	603297.25	15
14A	685365.44	600853.61	15
15A	685753.88	601541.97	15
17A	688075.46	602896.27	24
17B	688232.10	603025.93	24
17C	688393.41	603041.21	24
18A	686549.55	602233.75	15
18B	686887.64	602516.03	15
19A	687672.51	603107.63	15
20A	685083.01	600982.91	15
21A	685515.67	601316.1	15
25A	688852.43	603630.92	12
26A	688732.41	603856.06	8
27A	689049.74	603606.53	12
29A	688449.22	603326.8	24
29B	688725.61	603237.98	24
29C	688926.31	603379.45	24
30A	688432.30	603598.31	8

LEGEND

FEDERAL CHANNEL

MEAN HIGH WATER LINE (3.52 FT NGVD29)

EXISTING SHORELINE PROTECTION LIMITS (AS SURVEYED BY SEVENSON ENVIRONMENTAL SERVICES, INC. ON 11/30/2012)

LOW WATER LINE (APPROXIMATE)

7-A AS-BUILT LONG TERM MONITORING PLATE - YEAR 1

7-B AS-BUILT LONG TERM MONITORING PLATE - YEAR 5

GROUNDWATER SAMPLE LOCATION

BIOLOGICAL SAMPLE LOCATION

0.75" ARMOR PLACEMENT

1.0" ARMOR PLACEMENT

2.5" ARMOR PLACEMENT

3.5" ARMOR PLACEMENT

10.0" ARMOR PLACEMENT

MONITORED NATURAL RECOVERY AREA

PROPOSED SPI INVESTIGATION LOCATIONS - YEARS 1, 2, & 5

7 CAP AREA

7a SUB CAP AREAS

PORE WATER SAMPLING LOCATION

0 200
SCALE IN FEET

RAMBOLL ENVIRON

DRAFTED BY: BJK/MSB/KPM

DATE: 05/22/2015

LONG TERM MONITORING PLAN - SOUTHERN AREA

STUDY AREA 7
JERSEY CITY, NEW JERSEY

FIGURE
1

0220255F3

MSETTER 6/10/15 [0220255_LONG TERM MONITORING PLANS]
F:\0220255\DESIGN 100 PERCENT

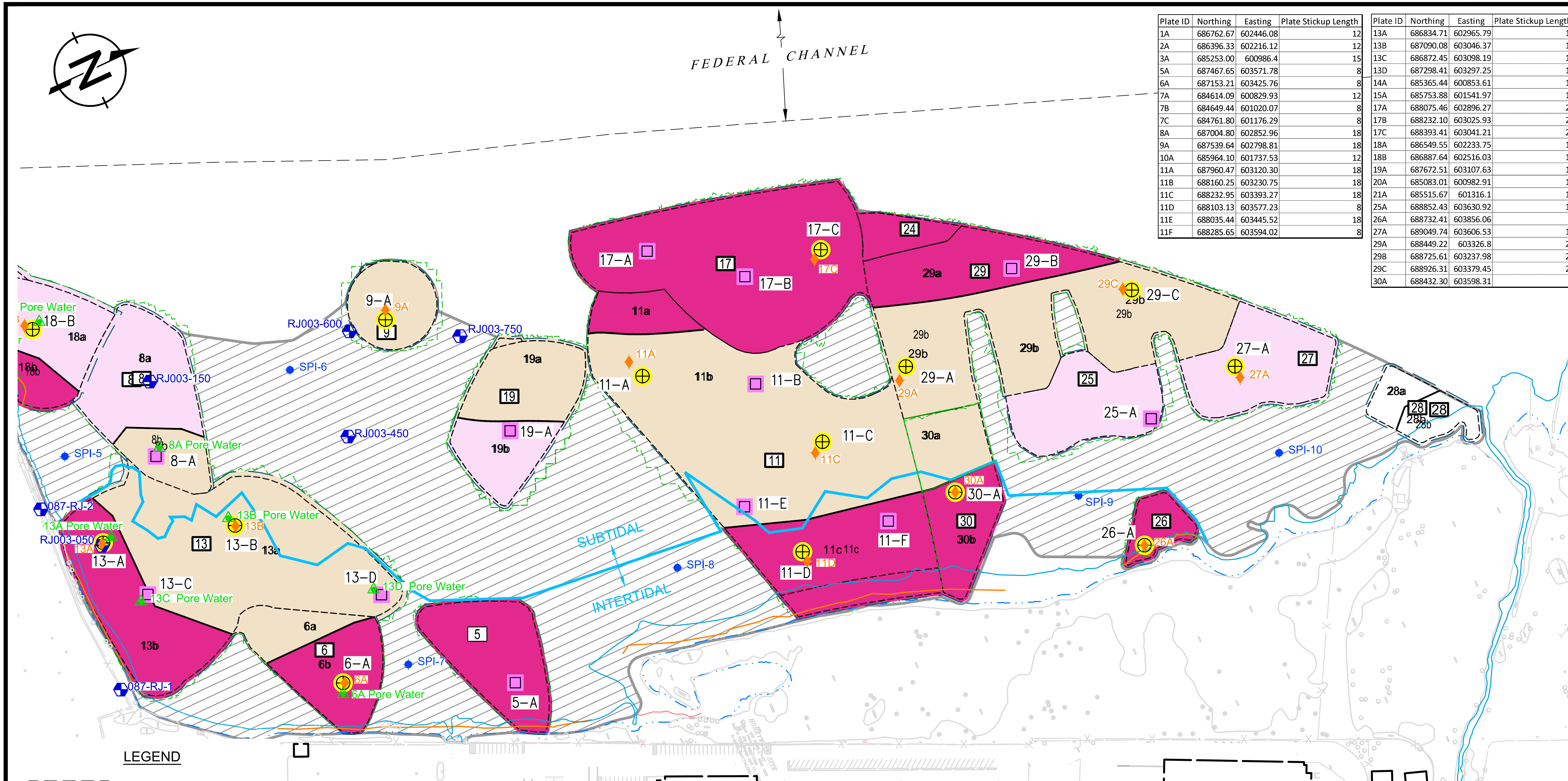


Plate ID	Northing	Easting	Plate Stickup Length
1A	686762.67	602446.08	12
2A	686396.33	602216.12	12
3A	685253.00	600986.4	15
5A	687467.65	603571.78	8
6A	687153.21	603425.76	8
7A	684614.09	600829.93	12
7B	684649.44	601020.07	8
7C	684761.80	601176.29	8
8A	687004.80	602852.96	18
9A	687539.64	602798.81	18
10A	685964.10	601737.53	12
11A	687960.47	603120.30	18
11B	688160.25	603230.75	18
11C	688232.95	603393.27	18
11D	688103.13	603577.23	8
11E	688035.44	603445.52	18
11F	688285.65	603594.02	8

Plate ID	Northing	Easting	Plate Stickup Length
13A	686834.71	602965.79	15
13B	687090.08	603046.37	15
13C	686872.45	603098.19	15
13D	687298.41	603297.25	15
14A	685365.44	600853.61	15
15A	685753.88	601541.97	15
17A	688075.46	602896.27	24
17B	688232.10	603025.93	24
17C	688393.41	603041.21	24
18A	686549.55	602233.75	15
18B	686887.64	602516.03	15
19A	687672.51	603107.63	15
20A	685083.01	600982.91	15
21A	685515.67	601316.1	15
25A	688852.43	603630.92	12
26A	688732.41	603856.06	8
27A	689049.74	603606.53	12
29A	688449.22	603326.8	24
29B	688725.61	603237.98	24
29C	688926.31	603379.45	24
30A	688432.30	603598.31	8

LEGEND

FEDERAL CHANNEL

MEAN HIGH WATER LINE (3.52 FT NGVD29)

EXISTING SHORELINE PROTECTION LIMITS (AS SURVEYED BY SEVENSON ENVIRONMENTAL SERVICES, INC. ON 11/30/2012)

LOW WATER LINE (APPROXIMATE)

7–A AS-BUILT LONG TERM MONITORING PLATE - YEAR 1

7–B AS-BUILT LONG TERM MONITORING PLATE - YEAR 5

GROUNDWATER SAMPLE LOCATION

BIOLOGICAL SAMPLE LOCATION

0.75" ARMOR PLACEMENT

1.0" ARMOR PLACEMENT

2.5" ARMOR PLACEMENT

3.5" ARMOR PLACEMENT

10.0" ARMOR PLACEMENT

MONITORED NATURAL RECOVERY AREA

PROPOSED SPI INVESTIGATION LOCATIONS - YEARS 1, 2, & 5

7 CAP AREA

7a SUB CAP AREAS

PORE WATER SAMPLING LOCATION

0 200
SCALE IN FEET

RAMBOLL ENVIRON

DRAFTED BY: BJK/MSB | DATE: 05/22/2015

LONG TERM MONITORING PLAN - NORTHERN AREA

STUDY AREA 7
JERSEY CITY, NEW JERSEY

FIGURE 2

0220255F3

MSETTER 6/10/15 [0220255_LONG TERM MONITORING PLANS]
F:\0220255\DESIGN 100 PERCENT

APPENDICES

APPENDIX A
Photographs

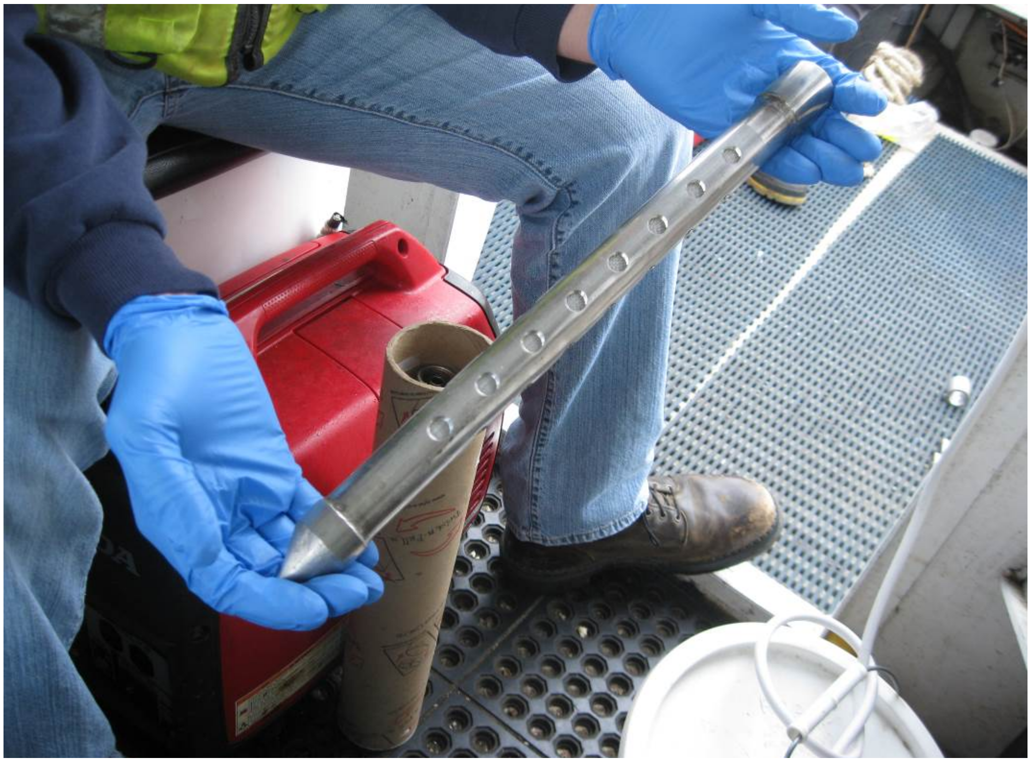


Photo 1: Pore water sampling device used at subtidal sampling locations

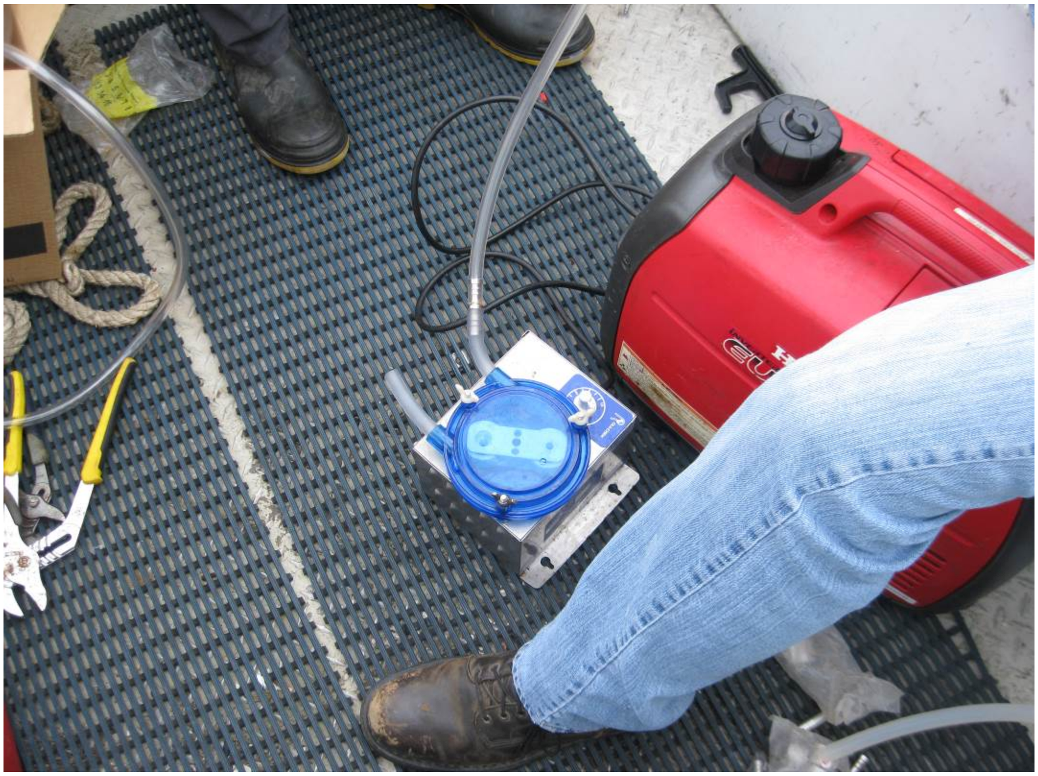


Photo 2: Peristaltic pump used to collect subtidal pore water samples

Photo 3: Snails observed on sediment cap armor layer in intertidal area

Photo 4: Algae observed on sediment cap armor layer in intertidal area

Photo 5: Blue heron observed in intertidal area

Photo 6: Sediment deposition over sediment cap armor layer in intertidal area

Photo 7: Intertidal cap area 13 at low tide

Photo 8: Egg sacks observed on sediment cap armor layer in intertidal area

Photo 9: Snails observed on sediment surface in MNR area

Photo 10: Intertidal cap area 11 at low tide

Photo 11: Scour hole at discharge point of 18-inch PVC pipe from the DeFeo property prior to repair

Photo 12: Scour hole at discharge point of 18-inch PVC pipe from the DeFeo property following repair

Photo 13: SPI Camera staged on deck of ASI vessel

Photo 14: Deploying the SPI Camera in subtidal MNR area

APPENDIX B
Hydraulic and Hydrodynamic Evaluation Summaries

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

							Assessment Required?
Monitoring Period:	**Year 2 - November 2014 through September 2015**						
Rainfall Event Data:							
Max Rainfall (in):	3.83	Date:	5/31/2015				
50-Year, 24-Hr event?	NO						NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.766	Date:	12/9/2014	Time:	20:00		
Exceeds event trigger criteria?	YES						
Max Tide Gauge Reading (m):	1.396	Date:	12/9/2014	Time:	15:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						NO
Wind Event Data:							
Max Wind (mph):	40 (1)	Date:	7/1/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	W	OK					
(1) Note that the maximum wind speed was experienced for less than 2 hours.							NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for KEWR - November, 2014

From: November 1 2014 To: September 30 2015

Get History

Daily | Weekly | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**98** °F	**63** °F	**20** °F	
Mean Temperature	**89** °F	**55** °F	**11** °F	
Min Temperature	**80** °F	**46** °F	**1** °F	
Degree Days				
Heating Degree Days (base 65)	54	15	0	4940
Cooling Degree Days (base 65)	24	5	0	1542
Growing Degree Days (base 50)	38	12	0	3891
Dew Point				
Dew Point	**79** °F	**40** °F	**-16** °F	
Precipitation				
Precipitation	**3.83** in	**0.14** in	**0.00** in	**39.08** in
Snowdepth	**8.0** in	**0.8** in	**0.0** in	-
Wind				
Wind	**40** mph	**9** mph	**0** mph	
Gust Wind	**51** mph	**22** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.83** in	**30.04** in	**29.29** in	

http://www.wunderground.com/history/airport/KEWR/2014/11/1/CustomHistory.html?dayend=30&monthend=9&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=


NOAA/NOS/CO-OPS
Verified Hourly Heights at 8518750, The Battery NY
From 2014/11/01 00:00 GMT to 2015/10/01 23:59 GMT
Height in meters (MSL)
Predictions
Verified
Preliminary
Datums (MSL)
MHHW
MHW
MTL
MSL
MLLW
MLW
Options for
8518750 The Battery, NY
From:
To:
Units
Meters
Timezone
GMT
Datum
MSL
Shift dates
Back 1 Day
Forward 1 Day
Interval
6 min
1 hr
H/L
Day
Month
Update
Plot
Data Only

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

Monitoring Period: **November 2014**	*Assessment Required?*

Rainfall Event Data:

Max Rainfall (in):	1.48	Date:	11/17/2014
50-Year, 24-Hr event?	NO		

Assessment Required? NO

Storm Surge Event Data:

Max Increase Above Predicted Normal Tidal Cycling (m):	0.646	Date:	11/2/2014	Time:	4:00
Exceeds event trigger criteria?	YES				
Max Tide Gauge Reading (m):	1.239	Date:	11/24/2014	Time:	14:00
Exceeds event trigger criteria?	NO				
10-year storm surge event defined as a hurricane?	NO				

Assessment Required? NO

Wind Event Data:

Max Wind (mph):	32	Date:	11/2/2014
Exceeds trigger criteria?	NO		
Wind direction over 6-hr period:	NW	OK	

Assessment Required? NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

November 1, 2014 through December 1, 2014 — View Current Weather Conditions

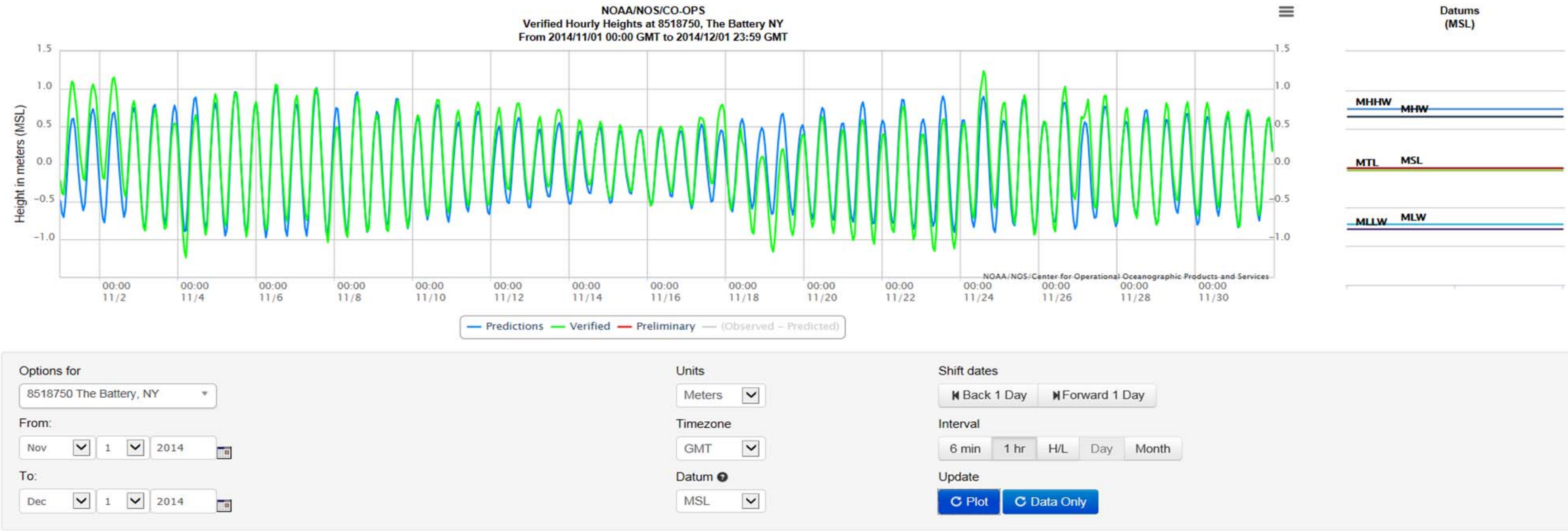
November 1, 2014 through December 1, 2014

November 1 2014 - TO - December 1 2014 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**74** °F	**52** °F	**33** °F	
Mean Temperature	**62** °F	**44** °F	**27** °F	
Min Temperature	**51** °F	**36** °F	**21** °F	
Degree Days				
Heating Degree Days (base 65)	38	21	3	637
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	12	2	0	50
Dew Point				
Dew Point	**59** °F	**30** °F	**0** °F	
Precipitation				
Precipitation	**1.48** in	**0.15** in	**0.00** in	**4.13** in
Snowdepth	**0.0** in	**0.0** in	**0.0** in	-
Wind				
Wind	**32** mph	**10** mph	**0** mph	
Gust Wind	**41** mph	**24** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.52** in	**30.04** in	**29.51** in	

http://www.wunderground.com/history/airport/KEWR/2014/11/1/CustomHistory.html?dayend=1&monthend=12&yearend=2014&req_city=NA&req_state=NA&req_statename=NA



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20141101&edate=20141201&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

Monitoring Period:	**December 2014**	*Assessment Required?*
Rainfall Event Data: Max Rainfall (in): 1.34 Date: 12/9/2014 50-Year, 24-Hr event? NO		NO
Storm Surge Event Data: Max Increase Above Predicted Normal Tidal Cycling (m): 0.766 Date: 12/9/2014 Time: 20:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.396 Date: 12/9/2014 Time: 15:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO		NO
Wind Event Data: Max Wind (mph): 35 Date: 12/9/2014 Exceeds trigger criteria? NO Wind direction over 6-hr period: N OK		NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

December 1, 2014 through January 1, 2015 — View Current Weather Conditions

December 1, 2014 through January 1, 2015

December | 1 | 2014 - TO - January | 1 | 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**66** °F	**46** °F	**33** °F	
Mean Temperature	**54** °F	**40** °F	**29** °F	
Min Temperature	**45** °F	**34** °F	**20** °F	
Degree Days				
Heating Degree Days (base 65)	36	25	11	800
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	4	0	0	4
Dew Point				
Dew Point	**63** °F	**30** °F	**2** °F	
Precipitation				
Precipitation	**1.34** in	**0.18** in	**0.00** in	**4.91** in
Snowdepth	**0.0** in	**0.0** in	**0.0** in	-
Wind				
Wind	**35** mph	**10** mph	**0** mph	
Gust Wind	**44** mph	**23** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.69** in	**30.12** in	**29.51** in	

http://www.wunderground.com/history/airport/KEWR/2014/12/1/CustomHistory.html?dayend=1&monthend=1&yearend=2015&req_city=NA&req_state=NA&req_statename=NA

http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20141201&edate=20150101&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

Monitoring Period: **January 2015**	*Assessment Required?*
Rainfall Event Data: Max Rainfall (in): 1.84 Date: 1/18/2015 50-Year, 24-Hr event? NO	NO
Storm Surge Event Data: Max Increase Above Predicted Normal Tidal Cycling (m): 0.723 Date: 1/27/2015 Time: 13:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.288 Date: 1/27/2015 Time: 7:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
Wind Event Data: Max Wind (mph): 37 Date: 1/5/2015 Exceeds trigger criteria? NO Wind direction over 6-hr period: W OK	NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

January 1, 2015 through February 1, 2015 — View Current Weather Conditions

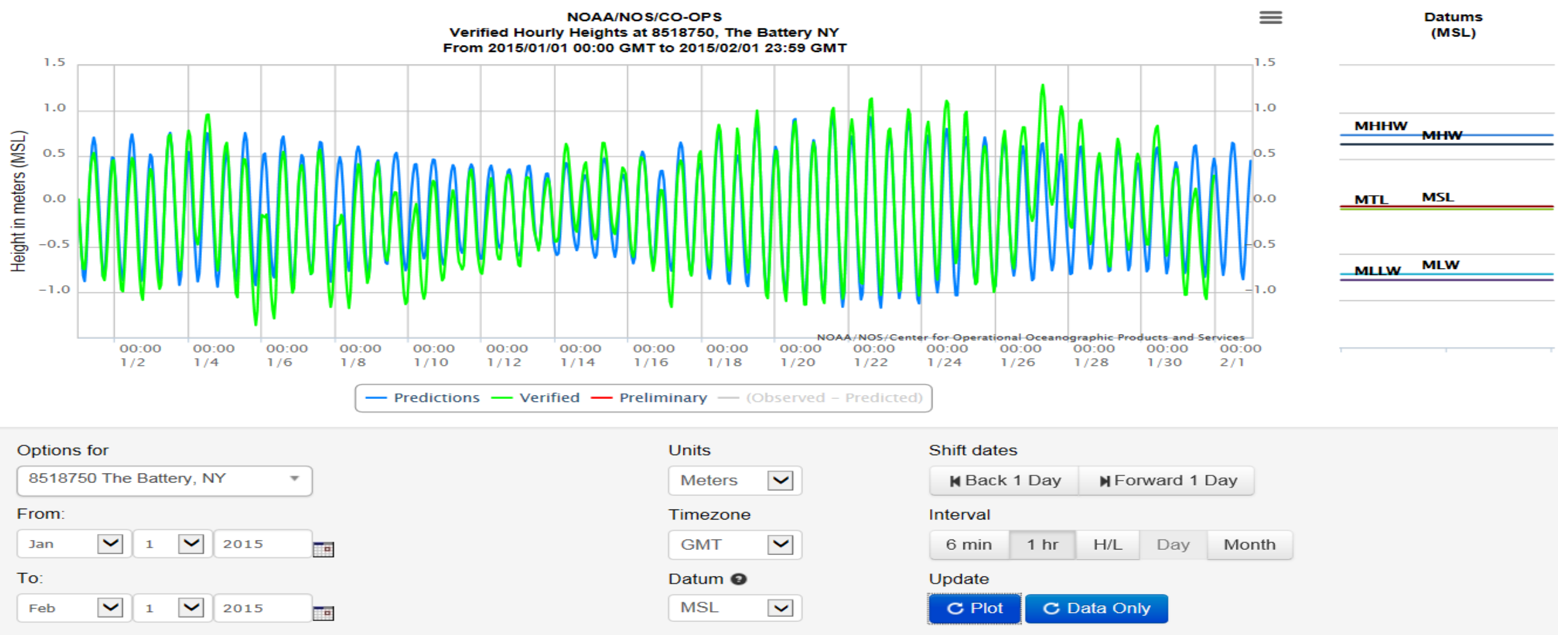
January 1, 2015 through February 1, 2015

January 1 2015 - TO - February 1 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**56** °F	**36** °F	**21** °F	
Mean Temperature	**48** °F	**29** °F	**14** °F	
Min Temperature	**39** °F	**21** °F	**6** °F	
Degree Days				
Heating Degree Days (base 65)	51	36	17	1162
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**52** °F	**16** °F	**-10** °F	
Precipitation				
Precipitation	**1.84** in	**0.16** in	**0.00** in	**4.45** in
Snowdepth	**8.0** in	**1.6** in	**0.0** in	-
Wind				
Wind	**37** mph	**11** mph	**0** mph	
Gust Wind	**47** mph	**24** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.69** in	**30.12** in	**29.29** in	

http://www.wunderground.com/history/airport/KEWR/2015/1/1/CustomHistory.html?dayend=1&monthend=2&yearend=2015&req_city=NA&req_state=NA&req_statename=NA



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150101&edate=20150201&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

	Assessment Required?
Monitoring Period: **February 2015**	
Rainfall Event Data: Max Rainfall (in): 1.14 Date: 2/2/2015 50-Year, 24-Hr event? NO	NO
Storm Surge Event Data: Max Increase Above Predicted Normal Tidal Cycling (m): 0.576 Date: 2/10/2015 Time: 0:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.157 Date: 2/18/2015 Time: 13:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
Wind Event Data: Max Wind (mph): 36 Date: 2/15/2015 Exceeds trigger criteria? NO Wind direction over 6-hr period: NW OK	NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

February 1, 2015 through March 1, 2015 — View Current Weather Conditions

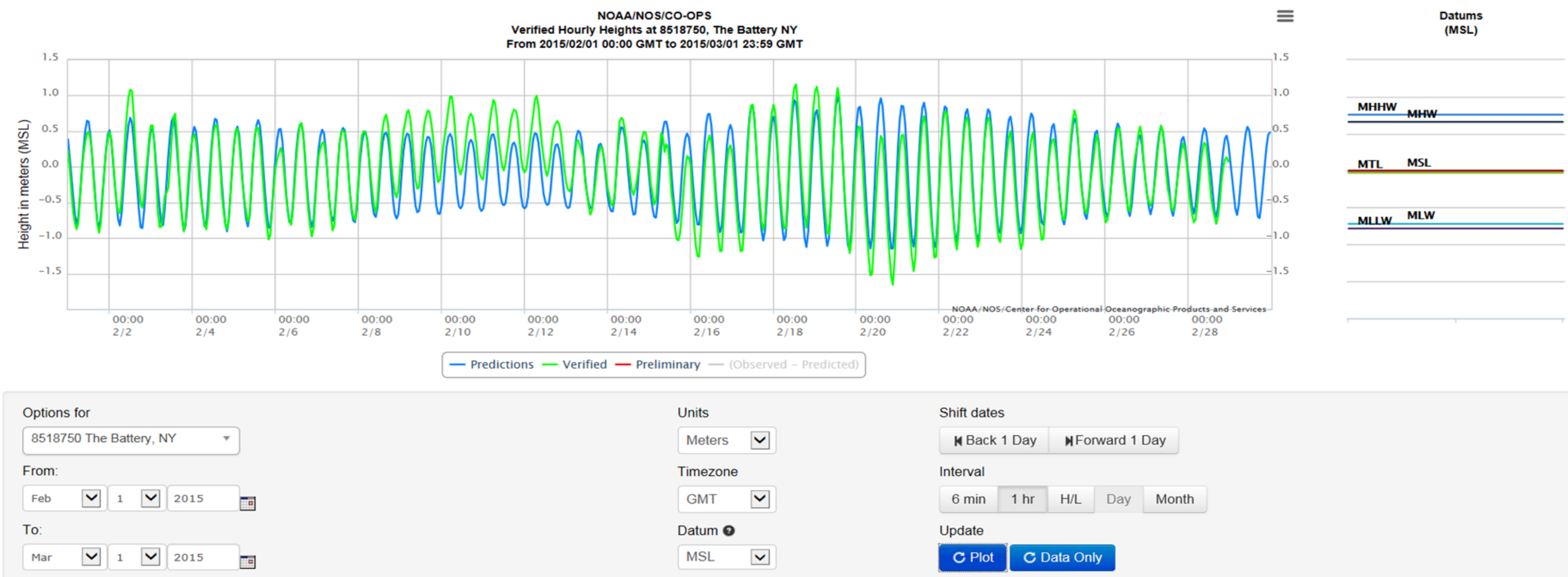
February 1, 2015 through March 1, 2015

February | 1 | 2015 - TO - March | 1 | 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**42** °F	**31** °F	**20** °F	
Mean Temperature	**37** °F	**23** °F	**11** °F	
Min Temperature	**31** °F	**14** °F	**1** °F	
Degree Days				
Heating Degree Days (base 65)	54	42	28	1225
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**34** °F	**11** °F	**-16** °F	
Precipitation				
Precipitation	**1.14** in	**0.11** in	**0.00** in	**2.57** in
Snowdepth	**8.0** in	**5.8** in	**3.0** in	-
Wind				
Wind	**36** mph	**10** mph	**0** mph	
Gust Wind	**46** mph	**23** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.83** in	**30.09** in	**29.40** in	

http://www.wunderground.com/history/airport/KEWR/2015/2/1/CustomHistory.html?dayend=1&monthend=3&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150201&edate=20150301&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

								Assessment Required?
Monitoring Period:	**March**	**2015**						
Rainfall Event Data:								
Max Rainfall (in):	0.87	Date:	3/5/2015					
50-Year, 24-Hr event?	NO							NO
Storm Surge Event Data:								
Max Increase Above Predicted Normal Tidal Cycling (m):	0.315	Date:	3/21/2015	Time:	7:00			
Exceeds event trigger criteria?	NO							
Max Tide Gauge Reading (m):	1.174	Date:	3/21/2015	Time:	13:00			
Exceeds event trigger criteria?	NO							
10-year storm surge event defined as a hurricane?	NO							NO
Wind Event Data:								
Max Wind (mph):	37	Date:	3/17/2015					
Exceeds trigger criteria?	NO							
Wind direction over 6-hr period:	NW	OK						NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots, coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

March 1, 2015 through April 1, 2015 — View Current Weather Conditions

March 1, 2015 through April 1, 2015

March 1 2015 - TO - April 1 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**64** °F	**46** °F	**27** °F	
Mean Temperature	**53** °F	**38** °F	**20** °F	
Min Temperature	**42** °F	**29** °F	**11** °F	
Degree Days				
Heating Degree Days (base 65)	45	27	12	860
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	2	0	0	4
Dew Point				
Dew Point	**58** °F	**22** °F	**-4** °F	
Precipitation				
Precipitation	**0.87** in	**0.17** in	**0.00** in	**4.63** in
Snowdepth	**8.0** in	**1.7** in	**0.0** in	-
Wind				
Wind	**37** mph	**10** mph	**0** mph	
Gust Wind	**51** mph	**24** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.73** in	**30.10** in	**29.56** in	

http://www.wunderground.com/history/airport/KEWR/2015/3/1/CustomHistory.html?dayend=1&monthend=4&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150301&edate=20150401&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

							Assessment Required?
Monitoring Period:	**April**	**2015**					
Rainfall Event Data:							
Max Rainfall (in):	0.94	Date:	4/20/2015				
50-Year, 24-Hr event?	NO						NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.507	Date:	4/20/2015	Time:	15:00		
Exceeds event trigger criteria?	NO						
Max Tide Gauge Reading (m):	1.353	Date:	4/21/2015	Time:	3:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						NO
Wind Event Data:							
Max Wind (mph):	36	Date:	4/4/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	WNW	OK					NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

April 1, 2015 through May 1, 2015 — View Current Weather Conditions

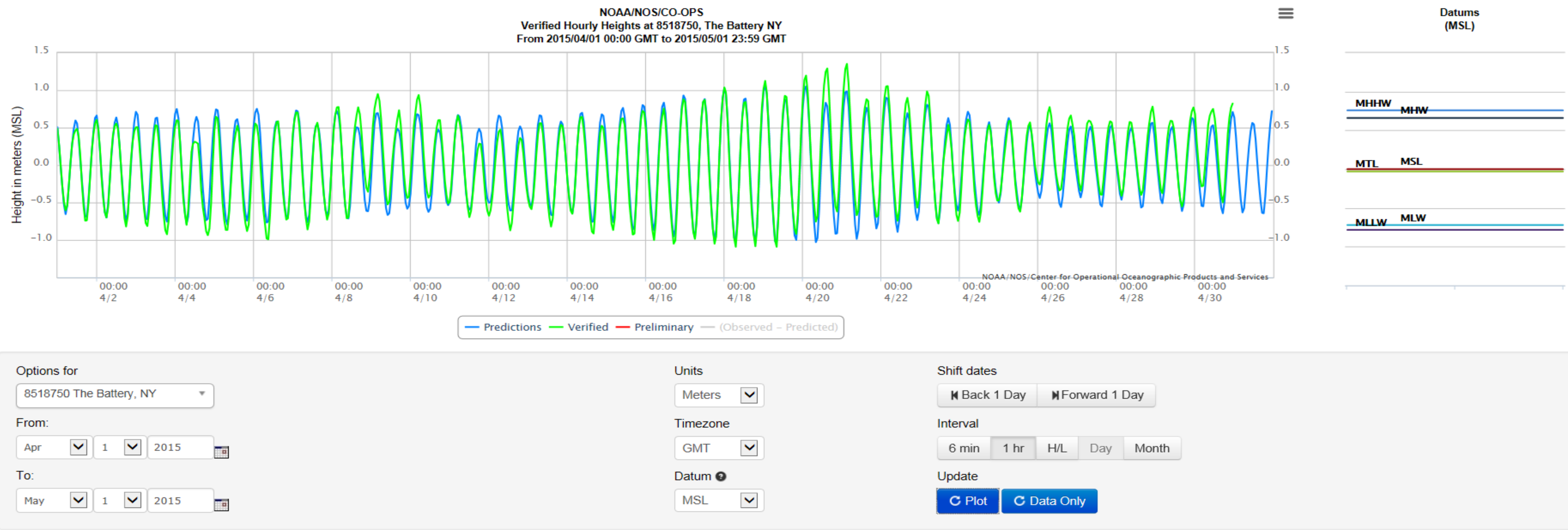
April 1, 2015 through May 1, 2015

April 1 2015 - TO - May 1 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**82** °F	**63** °F	**43** °F	
Mean Temperature	**68** °F	**54** °F	**41** °F	
Min Temperature	**59** °F	**45** °F	**33** °F	
Degree Days				
Heating Degree Days (base 65)	24	11	0	336
Cooling Degree Days (base 65)	3	0	0	3
Growing Degree Days (base 50)	18	5	0	153
Dew Point				
Dew Point	**59** °F	**35** °F	**12** °F	
Precipitation				
Precipitation	**0.94** in	**0.06** in	**0.00** in	**1.67** in
Snowdepth	**0.0** in	**0.0** in	**0.0** in	-
Wind				
Wind	**36** mph	**11** mph	**0** mph	
Gust Wind	**47** mph	**23** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.49** in	**29.98** in	**29.47** in	

http://www.wunderground.com/history/airport/KEWR/2015/4/1/CustomHistory.html?dayend=1&monthend=5&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150401&edate=20150501&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

	Assessment Required?
Monitoring Period: **May** **2015**	
Rainfall Event Data: Max Rainfall (in): 3.83 Date: 5/31/2015 50-Year, 24-Hr event? NO	NO
Storm Surge Event Data: Max Increase Above Predicted Normal Tidal Cycling (m): 0.246 Date: 5/1/2015 Time: 21:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.108 Date: 5/19/2015 Time: 1:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
Wind Event Data: Max Wind (mph): 31 Date: 5/12/2015 Exceeds trigger criteria? NO Wind direction over 6-hr period: WSW OK	NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

May 1, 2015 through June 1, 2015 — View Current Weather Conditions

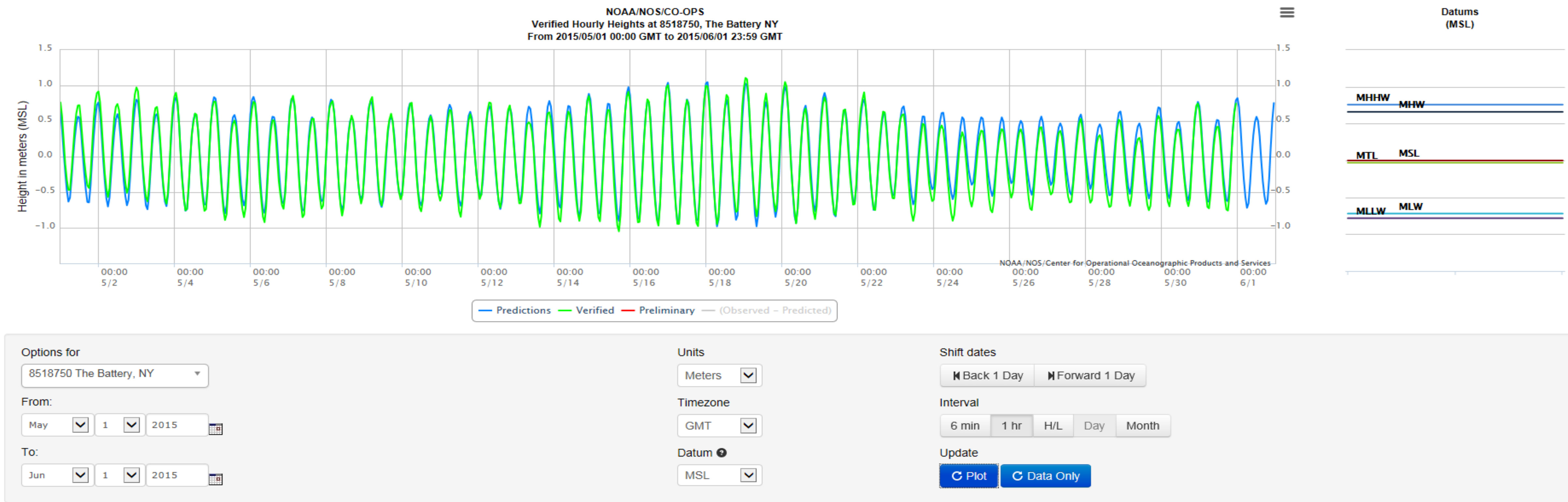
May 1, 2015 through June 1, 2015

May 1 2015 - TO - June 1 2015 Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	91 °F	79 °F	59 °F	
Mean Temperature	80 °F	68 °F	53 °F	
Min Temperature	70 °F	57 °F	46 °F	
Degree Days				
Heating Degree Days (base 65)	12	2	0	56
Cooling Degree Days (base 65)	15	5	0	157
Growing Degree Days (base 50)	30	18	4	567
Dew Point				
Dew Point	70 °F	51 °F	22 °F	
Precipitation				
Precipitation	3.83 in	0.25 in	0.00 in	6.60 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	31 mph	8 mph	0 mph	
Gust Wind	38 mph	22 mph	16 mph	
Sea Level Pressure				
Sea Level Pressure	30.43 in	30.12 in	29.75 in	

http://www.wunderground.com/history/airport/KEWR/2015/5/1/CustomHistory.html?dayend=1&monthend=6&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150501&edate=20150601&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

							Assessment Required?
Monitoring Period:	**June**	**2015**					
Rainfall Event Data:							
Max Rainfall (in):	1.66	Date:	6/1/2015				
50-Year, 24-Hr event?	NO						
							NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.461	Date:	6/28/2015	Time:	7:00		
Exceeds event trigger criteria?	NO						
Max Tide Gauge Reading (m):	1.112	Date:	6/3/2015	Time:	1:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						
							NO
Wind Event Data:							
Max Wind (mph):	26	Date:	6/9/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	WSW	OK					
							NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for Newark, NJ

June 1, 2015 through June 30, 2015 — View Current Weather Conditions

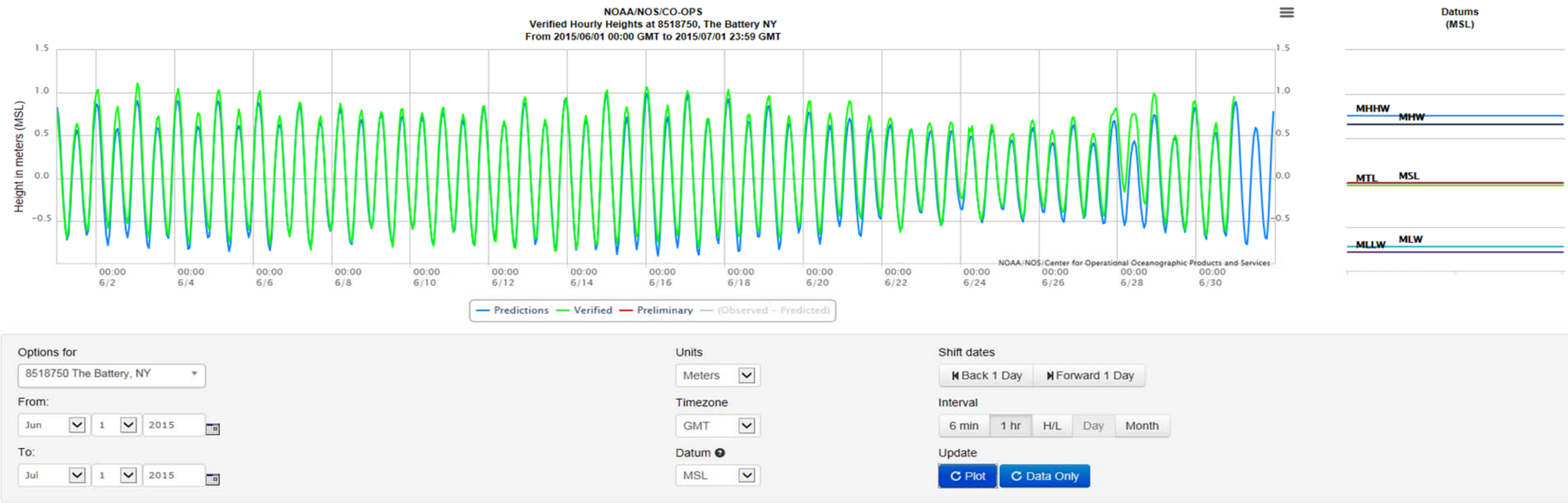
June 1, 2015 through June 30, 2015

June | 1 | 2015 - TO - June | 30 | 2015 | Go

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**93 °F**	**80 °F**	**57 °F**	
Mean Temperature	**84 °F**	**72 °F**	**53 °F**	
Min Temperature	**74 °F**	**64 °F**	**49 °F**	
Degree Days				
Heating Degree Days (base 65)	12	1	0	29
Cooling Degree Days (base 65)	19	8	0	249
Growing Degree Days (base 50)	33	22	3	653
Dew Point				
Dew Point	**75 °F**	**59 °F**	**31 °F**	
Precipitation				
Precipitation	**1.66** in	**0.23** in	**0.00** in	**5.90** in
Snowdepth	**0.0** in	**0.0** in	**0.0** in	-
Wind				
Wind	**26** mph	**9** mph	**0** mph	
Gust Wind	**35** mph	**21** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.28** in	**29.97** in	**29.64** in	

http://www.wunderground.com/history/airport/KEWR/2015/6/1/CustomHistory.html?dayend=30&monthend=6&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150601&edate=20150701&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

							Assessment Required?
Monitoring Period:	**July**	**2015**					
Rainfall Event Data:							
Max Rainfall (in):	0.99	Date:	7/1/2015				
50-Year, 24-Hr event?	NO						NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.309	Date:	7/14/2015	Time:	22:00		
Exceeds event trigger criteria?	NO						
Max Tide Gauge Reading (m):	1.151	Date:	7/4/2015	Time:	2:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						NO
Wind Event Data:							
Max Wind (mph):	40 (1)	Date:	7/1/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	W	OK					

(1) Note that the maximum wind speed was experienced for less than 2 hours.

NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for KEWR

See history from more local stations

Monthly Calendar | **Detailed History**

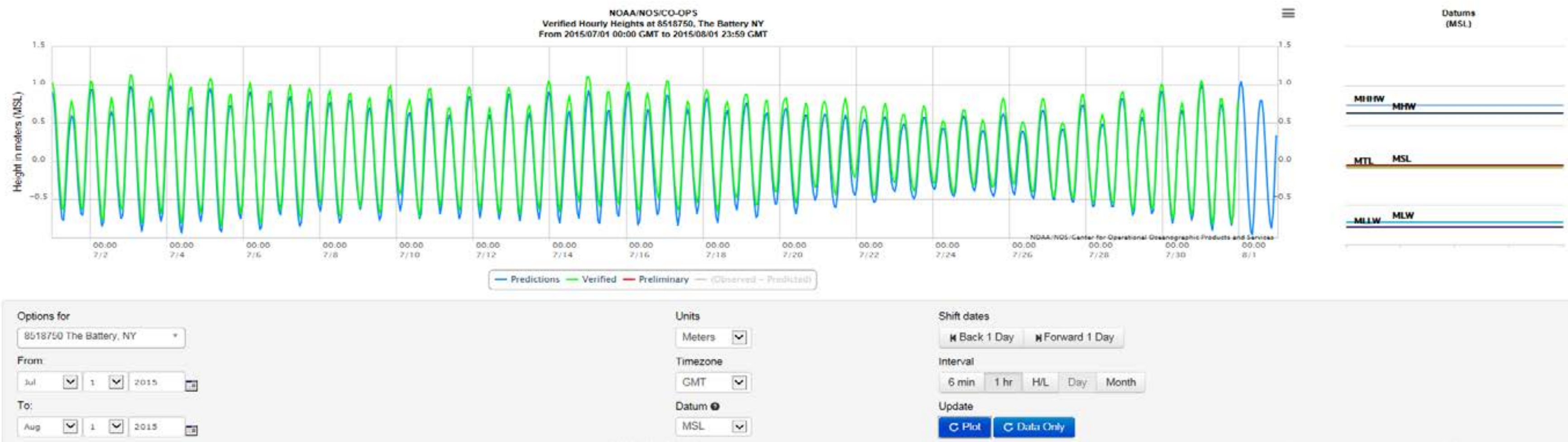
From: July 1 2015 To: August 1 2015

Get History

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	98 °F	88 °F	79 °F	
Mean Temperature	89 °F	79 °F	72 °F	
Min Temperature	80 °F	70 °F	63 °F	
Degree Days				
Heating Degree Days (base 65)	0	0	0	0
Cooling Degree Days (base 65)	24	14	7	458
Growing Degree Days (base 50)	38	29	22	925
Dew Point				
Dew Point	79 °F	63 °F	44 °F	
Precipitation				
Precipitation	0.99 in	0.10 in	0.00 in	2.69 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	40 mph	8 mph	0 mph	
Gust Wind	51 mph	21 mph	16 mph	
Sea Level Pressure				
Sea Level Pressure	30.17 in	29.91 in	29.55 in	

http://www.wunderground.com/history/airport/KEWR/2015/7/1/CustomHistory.html?dayend=1&monthend=8&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20150701&edate=20150801&timezone=GMT&datum=MSL&interval=h&action=

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

							Assessment Required?
Monitoring Period:	**August**	**2015**					
Rainfall Event Data:							
Max Rainfall (in):	0.96	Date:	8/11/2015				
50-Year, 24-Hr event?	NO						
							NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.334	Date:	8/10/2015	Time:	3:00		
Exceeds event trigger criteria?	NO						
Max Tide Gauge Reading (m):	1.125	Date:	8/1/2015	Time:	1:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						
							NO
Wind Event Data:							
Max Wind (mph):	28	Date:	8/4/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	W	OK					
							NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for KEWR

See history from more local stations

Monthly Calendar | **Detailed History**

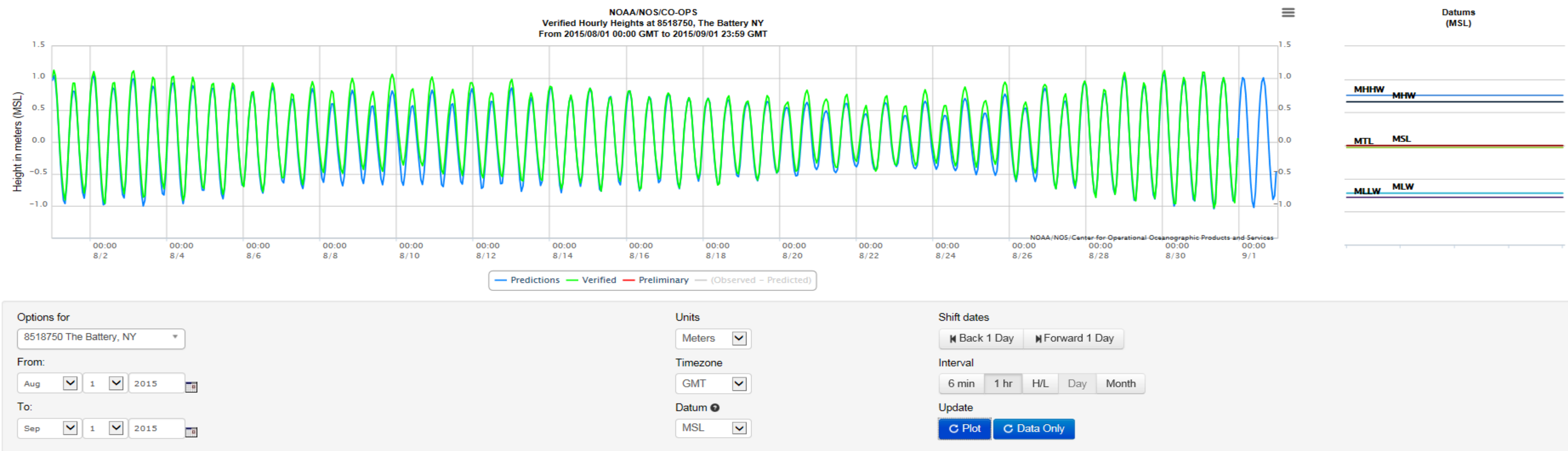
From: August 1 2015 To: August 31 2015

Get History

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	97 °F	88 °F	81 °F	
Mean Temperature	85 °F	79 °F	73 °F	
Min Temperature	77 °F	69 °F	63 °F	
Degree Days				
Heating Degree Days (base 65)	0	0	0	0
Cooling Degree Days (base 65)	20	14	8	432
Growing Degree Days (base 50)	35	28	22	881
Dew Point				
Dew Point	75 °F	61 °F	47 °F	
Precipitation				
Precipitation	0.96 in	0.05 in	0.00 in	1.40 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	28 mph	8 mph	0 mph	
Gust Wind	51 mph	20 mph	16 mph	
Sea Level Pressure				
Sea Level Pressure	30.22 in	29.98 in	29.71 in	

http://www.wunderground.com/history/airport/KEWR/2015/8/1/CustomHistory.html?dayend=31&monthend=8&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=


NOAA/NOS/CO-OPS
Verified Hourly Heights at 8518750, The Battery NY
From 2015/08/01 00:00 GMT to 2015/09/01 23:59 GMT
Height in meters (MSL)
NOAA/NOS/Center for Operational Oceanographic Products and Services
Predictions
Verified
Preliminary
(Observed - Predicted)
Datums
(MSL)
MHHW
MHW
MTL
MSL
MLLW
MLW
Options for
8518750 The Battery, NY
From:
Aug
1
2015
To:
Sep
1
2015
Units
Meters
Timezone
GMT
Datum
MSL
Shift dates
Back 1 Day
Forward 1 Day
Interval
6 min
1 hr
H/L
Day
Month
Update
Plot
Data Only

SA-7 Sediment Remedy
Long-Term Monitoring Program
Hydrologic Data Review

Monitoring Period:	**September 2015**						*Assessment Required?*
Rainfall Event Data:							
Max Rainfall (in):	1.16	Date:	9/30/2015				
50-Year, 24-Hr event?	NO						NO
Storm Surge Event Data:							
Max Increase Above Predicted Normal Tidal Cycling (m):	0.431	Date:	9/13/2015	Time:	6:00		
Exceeds event trigger criteria?	NO						
Max Tide Gauge Reading (m):	1.284	Date:	9/30/2015	Time:	15:00		
Exceeds event trigger criteria?	NO						
10-year storm surge event defined as a hurricane?	NO						NO
Wind Event Data:							
Max Wind (mph):	29	Date:	9/30/2015				
Exceeds trigger criteria?	NO						
Wind direction over 6-hr period:	N	OK					NO

CRITERIA FROM LTMP:

"Post-High Energy Event Monitoring Activities" will take place promptly following High Energy Events. The Consent Order defines "High Energy Events" as follows:

i. "A 50-year rainfall event defined by the National Weather Service as a 24-hour period of rainfall exceeding the maximum 50-year/24-hour accumulation (i.e., 7.2 inches of rainfall over a 24-hour period), as recorded at Newark Airport;

- See http://www.wunderground.com/history/

ii. A 10-year storm surge event defined as a hurricane event (not a "nor'easter") resulting in an increase in ocean level of either 0.64 meters above normal tidal cycling at the Battery Park tide gauge or 1.40 meters above mean sea level (MSL); or

- Note: Hurricane events are defined by NOAA.
- See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750

iii. A wind event achieving 34 to 40 knots (39.13 to 46.03 mph), coming from the south through the west, averaged over 6 hours, as recorded at Newark Airport."

- See http://www.wunderground.com/history/

CHECKED BY: TEA

Weather History for KEWR

See history from more local stations

Monthly Calendar | **Detailed History**

From: September | 1 | 2015

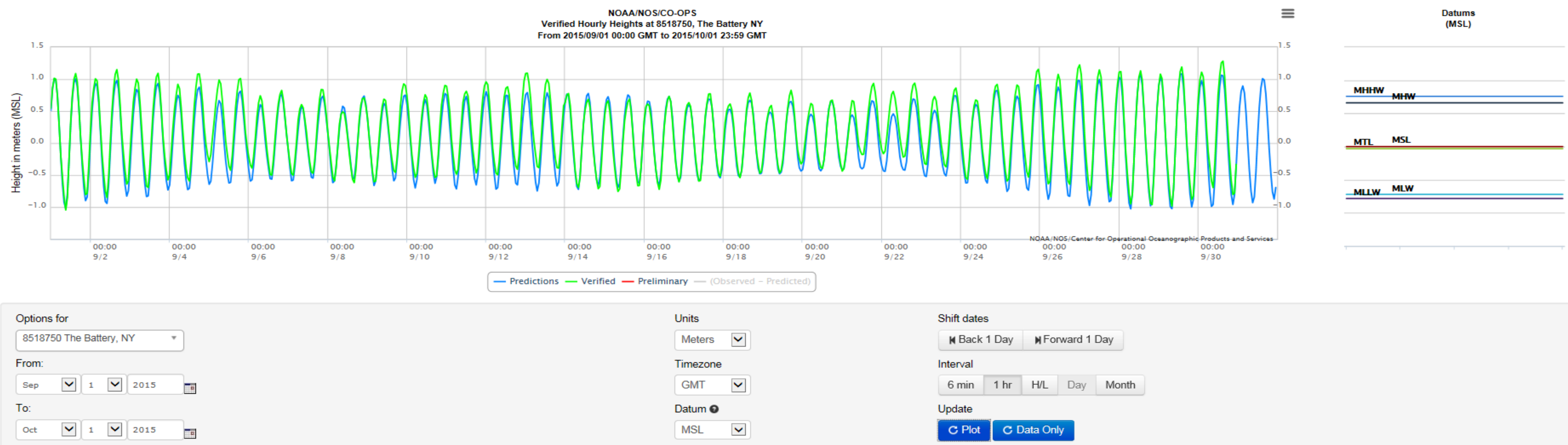
To: September | 30 | 2015

Get History

Daily | Weekly | Monthly | **Custom**

	Max	Avg	Min	Sum
Temperature				
Max Temperature	98 °F	83 °F	70 °F	
Mean Temperature	85 °F	74 °F	62 °F	
Min Temperature	75 °F	64 °F	54 °F	
Degree Days				
Heating Degree Days (base 65)	3	0	0	3
Cooling Degree Days (base 65)	20	9	0	260
Growing Degree Days (base 50)	35	23	12	699
Dew Point				
Dew Point	74 °F	60 °F	37 °F	
Precipitation				
Precipitation	1.16 in	0.09 in	0.00 in	2.33 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	29 mph	8 mph	0 mph	
Gust Wind	37 mph	20 mph	16 mph	
Sea Level Pressure				
Sea Level Pressure	30.48 in	30.07 in	29.64 in	

http://www.wunderground.com/history/airport/KEWR/2015/9/1/CustomHistory.html?dayend=30&monthend=9&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=


NOAA/NOS/CO-OPS
Verified Hourly Heights at 8518750, The Battery NY
From 2015/09/01 00:00 GMT to 2015/10/01 23:59 GMT
Height in meters (MSL)
1.5
1.0
0.5
0.0
-0.5
-1.0
00:00 9/2
00:00 9/4
00:00 9/6
00:00 9/8
00:00 9/10
00:00 9/12
00:00 9/14
00:00 9/16
00:00 9/18
00:00 9/20
00:00 9/22
00:00 9/24
00:00 9/26
00:00 9/28
00:00 9/30
NOAA/NOS/Center for Operational Oceanographic Products and Services
Predictions
Verified
Preliminary
(Observed - Predicted)
Datums (MSL)
MHHW
MHW
MTL
MSL
MLLW
MLW
Options for
8518750 The Battery, NY
From:
Sep
1
2015
To:
Oct
1
2015
Units
Meters
Timezone
GMT
Datum
MSL
Shift dates
Back 1 Day
Forward 1 Day
Interval
6 min
1 hr
H/L
Day
Month
Update
Plot
Data Only

APPENDIX C
Bathymetric Survey

LEGEND

BATHYMETRIC CONTOUR ELEVATION MAJOR

BATHYMETRIC CONTOUR ELEVATION MINOR

AS-BUILT CAPPING LIMIT

7-A AS-BUILT LONG TERM MONITORING PLATE – ODD YEARS

7-B AS-BUILT LONG TERM MONITORING PLATE – EVEN YEARS

NOTES:

1. TOPOGRAPHY: TOPOGRAPHIC ELEVATIONS ARE IN FEET AND ARE REFERENCED TO NATIONAL GEODETIC VERTICAL DATUM 1929 (NGVD 29) BASED ON BENCHMARK "PK-NAIL" WHICH HAS AN ELEVATION OF 6.94 FEET NORTH AMERICAN VERTICAL DATUM 1988 (NAVD 88) AS PROVIDED BY HONEYWELL. THE PLANE OF NGVD 29 IS 1.14 FEET BELOW THE PLANE OF NAVD 88 AT KEARNEY POINT, NEW JERSEY BASED ON NATIONAL GEODETIC SURVEY FIRST ORDER TIDAL BENCHMARK "W 16" WHICH HAS A PUBLISHED ELEVATION OF 17.00 FEET NAVD 88 AND 18.14 FEET NGVD 29.

2. BATHYMETRY: FOR THE BATHYMETRIC SURVEY, VERTICAL DATA WERE REFERENCED TO THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 29), AND HORIZONTAL COORDINATES WERE REFERENCED TO THE NORTH AMERICAN DATUM OF 1983 (NAD 83) USING THE NEW JERSEY STATE PLANE COORDINATE SYSTEM (NJ STATE PLANE). HORIZONTAL POSITIONING WAS PERFORMED WITH RTK-DGPS USING CORRECTIONS FROM KEYNET VRS. THE ACCURACY OF THE RTK-DGPS ROVER USING THE VRS CORRECTIONS WAS VERIFIED BY OCCUPYING CONTROL POINT ASI-PA AVE, LOCATED NEAR THE WESTERN END OF PENNSYLVANIA AVENUE IN KEARNY, NEW JERSEY.

3. SURVEYED BATHYMETRIC CONTOURS WERE PROVIDED IN MLLW DATUM AND CONVERTED TO NGVD 29 DATUM BY PERFORMING AN ELEVATION ADJUSTMENT OF -1.94 FEET. THE ELEVATION ADJUSTMENT IS BASED ON THE DIFFERENCE IN ELEVATION DATUM BETWEEN MLLW AND NGVD 29 AS DOCUMENTED AT TIDAL BENCHMARK "W16".

4. NEAR SHORE CONDITIONS (BETWEEN ELEVATION -1 FT AND +1 FT) ARE DEFINED BASED ON SURVEY DATA POINTS PROVIDED BY AQUA SURVEY INC. FOR THE 2010 BATHYMETRY.

SOURCES:

SITE LAYOUT BASED ON RIVERBED ELEVATIONS NORTHERN SITE, HONEYWELL SA7, SITE INVESTIGATION BY OCEAN SURVEYS, INC. HACKENSACK RIVER, JERSEY CITY, NJ OCTOBER 2007

LOTS BASED ON A MAP SHOWING REMAINING STATE TIDELANDS CLAIMS, BLOCK 1290.1, LOT A1 & A2, BLOCK 1751, LOTS 10K1, 10K2, 11 & 12, CMX, 8/6/09.

2014 BATHYMETRIC CONTOURS BASED ON A BATHYMETRIC SURVEY FOR HONEYWELL BY AQUA SURVEY INC., CONDUCTED ON 9/29/2014 AND DIGITALLY PROVIDED ON 12/18/2014.

TOPOGRAPHIC CONTOURS BASED ON A SURVEY MAP FOR HONEYWELL ENTITLED "ALTA / ACSM LAND TITLE SURVEY BLOCK 1290.1 ~ LOTS 2D, 2E, & 16A.99", BY CMX, DATED 5/23/08 & REVISED THROUGH 11/07/08

2014 BATHYMETRIC BASE MAP	RAMBOLL ENVIRON		
HONEYWELL INTERNATIONAL, INC. SA7 SEDIMENT REMEDIATION PROJECT JERSEY CITY, HUDSON COUNTY, NJ	PREPARED BY: EC/PRM	DATE: 01/13/2015	DRAWING 1
	DRAFTED BY: PRM	SCALE: AS SHOWN	
	APPROVED BY: JS/JMN	PROJECT: 0220255G	

LEGEND

2015 BATHYMETRIC CONTOUR ELEVATION

7-A AS-BUILT LONG TERM MONITORING PLATE – YEAR 1

7-B AS-BUILT LONG TERM MONITORING PLATE – YEAR 5

NOTES:

1. TOPOGRAPHY: TOPOGRAPHIC ELEVATIONS ARE IN FEET AND ARE REFERENCED TO NATIONAL GEODETIC VERTICAL DATUM 1929 (NGVD 29) BASED ON BENCHMARK "PK-NAIL" WHICH HAS AN ELEVATION OF 6.94 FEET NORTH AMERICAN VERTICAL DATUM 1988 (NAVD 88) AS PROVIDED BY HONEYWELL. THE PLANE OF NGVD 29 IS 1.14 FEET BELOW THE PLANE OF NAVD 88 AT KEARNEY POINT, NEW JERSEY BASED ON NATIONAL GEODETIC SURVEY FIRST ORDER TIDAL BENCHMARK "W 16" WHICH HAS A PUBLISHED ELEVATION OF 17.00 FEET NAVD 88 AND 18.14 FEET NGVD 29.

2. BATHYMETRY: FOR THE BATHYMETRIC SURVEY, VERTICAL DATA WERE REFERENCED TO THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 29), AND HORIZONTAL COORDINATES WERE REFERENCED TO THE NORTH AMERICAN DATUM OF 1983 (NAD 83) USING THE NEW JERSEY STATE PLANE COORDINATE SYSTEM (NJ STATE PLANE). THE POSITIONING SYSTEM USED WAS AN RTK-DGPS SYSTEM WHICH WAS CHECKED AGAINST AN NGS BENCHMARK AND FOUND TO HAVE AN X,Y ACCURACY WITHIN 0.2 FEET. THE RTK ANTENNA WAS MOUNTED DIRECTLY ABOVE THE MULTIBEAM PROJECTOR TO ELIMINATE OFFSET ERRORS. DATA FROM THE MULTIBEAM SYSTEM WAS CORRECTED USING THE RESULTS OF A PATCH TEST TO ACCOUNT FOR ANY LATENCY, ROLL, PITCH, OR YAW ERRORS IN THE HARDWARE INSTALLATION. SPEED OF SOUND READINGS WERE TAKEN REAL-TIME AT THE MULTIBEAM PROJECTOR AND WATER COLUMN SOUND VELOCITY PROFILES WERE TAKEN BEFORE AND AFTER DATA COLLECTION AND CORRECTIONS ARE APPLIED IN POST-PROCESSING.

3. SURVEYED BATHYMETRIC CONTOURS WERE PROVIDED IN MLLW DATUM AND CONVERTED TO NGVD 29 DATUM BY PERFORMING AN ELEVATION ADJUSTMENT OF -1.94 FEET. THE ELEVATION ADJUSTMENT IS BASED ON THE DIFFERENCE IN ELEVATION DATUM BETWEEN MLLW AND NGVD 29 AS DOCUMENTED AT TIDAL BENCHMARK "W16".

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SITE LAYOUT BASED ON RIVERBED ELEVATIONS NORTHERN SITE, HONEYWELL SA7, SITE INVESTIGATION BY OCEAN SURVEYS, INC. HACKENSACK RIVER, JERSEY CITY, NJ OCTOBER 2007

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2015 BATHYMETRIC BASE MAP

RAMBOLL ENVIRON

HONEYWELL INTERNATIONAL, INC.
SA7 SEDIMENT REMEDIATION PROJECT
JERSEY CITY, HUDSON COUNTY, NJ

PREPARED BY: EC/PRM	DATE: 02/17/2016	DRAWING
DRAFTED BY: PRM	SCALE: AS SHOWN	2
APPROVED BY: JS/JMN	PROJECT: 0220255G	

CAP Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
1-1	6976.69	1.85
1-2	5003.24	0.00
2-1	6653.60	5.42
2-2	10161.98	5.37
2-3	8085.63	5.45
3-1	9888.19	0.67
3-2	9557.30	1.46
3-3	7791.11	4.80
4-1	5475.30	1.29
5-1	10624.57	3.90
5-2	10775.32	2.76
5-3	3612.18	2.99
5-4	10226.65	3.46
5-5	5756.84	5.01
6A-1	9898.13	2.23
6A-2	6360.60	6.12
6B-1	10675.93	2.90
6B-2	10485.00	3.15
6B-3	9456.90	3.17
7A-1	9296.32	0.94
7A-2	10643.50	3.82
7A-3	10650.17	2.19
7A-4	10764.85	4.33
7A-5	10209.86	3.95
7A-6	10132.28	3.32
7A-7	10491.91	3.06
7A-8	10752.96	4.34
7B-1	6072.73	5.51
7B-2	8466.24	1.48
7B-3	9143.45	1.92
7C-1	6453.66	2.61
7C-2	3978.43	0.05
7C-3	2919.59	3.49
8A-1	5321.93	4.60
8A-2	10168.12	6.88
8A-3	9889.20	5.66
8A-4	11039.19	5.07
8A-5	10569.88	6.36
8B-1	7513.52	2.79
8B-2	10605.66	4.91
9-1	6727.34	1.27
9-2	11389.60	3.32
9-3	7319.95	10.10
10-1	9785.14	4.84
10-2	7908.97	3.43
10-3	7171.59	3.50
10-4	6714.88	3.82

CAP Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
11A-1	9384.73	2.86
11A-2	6289.34	5.42
11B-1	10369.32	1.95
11B-2	9341.93	0.62
11B-3	10241.08	1.48
11B-4	8967.65	2.35
11B-5	7093.74	0.81
11B-6	10888.92	3.11
11B-7	10888.92	3.00
11B-8	10888.92	2.86
11B-9	10120.85	1.93
11B-10	9594.19	1.99
11B-11	8621.65	4.32
11B-12	10888.92	4.11
11B-13	10888.92	3.16
11B-14	10888.92	2.51
11B-15	10651.11	2.66
11B-16	10806.33	3.84
11B-17	8332.10	2.22
11C-1	9079.90	5.07
11C-2	10856.57	1.24
11C-3	10755.43	1.84
11C-4	7657.32	2.03
11C-5	7390.58	1.31
11C-6	841.71	3.08
11C-7	246.64	2.13
12-1	1790.47	5.51
13A-1	10884.68	5.93
13A-2	10710.96	2.33
13A-3	10764.41	2.65
13A-4	9293.67	2.26
13A-5	10888.92	2.03
13A-6	10888.92	3.74
13A-7	10861.99	6.19
13A-8	9641.56	2.40
13A-9	10812.64	3.37
13A-10	10323.22	2.94
13A-11	9740.43	4.43
13A-12	8438.85	3.32
13B-1	9217.30	2.59
13B-2	8462.51	0.98
13B-3	7976.22	1.52
13B-4	4814.42	3.32
13B-5	10721.25	5.32
14-1	10869.50	3.22
14-2	9740.21	2.14
14-3	10133.25	3.72
14-4	10013.68	2.54

CAP Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
15-1	7685.85	3.22
15-2	9968.47	3.29
15-3	10802.38	3.40
17A-1	9130.55	1.58
17A-2	10755.48	1.24
17A-3	10532.40	2.84
17A-4	10842.36	1.25
17A-5	10757.17	2.21
17A-6	10601.60	3.51
17A-7	10792.51	3.44
17A-8	6603.19	3.06
17A-9	10888.92	1.61
17A-10	10888.92	2.54
17A-11	10888.92	2.63
17A-12	4662.45	5.08
17A-13	9474.69	3.03
17A-14	6461.97	5.04
18A-1	9865.12	4.37
18A-2	8551.72	6.81
18A-3	9161.56	4.24
18A-4	9060.05	3.61
18A-5	9378.66	4.07
18A-6	10617.44	5.30
18A-7	10466.84	4.65
18A-8	10714.65	1.61
18A-9	10386.36	3.95
18A-10	8639.41	0.93
18A-11	10502.08	2.20
18B-1	6214.48	2.55
18B-2	2603.56	3.62
19A-1	9669.00	4.24
19A-2	10879.72	2.38
19A-3	7855.43	3.22
19A-4	5550.86	0.12
19B-1	10040.58	4.04
19B-2	8108.89	5.31
19B-3	5817.84	2.98
20-1	7071.05	2.43
20-2	9504.85	1.84
20-3	10011.35	2.46
20-4	10441.14	3.47
21-1	5754.80	3.37
21-2	5276.55	4.07
23-1	9961.66	2.80
23-2	10887.70	3.65
24-1	8939.90	5.58
24-2	3451.14	2.69

CAP Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
25-1	10886.41	3.31
25-2	10887.38	3.33
25-3	10834.03	3.36
25-4	10889.45	4.78
26-1	4491.28	4.52
26-2	4644.31	4.75
27-1	10145.65	3.94
27-2	9720.15	4.23
27-3	9556.33	3.68
27-4	10336.69	3.87
27-5	6606.32	5.39
29A-1	10340.97	2.53
29A-2	10751.43	4.20
29A-3	9766.71	6.42
29A-4	8156.62	7.63
29A-5	5649.17	2.84
29B-1	9404.02	3.66
29B-2	9200.77	4.41
29B-3	8906.93	1.69
29B-4	9288.71	1.39
29B-5	10888.31	2.29
29B-6	8260.06	4.60
29B-7	10126.47	1.49
29B-8	10586.06	3.41
29B-9	10678.16	2.68
29B-10	8540.15	1.25
29B-11	10650.20	1.73
29B-12	9738.45	2.63
30A-1	10837.09	3.34
30A-2	10175.73	3.36
30B-3	3431.11	4.82
30B-1	7786.37	2.53
30B-2	9544.75	3.94

MNR Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
1 MNR	6864.23	2.84
2 MNR	8090.02	4.05
3 MNR	6286.41	5.20
4 MNR	10694.97	3.47
5 MNR	9435.02	2.72
6 MNR	8461.53	3.53
7 MNR	8082.83	2.18
8 MNR	7968.10	2.11
9 MNR	8439.23	2.00
10 MNR	10515.53	3.43
11 MNR	8761.27	5.36
12 MNR	3658.42	1.04
13 MNR	10888.92	3.33
14 MNR	10888.92	3.01
15 MNR	10888.92	4.50
16 MNR	9349.09	5.52
17 MNR	10888.92	4.01
18 MNR	10888.92	3.62
19 MNR	10888.92	5.45
20 MNR	4241.70	2.23
21 MNR	9550.74	3.39
22 MNR	10888.92	3.71
23 MNR	10888.92	5.26
24 MNR	8875.36	6.22
25 MNR	10758.22	6.08
26 MNR	10888.92	6.90
27 MNR	10888.92	4.05
28 MNR	8127.54	2.70
29 MNR	8536.80	4.18
30 MNR	10888.92	4.82
31 MNR	10770.70	5.95
32 MNR	10888.92	7.62
33 MNR	8956.79	4.42
34 MNR	9163.43	7.62
35 MNR	10202.12	3.06
36 MNR	10722.76	3.65
37 MNR	7542.29	3.41
38 MNR	10348.98	4.34
39 MNR	8256.15	4.22
40 MNR	11966.63	3.29
41 MNR	4305.33	0.52
42 MNR	8506.57	3.21
43 MNR	10376.52	0.15
44 MNR	10887.46	2.49
45 MNR	10888.92	2.44
46 MNR	6762.11	2.80
47 MNR	7194.82	5.79

MNR Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
48 MNR	7375.15	3.31
49 MNR	7950.86	1.31
50 MNR	5884.05	6.32
51 MNR	8864.18	5.59
52 MNR	10687.55	7.65
53 MNR	10934.77	8.18
54 MNR	10972.97	3.91
55 MNR	10189.85	3.28
56 MNR	8762.19	4.46
57 MNR	8673.42	5.07
58 MNR	7469.82	3.32
59 MNR	5102.26	2.29
60 MNR	6984.14	5.82
61 MNR	8839.43	3.21
62 MNR	7126.33	11.59
63 MNR	5303.98	3.94
64 MNR	7225.37	3.78
65 MNR	6904.12	1.83
66 MNR	10458.39	3.11
67 MNR	10595.07	4.93
68 MNR	10752.68	9.52
69 MNR	10888.92	9.08
70 MNR	6051.29	7.85
71 MNR	10588.92	0.61
72 MNR	10476.67	-2.88
73 MNR	5760.04	5.21
74 MNR	7984.39	0.11
75 MNR	7984.39	0.11
76 MNR	10812.61	7.10
77 MNR	10888.92	7.96
78 MNR	10888.92	8.16
79 MNR	10888.92	6.23
80 MNR	10877.93	4.68
81 MNR	10391.12	4.40
82 MNR	10888.92	5.56
83 MNR	10888.92	5.68
84 MNR	9159.44	4.77
85 MNR	11298.49	2.95
86 MNR	10888.92	3.41
87 MNR	10888.92	4.72
88 MNR	12560.30	4.11
89 MNR	10763.67	4.78
90 MNR	7000.50	0.17
91 MNR	10550.75	0.01
92 MNR	5625.47	6.09
93 MNR	6936.04	3.29
94 MNR	2979.13	3.33

MNR Areas		
Grid Name	Grid Area (square feet)	Net Cut/Fill (inches)
95 MNR	8930.48	5.15
96 MNR	10888.92	3.74
97 MNR	6487.33	1.79
98 MNR	7613.48	5.23
99 MNR	9911.58	7.75
100 MNR	10888.92	4.42
101 MNR	10888.92	3.42
102 MNR	10888.92	2.71
103 MNR	10855.85	1.91
104 MNR	5961.38	1.65
105 MNR	10330.10	6.09
106 MNR	10888.92	4.51
107 MNR	10888.92	3.24
108 MNR	10888.92	2.33
109 MNR	3734.59	3.18
110 MNR	1869.89	4.37
111 MNR	2054.66	4.70
112 MNR	9710.16	5.21
113 MNR	10888.92	4.01
114 MNR	10146.85	2.98
115 MNR	9847.77	3.35
116 MNR	6387.47	3.30
117 MNR	5917.00	1.67
118 MNR	8104.49	2.01
119 MNR	10427.64	2.57
120 MNR	7942.80	2.82
121 MNR	6617.54	2.69
122 MNR	9677.65	4.00
123 MNR	7563.36	4.41
124 MNR	9749.27	2.52
125 MNR	10828.50	3.14
126 MNR	10423.30	2.91
127 MNR	10888.92	4.10
128 MNR	10345.18	4.35
129 MNR	7899.39	4.96
130 MNR	10270.15	4.51
131 MNR	7194.11	5.15
132 MNR	8898.16	4.59
133 MNR	9340.87	5.65
134 MNR	10888.92	3.79
135 MNR	7852.83	4.09
136 MNR	10362.04	4.29
137 MNR	10594.41	6.10
138 MNR	10886.66	6.14
139 MNR	8141.32	4.51
140 MNR	8827.27	4.75
141 MNR	10511.70	6.04

LEGEND

NET CUT OVER GRID

NET FILL OVER GRID

NOTES:

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5. GRID LAYOUT FOR CAP AREAS MAINTAINS SUBDIVISIONS WITHIN AREA (EG., 13A AND 13B.

SOURCES:

SITE LAYOUT BASED ON RIVERBED ELEVATIONS NORTHERN SITE, HONEYWELL SA7, SITE INVESTIGATION BY OCEAN SURVEYS, INC. HACKENSACK RIVER, JERSEY CITY, NJ OCTOBER 2007

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200 0 200 400 600

Scale in Feet

DRAFT

BATHYMETRIC COMPARISON
2014 - 2015

RAMBOLL ENVIRON

HONEYWELL INTERNATIONAL, INC.
SA7 SEDIMENT REMEDIATION PROJECT
JERSEY CITY, HUDSON COUNTY, NJ

PREPARED BY: EC/PRM	DATE: 02/17/2016	DRAWING
DRAFTED BY: PRM	SCALE: AS SHOWN	3
APPROVED BY: JS/JMN	PROJECT: 0220255G	

APPENDIX D
Sediment Profile Imaging Report

December 2015

Sediment Profile Imaging Report

Sediment Profile Imaging Survey of the Hackensack River Near Honeywell Study Area 7

Prepared for

Aqua Survey, Inc.
469 Point Breeze Rd.
Flemington, NJ 08822

Prepared by

Germano & Associates, Inc.
12100 SE 46th Place
Bellevue, WA 98006

Sediment Profile Imaging Report

SEDIMENT PROFILE IMAGING SURVEY OF THE HACKENSACK RIVER NEAR HONEYWELL STUDY AREA 7

Prepared for

Aqua Survey, Inc.
469 Point Breeze Rd.
Flemington, NJ 08822

Purchase Order TD101515

Prepared by

Germano & Associates, Inc.
12100 SE 46th Place
Bellevue, WA 98006

December, 2015

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LIST OF FIGURES

1.0
INTRODUCTION

Under contract to Aqua Survey Inc (ASI) of Flemington, NJ, Germano & Associates, Inc. (G&A) performed a Sediment Profile Imaging (SPI) survey in the lower Hackensack River in the vicinity of the former Honeywell facility. This area (formerly known as Study Area 7) was surveyed extensively with SPI technology almost 10 years ago (October 2006); at that time, 162 stations were surveyed in Droyers Cove as well as the area immediately to the Study Area 7 site, and the cove just north of the site beyond the abandoned trestle piers (G&A 2006). Following shoreline restoration of the former Honewell facility, a follow-up survey was conducted in October, 2014, at 10 stations (NewFields, 2014) as part of the "Year 1 Monitoring Program." These same 10 stations were surveyed once more in 2015 to assess seafloor conditions in the vicinity of the remediation site.

2.0 MATERIALS AND METHODS

On November 2, 2015, scientists from G&A and ASI collected sediment profile images at ten stations in the lower Hackensack River (Figure 1); these are the same 10 stations that were sampled the previous year by NewFields (2014). ASI provided the sampling platform and navigation services for station positioning aboard the *R/V Tesla*. An Ocean Imaging Systems Model 3731 sediment profile camera was used for this survey; a total of 51 sediment profile images were collected during the course of the day.

SPI was developed more than three decades ago as a rapid reconnaissance tool for characterizing physical, chemical, and biological seafloor processes and has been used in numerous seafloor surveys throughout North America, Asia, Europe, and Africa (Germano et al. 2011; Rhoads and Germano 1982, 1986, 1990; Revelas et al. 1987; Diaz and Schaffner, 1988; Valente et al. 1992). The sediment profile camera works like an inverted periscope. A Nikon D7100 24.2-megapixel SLR camera with two 32-gigabyte secure digital (SD) memory cards is mounted horizontally inside a watertight housing on top of a wedge-shaped prism. The prism has a Plexiglas® faceplate at the front with a mirror placed at a 45° angle at the back. The camera lens looks down at the mirror, which is reflecting the image from the faceplate. The prism has an internal strobe mounted inside at the back of the wedge to provide illumination for the image; this chamber is filled with distilled water, so the camera always has an optically clear path. This wedge assembly is mounted on a moveable carriage within a stainless steel frame. The frame is lowered to the seafloor on a winch wire, and the tension on the wire keeps the prism in its "up" position. When the frame comes to rest on the seafloor, the winch wire goes slack and the camera prism descends into the sediment at a slow, controlled rate by the dampening action of a hydraulic piston so as not to disturb the sediment-water interface. On the way down, it trips a trigger that activates a time-delay circuit of variable length (operator-selected) to allow the camera to penetrate the seafloor before any image is taken (Figure 2). The knife-sharp edge of the prism transects the sediment, and the prism penetrates the bottom. The strobe is discharged after an appropriate time delay to obtain a cross-sectional image of the upper 20 cm of the sediment column. The resulting images give the viewer the same perspective as looking through the side of an aquarium half-filled with sediment. After the first image is obtained at the first location, the camera is then raised up about 2 to 3 meters off the bottom to allow the strobe to recharge; a wiper blade mounted on the frame removes any mud adhering to the faceplate. The strobe recharges within 5 seconds, and the camera is ready to be lowered again for a replicate image. Surveys can be accomplished rapidly by "pogo-sticking" the camera across an area of seafloor while recording positional fixes on the surface vessel.

Two types of adjustments to the SPI system are typically made in the field: physical adjustments to the chassis stop collars or adding/subtracting lead weights to the chassis to control penetration in harder or softer sediments, and electronic software adjustments to the Nikon D7100 to control camera settings. Camera settings (f-stop, shutter speed, ISO equivalents, digital file format, color balance, etc.) are selectable through a water-tight USB port on the camera housing and Nikon Control Pro® software. At the beginning of the survey, the time on the sediment profile camera's internal data logger was synchronized with the internal clock on the computerized navigation system to local time. Details of the camera settings for each digital image are available in the associated parameters file embedded in the electronic image file; for this survey, the ISO-equivalent was set at 640. The additional camera settings used were as follows: shutter speed was 1/250, f9, white balance set to flash, color mode to Adobe RGB, sharpening to none, noise reduction off, and storage in compressed raw Nikon Electronic Format (NEF) files (approximately 30 MB each). Electronic files were converted to high-resolution jpeg (8-bit) format files prior to analysis using Nikon Capture NX2® software (Version 2.2.7).

Four replicate images were taken at each station; each SPI replicate is identified by the time recorded on the digital image file in the camera and on disk along with vessel position on the navigation computer. The unique time stamp on the digital image was then cross-checked with the time stamp in the navigational system's computer data file. The field crew kept redundant written sample logs. Images were downloaded periodically (sometimes after each station) to verify successful sample acquisition or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were re-named with the appropriate station name immediately after downloading on deck as a further quality assurance step.

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of each survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. A spare camera and charged battery were carried in the field at all times to insure uninterrupted sample acquisition. After deployment of the camera at each station, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth. If images were missed (frame counter indicator or verification from digital download) or the penetration depth was insufficient (penetration indicator), chassis stops were adjusted and/or weights were added or removed, and additional replicate images were taken. Changes in prism weight amounts, the presence or absence of mud doors, and chassis stop positions were recorded for each replicate image. Images were inspected periodically during the survey to determine whether any stations needed resampling with different stop collar or weight settings.

Following completion of the field operations, the raw NEF image files were converted to high-resolution Joint Photographic Experts Group (jpeg) format files using the minimal amount of image file compression. Once converted to jpeg format, the intensity histogram (RGB channel) for each image was adjusted in Adobe Photoshop® to maximize contrast without distortion. The jpeg images were then imported to Sigmascan Pro® (Aspire Software International) for image calibration and analysis. Calibration information was determined by measuring 1-cm gradations from the Kodak® Color Separation Guide. This calibration information was applied to all SPI images analyzed. Linear and area measurements were recorded as number of pixels and converted to scientific units using the calibration information.

Measured parameters were recorded on a Microsoft® Excel© spreadsheet. G&A's senior scientist (Dr. J. Germano) subsequently checked all these data as an independent quality assurance/quality control review of the measurements before final interpretation was performed.

2.1 MEASURING, INTERPRETING, AND MAPPING SPI PARAMETERS

2.1.1 Sediment Type

The sediment grain-size major mode and range were visually estimated from the color images by overlaying a grain-size comparator that was at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) with the SPI camera. Seven grain-size classes were on this comparator: >4 ϕ (silt-clay), 4-3 ϕ (very fine sand), 3-2 ϕ (fine sand), 2-1 ϕ (medium sand), 1-0 ϕ (coarse sand), 0 - (-1) ϕ (very coarse sand), < -1 ϕ (granule and larger). The lower limit of optical resolution of the photographic system was about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt ($\geq$ 4 ϕ). The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (Germano et al. 2011).

The comparison of the SPI images with Udden-Wentworth sediment standards photographed through the SPI optical system was also used to map near-surface stratigraphy such as sand-over-mud and mud-over-sand. When mapped on a local scale, this stratigraphy can provide information on relative transport magnitude and frequency.

2.1.2 Prism Penetration Depth

The SPI prism penetration depth was measured from the bottom of the image to the sediment-water interface. The area of the entire cross-sectional sedimentary portion of the image was digitized, and this number was divided by the calibrated linear width of the image to determine the average penetration depth. Linear maximum and minimum depths of penetration were also measured. All three measurements (maximum, minimum, and average penetration depths) were recorded in the data file.

Prism penetration is a noteworthy parameter; if the number of weights used in the camera is held constant throughout a survey, the camera functions as a static-load penetrometer. Comparative penetration values from sites of similar grain size give an indication of the relative water content of the sediment. Highly bioturbated sediments and rapidly accumulating sediments tend to have the highest water contents and greatest prism penetration depths.

The depth of penetration also reflects the bearing capacity and shear strength of the sediments. Overconsolidated or relic sediments and shell-bearing sands resist camera penetration. Highly bioturbated, sulfitic, or methanogenic muds are the least consolidated, and deep penetration is typical. Seasonal changes in camera prism penetration have been observed at the same station in other studies and are related to the control of sediment geotechnical properties by bioturbation (Rhoads and Boyer 1982). The effect of water temperature on bioturbation rates appears to be important in controlling both biogenic surface relief and prism penetration depth (Rhoads and Germano 1982).

2.1.3 Small-Scale Surface Boundary Roughness

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

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

2.1.4 Thickness of Depositional Layers

Because of the camera's unique design, SPI can be used to detect the thickness of depositional and dredged material layers. SPI is effective in measuring layers ranging in thickness from 1 mm to 20 cm (the height of the SPI optical window). During image analysis, the thickness of the newly deposited sedimentary layers can be determined by measuring the distance between the pre- and post-disposal sediment-water interface. Recently deposited material is usually evident because of its unique optical reflectance and/or color relative to the underlying material representing the pre-disposal surface. Also, in most cases, the point of contact between the two layers is clearly visible as a textural change in sediment composition, facilitating measurement of the thickness of the newly deposited layer.

2.1.5 Mud Clasts

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity, e.g., decapod foraging, intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in SPI images. During analysis, the number of clasts was counted, the diameter of a typical clast was measured, and their oxidation state was assessed. The abundance, distribution, oxidation state, and angularity of mud clasts can be used to make inferences about the recent pattern of seafloor disturbance in an area.

Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. In SPI images, the oxidation state is apparent from the reflectance; see Section 2.1.6. Also, once at the sediment-water interface, these mud clasts are subject to bottom-water oxygen concentrations and currents. Evidence from laboratory microcosm observations of reduced sediments placed within an aerobic environment indicates that oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6 to 12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of the mud clasts are also revealing; some clasts seen in the profile images are artifacts caused by the camera deployment (mud clots falling off the back of the prism or the wiper blade). Naturally-occurring mud clasts may be moved and broken by bottom currents and animals (macro- or meiofauna; Germano 1983). Over time, these naturally-occurring, large angular clasts become small and rounded.

2.1.6 Apparent Redox Potential Discontinuity Depth

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

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

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated porewaters must be considered with caution. The actual RPD is the boundary or horizon that separates the positive Eh region of the sediment column from the underlying negative Eh region. The exact location of this Eh = 0 boundary can be determined accurately only with microelectrodes; hence, the relationship between the change in optical reflectance, as imaged with the SPI camera, and the actual RPD can be determined only by making the appropriate *in situ* Eh measurements. For this reason, the optical reflectance boundary, as imaged, was described in this study as the "apparent" RPD and it was mapped as a mean value. In general, the depth of the actual Eh = 0 horizon will be either equal to or slightly shallower than the depth of the optical reflectance boundary (Rosenberg et al., 2001). This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the Eh = 0 horizon. As a result, the mean aRPD depth can be used as an estimate of the depth of porewater exchange, usually through porewater irrigation (bioturbation). Biogenic particle mixing depths can be estimated by measuring the maximum and minimum depths of imaged feeding voids in the sediment column. This parameter represents the particle mixing depths of head-down feeders, mainly polychaetes.

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

The mean aRPD depth also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This scouring can wash away fines and shell or gravel lag deposits, and can result in very thin surface oxidized layer. During storm periods, erosion may completely remove any evidence of the aRPD (Fredette et al. 1988).

Another important characteristic of the aRPD is the contrast in reflectance at this boundary. This contrast is related to the interactions among the degree of organic loading, the bioturbation activity in the sediment, and the concentrations of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase SOD and, subsequently, sulfate reduction rates and the associated abundance of sulfide end products. This results in more highly reduced, lower-reflectance sediments at depth and higher aRPD contrasts. In a region of generally low aRPD contrasts, images with high aRPD contrasts indicate localized sites of relatively large inputs of organic-rich material such as phytoplankton, other naturally-occurring organic detritus, dredged material, or sewage sludge.

Because the determination of the aRPD requires discrimination of optical contrast between oxidized and reduced particles, it is difficult, if not impossible, to determine the depth of the aRPD in well-sorted sands of any size that have little to no silt or organic matter in them (Painter et al, 2007). When using SPI technology on sand bottoms, little information other than grain-size, prism penetration depth, and boundary roughness values can be measured; while oxygen has no doubt penetrated the sand beneath the sediment-water interface just due to physical forcing factors acting on surface roughness elements (Ziebis et al., 1996; Huettel et al., 1998), estimates of the mean aRPD depths in these types of sediments are indeterminate with conventional white light photography.

2.1.7 Sedimentary Methane

If organic loading is extremely high, porewater sulfate is depleted and methanogenesis occurs. The process of methanogenesis is indicated by the appearance of methane bubbles in the sediment column, and the number and total area covered by all methane pockets is measured. These gas-filled voids are readily discernable in SPI images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas bubble).

2.1.8 Infaunal Successional Stage

The mapping of infaunal successional stages is readily accomplished with SPI technology. These stages are recognized in SPI images by the presence of dense assemblages of near-surface polychaetes and/or the presence of subsurface feeding voids; both may be present in the same image. Mapping of successional stages is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest..., our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is presented in Pearson and Rosenberg (1978) and further developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

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

After an area of bottom is disturbed by natural or anthropogenic events, the first invertebrate assemblage (Stage 1) appears within days after the disturbance. Stage 1 consists of assemblages of tiny tube-dwelling marine polychaetes that reach population densities of 10^4 to 10^6 individuals per m². These animals feed at or near the sediment-water interface and physically stabilize or bind the sediment surface by producing a mucous "glue" that they use to build their tubes. Sometimes deposited dredged material layers contain Stage 1 tubes still attached to mud clasts from their location of origin; these transported individuals are considered as part of the *in situ* fauna in our assignment of successional stages.

If there are no repeated disturbances to the newly colonized area, then these initial tube-dwelling suspension or surface-deposit feeding taxa are followed by burrowing, head-down deposit-feeders that rework the sediment deeper and deeper over time and mix oxygen from the overlying water into the sediment. The animals in these later-appearing communities (Stage 2 or 3) are larger, have lower overall population densities (10 to 100 individuals per m²), and can rework the sediments to depths of 3 to 20 cm or more. These animals "loosen" the sedimentary fabric, increase the water content in the sediment, thereby lowering the sediment shear strength, and actively recycle nutrients because of the high exchange rate with the overlying waters resulting from their burrowing and feeding activities.

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

While the successional dynamics of invertebrate communities in fine-grained sediments have been well-documented, the successional dynamics of invertebrate communities in sand and coarser sediments are not well-known. Subsequently, the insights gained from sediment profile imaging technology regarding biological community structure and dynamics in sandy and coarse-grained bottoms are fairly limited.

2.1.9 Biological Mixing Depth

During the past two decades, there has been a considerable emphasis on studying the effects of bioturbation on sediment geotechnical properties as well as sediment diagenesis (Ekman et al., 1981; Nowell et al., 1981; Rhoads and Boyer, 1982; Grant et al., 1982; Boudreau, 1986; 1994; 1998). However, an increasing focus of research is centering on the rates of contaminant flux in sediments (Reible and Thibodeaux, 1999; François et al., 2002; Gilbert et al., 2003), and the two parameters that affect the time rate of contaminant flux the greatest are erosion and bioturbation (Reible and Thibodeaux, 1999). The depth to which sediments are bioturbated, or the biological mixing depth, can be an important parameter for studying either nutrient or contaminant flux in sediments. While the apparent RPD is one potential measure of biological mixing depth, it is quite common in profile images to see evidence of biological activity (burrows, voids, or actual animals) well below the mean apparent RPD. Both the minimum and maximum linear distance from the sediment surface to both the shallowest and deepest feature of biological activity can be measured along with a notation of the type of biogenic structure measured. From these, either the minimum, maximum, or average biological mixing depth can be mapped across a surveyed area of interest.

2.2 USING SPI DATA TO ASSESS BENTHIC QUALITY & HABITAT CONDITIONS

While various measurements of water quality such as dissolved oxygen, contaminants, or nutrients are often used to assess regional ecological quality, interpretation is difficult because of the transient nature of water-column phenomena. Measurement of a particular value of any water-column variable represents an instantaneous “snapshot” that can change within minutes after the measurement is taken. By the time an adverse signal in the water column such as a low dissolved oxygen concentration is persistent, the system may have degraded to the point where resource managers can do little but map the spatial extent of the phenomenon while gaining a minimal understanding of factors contributing to the overall degradation.

The seafloor, on the other hand, is a long-term time integrator of sediment and overlying water quality; values for any variable measured are the result of physical, chemical, and biological interactions on time scales much longer than those present in a rapidly moving fluid. The seafloor is thus an excellent indicator of environmental quality, both in terms of historical impacts and of future trends for any particular variable.

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

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

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

The metabolic energy expended in bioturbation is rewarded by creating a sedimentary environment where refractory organic matter is converted to usable food. Stage 3 bioturbation has been likened to processes such as stirring and aeration used in tertiary sewage treatment plants to accelerate organic decomposition. These processes can be interpreted as a form of human bioturbation. Physical disturbance, contaminant loading, and/or over-enrichment result in habitat destruction and in local extinction of the climax seres. Loss of Stage 3 species results in the loss of sediment stirring and aeration and may be followed by a buildup of organic matter (sediment eutrophication). Because Stage 3 species tend to have relatively conservative rates of recruitment, intrinsic population increase, and ontogenetic growth, they may not reappear for several years once they are excluded from an area.

The presence of Stage 1 seres (in the absence of Stage 3 seres) can indicate that the bottom is an advanced state of organic enrichment, has received high contaminant loading, or experienced a substantial physical disturbance. Unlike Stage 3 communities, Stage 1 seres have a relatively high tolerance for organic enrichment and contaminants. These opportunistic species have high rates of recruitment, high ontogenetic growth rates, and live and feed near the sediment-water interface, typically in high densities. Stage 1 seres often co-occur with Stage 3 seres in marginally enriched areas. In this case, Stage 1 seres feed on labile organic detritus settling onto the sediment surface, while the subsurface Stage 3 seres tend to specialize on the more refractory buried organic reservoir of detritus.

Stage 1 and 3 seres have dramatically different effects on the geotechnical properties of the sediment (Rhoads and Boyer 1982). With their high population densities and their feeding efforts concentrated at or near the sediment-water interface, Stage 1 communities tend to bind fine-grained sediments physically, making them less susceptible to resuspension and transport. Just as a thick cover of grass will prevent erosion on a terrestrial hillside, so too will these dense assemblages of tiny polychaetes serve to stabilize the sediment surface. Conversely, Stage 3 taxa increase the water content of the sediment and lower its shear strength through their deep burrowing and pumping activities, rendering the bottom more susceptible to erosion and resuspension. In shallow areas of fine-grained sediments that are susceptible to storm-induced or wave orbital energy, it is quite possible for Stage 3 taxa to be carried along in the water column in suspension with fluid muds. When redeposition occurs, these Stage 3 taxa can become quickly re-established in an otherwise physically disturbed surface sedimentary fabric.

SPI has been shown to be a powerful reconnaissance tool that can efficiently map gradients in sediment type, biological communities, or disturbances from physical forces or organic enrichment. The conclusions reached at the end of this report are about dynamic processes that have been deduced from imaged structures; as such, they should be considered hypotheses available for further testing/confirmation. By employing Occam's Razor, we feel reasonably assured that the most parsimonious explanation is usually the one borne out by subsequent data confirmation.

3.0
RESULTS

A complete set of all the summary data measured from each image is presented in Appendix A. Copies of all digital image files collected were transferred to a DVD and sent to ASI in a separate mailing from this report.

Parameters such as boundary roughness and mud clast data (number, size) provide supplemental information pertaining to the physical regime and bottom sediment transport activity at a site. Even though mud clasts are definitive characteristics whose presence can indicate physical disturbance of some form, the mud clasts noted in the images from this survey were mainly artifacts due to sampling (mud clumps clinging to the frame base) and not indicative of physical disturbance or sediment transport activities. Therefore, mud clast data were not used as individual parameters for interpretation.

The results for some SPI parameters are sometimes indicated in the data appendix or on the maps as being "Indeterminate" (Ind). This is a result of the sediments being either: 1) too compact for the profile camera to penetrate adequately, preventing observation of surface or subsurface sediment features, 2) too soft to bear the weight of the camera, resulting in over-penetration to the point where the sediment/water interface was above the window (imaging area) on the camera prism (the sediment/water interface must be visible to measure most of the key SPI parameters like aRPD depth, penetration depth, and infaunal successional stage), or 3) the sediment consisted of light-colored sand lacking a visible aRPD contrast and for which infaunal successional dynamics, generally speaking, are not well-known.

3.1 GRAIN SIZE

The sediments throughout the area surveyed were primarily fine-grained, with silt-clay being the dominant major mode at 8 of the 10 stations surveyed (Figure 4) with varying minor fractions of very fine to fine sand (Figure 5). Stations 2 and 7 (Figure 6) had a major mode of fine sand (3-2 phi) with a significant fraction of silt-clay mixed in.

3.2 PRISM PENETRATION DEPTH

With the exception of one station (Station 6; see Appendix A), the stops and weights used in the camera frame were constant, so the variation in prism penetration was a good indicator of relative sediment shear strength. The average prism penetration depth at the stations in the study area ranged from 3.2 cm (Station 2 with a higher sand fraction and pebbles on the surface; Figure 7) to 20.5 cm (Station 3), with an overall site average penetration of 13.0 cm; the spatial distribution of mean penetration depth at all stations sampled is shown in Figure .

3.3 Surface Boundary Roughness

Surface boundary roughness ranged from 0.51 to 1.78 cm (Figure 9), with an overall site average station boundary roughness values of 0.94 cm. The small scale topography seen in all of the images except for those at Station 2 (Figure 7) were biogenic in origin and due to fecal mounds or burrow openings caused by infaunal activities (Figure 10).

3.4 Bottom Kinetics & Depositional Layers

The profile pictures from Stations 4, 5, 6, and 10 showed depositional intervals ranging in size from approximately 6 – 12 cm in the cross-sectional images (Figure 11); the contact horizon with the buried lighter layer indicates where the former sediment surface was at some point within the past year. This quantum input of sediment was most likely the results of a heavy sediment load being carried by the river during a major storm event.

3.5 Apparent Redox Potential Discontinuity Depth

The distribution of mean apparent RPD depths is shown in Figure 12; the average station mean apparent RPD depths ranged from 0.91 – 4.56 cm, with an overall site average of 2.18 cm. The two lowest values encountered were found at Stations 1 and 7 (Figure 12; Appendix A); Station 7 is located near a storm water discharge outlet.

3.6 Sediment Methane

Evidence of subsurface methane was found at only 3 of the 10 locations surveyed (Figure 13). Despite methane being present at a third of the stations sampled, there was no evidence of extremely reduced (low albedo) subsurface sediments at any of the locations that would have indicated an over-enrichment of organic carbon. Figure 14 shows a profile image with subsurface methane being generated in addition to having a well-developed surface oxidized layer and subsurface deposit feeders present.

3.7 Infaunal Successional Stage

The mapped distribution of infaunal successional stages is shown in Figure 15. With the exception of Station 7 (located near the storm water discharge outlet), evidence of subsurface deposit feeders were found in at least one or more images at every station surveyed.

3.8 BIOLOGICAL MIXING DEPTH

While evidence of Stage 3 deposit-feeding taxa was found in most of the images (Figure 15) mainly in the form of transected burrows, active feeding voids (Figure 14) indicating the depth to which particles were being actively advected were present at six of the ten stations surveyed (Figure 16). The average station depth at which feeding voids were found ranged from 3.68 – 11.85 cm. Of the four stations (Stations 2, 7, 8, and 9) where active feeding voids were not seen in any of the analyzed replicate images, only one of them (Station 7) did not have evidence of Stage 3 taxa.

4.0
DISCUSSION

The Year 1 Monitoring performed in October, 2014 showed most of the 10 stations having silt-clay sediments with aRPD depths varying from 0.72 -5.77 cm (NewFields, 2014). The prevalence of Stage 3 assemblages at the majority of stations and well-developed aRPD depths suggested that sufficient time had passed since initial site restoration efforts so that successful infaunal recolonization had occurred at the majority of locations by the time of the Year 1 monitoring event (NewFields, 2014).

Comparing the results from the 2015 survey to both the general site characteristics mapped in October 2006 (Germano & Associates, 2006) and in the Year 1 monitoring effort carried out in 2014 (NewFields, 2014), it is not surprising some general characteristics of the area remained constant: the sediment grain-size and deposition patterns reflected the physical setting of the site; both river and tidally-driven currents are the main determining force for subtidal sediment major-mode and range. Periodic storms will always carry high sediment loads in the river from watershed run-off and result in quantum depositional intervals near the mouth of the river, as recent historical evidence showed at some of the sampling locations (Figure 11).

In order to do a more detailed comparison of the Year 1 results (NewFields, 2014) with this year's efforts, both the original images and data (both SPI image analysis results and navigation log fixes) from the 2014 survey were obtained. Even though the same stations were sampled, we needed to first calculate the distance between replicate imaging locations between years and compare that to the distance between replicate images within stations in order to see if the spatial variability between years was on the same scale as within year. Across all stations, the intra-station distances had the following ranges (Figure 17):

- between 0.4 ft and 32 ft apart (the maximum occurred at Station 06) in 2014;
- between 0.3 ft and 6 ft apart (the maximum occurred at Station 04) in 2015.

Using the average of northing and easting values among replicate image navigational fixes to represent each station's position, distances between stations' annual positions were calculated. Nine out of ten of these station centroids were within 12 and 30 feet between the two years; the maximum occurred at Station 03 with 99 feet between the two years (Figure 17). Most of the stations were closely co-located, both within and between years, with just a few exceptions.

An initial comparison between the two years' data was carried out for the following parameters: aRPD depth, successional stage rank, methane presence/absence, and sediment grain-size major mode. After we made the first comparison of the two data sets, there were four stations (Stations 3, 5, 6, and 10) that stood out because of substantial changes in aRPD depth. To verify the initial measurements for aRPD depths from 2014 were accurate, the images from those four stations were re-analyzed so that an equivalent comparison could be carried out. The re-analysis produced the following results (Table 1):

Table 1. Depth of aRPD (cm) at stations showing the largest change between 2014 & 2015.

Station/Rep	Newfields 2014	2015 Verification Assessment
3-D	4.27	Agree – close enough
3-E	4.33	3.12
3-G	5.77	Agree – close enough
5-A	3.96	3.43
5-C	3.57	2.13
5-D	2.82	1.81
6-B	2.58	2.81
6-C	2.05	Indeterminate (photo is too disturbed to get an accurate measurement)
6-D	5.36	5.06
10-A	4.85	3.31
10-B	3.29	3.01
10-C	2.97	2.25

NewFields' analyst had a tendency to "overmeasure" the aRPD depth because he/she was incorporating some of the smear of oxidized surface sediment that occurs during prism penetration into the aRPD measurement. These revised numbers were used for the final comparison of results between the two years (Table 2).

Table 2. Station Results from the two Survey Years

Station	aRPD 2014	aRPD 2015	aRPD Change[1]	SS Rank 2014	SS Rank 2015	SS Rank Change[1]	Methane 2014	Methane 2015	Grain Size Major Mode 2014	Grain Size Major Mode 2015
01	1.52	1.07	-0.45	3	3	0	Yes	Yes	> 4	>4
02	2.78	2.88	0.1	1	3	2	No	No	4 to 3	3 to 2
03[2]	4.39	2.98	-1.41	3	3	0	Yes	No	> 4	>4
04	1.6	1.31	-0.29	3	3	0	No	Yes	> 4	>4
05[3]	2.46	2.41	-0.05	3	3	0	No	No	> 4	>4
06[3]	3.94	4.56	0.62	3	3	0	Yes	No	> 4	>4
07[3]	1.17	0.91	-0.26	2	1.5	-0.5	No	Yes	4 to 3	3 to 2
08	1.73	1.57	-0.16	3	2.5	-0.5	No	No	> 4	>4
09	2.63	2.11	-0.52	2	2.5	0.5	No	No	> 4	>4
10	2.86	2.01	-0.85	3	3	0	No	No	> 4	>4

Declined	Apparent decline in conditions over time
Improved	Apparent improvement in conditions over time

[1] Change calculated as the 2015 result minus the 2014 result, so a negative value is a decrease over time.
[2] A distance of 99 feet between station centroids for the two years – cannot attribute differences to temporal shift.
[3] Maximum distance among reps was 17 feet or greater (always in 2014).

Summary of the biggest Station Changes

- Station 07
  - lowest aRPD in both years;
  - successional stage dropped from stage 2 to 1→2;
  - Methane appeared in 2015 (absent in 2014);
  - got slightly coarser over time (4 to 3 phi in 2014; 3 to 2 phi in 2015);
  - Relatively low station fidelity in 2014 (Rep C was as much as 18 feet from the other reps; greater than the distance between station centroids, 14 feet).
  - Consistent relatively poor results in both years.
- Station 06
  - Maximum aRPD in 2015 and was most improved (aRPD increased 0.6 cm);
  - Successional stage was stage 3 or equivalent in all reps in both years;
  - Methane absent in 2015 (was present in 2014);
  - Low station fidelity in 2014 (Rep D was as much as 32 feet from the other reps; much greater than the distance between station centroids, 12 feet);
- Station 03
  - Maximum aRPD in 2014, showed the greatest decline in aRPD (1.4 cm);
  - Successional stage was stage 3 or equivalent in 5 out of 6 reps across both years;
  - Methane disappeared between 2015 and 2014;
  - Lowest station relocation between the two years (99 feet between station centroids; all reps within 5 feet for each year); 2015 locations were to the NE of the 2014 locations.

Methane

Table 3. Contingency table showing presence/absence of Methane by year.

	2015 Methane		
2014 Methane	**No**	**Yes**	**Total # Stns**
No	5	2 (Stations 04 and 07)	7
Yes	2 (Stations 03 and 06)	1	3
Total # Stns	7	3	10

The same number of stations (3) were reported with some methane in each of the two surveys, but the stations were not the same each year.

- The two stations that had no methane in 2014 but had methane in 2015 were Stations 04 (methane observed at two out of the three reps) and 07 (methane present at one rep).

- The two stations that had methane in 2014 but NOT in 2015 were Stations 03 and 06.
- Station 01 was the only station with methane present in both years.

Grain Size Major Mode

Table 4. Contingency table showing the number of stations in each grain size major mode category.

2014 Grain Size Major Mode	2015 Grain Size Major Mode: > 4 phi	2015 Grain Size Major Mode: 3 to 2 phi	Total # Stns
> 4 phi	8	0	8
4 to 3 phi	0	2 (Stations 02 and 07)	2
Total # Stns	8	2	10

The two stations that were coarse in 2014 (4 to 3 phi) and got coarser in 2015 (3 to 2 phi) were Stations 02 and 07.

Sucessional Stage

Table 5. Contingency table showing the number of stations in each Successional stage rank category (Stage 3 is all Stage 3 equivalents).

2014 Successional Stage	2015 Successional Stage: Stage 1-2	2015 Successional Stage: Stage 2-3	2015 Successional Stage: Stage 3 eq.	Total # Stns
Stage 1	0	0	1 (Station 02)	1
Stage 2	1 (Station 07)	1 (Station 09)	0	2
Stage 3 eq.	0	1 (Station 08)	6	7
Total # Stns	1	2	7	10

Most stations were Stage 3 in 2014 and stayed that way. Station 02 improved the most, from Stage 1 to Stage 3, while Station 09 improved from Stage 2 to a Stage 2 to 3. Stations 07 and 08 had slightly decreased successional stages.

Apparent RPD Depth

Changes in the aRPD depths are summarized in Table 6:

Table 6. Summary of aRPD depths (cm) by survey year, and the station-specific change over time.

	aRPD Depth (cm)			
	Mean	**SD**	**Min**	**Max**
2014 Survey	2.51	1.05	1.2 (HSR_07)	4.4 (HSR_03)
2015 Survey	2.18	1.10	1.0 (HSR_07)	4.6 (HSR_06)
Temporal Change (2015 – 2014)	-0.33	0.55	-1.4 (HSR_03)	0.62 (HSR_06)

Station-level results for the aRPD values are shown by year in Table 6 and Figure 18, and by station and year in Figure 19. In 2014 the station values ranged from 1.2 cm to 4.4 cm, with an average across stations of 2.5 cm. In 2015, the range of station values was wider 1.0 cm to 4.6cm, with an average of 2.2 cm. The decrease in the station aRPD values over time was, on average, 0.3 cm.

The data were statistically evaluated using an ANOVA model (a two-factor crossed design with replication, both station and year as fixed factors). Parametric equations were used for the normally distributed data (Shapiro-Wilk's p = 0.9), to generate the F-tests (Table 7).

Table 7. ANOVA model results for the aRPD depth values

	Df	Sum of Sq	Mean Sq	F-value	p-value
Station	9	55.95	6.216	12.208	6.8E-09
Year	1	1.74	1.737	3.412	0.072
Station x Year	9	3.76	0.418	0.821	0.600
Residual	39	19.86	0.509		
Total	58*				

*There was one IND result in 2014 at Station 06-C, for a total sample size of 59.

The interaction term was not significant (p = 0.6), indicating that the change over time was similar in all stations. This is illustrated by predominantly parallel lines in Figure 19; this figure also clearly illustrates which stations had the greatest decline in aRPD depths (Stations 03 and 10), and which had the greatest increase (Station 06), as well as the general ranking of the lowest and highest aRPD depths.

Both the Year and the Station main effects were significant at 0.10, indicating that

- Responses among stations, averaged over both years, were not equal; and
- Responses between years, averaged over all stations, were not equal.

The 90% confidence interval on the level of temporal change across all stations was calculated as [-0.64 cm, -0.01]. This decrease was statistically significant, but very small. For context, the differences observed among replicates within each station and year averaged 0.7 cm. There were two stations which exhibited a temporal change greater than this level of noise, specifically Station 03 (1.4 cm decrease), and Station 10 (0.85 cm decrease).

It is important to note that Station 06 had the greatest spatial imprecision in 2014 (maximum distance between reps was 32 ft) and it had the largest difference in observed aRPD values among replicate images. Station 03 had the greatest spread between years (99 feet between station centroids in the two years) had the largest temporal change. So, the overall conclusion from all this is that spatial variability is fairly high. Given the relatively low level of temporal change observed within the stations, the aRPD results do not indicate a negative trend.

Overall, the infaunal benthic community was quite robust throughout the area. Locations affected by organic enrichment usually coincide with impaired biological response. The two indicators of organic enrichment in sediment profile images are high contrast and low reflection of subsurface sediments, and/or presence of methane gas vesicles in subsurface layers. While the latter is not necessarily correlated with impaired benthic community response (Figure 14), the combination of both conditions is usually a good indication of impaired habitat quality. The only location in 2015 where a mature benthic successional assemblage did not exist was the area near Station 7 (Figure 15); however this location was near a combined sewage/storm water outlet (Figure 20), so it is no surprise that a somewhat impaired benthic community would be found near an effluent discharge point.

Other indicators of impaired benthic habitat conditions are low dissolved oxygen in the overlying water (no aRPD present due to extremely high sediment-oxygen demand) or the presence of thiophilic bacterial colonies such at *Beggiatoa* that will multiply and dominate the sediment surface during hypoxic conditions. Unlike the results found in 2006, there was no evidence of either of these impaired conditions at any of the locations surveyed in 2014 or 2015.

Given the high population density and amount of industrial activity along the shoreline surrounding the sampled area, the benthic community is surprisingly robust at the ten stations surveyed; evidence of mature, deposit-feeding assemblages was found at all stations except one (Station 7), and even Station 7 had a healthy oxidized surface layer (Figure 12) and evidence of shallow dwelling (Stage 2) deposit feeders present. There was no evidence of excessive organic loading or associated sediment contamination resulting in toxicity at the population level at any of the locations surveyed.

5.0
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Figures

Figure 1: Location of the ten stations sampled with SPI technology in the Lower Hackensack River on November 2, 2015.

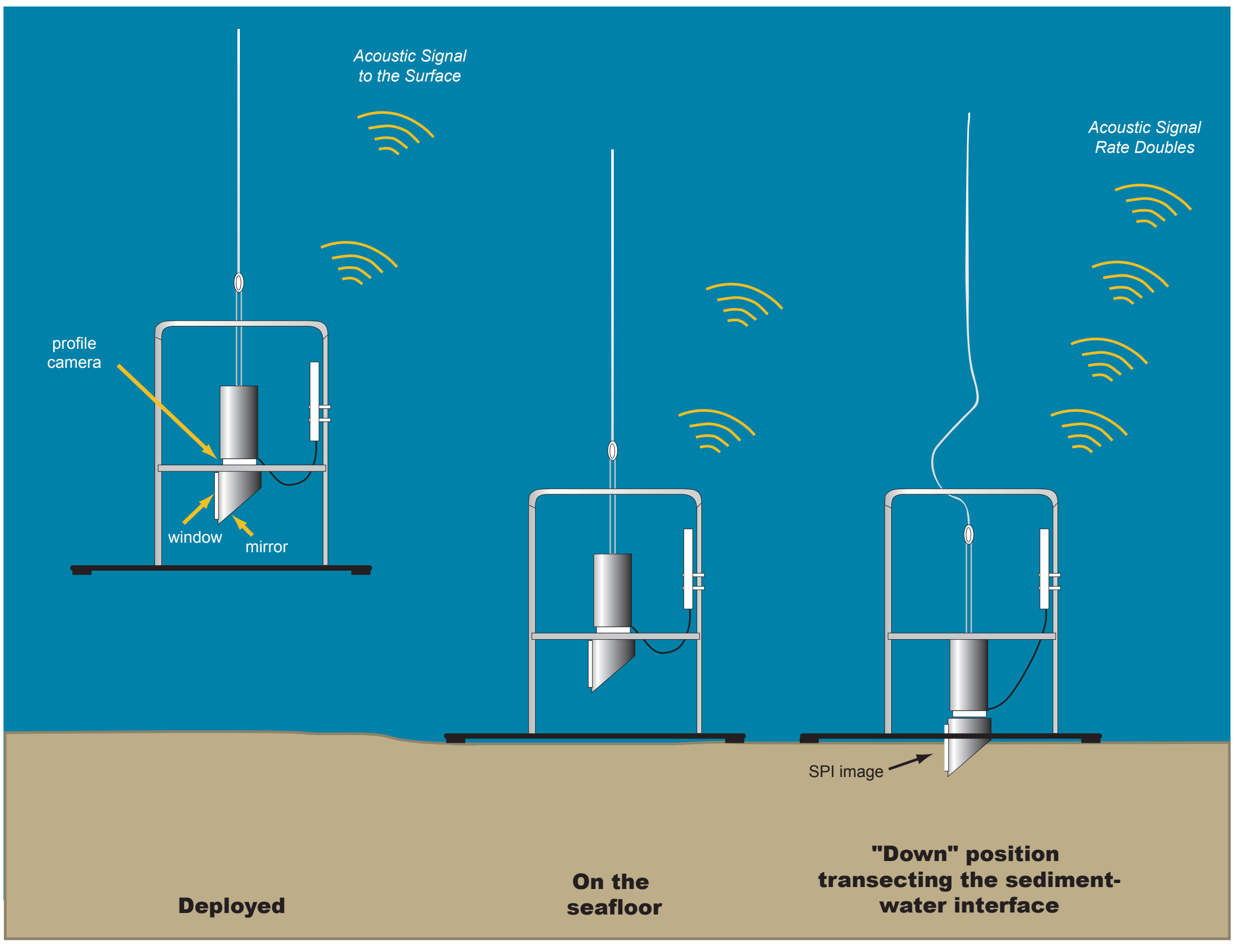


Figure 2: Deployment and operation of the Ocean Imaging Model 3731 Sediment Profile Camera.

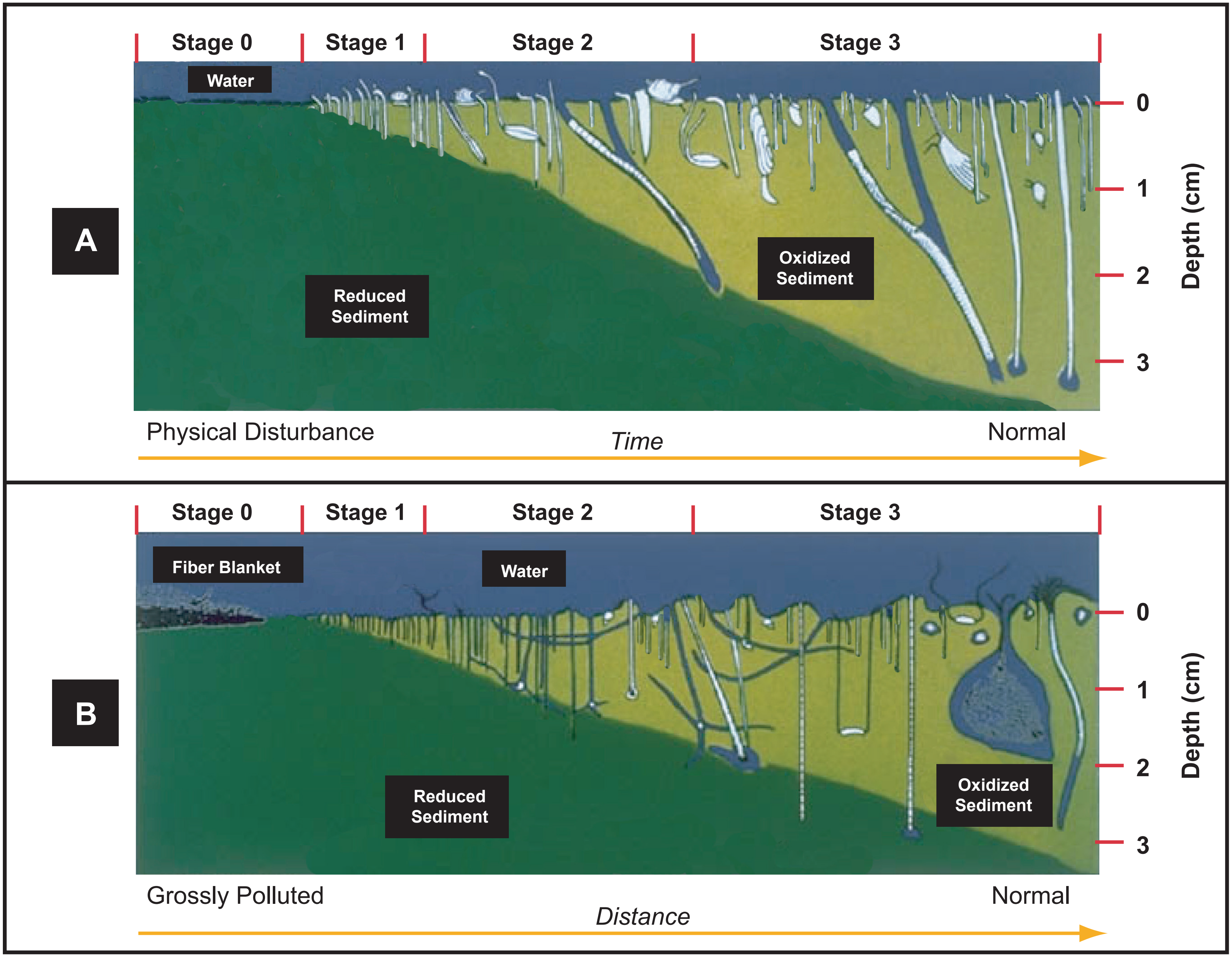


Figure 3: Soft-bottom benthic community response to physical disturbance (top panel) or organic enrichment (bottom panel). From Rhoads and Germano (1982).

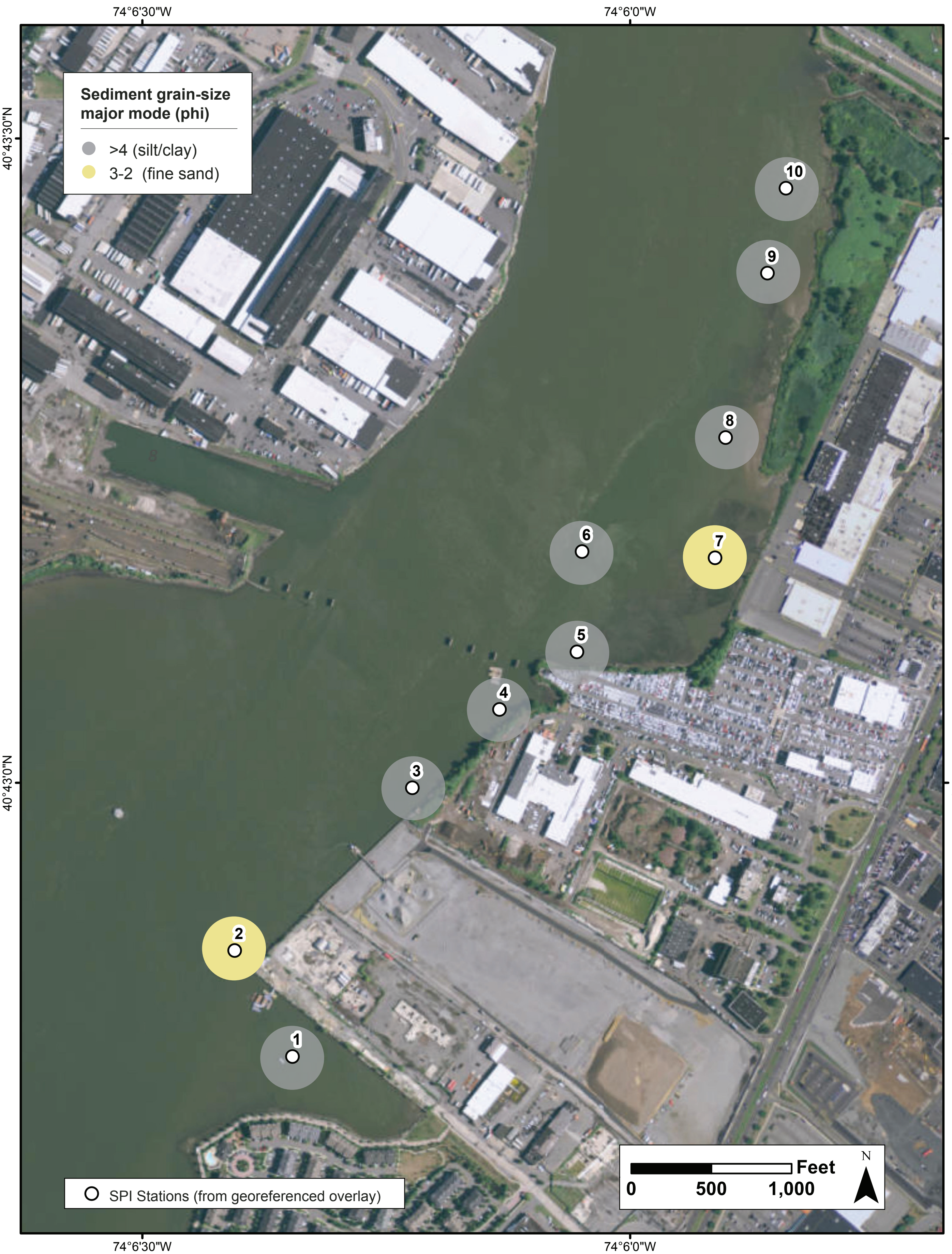


Figure 4: Sediment grain size major mode (phi units) at the 10 stations surveyed in the lower Hackensack River in November 2015.

Figure 5: This profile image from Station 10 shows the silt-clay sediments with a minor fraction of very fine sand in the surface 1-2 cm that was typically encountered at most of the stations surveyed. Scale: width of profile image = 14.7 cm.

Figure 6: This profile image from Station 7 shows the higher percentage of sand that was found at this location and also at Station 2. Scale: width of profile image = 14.7 cm.

Figure 7: This profile image from Station 2 had the lowest prism penetration values found at the site because of the armoring of small rocks and pebbles on the sediment surface. Scale: width of profile image = 14.7 cm.

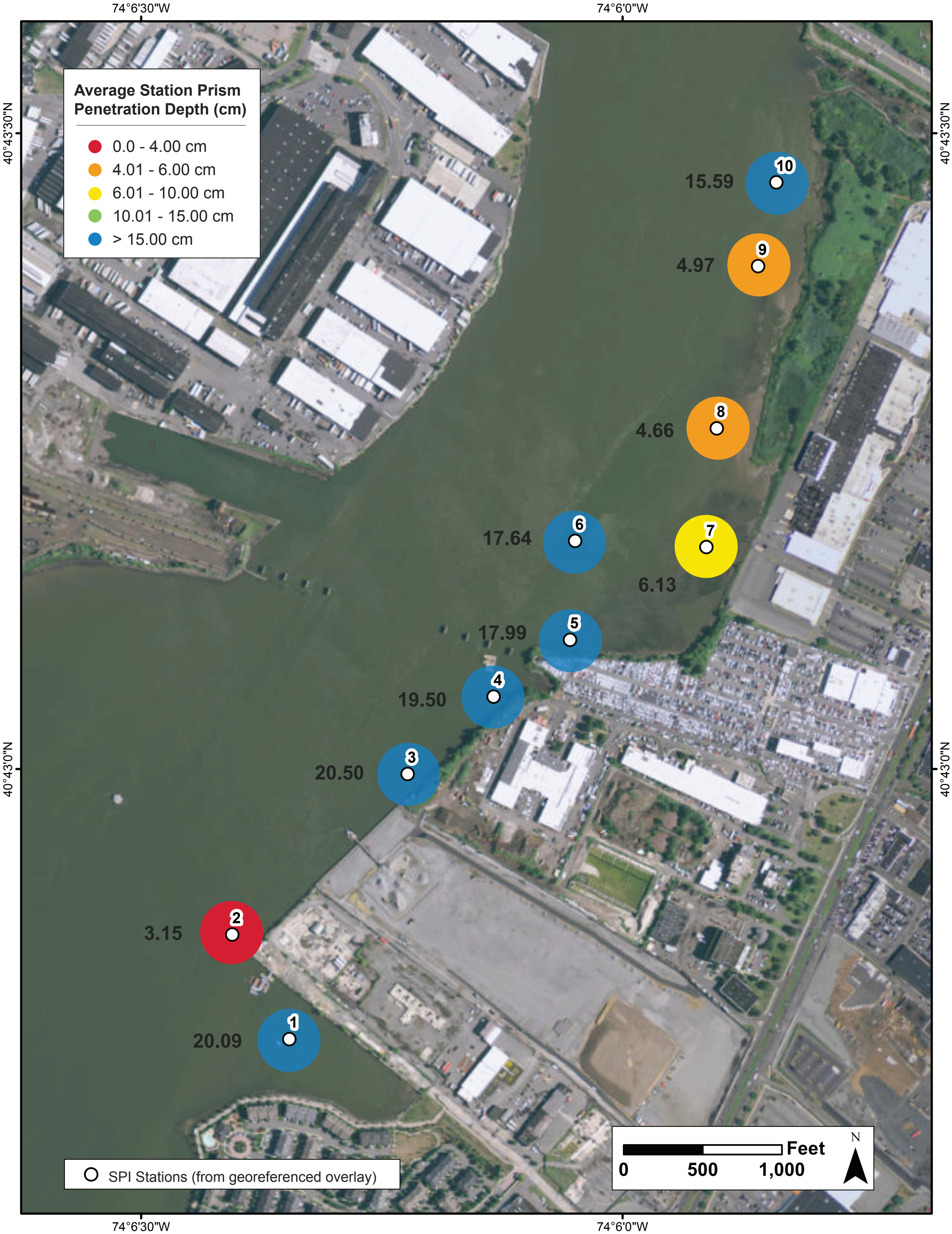


Figure 8: Spatial distribution of average station prism penetration depth (cm) at the 10 stations surveyed in the lower Hackensack River in November 2015.

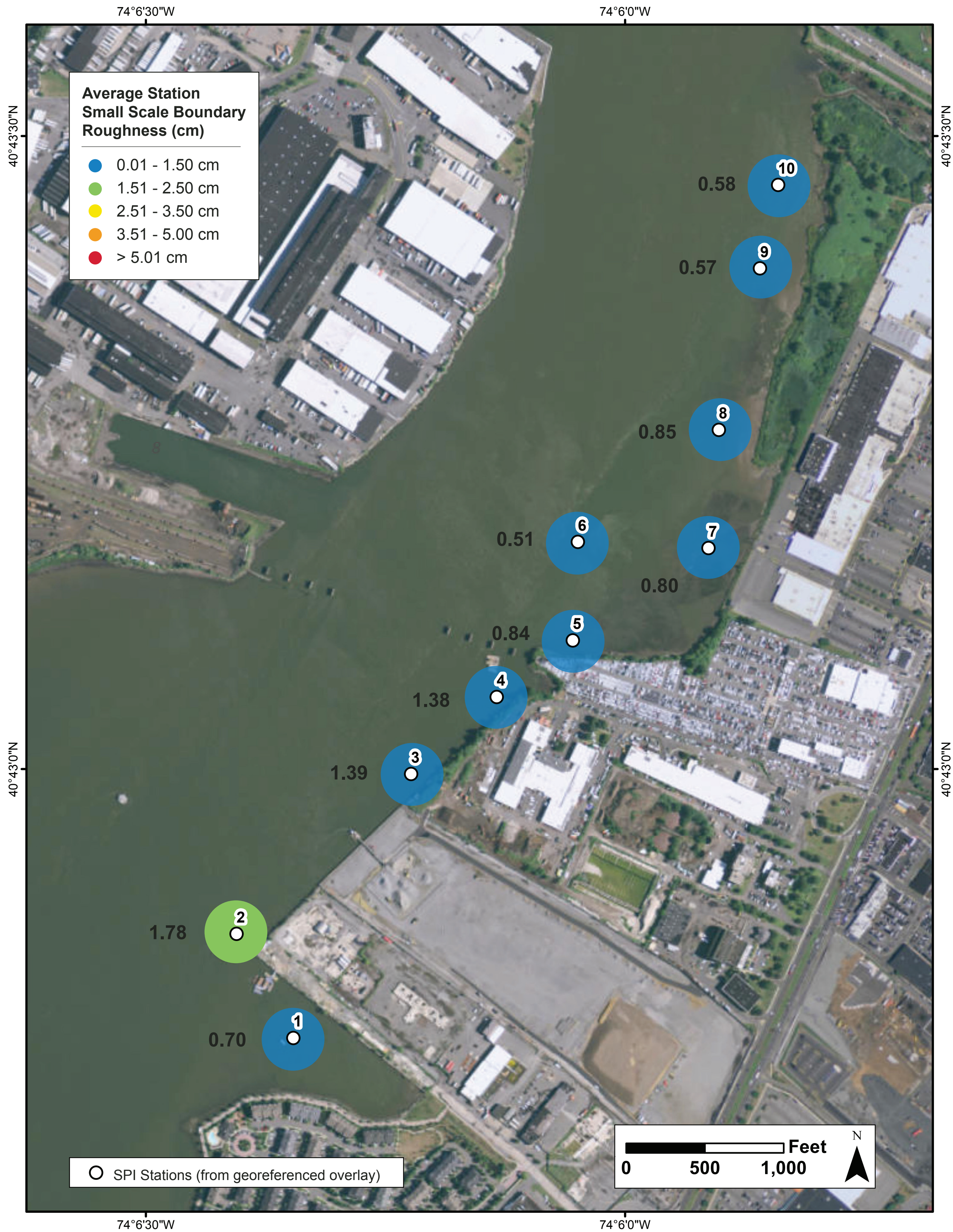
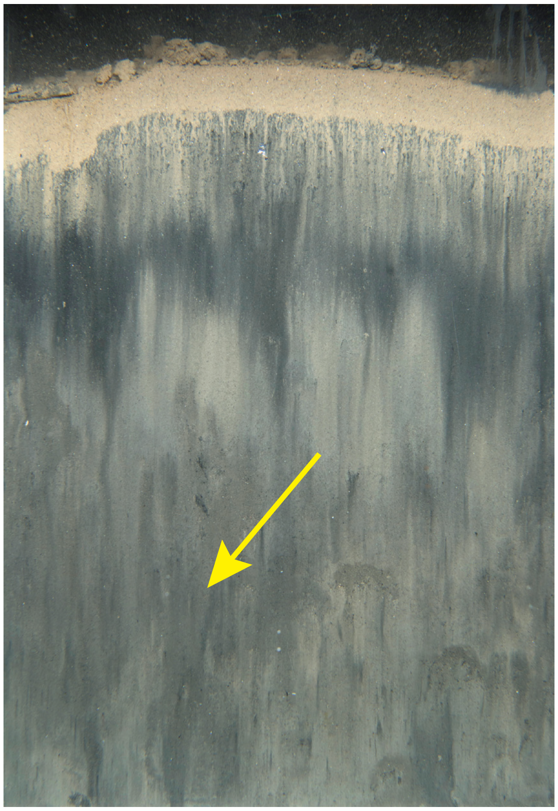


Figure 9: Spatial distribution of average station small scale boundary roughness (cm) at the 10 stations surveyed in the lower Hackensack River in November 2015.

Figure 10: This profile image from Station 3 shows biogenic surface topography caused by a fecal mound (left) and a burrow opening (right) on the sediment surface. Scale: width of profile image = 14.7 cm.



Station 4

Station 5

Station 6

Station 10

Figure 11: These profile images from Stations 4, 5, 6 and 10 show buried contact horizons (arrows) of the former sediment-water interface, indicating a quantum deposition of sediment at some point in the past year. Scale: width of each profile image = 14.7 cm.

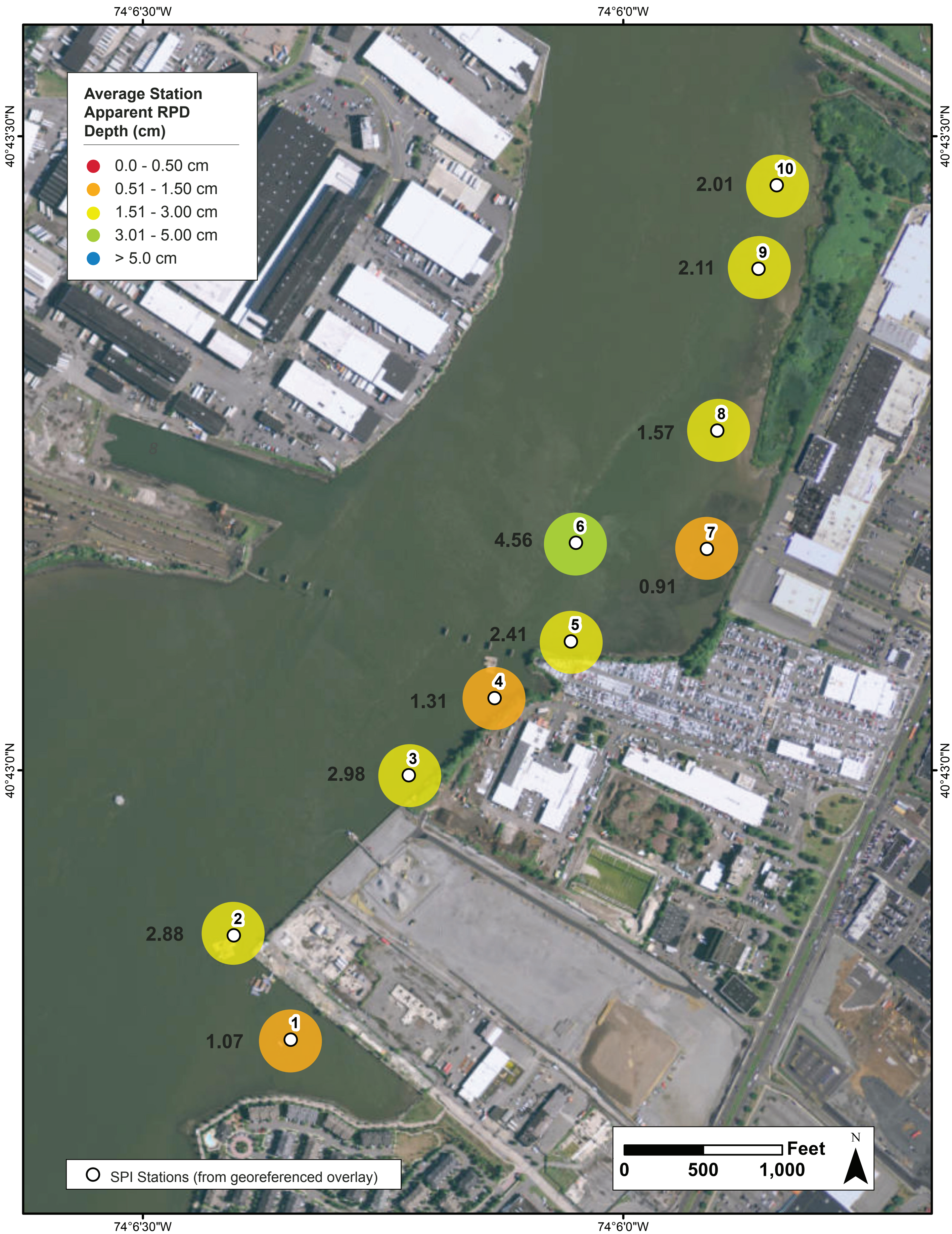


Figure 12: Spatial distribution of average station mean aRPD depths (cm) at the 10 stations surveyed in the lower Hackensack River in November 2015.

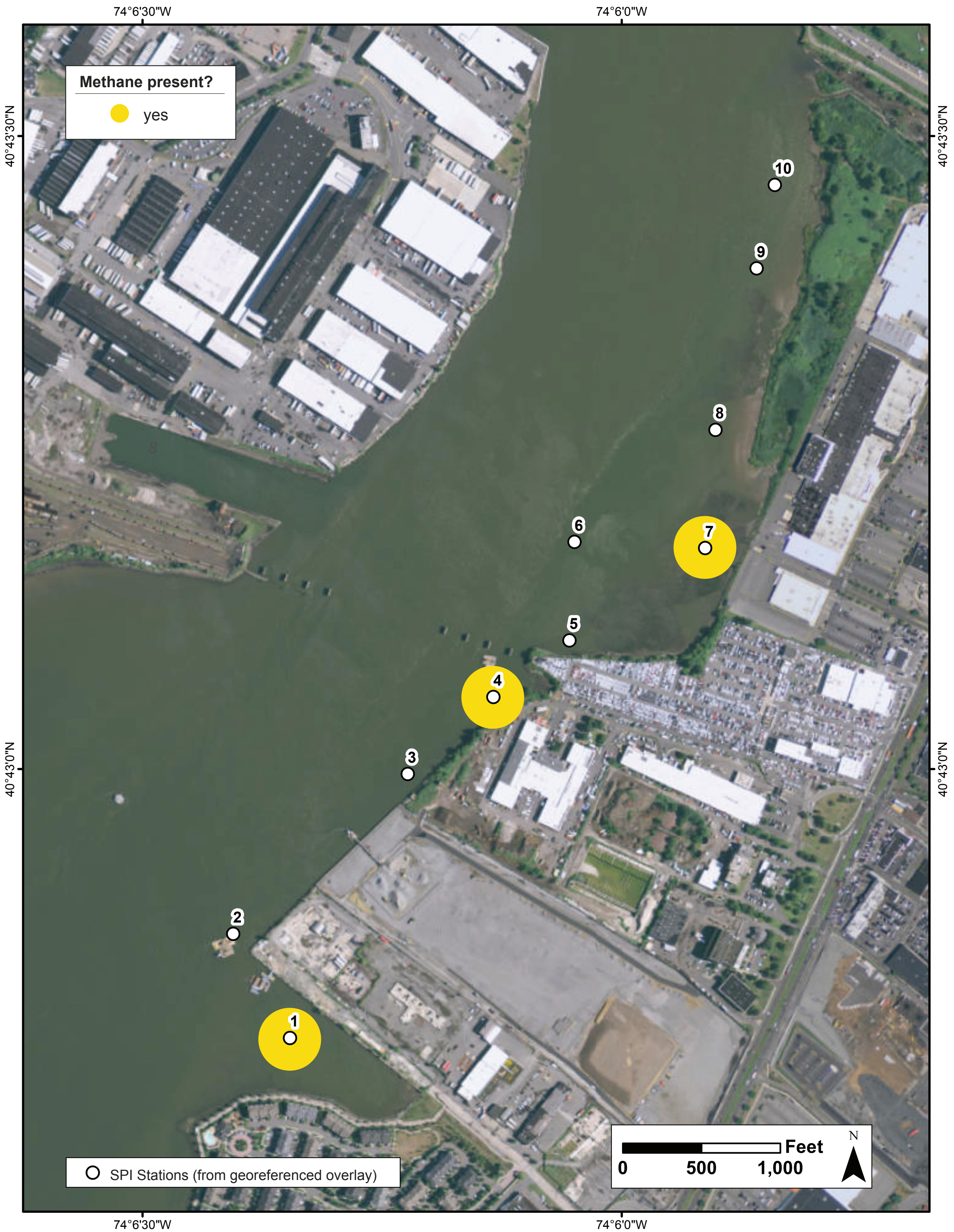


Figure 13: Spatial distribution showing the presence of subsurface methane at the 10 stations surveyed in the lower Hackensack River in November 2015.

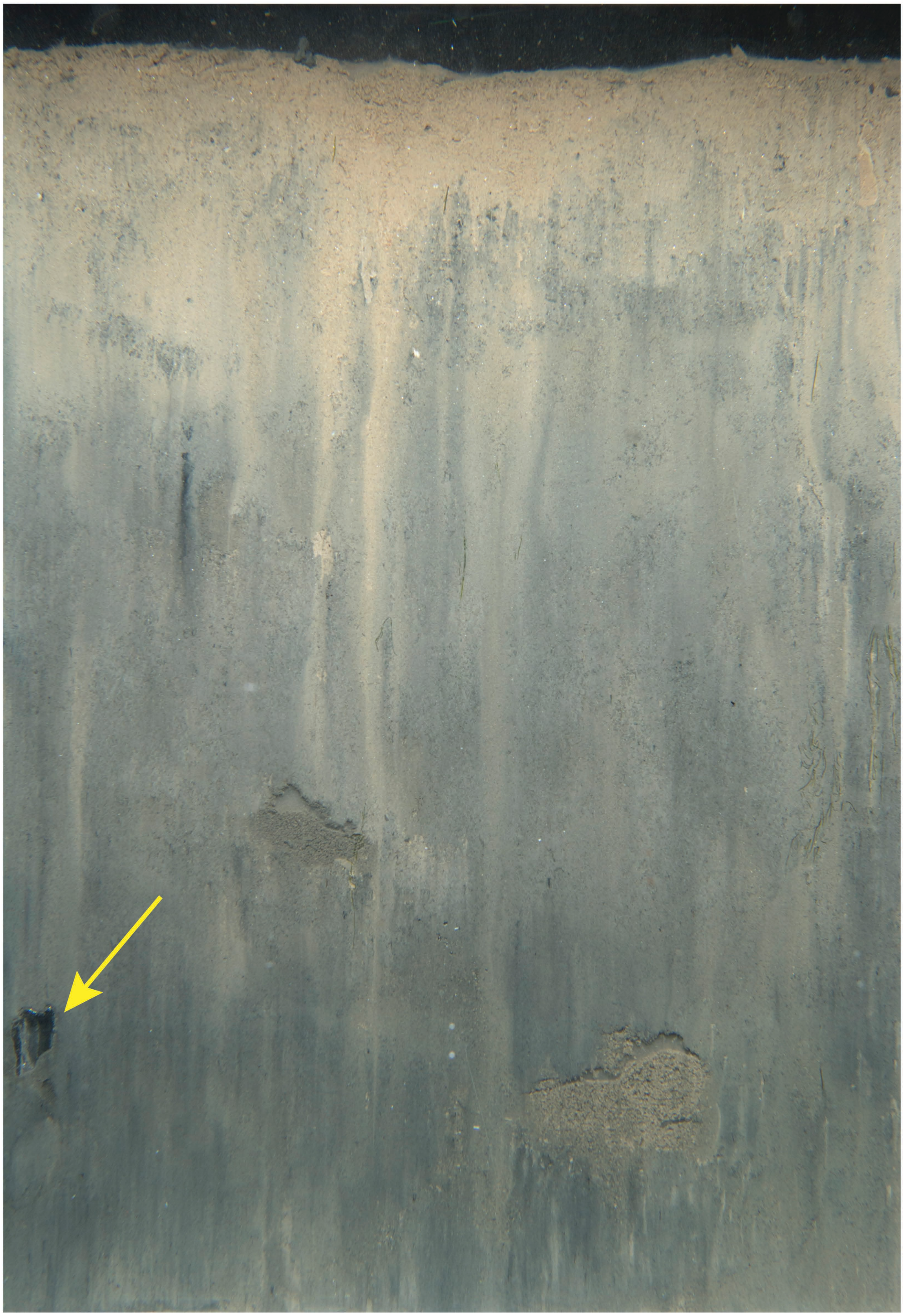


Figure 14: This profile image from Station 1 shows trapped subsurface methane (arrow) in sediments with a healthy infaunal community; note the two large feeding voids and the well-developed oxidized surface layer. Scale: width of profile image = 14.7 cm.

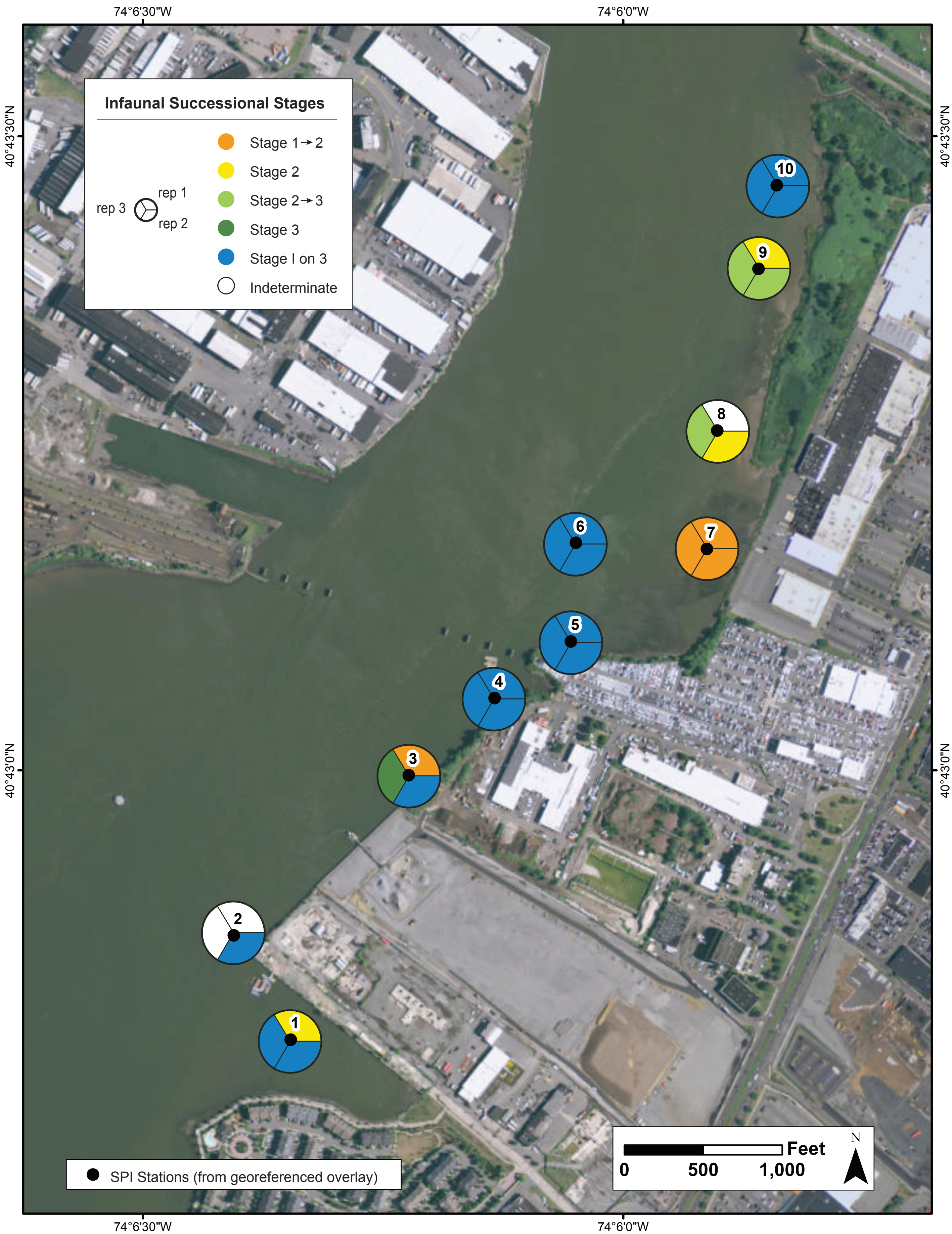


Figure 15: Spatial distribution of infaunal successional stages at the 10 stations surveyed in the lower Hackensack River in November 2015.

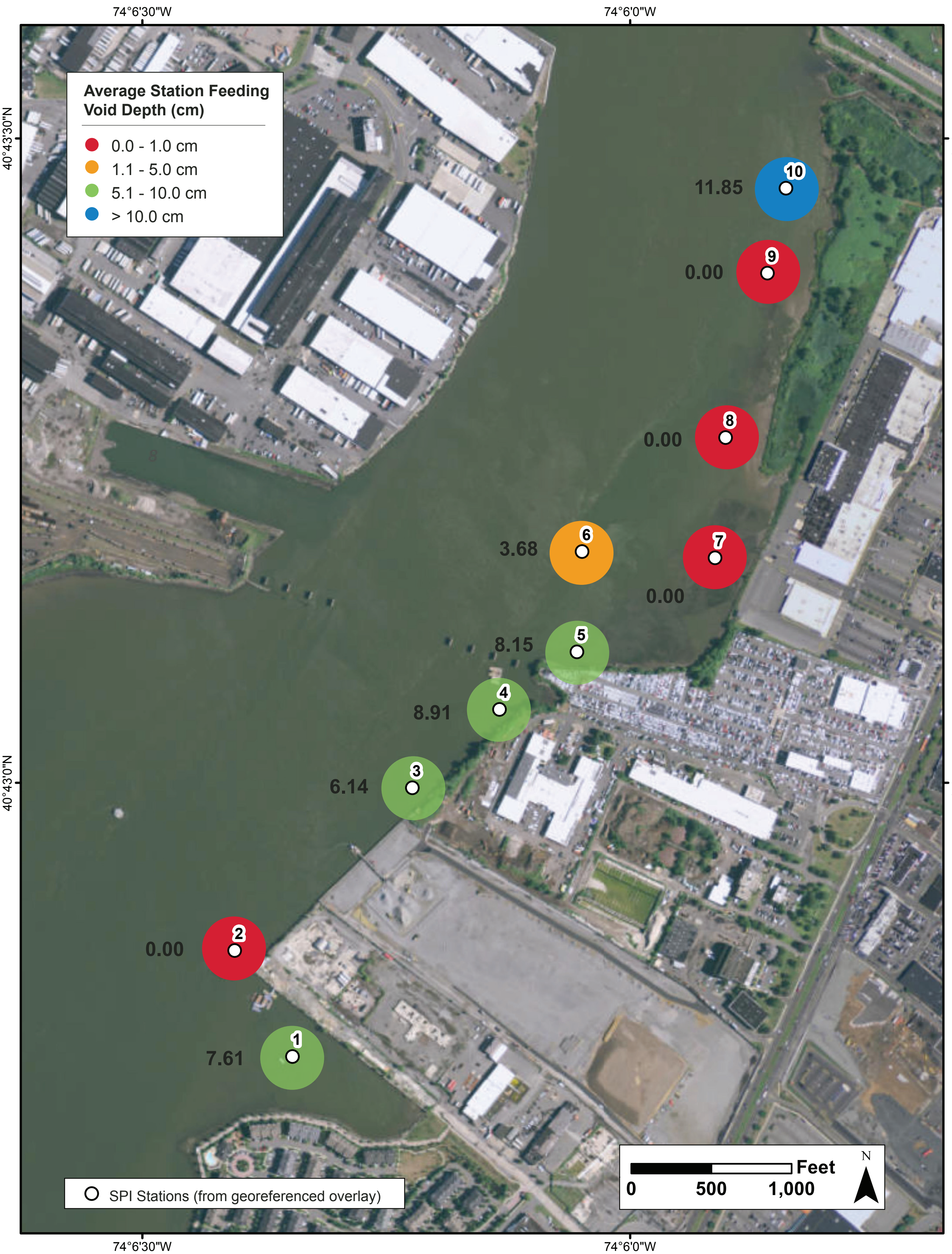


Figure 16: Spatial distribution of average station feeding void depths (cm) at the 10 stations surveyed in the lower Hackensack River in November 2015.

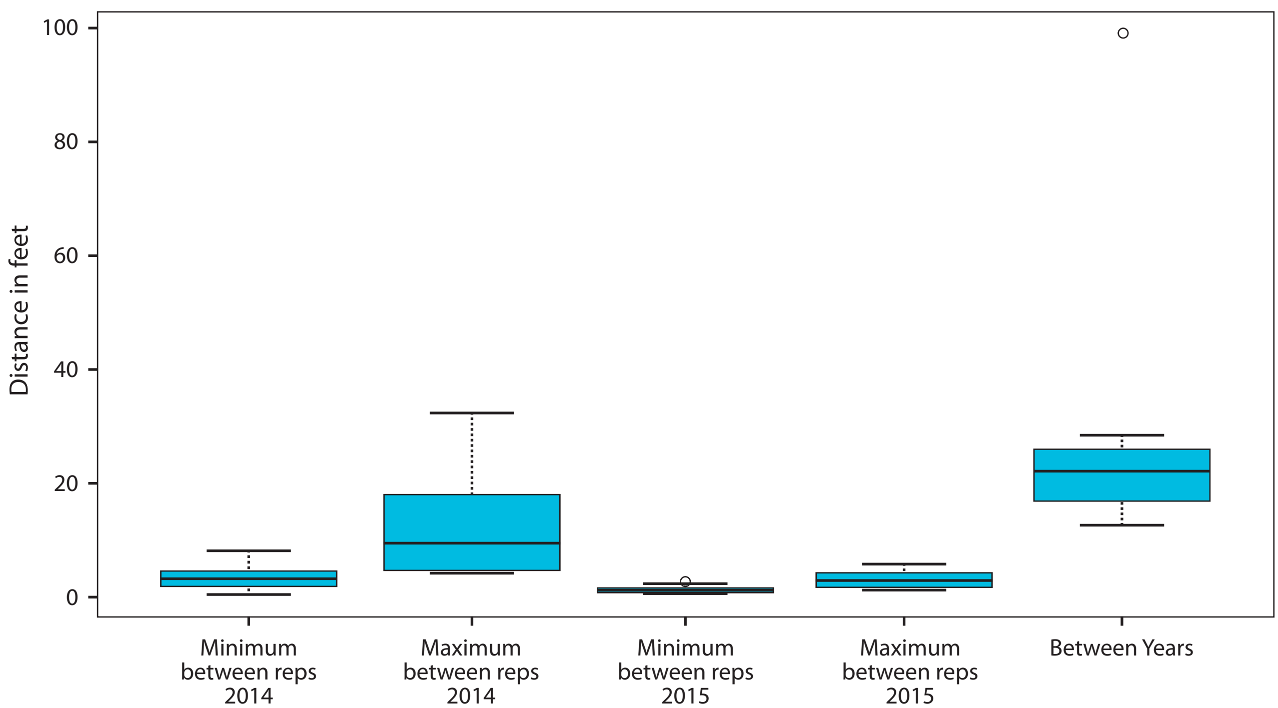


Figure 17. Boxplots showing distributions of distances (feet) between locations of replicate images for a station within each year, and between station centroids across years.

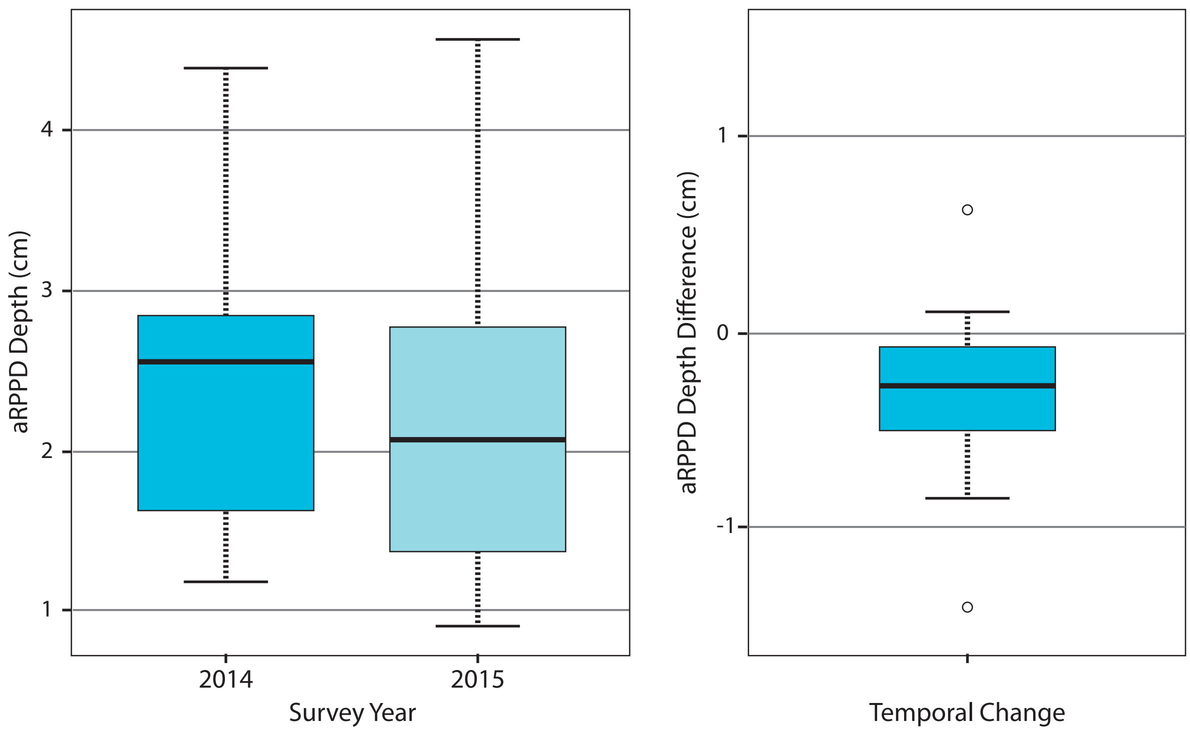


Figure 18. Boxplots showing the distribution of aRPD depths (cm) across all stations in the two survey years (left), and the distribution of station-wise temporal changes (right; 2015 minus 2014, so negative values indicate a decline in aRPD depth over time).

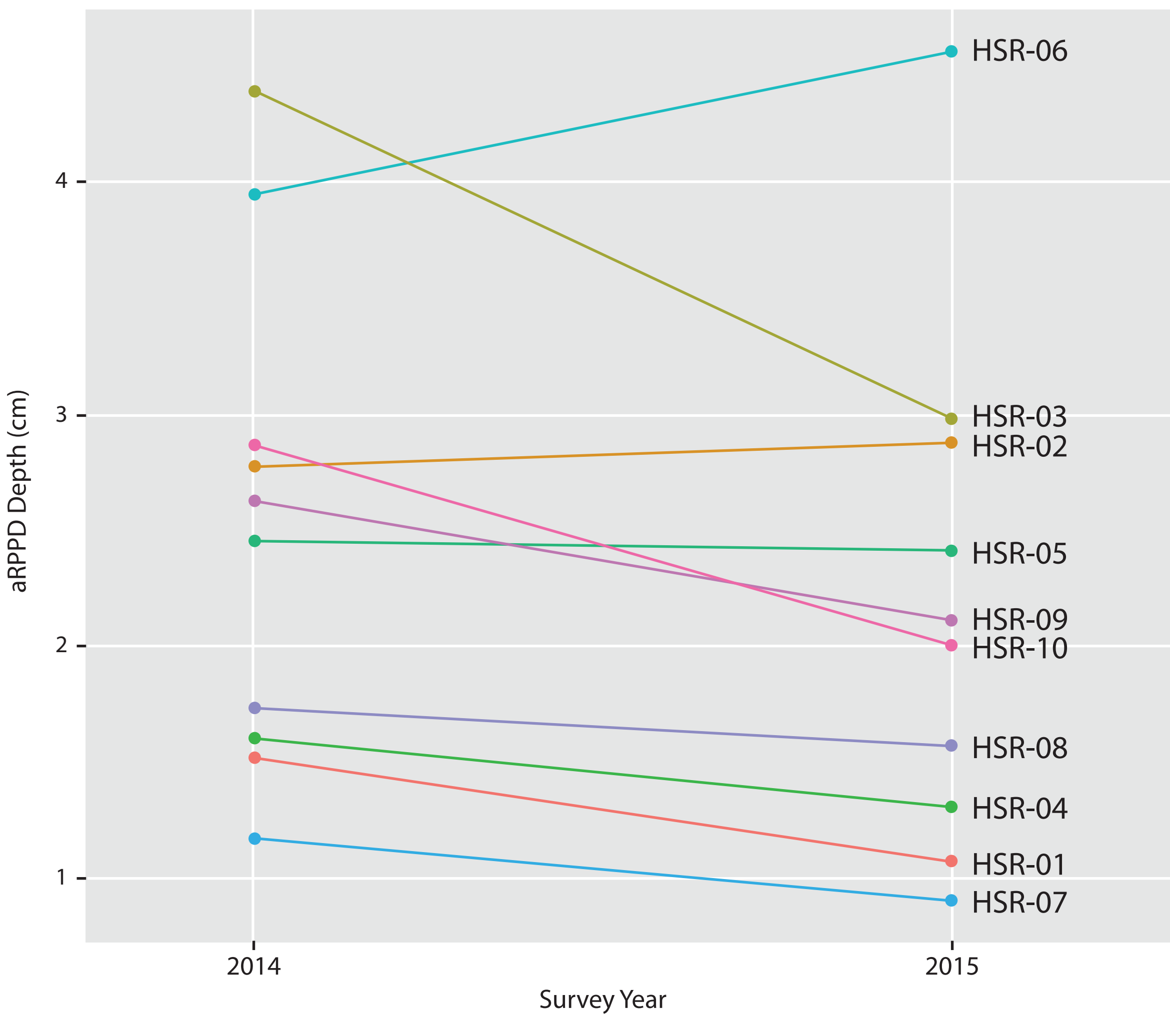


Figure 19. Line plot showing the change in each station's average aRPD depth (cm) by year.

Figure 20: This combined sewage/storm water outlet near Station 7 continues to be a source of organic loading and disturbance to sediments in the immediate vicinity of this structure.

APPENDIX A

Sediment Profile Image Analysis Results

Station	Replicate	SPI_Date	SPI_Time	Water Depth (ft)	Stop Collar Setting (in)	# of Weights (per side)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	GrnSize RANGE	Penetration Area (sq cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)
1	A	11/2/2015	14:05:02	7	15	5	>4	>4	1	>4 to 1	293.66	19.98	19.73	20.30	0.58
1	B	11/2/2015	14:06:12	7	15	5	>4	>4	1	>4 to 1	300.16	20.43	20.04	20.73	0.68
1	D	11/2/2015	14:08:32	7	15	5	>4	>4	1	>4 to 1	291.72	19.85	19.38	20.21	0.84
2	A	11/2/2015	13:53:36	19	15	5	3-2	>4	-4	>4 to -4	41.55	2.83	1.62	3.24	1.62
2	B	11/2/2015	13:54:55	19	15	5	3-2	>4	-4	>4 to -4	65.67	4.47	3.64	5.26	1.61
2	C	11/2/2015	13:55:40	19	15	5	3-2	>4	0	>4 to 0	31.68	2.16	0.83	2.92	2.10
3	F	11/2/2015	14:27:02	9	15	5	>4	>4	1	>4 to 1	311.48	21.20	20.92	21.33	0.42
3	G	11/2/2015	14:28:17	9	15	5	>4	>4	1	>4 to 1	292.36	19.89	19.13	20.82	1.69
3	H	11/2/2015	14:32:04	9	15	5	>4	>4	0	>4 to 0	300.04	20.42	19.33	21.40	2.07
4	A	11/2/2015	13:17:21	6.8	15	5	>4	>4	1	>4 to 1	295.52	20.11	19.42	20.94	1.52
4	B	11/2/2015	13:18:30	6.8	15	5	>4	>4	2	>4 to 2	286.10	19.47	18.71	19.89	1.17
4	C	11/2/2015	13:19:52	6.8	15	5	>4	>4	2	>4 to 2	278.26	18.94	18.30	19.75	1.45
5	A	11/2/2015	13:04:06	6	15	5	>4	>4	2	>4 to 2	219.72	14.95	14.53	15.51	0.98
5	B	11/2/2015	13:05:11	6	15	5	>4	>4	1	>4 to 1	292.46	19.90	19.42	20.22	0.80
5	C	11/2/2015	13:06:15	6	15	5	>4	>4	1	>4 to 1	280.69	19.10	18.63	19.36	0.73
6	A	11/2/2015	11:46:30	19.5	15	2	>4	>4	1	>4 to 1	248.46	16.91	16.53	17.10	0.57
6	B	11/2/2015	11:53:18	19.5	15	2	>4	>4	1	>4 to 1	271.75	18.49	18.22	18.63	0.41
6	E	11/2/2015	12:02:21	19.5	15	2	>4	>4	0	>4 to 0	257.56	17.53	17.26	17.81	0.55
7	A	11/2/2015	12:53:22	3	15	5	3 to 2 / >4	>4	0	>4 to 0	98.25	6.69	6.36	6.85	0.49
7	B	11/2/2015	12:54:14	3	15	5	3 to 2	>4	0	>4 to 0	89.70	6.10	5.68	6.41	0.73
7	D	11/2/2015	12:55:47	3	15	5	3 to 2	>4	0	>4 to 0	82.28	5.60	5.16	6.33	1.17
8	A	11/2/2015	12:41:13	4	15	5	>4	>4	2	>4 to 2	47.40	3.23	2.73	3.58	0.86

Station	Replicate	SPI_Date	SPI_Time	Water Depth (ft)	Stop Collar Setting (in)	# of Weights (per side)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	GrnSize RANGE	Penetration Area (sq cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)
8	B	11/2/2015	12:42:09	4	15	5	>4	>4	2	>4 to 2	73.33	4.99	3.99	5.33	1.35
8	D	11/2/2015	12:43:33	4	15	5	>4	>4	2	>4 to 2	84.58	5.76	5.58	5.93	0.35
9	A	11/2/2015	12:28:26	5	15	5	>4	>4	1	>4 to 1	70.77	4.82	4.56	5.26	0.70
9	B	11/2/2015	12:30:57	5	15	5	>4	>4	1	>4 to 1	72.00	4.90	4.66	5.06	0.40
9	D	11/2/2015	12:32:30	5	15	5	>4	>4	1	>4 to 1	76.41	5.20	4.92	5.54	0.62
10	B	11/2/2015	12:16:48	5	15	5	>4	>4	1	>4 to 1	204.83	13.94	13.58	14.18	0.60
10	C	11/2/2015	12:19:28	5	15	5	>4	>4	1	>4 to 1	232.80	15.84	15.58	16.09	0.51
10	D	11/2/2015	12:20:44	5	15	5	>4	>4	1	>4 to 1	249.63	16.99	16.60	17.24	0.64

Station	Replicate	Boundary Roughness Type	aRPD > Pen	RPD Area (sq cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Sediment Oxygen Demand	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)
1	A	Biological	FALSE	17.05	1.16	0	-	No	No	Moderate	No	0	0.00	0.00	0.00
1	B	Biological	FALSE	18.88	1.28	0	-	Yes	No	Moderate	No	2	11.88	17.94	14.91
1	D	Biological	FALSE	11.37	0.77	0	-	No	No	Moderate	No	1	7.53	8.32	7.93
2	A	Physical	TRUE	65.67	4.47	0	-	No	No	Low	No	0	0.00	0.00	0.00
2	B	Physical	FALSE	29.53	2.01	0	-	No	No	Low	No	0	0.00	0.00	0.00
2	C	Physical	TRUE	31.68	2.16	0	-	No	No	Low	No	0	0.00	0.00	0.00
3	F	Biological	FALSE	49.30	3.35	0	-	No	No	Low	No	0	0.00	0.00	0.00
3	G	Biological	FALSE	24.47	1.67	0	-	No	No	Low	No	2	17.53	19.33	18.43
3	H	Biological	FALSE	57.47	3.91	0	-	No	No	Low	No	0	0.00	0.00	0.00
4	A	Biological	FALSE	17.41	1.18	0	-	Yes	No	Moderate	No	3	8.52	15.66	12.09
4	B	Biological	FALSE	20.39	1.39	>10	Mix	Yes	No	Moderate	No	2	13.44	15.81	14.63
4	C	Biological	FALSE	20.12	1.37	0	-	No	No	Moderate	No	0	0.00	0.00	0.00
5	A	Biological	FALSE	33.98	2.31	1	Ox	No	No	Low	No	0	0.00	0.00	0.00
5	B	Biological	FALSE	42.50	2.89	0	-	No	No	Low	No	2	12.71	16.18	14.44
5	C	Biological	FALSE	29.92	2.04	0	-	No	No	Low	No	1	9.83	10.18	10.01
6	A	Biological	FALSE	70.56	4.80	0	-	No	No	Low	No	0	0.00	0.00	0.00
6	B	Biological	FALSE	70.91	4.83	0	-	No	No	Moderate	No	3	5.24	16.81	11.03
6	E	Biological	FALSE	59.52	4.05	0	-	No	No	Low	No	0	0.00	0.00	0.00
7	A	Biological	FALSE	16.53	1.12	0	-	Yes	No	Low	No	0	0.00	0.00	0.00
7	B	Biological	FALSE	8.05	0.55	0	-	No	No	Moderate	No	0	0.00	0.00	0.00
7	D	Biological	FALSE	15.59	1.06	0	-	No	No	Low	No	0	0.00	0.00	0.00
8	A	Biological	FALSE	20.84	1.42	3	Ox	No	No	Low	No	0	0.00	0.00	0.00

Station	Replicate	Boundary Roughness Type	aRPD > Pen	RPD Area (sq cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State	Methane?	Low DO?	Sediment Oxygen Demand	Beggiatoa Present?	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)
8	B	Biological	FALSE	21.65	1.47	0	-	No	No	Low	No	0	0.00	0.00	0.00
8	D	Biological	FALSE	26.53	1.81	2	Ox	No	No	Low	No	0	0.00	0.00	0.00
9	A	Biological	FALSE	31.62	2.15	3	Ox	No	No	Low	No	0	0.00	0.00	0.00
9	B	Biological	FALSE	30.37	2.07	3	Ox	No	No	Low	No	0	0.00	0.00	0.00
9	D	Biological	FALSE	31.00	2.11	4	Ox	No	No	Low	No	0	0.00	0.00	0.00
10	B	Biological	FALSE	31.89	2.17	0	-	No	No	Low	No	2	8.23	12.41	10.32
10	C	Biological	FALSE	28.63	1.95	0	-	No	No	Low	No	1	13.50	14.18	13.84
10	D	Biological	FALSE	28.26	1.92	0	-	No	No	Low	No	2	7.07	15.72	11.39

Station	Replicate	Successional Stage	COMMENT
1	A	2	Well sorted fines with few sand sized particles. Sediment column tan near SWI, becoming neutral gray and much darker below aRPD. Many small pellets are visible at SWI. Long halos of oxidized material penetrate reduced layer.
1	B	1 on 3	Well sorted fines with few sand sized particles. Many small pellets are visible at SWI. Sediment column features two large feeding voids filled with both reduced and oxidized pellets as well as biogenic sorting of larger sediment grains
1	D	1 on 3	Well sorted fines with few sand sized particles. Sediment column tan near SWI, becoming neutral gray and much darker below a thin and dragged down aRPD. Very small stage 1 tubes at SWI. Many small pellets are visible at SWI. Sediment column features single large feeding void filled with both reduced & oxidized pellets.
2	A	IND	Disturbed SWI from prism trying to penetrate pebbles & wood fragments with medium sand and silt/clay. Small shell fragments litter SWI. Pellets and small stage 1 tubes at SWI. Low penetration.
2	B	1 on 3	Poorly sorted fine sand with medium sand, pebbles, and silt/clay. Small shell fragments litter SWI. Pellets and small stage 1 tubes at SWI. Small clump of red algae visible; transected burrows throughout profile.
2	C	IND	Distrubed SWI with wood fragments over fine sand and silt/clay. Small shell fragments litter SWI. Insufficient penetration to determine succesional stage, but most likely 1 on 3 given amount & shape of fecal pellets on surface
3	F	1 -> 2	Very fine sandy silt-clay with small tubes at SWI and Capitellid worm visible at about 10 cm below SWI. Small mound of pellets directly above worm.
3	G	1 on 3	Very fine sandy silt-clay with depression in SWI caused by dragdown of algae. Several small voids near penetration depth.
3	H	3	Deep penetration of very fine sediment, mostly a neutral gray with light tan aRPD. Large burrow opening is filled with coarse material and spilling out over SWI, an artifact from prism penetration.
4	A	1 on 3	Deep penetration, mostly dark colored neutral fine sediment with a very distinct thin aRPD of light tan silt/clay at SWI. Tiny pellets are abundant at SWI. Single very small methane bubble near aRPD.
4	B	1 on 3	Deep penetration, mostly dark colored neutral fine sediment with a very distinct thin aRPD of light tan silt/clay at SWI. Few small methane bubbles just below aRPD. Many small clasts at SWI (camera artifacts). Deep burrowing is evident in textures near penetration maximum; recent rapid deposition (storm runoff?) of approximately 6 cm of reduced sediment)
4	C	1 on 3	Deep penetration, mostly dark colored neutral fine sediment with a thin aRPD of light tan silt/clay at SWI. Few very small tubes at SWI, surrounded by tiny pellets. Transected burrows at depth, evidence of Stage 3 taxa present; no obvious depositional horizon as in last 2 replicates
5	A	1 on 3	Silt-clay with light tan aRPD over reduced layer of dark gray silt/clay. Pellets are visible at SWI. Single large clast. No fully formed voids in sediment column are visible; however transected burrows are present throughout profile & portion of subsurface worm visible against faceplate.
5	B	1 on 3	Silt-clay with light tan aRPD over reduced layer of dark gray silt/clay. Two voids visible deep in sediment column. Single worm visible at around 11 cm below aRPD. Many pellets at SWI. Short halo of bright orange at SWI extending into aRPD layer.
5	C	1 on 3	Silt-clay with light tan aRPD over reduced layer of gray silt/clay. Few stage 1 tubes at SWI (very small) Single voids visible deep in sediment column. Many pellets at SWI. Small bivalves present buried in oxidized surface layer
6	A	1 on 3	Approx 12 cm of mostly fine sediment (silt/clay) with a small fraction of fine and medium sand deposited on former SWI at depth (quantum input of deposition most likely from storm runoff). Few stage 1 tubes at SWI. SWI is loosely packed. Upper layer of sediment contains small black particles of plant debris (evidence of storm runoff), transected burrows at depth.
6	B	1 on 3	Stratigraphy shows same quantum depositional input as in last replicate; few stage 1 tubes at SWI. SWI is loosely packed. Upper layer of sediment contains small blackparticles of plant debris. Several voids are visible in sediment column.
6	E	1 on 3	Stratigraphy shows same quantum depositional input as in last replicate; few stage 1 tubes at SWI. SWI is loosely packed. Upper layer of sediment contains small blackparticles of plant debris. Transected burrows at depth, evidence of Stage 3 taxa present
7	A	1 -> 2	Silty fine sand over silt/clay. Thin aRPD is bright tan with a reddish brown layer of organic material draped on SWI. Several very small methane bubbles at SWI. Leaf litter and other decaying plant debris at SWI. Evidence of subsurface burrowing
7	B	1 -> 2	Silty fine sand. Thin aRPD is bright tan with a reddish brown layer of organic material draped on SWI. Leaf litter and other decaying plant debris at SWI.
7	D	1 -> 2	Silty fine sand. Thin aRPD is bright tan with a reddish brown layer of organic material draped on SWI. Multiple depositional horizons
8	A	IND	Very fine sandy silt/clay, bright tan in color, becoming slightly darker and more neutral in aRPD dragdown area. Pellets and loose material at SWI. Several calsts/camera artifacts on SWI. Well formed aRPD, penetration too shallow to accurately determine successional stage.

Station	Replicate	Successional Stage	COMMENT
8	B	2	Very fine sandy silt/clay, bright tan in color, becoming slightly darker and more neutral in aRPD dragdown area. Pellets and loose material at SWI. Several calsts/camera artifacts on SWI. Well formed aRPD. Small black fragments of plant material at SWI and in sediment column. Stage 1 tubes at SWI, shallow burrows transected.
8	D	2 -> 3	Very fine sandy silt/clay, with pellets and loose material at SWI. Several calsts/camera artifacts on SWI. Well formed aRPD. Evidence of transected burrows at depth, low density of Stage 3 taxa present
9	A	2	Poorly sorted very fine sandy silt/clay, Several calsts/camera artifacts on SWI. Well formed aRPD. Small black fragments of plant material at SWI and in sediment column. Halo of orange oxidized material in sediment column.
9	B	2 -> 3	Poorly sorted very fine sandy silt/clay, Several calsts/camera artifacts on SWI. Well formed aRPD. Small black fragments of plant material at SWI and in sediment column. Halo of orange oxidized material in sediment column. Worm visible just under aRPD; transected burrows at depth
9	D	2 -> 3	Fine sediment (silt/clay), bright tan in color, becoming slightly darker and more neutral in aRPD dragdown area. Pellets and loose material at SWI. Several calsts/camera artifacts on SWI. Well formed aRPD. Small black fragments of plant material at SWI and in sediment column. Halos of orange oxidized material in sediment column. Several segments of worms visible in sediment column.
10	B	1 on 3	Very fine sandy silt/clay. Sediment is mostly pale gray with a bright tan aRPD that is well formed. SWI is pelleted with very small tubes present. Large worm is visible in sediment column. Several voids.
10	C	1 on 3	Very fine sandy silt-clay with a bright tan aRPD that is well formed. SWI features a thin drape of organic brown material and a loose tan sediment. Swi is pelleted with very small tubes present. Single void deep in sediment column. Small worm deep in sed column.
10	D	1 on 3	Very fine sandy silt/clay sed column. Sediment is mostly pale gray with a bright tan aRPD that is well formed. SWI is pelleted with very small tubes present. Two distinct voids with extensive burrowing evident in textural changes of sediment column.