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LONG TERM MONITORING PROGRAM YEAR 5 IMPLEMENTATION REPORT STUDY AREA 7 SEDIMENT REMEDY JERSEY CITY, NEW JERSEY

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ACRONYMS AND ABBREVIATIONS

ASI:	Aqua Survey, Inc.
BEP:	Beneficial Environmental Project
cm:	centimeter
CSO:	combined sewer outfall
ENVIRON:	ENVIRON International Corporation
ft:	feet
LTMP:	Long Term Monitoring Plan or Program
m ² :	square meters
MDL:	method detection limit
MNR:	Monitored Natural Recovery
MSL:	mean sea level
No/m ² :	number per square meter
OSI:	Organism-Sediment Index
ppm:	parts per million
Ramboll:	Ramboll US Corporation
Ramboll Environ:	Ramboll Environ US Corporation
RPD:	redox potential discontinuity
SA-7:	Study Area 7
SE:	NJDEP's acute and chronic saline Surface Water Quality Criteria
SPI:	sediment profile imaging

1. 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.

Capping of 27 out of 30 areas was completed in 2012 and 2013. All parties agreed to defer capping of the remaining 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. Capping of Areas 16 and 22 was completed as part of the Droyers Cove Beneficial Environmental Project (BEP) in December 2018. These areas will be included in the ongoing monitoring program going forward. Capping of Area 28 is still pending. This area will be added into the ongoing monitoring program once it is 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:
 - "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;
 - 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
 - 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 ("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 2015b). 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. Biological Monitoring in Capped Areas – Year 2 requirement eliminated.
- b. Sediment Cap Thickness Verification – Year 2 requirement eliminated.
- c. Pore Water Sampling in Capped Areas for Hexavalent Chromium – Honeywell would stop pore water sampling at Locations 6A and 13D. However, Honeywell would 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 (Ramboll Environ 2015a), 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**. The results of the Year 2 monitoring were reported in the Long-Term Monitoring Program, Year 2 Implementation Report ("Year 2 Implementation Report"; Ramboll Environ 2016).

In conformance with the Revised Implementation Plan, the monitoring activities for Year 5 of the long-term monitoring program were conducted from March to December 2018, and included the following:

- Hydraulic and Hydrodynamic Evaluation
- Bathymetric Survey
- Cap Integrity Monitoring
- Pore Water Sampling
- Sediment Profile Imaging (SPI)
- Biological Sampling (Sediment Macroinvertebrates)
- Surface Sediment Sampling

As detailed in the remainder of this report, the fifth-year monitoring program demonstrated that the remediation area remains stable relative to constructed conditions. Overall, the planned methods of verification were successfully implemented, although as described in this report (refer to Section 2.7), additional effort was required to collect representative surface sediment samples from some of the armored sediment caps. Therefore, this report concludes that no changes in future scope or verification methods are necessary.

In accordance with the LTMP, pore water sampling, biological sampling, and surface sediment sampling will be discontinued after Year 5, as the data collected during the first five years of monitoring do not indicate that further monitoring is warranted. Bathymetric surveys will continue at 5-year intervals for a period of 15 years and through two high-energy events, or a total period of 25 years, whichever is shorter. Hydraulic and hydrodynamic monitoring will continue to be performed on a continuous basis through Year 15 to identify any high energy events that would trigger additional assessment in the form of bathymetric surveys, cap integrity monitoring, and SPI surveys in MNR areas.

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
<p>HEV: Following all High Energy Events</p> <p>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.</p> <p>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.</p> <p>Note 3: After Year 5, routine sediment cap integrity 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)</p> <p>Note 4: The first year of pore water sampling is limited to those areas of potential intermediate groundwater plume upwelling identified in the 2007 <i>Final Groundwater Investigation Report, Honeywell Study Area 7 Site</i>; 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.</p> <p>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.</p> <p>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.</p>								

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
<p>HEV: Following all High Energy Events</p> <p>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.</p> <p>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.</p> <p>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</p> <p>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.</p>								

2. SCOPE OF WORK AND YEAR 5 RESULTS

The scope of work and results for Year 5 of the LTMP included the following tasks, described in this section:

- Hydraulic and Hydrodynamic Evaluation
- Bathymetric Survey
- Cap Integrity Monitoring
- Pore Water Sampling
- SPI
- Biological Sampling
- Surface Sediment Sampling

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

In conformance with the Revised Implementation Plan, monitoring to identify any high energy events that would trigger additional assessment has been performed on a continuous basis. Records of river stage elevations and weather events 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/>

At the request of the plaintiffs, the results of the monitoring performed during Year 3 (October 2015 through September 2016) and Year 4 (October 2016 through September 2017) of the LTMP were presented in a memorandum dated May 4, 2018 (Ramboll 2018). The monitoring data for both Year 3 and Year 4 indicated that no high energy events meeting the defined criteria occurred during these monitoring periods. The monitoring data for Year 5 of the LTMP (October 2017 through December 2018) also indicate that no high energy events occurred during this monitoring period. Monthly summaries generated from the monitoring data for Year 5 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 5 survey was conducted by Aqua Survey, Inc. (ASI) on March 19 and 21, 2018, with some additional data collected along the shoreline in the Northern Area on April 26, 2018 because it could not be accessed in March. The survey was conducted over the 70-acre remedy area 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 the Year 5 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 loss-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.

Of the 175 sediment cap subareas, only nine subareas (subareas 3-3, 5-2, 6B-2, 11C-6, 11C-7, 13A-1, 13A-5, 30B-1, and 30B-3) showed net decrease in the bed elevation (i.e., net loss). In these sediment cap subareas, the average elevation difference ranged from 0.02 to 2.55 inches, which are 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 these subareas.

Of the 141 MNR subareas, only eight subareas (subareas 43 MNR, 44 MNR, 47 MNR, 48 MNR, 49 MNR, 90 MNR, 93 MNR, and 94 MNR) showed net loss in the bed elevation. In these MNR subareas, the average elevation difference ranged from 0.23 to 2.12 inches, which are less than the 4-inch threshold established in the 100% Design and, thus, do not require action at this time. The one subarea that showed a net loss in Year 2 (i.e., 72 MNR) showed a net increase in the bed elevation of 2.42 inches.

2.3 Cap Integrity Monitoring

Cap thickness verification was conducted from December 7 to December 19, 2018 to determine if there was any observable loss of cap material. This task was performed at and around 18 of the 38 long-term monitoring plates that were installed within capped areas during remedy implementation (refer to **Figures 1** and **2** for the Year 5 designated monitoring points). Fourteen of the inspected plate locations were within subtidal areas and four plate locations were within intertidal areas. The as-built cap thicknesses and the estimated exposed length of the monitoring plate stickup posts are listed on **Table 3**. The approach and results of the inspections are summarized below.

2.3.1 Subtidal Areas

A vessel equipped with a Trimble SPS855 unit was used to navigate to the as-built GPS coordinates of the subtidal long-term monitoring plates within the SA-7 remedy area. Upon arrival at each long-term monitoring plate location, the vessel dropped anchor to secure its position. The anchor line also served as a visual marker for the diver at the GPS located plate location. A diver then disembarked the vessel and descended to the surface of the cap and inspected an area of at least 10-ft by 10-ft around the GPS-defined plate location. The diver documented the inspection using an underwater video camera and determined whether the long-term monitoring plate posts were exposed. The diver also made general observations of cap conditions including thickness of silt layer formed on the armor stone. Diver observations were recorded on cap thickness verification forms; these observations are summarized on **Table 4**.

Inspections of the 14 plate locations within subtidal areas (plates 7B, 8A, 10A, 11B, 11E, 14A, 17A, 17B, 18A, 19A, 20A, 21A, 25A, and 29B) determined that at all plate locations the posts of the long-term monitoring plates were not observed and armor stone was present, indicating that the plates have remained buried and no observable loss of cap material has occurred. In fact, light siltation (¼ to ½-inch) and shells/shell fragments were observed at all locations except plate locations 11E, 17A, 17B, 25A and 29B, where areas of heavier siltation (three to seven inches) were observed. At plate location 19A, heavy siltation (up to 18 inches) was observed in some areas. Videos taken of

plate locations also revealed the presence of biological growth on some cap areas. A summary of video observations is included on **Table 4**.

2.3.2 Intertidal Areas

A Trimble GeoXH6000 unit was used at low tide when the intertidal cap areas were exposed to navigate to the as-built GPS coordinates of the intertidal long-term monitoring plate locations. Upon arrival at each long-term monitoring plate locations, a white-board displaying the plate location ID was placed at the as-built GPS coordinates as a visual marker, and an inspection of an area at least 10-ft by 10-ft around the GPS-defined plate location was conducted. The field inspector documented the inspection using a video camera and determined whether the long-term monitoring plate was exposed. The field inspector also made general observations about cap conditions including thickness of silt layer formed around the armor stone. Field inspector observations were recorded on cap thickness verification forms which are summarized on **Table 4**.

Inspections of the four plate locations within intertidal areas (i.e., plates 5A, 11F, 13C, and 13D) revealed that the posts of all of the long-term monitoring plates were not observed and armor stone was present. This indicates that the plates are buried and no observable loss of cap material has occurred. In fact, trace to light siltation ($\frac{1}{4}$ -to $\frac{1}{2}$ -inch) and shells/shell fragments were observed at all locations except plate locations 13C and 13D, where heavier siltation (up to 4.5 inches of very soft silt) was observed. A summary of video observations is presented on **Table 4**. Overall, the field inspectors observed the sediment caps to be in good condition.

In addition, the field inspector checked the area where a scour hole-like depression adjacent to Cap Area 13 was observed during the Year 2 cap inspection activities and repaired on October 23, 2015. The field inspector's observations were consistent with those made during the June 20, 2017 inspection event (as documented by Ramboll in a memorandum dated June 29, 2017) that the repaired area is effectively intact and there is no evidence of scour around the repaired area.

2.4 Sediment Profile Imaging

The Sediment Profile Imaging (SPI) survey was completed on July 17, 2018 by RJ Diaz and Daughters of Ware Neck, Virginia to evaluate surface sediment deposition and sediment bed stability in MNR areas. The SPI survey was conducted at 10 designated locations distributed across the SA-7 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 (Canon 7D digital single lens reflex camera) system 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. The profile camera was controlled from the surface vessel via a cable that supplies power and allows real-time monitoring of the Canon 7D operation and image capture. As the camera was lowered, tension on the winch wire kept the prism in the up position. Once the camera frame touched the river bottom, slack on the winch wire allowed the prism to vertically intersect the sediment bed. The rate of fall of the prism was controlled by an adjustable passive hydraulic piston, which minimized the disturbance of the sediment-water interface. The profile camera prism window was 15.5 cm wide and 30 cm tall. One hundred pounds of weight were added to the camera frame to increase prism penetration. Approximately 1 second after river bottom contact and after the prism stopped penetrating the sediment, the camera was triggered from the surface vessel and captured 18-megapixel images on an internal memory card using Canon's raw image format.

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 relief or boundary roughness (cm)
4. Apparent redox potential discontinuity (RPD) depth (cm)
5. Subsurface features (type and frequency of occurrence and minimum and maximum depth of infauna and voids)
6. Infaunal successional stages
7. Organism-Sediment Index (OSI)
8. Biological mixing depth (cm)

The SPI 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.). As described in **Appendix D**, the Year 5 results were compared to the results from Years 1 and 2.

The Year 5 SPI survey indicates that biological communities are present at each the ten SA7 stations. There were some limited changes over space and time, but the SPI results for SA7 are consistent with other portions of the Newark Bay ecosystem. The numeric comparison of results for Years 1, 2, and 5 are provided in Table 7 of **Appendix D**. A brief summary for each metric is provided, and specific stations are discussed when pertinent.

- Sediment grain size: The Year 5 results indicate that SA7 sediments are unconsolidated, silt-clay, flocculent sediments. This is consistent with the unconsolidated and hard fine-sand bottoms described in Year 2. The SPI report in **Appendix D** concludes that there is spatial variability in sediment grain size among the SA7 stations but very little difference in sediment characteristics from Years 1, 2, and 5.
- Camera prism penetration depth: The prism depth reflects the depth the camera can penetrate into the sediments. The further the camera can penetrate indicates less consolidated sediments. The penetration depths in Year 5 ranged from approximately 2 to 25 cm. The Year 5 results are similar to those seen in Years 1 and 2. Station 2 has shown the most variability over time (6.7 cm in Year 1; 3.2 cm in Year 2; and 13.1 cm in Year 5) but results for Station 2 are well within the range seen for other stations (2.1 cm at Station 8 to 24.8 at Station 6).
- Surface relief or boundary roughness: This metric provides an indication of surface conditions that are dominated by biological processes (sediment dwelling organisms burrowing) or physical processes (such as ripples or bedforms). The Year 5 results show that conditions at SA7 are influenced by both physical and biological processes. The conditions are comparable over time for the majority of locations. Stations 6 and 7 changed from domination by biological processes to physical processes between Years 2 and 5, and Stations 3 and 8 show a mixture of biological and physical processes in Year 5 compared to past conditions dominated by biological processes (Years 1 and 2).

- Apparent RPD depth: The Year 5 SPI study indicated variable RPDs for the stations surveyed. The Year 5 results are highly variable but overall, Year 5 compared to Years 1 and 2 indicate that RPD results were similar at SA7 stations monitored over time. The recorded RPDs for Year 5 are typical of those in summer conditions.
- Subsurface features (type and frequency of occurrence and minimum and maximum depth of infauna and voids): Gas voids were present in many of the Year 5 stations surveyed. There were more voids seen in Year 5 compared to previous years, which most likely reflects summer conditions when microbial activity is higher.
- Infaunal successional stages: The conditions at SA7 demonstrated a biological community at all locations. SPI can measure 3 successional stages (Stage I, II, and III) that demonstrate young, surface communities (Stage I) to progressively more mature and deeper dwelling community (Stage III). **Appendix D** indicates that the Year 5 SPI demonstrated a mature biological community (Stage III) at four locations, no Stage II communities and four communities progressing from pioneering to intermediate (between Stage I and II). There were two stations (Stations 4 and 7) that demonstrated the presence of Stage I communities. Relative to Year 2, there has been a decline in successional conditions, possibly due to seasonal changes at the time of the SPI surveys.
- OSI: Variable OSI results were observed in Year 5, ranging from healthy habitats (Station 1 and 3) to degraded habitats at Stations 4 and 7. The other stations had OSI results between these endpoints of healthy to degraded. **Appendix D** notes that the factor that appeared to cause the habitat degradation was hypoxia, a common factor in summer months. OSI was not recorded in Year 2. The Year 1 SPI survey was completed in autumn, but the Year 5 SPI survey was completed during the summer and it is possible that benthic habitats within the SA-7 MNR areas were exposed to summertime hypoxia. Particularly at SPI-4 and SPI-7, the combination of higher organic content and hypoxic conditions may explain the degraded benthic habitat documented in Year 5.
- Biological mixing depth: The 2018 results for biological mixing depths ranged from 0 to 10.7 cm, and **Appendix D** notes that these results for SA7 were consistent with other portions of the Newark Bay ecosystem. The biological mixing depths for 2018 were shallower compared to depths in 2015, which can also be related lower oxygen conditions in the summer.

The SPI survey conducted in Year 5 and comparisons to the SPI surveys in Years 1 and 2 do not indicate evidence of excessive organic loading or associated sediment contamination resulting in toxicity to the sediment dwelling community 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 5 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 July 18 and 19, 2018 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 Solinst® 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 SGS Accutest (a New Jersey certified laboratory) for hexavalent chromium analysis.

As presented on **Table 5**, hexavalent chromium was not detected in any of the pore water samples. In addition, the method detection limits (MDLs) were reviewed and confirmed to be below both the NJDEP's acute and chronic saline (SE) Surface Water Quality Criteria.

2.6 Biological Sampling

In conformance with the Revised Implementation Plan, biological monitoring was conducted in Year 5 within capped areas and at background reference locations to evaluate the recolonization of benthic species within the remediated areas. Benthic community sampling and analysis was conducted between July 24 through July 30, 2018 at locations proximate to 20 of the 38 long-term monitoring plates that were installed within capped areas (see **Figures 1** and **2**) and at three (3) designated off-site reference locations (see **Figure 3**).

A Trimble SPS855 unit was used to navigate to and record biological sampling locations in both intertidal and subtidal areas. Samples were collected using either a Petit Ponar or a Dredge sampler, preserved using a formalin solution, and transported to ASI's laboratory in Flemington, New Jersey for taxonomic identification. At the laboratory, samples were rinsed with tap water and sieved through a 500- μm sieve to remove the formalin and debris prior to picking. ASI collected all invertebrate specimens from each grab sample and identified them to the lowest genus and species levels possible. The number of specimens from each grab sample was recorded, taxa diversity was counted, and the percent of each genus and species that comprised each sample was estimated. Each grab sample represented approximately 0.023 square meters (m^2) and ASI used the total number of specimens to estimate the benthic community density reported in number per square meter (No/m^2). The results of the benthic survey are presented in **Appendix E**.

The results for density and diversity are presented in **Figures 4** and **5**, based on the summary of data presented in **Appendix E** and **Table 6**. The results indicate that the diversity and density within the cap areas is generally similar to or greater than at the background locations, with the exception of one location (Location 29A) where no organisms were found¹. Diversity ranged from 1 to 20 in the capped areas and from 1 to 3 in the three reference areas. Within the cap areas, diversity of 1 was seen at Locations 6A, 11D, and 26A in the Northern Area and Location 15A adjacent to the SA-7 bulkhead. The highest diversity of 20 was seen at Location 7A in Droyers Cove. There was a considerable range of taxa density values within the sediment cap areas, with values ranging from 43 to 8,304 No/m^2 , with an average of 2,176 No/m^2 . The density values at the three background areas were 43, 87, and 174 No/m^2 ; the lowest density of 43 was seen at Location RF2. When compared with the Year 1 results, the diversity and density values at many locations are lower in Year 5. This difference is likely due to summer Year 5 sampling compared to autumn Year 1 sampling. Overall, however, the Year 5 findings show that diverse and abundant sediment dwelling organisms are developing on the cap areas.

¹ This finding at Location 29A is likely an artifact of variability in the sediment community or potentially reflects a recent event that may have scoured organisms from the surface. The lack of organisms at Location 29A is not considered related to the presence of chromium because chromium was present at higher concentrations at other locations with a diverse and abundant community.

2.7 Surface Sediment Sampling

In conformance with the Revised Implementation Plan, surface sediment sampling was conducted between July 26 and July 30, 2018 at locations proximate to 20 of the 38 long-term monitoring plates that were installed within the capped areas (refer to **Figures 1** and **2**). Locations were distributed between both intertidal and subtidal capped areas. A vessel equipped with a Trimble SPS855 unit was used to navigate to and record sampling locations in both the intertidal and subtidal areas. Sampling was conducted using vibracoring equipment to retrieve 4-inch diameter samples. While only the upper 12 inches of material was targeted for sampling and analysis purposes, cores were advanced into the underlying sediment to “plug” the core and prevent loss of sample. After retrieval, cores were cut lengthwise and samples were collected from the upper 12 inches of the retrieved core. Samples were submitted to SGS Accutest for total chromium analysis. Even with the use of vibration, the variable-sized armor stone proved difficult to penetrate and capture with the 4-inch diameter core liner and, in some locations, multiple cores had to be attempted before material that could be sampled (i.e., sand and/or sediment material) was recovered. In addition, as discussed below, at three locations recovery of armor material could not be achieved using vibracoring equipment. This is not uncommon where the armor material is essentially pushed away from the core as it is advanced.

As presented on **Table 7**, of the 20 locations sampled, total chromium was detected in exceedance of the Consent Order specified limit of 370 parts per million (ppm) at three locations where poor recovery of the upper 12 inches of material was observed: Locations 1A, 17C, and 29A. In these three areas, diver inspections were utilized to support the surface sediment sampling.² A review of documentation provided in the May 2014 Summary Report and photos and field notes generated during this sampling event indicated that the material sampled at these three locations is not representative of the uppermost 12 inches of material, but rather the underlying native sediments. Most importantly, the cap inspections documented in Section 2.3 of this report demonstrated that the armored caps are still in place with no evidence of loss of cover material (most areas inspected showed sediment deposition over the caps). Thus, confirmatory sampling was performed at Locations 1A, 17C, and 29A between December 17 and December 19, 2018 in conjunction with the Year 5 diver-assisted cap thickness verification activities. These sampling activities are summarized below.

2.7.1 Location 1A

As summarized on **Table 7**, the detected chromium concentration in the July 2018 sample collected at Location 1A was 3,680 ppm. However, inspection of the conditions at this location indicates that the cap is intact and meets required cover thickness (the Consent Order thickness requirement for Cap Area 1 is 6 inches), and the material sampled is not representative of the uppermost 12 inches of material:

- **Cap Material Placement Records:** As indicated in the Summary Report, a total of 1,726 tons of buttress and capping material (442 tons of sand, 1,003 tons of filter material used for buttress construction, and 281 tons of 0.75-inch armor) were placed for Cap Area 1. This quantity is over three times the Consent Order tonnage requirement of 510 tons. In addition, quality control (QC) verification measurements indicate an average³ cap thickness of 10.2 inches (4.2 inches of sand and 6.0 inches of armor), which exceeds the Consent Order thickness requirement of 6 inches.

² The potential limitations with coring of armored sediment caps were identified in the 2012 LTMP, as it was anticipated that sediment coring may not be feasible in areas where the core cannot penetrate the cap, such as in areas where larger stone is used for armoring.

³ The total depth range in the QC verification measurements in Cap Area 1 is from 8.4 to 15 inches.

For reference purposes, **Appendix F** includes a modified version of the Cap Area 1 Data figure from Appendix J.1 of the Summary Report, where the Year 5 surface sediment sampling location has been added to the QC verification measurement locations presented in the original figure.

- **Sediment Sampling Observations:** According to field records of the Year 5 sediment sampling event, the first and second coring attempts at Location 1A each recovered approximately 1 foot of $\frac{3}{4}$ -inch armor stone; however, no sand or sediment was recovered in either of the cores in these two attempts to allow for collection of a sample for analytical testing. The third coring attempt was also unsuccessful due to the presence of armor material (i.e., the armor layer could not be penetrated with the 4-inch diameter liner). The fourth attempt recovered approximately 4 feet of a dark gray-brown sandy silt (refer to Photo 1 below). However, the materials recovered did not include any cap materials (i.e., armor stone, filter or sand) and, though slightly sandier, the recovered material resembled the native sediments. These observations of the material sampled for analysis are inconsistent with the cap material placement records, and therefore, not considered representative of the upper 12-inches of material at this location.



Photo 1: Sediment core from Location 1A – no cap material present.

Based on a review of the observations of the material collected in the sample core and cap placement records, confirmatory sampling at Location 1A was performed. Location 1A was inspected as part of the diver-assisted sediment cap thickness verification activities in December 2018. The diver's inspection was recorded on video and observed in real-time by the field team aboard the supporting vessel. The diver visually inspected the area around the previous sampling location and did not observe any potential cap integrity issues; in fact, an average of $\frac{1}{2}$ -inch of deposited silt was observed in the inspected area.⁴ A summary of video observations is presented on **Table 8**. The diver also visually inspected the long-term monitoring plate location in this area to assess any potential cap material loss. The plate was not observed, which is consistent with the results of the Year 1

⁴ Location 1A is within a bathymetric survey grid showing net gain in Year 5.

inspection of this area and indicates that the plate has remained buried and no observable loss of cap material has occurred.

Attempts by the dive team to re-core the uppermost 12 inches of the cap were unsuccessful at penetrating the armor layer. Therefore, the diver used a clean glass sample jar to collect a sample of the approximately 1/2-inch thick layer of silt overlying the armor layer of the cap by scraping the jar directly on the cap. In addition, the diver used a 32-inch metal rod marked with white electrical tape at 6-inch intervals to qualitatively measure the total thickness of the cap⁵; this direct measurement reported approximately 30 inches of cover material (including layers of sand, armor stone, and silt deposited on top of the armor stone).

As presented in **Table 9**, the total chromium concentration in the sample collected by the diver on December 17, 2018 was 183 ppm, which is below the Consent Order specified limit of 370 ppm. Based on this result and the observations made by the diver during his visual inspection, at least 12 inches of conforming cap material exists above the native sediment surface and no additional action is warranted.

2.7.2 Location 17C

As summarized on Table 7, the detected chromium concentration in the July 2018 sample collected at Location 17C was 1,080 ppm. However, inspection of the conditions at this location indicates that the cap is intact and meets required thickness (the Consent Order thickness requirement for Cap Area 17 is 12 inches), and the material sampled is not representative of the uppermost 12 inches of material:

- **Cap Material Placement Records:** As indicated in the Summary Report, a total of 22,430 tons of capping material (6,921 tons of sand, 5,685 tons of filter, and 9,824 tons of 2.5-inch armor) were placed for Cap Area 17. This quantity is over two times the Consent Order tonnage requirement of 9,030 tons. In addition, QC verification measurements indicate an average⁶ cap thickness of 24.0 inches (9.1 inches of sand, 7.1 inches of filter, and 7.8 inches of armor), which is twice the Consent Order thickness requirement of 12 inches. For reference purposes, **Appendix F** includes a modified version of the Cap Area 17 Data figure from Appendix J.16 of the Summary Report, where the Year 5 surface sediment sampling location has been added to the QC verification measurement locations presented in the original figure.
- **Sediment Sampling Observations:** According to field records of the Year 5 sediment sampling event, the first coring attempt failed to recover any material (likely due to armor stone clogging the 4-inch diameter core liner and preventing the core catcher at the end of the barrel from closing). The second attempt recovered approximately 3.6 feet of material. The uppermost approximately 2 inches consisted of dark gray silt mixed with some 2.5-inch armor stone and fine sand. The remainder of the core consisted of a dark gray fine sandy silt that resembled the native sediments (refer to Photo 2 below). These observations are inconsistent with the cap material placement records.

⁵ The rod was manually driven through the cap by the diver until it reached a point of no resistance, signaling that the rod had penetrated through the armor and sand layers and into the underlying soft native sediment. Cap thickness was measured using the number of intervals on the rod above the cap surface.

⁶ The total depth range in the QC verification measurements in Cap Area 17 is from 17 to 35 inches.



Photo 2: Sediment core from Location 17C – little to no cap material present.

Based on a review of the observations of the material collected in the sample core and the cap placement records, confirmatory sampling at Location 17C was conducted. Location 17C was inspected and re-sampled as part of the diver-assisted sediment cap thickness verification activities in December 2018, using the same means and methods as used at Location 1A (see **Section 2.7.1** above). The diver did not observe any potential cap integrity issues in the area around the previous sampling location; in fact, between 2 and 3 inches of deposited silt was observed in the inspected area⁷. A summary of video observations is presented on **Table 8**. The diver also visually inspected the long-term monitoring plate location in the area to assess any potential cap material loss. The plate was not observed, which is consistent with the results of the Year 1 inspection of this area and indicates that the plate has remained buried and no observable loss of cap material has occurred.

The diver collected the sample directly from the approximately 2- to 3-inch thick silt layer overlying the armor layer of the cap and used the 32-inch metal rod to qualitatively measure the total cap thickness. At this location, the cap thickness exceeded the length of the rod (i.e., the native sediment was not encountered in the upper 32 inches).

As presented in **Table 9**, the total chromium concentration in the sample collected by the diver on December 17, 2018 was 47.6 ppm, which is below the Consent Order specified limit of 370 ppm. Based on this result and the observations made by the diver during his visual inspection, at least 12 inches of conforming cap material exists above the native sediment surface and no additional action is warranted.

2.7.3 Location 29A

As summarized on Table 7, the detected chromium concentration in the July 2018 sample collected at Location 29A was 451 ppm. However, inspection of the conditions at this location indicates that the

⁷ Location 17C is within a bathymetric survey grid showing net gain in Year 5.

cap is intact and meets required thickness (the Consent Order thickness requirement for Cap Area 29 is 12 inches), and the material sampled is not representative of the uppermost 12 inches:

- **Cap Material Placement Records:** As indicated in the Summary Report, a total of 24,415 tons of capping material (10,638 tons of sand, 8,172 tons of filter, and 3,412 tons of 1.0-inch armor) were placed for Cap Area 29. This quantity is over two times the Consent Order tonnage requirement of 10,920 tons. In addition, for Cap Area 29B (where long-term monitoring plate 29A is located), QC verification measurements indicate an average⁸ cap thickness of 22.2 inches (7.8 inches of sand, 6.8 inches of filter, and 6.8 inches of armor), which is almost twice the Consent Order thickness requirement of 12 inches. For reference purposes, **Appendix F** includes a modified version of the Cap Area 29 Data figure from Appendix J.26 of the Summary Report, where the Year 5 surface sediment sampling location has been added to the QC verification measurement locations presented in the original figure.
- **Sediment Sampling Observations:** According to field records of the Year 5 sediment sampling event, approximately 3.4 feet of material was recovered by the sampler. The uppermost approximately 5 inches consisted of filter and armor stone, followed by approximately 3 inches of coarse sand. The remainder of the core consisted of a dark gray clayey silt consistent with the characteristics of the native sediments (refer to Photos 3 and 4 below). The observation of native sediments in the upper 12 inches is inconsistent with the cap material placement records and the location.



Photo 3: Sediment core from Location 29A – approx. 8 inches of cap material present.



Photo 4: Transition between cap material and native sediment in core from Location 29A.

Based on a review of the observations of material collected in the sample core and the cap placement records, confirmatory sampling at Location 29A was performed. Location 29A was inspected and re-sampled as part of the diver-assisted sediment cap thickness verification activities in December 2018, using the same means and methods as used at Locations 1A and 17C (see **Sections 2.7.1** and **2.7.2** above). The diver did not observe any potential cap integrity issues in the area around the previous sampling location; in fact, an average of 1-inch of deposited silt was observed in the inspected area⁹. A summary of video observations is presented on **Table 8**. The diver also visually inspected the long-term monitoring plate location in the area to assess any potential cap material loss. The plate was not

⁸ The total depth range in the QC verification measurements in Cap Area 29 is from 16.5 to 34.3 inches.

⁹ Location 29A is within a bathymetric survey grid showing net gain in Year 5.

observed, which is consistent with the results of the Year 1 inspection of this area and indicates that the plate has remained buried and no observable loss of cap material has occurred.

The diver collected the sample directly from the approximately 1-inch thick layer of silt overlying the armor layer of the cap and used the 32-inch metal rod to qualitatively measure the total cap thickness; this direct measurement reported approximately 22 inches of cover material (including layers of sand, armor stone, and silt deposited on top of the armor stone).

As presented in **Table 9**, the total chromium concentration in the sample collected by the diver on December 17, 2018 was 89.7 ppm, which is below the Consent Order specified limit of 370 ppm. Based on this result and the observations made by the diver during his visual inspection, at least 12 inches of conforming cap material exist above the native sediment surface and no additional action is warranted.

3. SUMMARY

This monitoring report presents the results of the Year 5 long-term monitoring event conducted for the SA-7 sediment remediation program, and includes assessment of capped, MNR, and reference areas (i.e., the three offsite biological monitoring locations). 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 through Year 15 to identify any high energy events that would trigger additional assessment. After 15 years, assessments of high energy events will be discontinued if at least two high energy events have been captured in the analysis. The results of this monitoring for Years 6 through 10 will be provided in annual monitoring reports.
- A comparison between the baseline and Year 5 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 5 survey with the baseline survey identified nine of the 175 sediment cap subareas and eight of the 140 MNR subareas (up to ¼-acre in size) with a loss in bed elevation (ranging from 0.02 to 2.55 inches); however, the losses are less than the 4-inch threshold for identifying an Erosional Area and therefore do not require further evaluation at this time. Further, the one MNR subarea that showed a net loss in Year 2 (i.e., 72 MNR) showed a net increase in the bed elevation of 2.42 inches in Year 5. As specified in the Long-Term Monitoring Plan, the bathymetric survey will be repeated in Year 10, and following up to two high energy events, and the results compared to the Year 1 baseline survey to identify areas of potential erosion in both capped and MNR areas. 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.
- The cap thickness inspections confirmed that the armoring of the caps remains in-place with no evidence of erosion of cap materials. Routine sediment cap integrity monitoring will be discontinued as the data collected during the first five years of monitoring do not indicate that further monitoring is warranted. Monitoring will be conducted following up to two high-energy events and may also be performed if the Year 10 bathymetric survey identifies an area of potential erosion warranting further assessment. If cap integrity monitoring is triggered by the high-energy events, monitoring locations would be selected following the alternating selection process (i.e., next event, if any, would monitor cap locations inspected in Year 1). If the bathymetric survey identifies specific areas with a net bed elevation reduction of more than 4 inches, these areas would be targeted for further assessment.
- The SPI survey in MNR areas indicates an established sediment dwelling benthic community that is typical of the estuarine environment. There are no indications of surface sediment erosion. Following up to two high energy events, SPI surveys will be performed in MNR areas where erosion may have resulted in more than a 4-inch decrease in surface sediment elevations based on the hydrodynamic evaluation and measured bathymetric observations.
- Hexavalent chromium was not detected in any of the pore water samples. Pore water sampling will be discontinued as the data collected during the first five years of monitoring do not indicate that further monitoring is warranted.
- The benthic community survey indicates diverse and abundant sediment dwelling communities are continuing to develop on the cap areas. Biological monitoring will be discontinued as the data

collected during the first five years of monitoring do not indicate that further monitoring is warranted.

- Total chromium concentrations did not exceed the Consent Order specified limit of 370 ppm in any of the surface sediment samples characterizing the uppermost 12 inches. Surface sediment sampling will be discontinued as the data collected in Year 5 do not indicate that further monitoring is warranted.

In summary, the five years of post-construction monitoring have 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.

4. REFERENCES

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TABLES

Table 3
As-Built Cap Construction and Monitoring Plate Details
Study Area 7 Sediment Remedy
Jersey City, NJ

Cap Area	CAP DETAILS					MONITORING PLATES			
	Average Sand Layer Thickness (inches)	Average Filter Layer Thickness (inches)	Average Armor Layer Thickness (inches)	Armor Size (inches)	Average Total Thickness (inches)	Plate ID	Intertidal or Subtidal	Stickup Length (inches)	Expected Exposed Length (inches)
1	4.7	NA	6.6	0.75	11.2	1A	Subtidal	12	1
2	7.2	NA	6.7	0.75	13.9	2A	Subtidal	12	0
3	4.6	NA	6.4	0.75	11.0	3A	Subtidal	15	0
4	5.2	NA	6.3	0.75	11.5	NA	Subtidal	NA	NA
5	6.0	6.6	6.2	2.5	18.8	5A	Intertidal	8	0
6A	6.4	6.2	6.0	1	18.6	NA	Intertidal	NA	NA
6B	6.1	5.8	6.3	2.5	18.2	6A	Subtidal	8	0
7A	7.6	NA	5.6	0.75	13.3	7A	Subtidal	12	3
						7C	Subtidal	8	0
7B	6.1	8.4	10.4	2.5	24.9	7B	Subtidal	8	0
7C	5.7	6.7	11.9	3.5	24.3	NA	Subtidal	NA	NA
8A	7.6	NA	5.5	0.75	13.0	NA	Subtidal	NA	NA
8B	8.5	5.7	5.3	1	19.5	8A	Subtidal	18	5
9	6.2	4.4	6.1	1	16.7	9A	Subtidal	18	5
10	9.3	NA	4.4	0.75	13.7	10A	Subtidal	12	0
11A	6.1	8.7	9.9	2.5	24.7	NA	Subtidal	NA	NA
11B	6.8	6.6	5.9	1	19.3	11A	Subtidal	18	0
						11B	Subtidal	18	0
						11C	Subtidal	18	1
						11E	Subtidal	18	0
11C	5.4	5.9	6.7	2.5	18.0	11D	Subtidal	8	0
						11F	Intertidal	8	0
12	NA	NA	24.2	10	24.2	NA	Subtidal	NA	NA
13A	7.5	5.2	6.2	1	19.0	13B	Intertidal	15	0
						13D	Intertidal	15	0
13B	6.7	5.9	6.5	2.5	19.1	13A	Intertidal	15	0
						13C	Intertidal	15	0
14	10.3	NA	7.1	0.75	17.4	14A	Subtidal	15	0
15	8.6	NA	7.2	0.75	15.8	15A	Subtidal	15	0
17	9.4	7.2	7.8	2.5	24.3	17A	Subtidal	24	3
						17B	Subtidal	24	2
						17C	Subtidal	24	2
18A	8.9	NA	7.1	0.75	16.0	18A	Subtidal	15	0
						18B	Subtidal	15	0
18B	8.6	6.7	7.8	2.5	23.1	NA	Subtidal	NA	NA
19A	9.9	6.0	7.4	1	23.3	NA	Subtidal	NA	NA
19B	11.1	NA	7.2	0.75	18.4	19A	Subtidal	15	0
20	10.7	NA	8.0	0.75	18.6	20A	Subtidal	15	0
21	9.5	NA	7.8	0.75	17.3	21A	Subtidal	15	0
23	10.8	NA	10.3	0.75	21.1	NA	Subtidal	NA	NA
24	5.7	7.1	7.5	2.5	20.3	NA	Subtidal	NA	NA
25	6.5	NA	5.4	0.75	11.9	25A	Subtidal	12	0
26	7.0	7.1	8.0	2.5	22.1	26A	Intertidal	8	0
27	6.1	NA	7.1	0.75	13.3	27A	Subtidal	12	3
29A	8.1	8.0	8.0	2.5	24.1	29B	Subtidal	24	1
29B	7.7	6.9	6.9	1	21.5	29A	Subtidal	24	5
						29C	Subtidal	24	4
30A	3.5	7.2	5.6	1	16.3	NA	Subtidal	NA	NA
30B	6.7	6.7	7.6	2.5	20.9	30A	Intertidal	8	0

* = Expected exposed length was determined based on plate stickup length and average cap thickness measurement around the plate location.

Table 4
Long-Term Monitoring Plate Inspection Summary
Study Area 7 Sediment Remedy
Jersey City, NJ

Plate ID	Inspection Year	Cap Location (Subtidal or Intertidal)	As-Built Plate Northing	As-Built Plate Easting	Inspection Date	Video Completed? (Y/N)	Video Length (min)	Observations (Time Markers)	Plate Length Exposed (inches)	Notes
5A	2018	Intertidal	687467.65	603571.78	12/7/2018	Y	1:06	None	0	Inspection conducted at low tide, when cap area was exposed. Plate was not observed at the as-built coordinates. No signs of erosion were observed; rather, trace siltation (less than 1/4 inch) and shells/shell fragments observed on cap material.
7B	2018	Subtidal	684649.44	601020.07	12/19/2018	Y	4:38	(3:36) Crab leg	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, light siltation (1/4 inch), shells/shell fragments, and biological growth observed on cap material.
8A	2018	Subtidal	687004.80	602852.96	12/17/2018	Y	5:58	None	0	Plate was not observed at the as-built coordinates. Low visibility due to shallow water. No signs of erosion were observed; rather, light siltation (up to 1/2 inch) and some biological growth observed on cap material.
10A	2018	Subtidal	685964.10	601737.53	12/19/2018	Y	6:09	(0:22) Approx. 1-inch thick, 18 inches wide, 12 inches tall debris sticking up from cap surface (see Photo 25 in Appendix A)	0	Plate was not observed at the as-built coordinates. Good visibility, moderate to strong current. No signs of erosion were observed; rather, light siltation (up to 1/2 inch), shells/shell fragments, and trace biological growth observed on cap material.
11B	2018	Subtidal	688160.25	603230.75	12/17/2018	Y	5:58	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, light siltation (up to 1/2 inch on average, with pockets of heavier deposition) and some biological growth observed on cap material.
11E	2018	Subtidal	688035.44	603445.52	12/19/2018	Y	4:15	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, siltation (up to 4 inches on average, with pockets up to 7 inches) and some biological growth observed on cap material.
11F	2018	Intertidal	688285.65	603594.02	12/7/2018	Y	1:01	None	0	Inspection conducted at low tide, when cap area was exposed. Plate was not observed at the as-built coordinates. No signs of erosion were observed; rather, some light siltation (1/4 inch to 3/4 inch) and biological growth observed on cap material, as well as few shells/shell fragments.

Table 4
Long-Term Monitoring Plate Inspection Summary
Study Area 7 Sediment Remedy
Jersey City, NJ

Plate ID	Inspection Year	Cap Location (Subtidal or Intertidal)	As-Built Plate Northing	As-Built Plate Easting	Inspection Date	Video Completed? (Y/N)	Video Length (min)	Observations (Time Markers)	Plate Length Exposed (inches)	Notes
13C	2018	Intertidal	686872.45	603098.19	12/7/2018	Y	0:58	None	0	Inspection conducted at low tide, when cap area was exposed. Plate was not observed at the as-built coordinates. No signs of erosion were observed. Heavy siltation (3 to 4.5 inches) in pooled area immediately adjacent to (west of) inspection location. Trace siltation and biological growth in areas north, east, and south of inspection location. Few shells/shell fragments observed.
13D	2018	Intertidal	687298.41	603297.25	12/7/2018	Y	1:10	None	0	Inspection conducted at low tide, when cap area was exposed. Plate was not observed at the as-built coordinates. No signs of erosion were observed; rather, some light siltation with pockets of heavier siltation (up to 3 inches), trace shells/shell fragments, and biological growth observed on cap material.
14A	2018	Subtidal	685365.44	600853.61	12/18/2018	Y	4:57	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, siltation (up to 2 inches) and biological growth observed on cap material.
17A	2018	Subtidal	688075.46	602896.27	12/19/2018	Y	6:05	(4:10, 4:42) Fish	0	Plate was not observed at the as-built coordinates. Good visibility, moderate to strong current. No signs of erosion were observed; rather, siltation (1/2 to 4 inches), biological growth, and shells/shell fragments observed on cap material.
17B	2018	Subtidal	688232.10	603025.93	12/18/2018	Y	5:37	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, siltation (1/2 inch on average, up to 3 to 4 inches in some areas), biological growth, and shells/shell fragments observed on cap material.
18A	2018	Subtidal	686549.55	602233.75	12/19/2018	Y	5:40	(1:38) Small bottle	0	Plate was not observed at the as-built coordinates. Good visibility, moderate to strong current. No signs of erosion were observed; rather, siltation (up to 1/2 inch), shells/shell fragments, and trace biological growth observed on cap material.
19A	2018	Subtidal	687672.51	603107.63	12/17/2018	Y	6:25	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, heavy siltation (up to 18 inches in some locations) was observed across the inspection area. Armor stone was identified at approximately 15 inches below water/sediment interface.

Table 4
Long-Term Monitoring Plate Inspection Summary
Study Area 7 Sediment Remedy
Jersey City, NJ

Plate ID	Inspection Year	Cap Location (Subtidal or Intertidal)	As-Built Plate Northing	As-Built Plate Easting	Inspection Date	Video Completed? (Y/N)	Video Length (min)	Observations (Time Markers)	Plate Length Exposed (inches)	Notes
20A	2018	Subtidal	685083.01	600982.91	12/18/2018	Y	4:39	None	0	Plate was not observed at the as-built coordinates. Good visibility, strong current. No signs of erosion were observed; rather, siltation (up to 1/4 inch), some shells/shell fragments, and some biological growth was observed on the cap material.
21A	2018	Subtidal	685515.67	601316.1	12/19/2018	Y	5:56	(2:47) 1/4- to 1/2-inch electrical cable (see Photo 27 in Appendix A)	0	Plate was not observed at the as-built coordinates. Good visibility, strong current. No signs of erosion were observed; rather, siltation (1/4 inch on average, up to 1 to 2 inches in isolated pockets), shells/shell fragments, and some biological growth was observed on the cap material.
25A	2018	Subtidal	688852.43	603630.92	12/17/2018	Y	4:53	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, siltation (up to 5 inches) and biological growth observed on cap material.
29B	2018	Subtidal	688725.61	603237.98	12/17/2018	Y	6:43	None	0	Plate was not observed at the as-built coordinates. Good visibility. No signs of erosion were observed; rather, siltation (1/4 inch to 3 inches), trace shells/shell fragments, and some biological growth matter observed on cap material.

TABLE 5
Summary of Pore Water Sampling Results
Honeywell SA-7; Jersey City; NJ

Location	NJDEP	NJDEP	1A	8A	13A	13B	13C	13C	18B
Field Sample ID	Salt Water	Salt Water	PW1A-	PW8A-	PW13A-	PW13B-	PW13C-	DUP-	PW18B-
Lab Sample ID	Aquatic	Aquatic	20180719	20180719	20180718	20180718	20180718	20180718	20180719
Sample Date	Acute	Chronic	JC70190-2	JC70190-3	JC70095-3	JC70095-2	JC70095-1	JC70095-4	JC70190-1
Comments	Values	Values	7/19/2018	7/19/2018	7/18/2018	7/18/2018	7/18/2018	7/18/2018	7/19/2018
INORG									
Chromium VI	1100	50	U (6.0)	U (6.0)	U (5.5)				

Notes:

- 1 All concentrations are presented in ug/L.
- 2 None of the concentrations exceed the published criteria.

Abbreviations:

- U -- Not Detected.
- () -- Reporting Detection Limit.

Table 6
Taxa Diversity and Taxa Density Summary for Benthic Community Assessment Grab Samples
Study Area 7 Sediment Remedy
Jersey City, NJ

Station	General Location	Diversity ^(a)	Density ^(b) (No./m ²)	Total Specimens ^(c)	Summary of Taxon (Common Name)
7A	Droyers Cove	20	2,391	55	worms: blood, fan, fringed, mud, pile, thread, white ribbon, others mollusk, sea anemone, sea squirt, side swimmer, skeleton shrimp, tube maker, other estuarine amphipod
7C		8	826	19	worms: clam, mud, paddle, others snail, other estuarine amphipod
3A		6	1,217	28	worms: blood, thread, others
15A	SA-7	1	43	1	sea squirt
2A	SA-6	9	8,304	191	worms: mud, paddle, thread, others eastern mudsnail
1A	CSO	12	7,783	179	worms: mud, paddle, pile, thread, others hooded shrimp, sand shrimp
6A	Northern Cove / Northern Area	1	43	1	sea pill bug
9A		6	739	17	worms: trumpet, other opossum shrimp, sea squirt, soft-shell clam, other estuarine amphipod
11A		3	870	20	worms: mud, others
11C		3	261	6	bay barnacle, hooded shrimp, other estuarine amphipod
11D		1	43	1	slender isopod
13A		4	522	12	worms: ampharetid, clam, paddle, mud
13B		7	4,087	94	worms: mud, pile, others sea pill bug, other estuarine amphipods
17C		16	3,870	89	worms: fan, mud, paddle, thread, others sea swimmer, side swimmer, other estuarine amphipods
18B		3	435	10	sea squirt, fan worm, other estuarine amphipod
26A		1	87	2	worm
27A		14	7,348	169	worms: ampharetid, fringed, mud, paddle, pile, round, thread, others estuarine amphipod
29A		N/A	0	0	N/A
29C		12	1,826	42	worms: ampharetid, blood, fan, fringed, mud, paddle, pile, ribbon, thread, others estuarine amphipod
30A		10	2,826	65	worms: ampharetid, mud, paddle, pile, thread, others sea pill bug, slender isopod, other amphipod
RF1		Background	2	87	2
RF2	1		43	1	mud worm
RF3	3		174	4	worms: mud, thread opossum shrimp

Notes:

- (a) Diversity is the total number of taxa seen at each location.
- (b) Density is an estimated value based on the total number of specimens in the grab sample.
- (c) Total number of specimens is the number of individual organisms collected in each grab sample.

TABLE 7
Summary of Sediment Sampling Results - July 2018
Honeywell SA-7; Jersey City, NJ

Location		1A	2A	2A	03A	6A
Field Sample ID	Consent	SED01A-20180726	SED02A-20180726	DUP-20180726	SED03A-20180726	SED06A-20180727
Lab Sample ID	Order	JC70918-1	JC70918-2	JC70918-3	JC70918-4	JC70918-15
Collection Depth (ft bgs)	Specified	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
Sample Method	Limit	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push
Sample Date		7/26/2018	7/26/2018	7/26/2018	7/26/2018	7/27/2018
Comments				Field Duplicate		
INORG						
Chromium (total)	370	3680 (8.3)	289 (1.5)	318 (1.5)	68.3 (1.5)	343 (1)

Notes:

- 1 All concentrations are presented in mg/kg (ppm).
- 2 All compounds analyzed for are shown.
- 3 Concentrations that exceed the Consent Order Specified Limit are **boldfaced**.

Abbreviations:

() -- Detection Limit.

TABLE 7
Summary of Sediment Sampling Results - July 2018
Honeywell SA-7; Jersey City, NJ

Location	7A	7C	9A	11A	11C	11D
Field Sample ID	SED07A-20180726	SED07C-20180726	SED09A-20180730	SED11A-20180730	SED11C-20180727	SED11D-20180727
Lab Sample ID	JC70918-5	JC70918-6	JC70918-19	JC70918-22	JC70918-18	JC70918-14
Collection Depth (ft bgs)	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
Sample Method	Direct Push					
Sample Date	7/26/2018	7/26/2018	7/30/2018	7/30/2018	7/27/2018	7/27/2018
Comments						
INORG						
Chromium (total)	115 (1.9)	151 (1.7)	4.1 (1.2)	204 (1.4)	344 (1)	53.6 (1.4)

Notes:

- 1 All concentrations are presented in mg/kg (ppm).
- 2 All compounds analyzed for are shown.
- 3 Concentrations that exceed the Consent Order Specified Limit are **boldfaced**.

Abbreviations:

() -- Detection Limit.

TABLE 7
Summary of Sediment Sampling Results - July 2018
Honeywell SA-7; Jersey City, NJ

Location	13A	13B	15A	17C	18B	26A
Field Sample ID	SED13A-20180727	SED13B-20180727	SED15A-20180730	SED17C-20180730	SED18B-20180730	SED26A-20180727
Lab Sample ID	JC70918-16	JC70918-17	JC70918-20	JC70918-23	JC70918-21	JC70918-12
Collection Depth (ft bgs)	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
Sample Method	Direct Push					
Sample Date	7/27/2018	7/27/2018	7/30/2018	7/30/2018	7/30/2018	7/27/2018
Comments						
INORG						
Chromium (total)	296 (0.99)	3.8 (1.2)	7.3 (1.2)	1080 (2)	14.5 (1.2)	35.4 (1)

Notes:

- 1 All concentrations are presented in mg/kg (ppm).
- 2 All compounds analyzed for are shown.
- 3 Concentrations that exceed the Consent Order Specified Limit are **boldfaced**.

Abbreviations:

() -- Detection Limit.

TABLE 7
Summary of Sediment Sampling Results - July 2018
Honeywell SA-7; Jersey City, NJ

Location	27A	29A	29C	30A
Field Sample ID	SED27A-20180727	SED29A-20180727	SED29C-20180727	SED30A-20180727
Lab Sample ID	JC70918-10	JC70918-9	JC70918-11	JC70918-13
Collection Depth (ft bgs)	0 - 1	0 - 1	0 - 1	0 - 1
Sample Method	Direct Push	Direct Push	Direct Push	Direct Push
Sample Date	7/27/2018	7/27/2018	7/27/2018	7/27/2018
Comments				
INORG				
Chromium (total)	199 (1)	451 (1)	204 (1)	259 (0.99)

Notes:

- 1 All concentrations are presented in mg/kg (ppm).
- 2 All compounds analyzed for are shown.
- 3 Concentrations that exceed the Consent Order Specified Limit are **boldfaced**.

Abbreviations:

() -- Detection Limit.

Table 8
Sampling Location Inspection Summary
Study Area 7 Sediment Remedy
Jersey City, NJ

Sample Location ID	Cap Location (Subtidal or Intertidal)	Inspection Date	Sample Location Northing	Sample Location Easting	Cap Thickness (inches)	Video Completed? (Y/N)	Video Length (min)	Notes and Observations (Time Markers)
1A	Subtidal	12/19/2018	686759.40	602456.5	30	Y	9:26	<p>Good visibility. No signs of erosion were observed; rather, light siltration (approximately 1/2 inch on average) and some shells/shell fragments observed on cap material.</p> <p>(2:10) Diver reports that rod has advanced through approximately 6 inches of stone. (4:45) Diver reports that rod is advancing through what feels like compact sand layer. (8:08) Diver reports that rod has advanced to underlying soft sediments. Approximately 2 inches of 32-inch long rod remain exposed above the cap surface.</p>
17C	Subtidal	12/19/2018	688374.64	603057.05	> 32	Y	2:26	<p>Good visibility. No signs of erosion were observed; rather, siltation (approximately 2-3 inches on average) and trace shells/shell fragments observed on cap material.</p> <p>(1:54) Diver reports that full length of 32-inch long rod has been advanced through cap materials; the soft sediments offering no resistance were not encountered.</p>
29A	Subtidal	12/19/2018	688429.29	603351.38	22	Y	1:54	<p>Good visibility. No signs of erosion were observed; rather, siltation (approximately 1 inch on average) and trace shells/shell fragments observed on cap material.</p> <p>(0:51) Diver reports that rod has advanced to underlying soft sediments. Approximately 10 inches of 32-inch long rod remain exposed above the cap surface.</p>

TABLE 9
Summary of Sediment Sampling Results - December 2018
Honeywell SA-7; Jersey City, NJ

Location		1A	1A	17C	29A
Field Sample ID	Consent	SED1A-20181217	FD-20181217	SED17C-20181217	SED29A-20181217
Lab Sample ID	Order	JC79884-3	JC79884-5	JC79884-2	JC79884-1
Collection Depth (ft bgs)	Specified	0 - 1	0 - 1	0 - 1	0 - 1
Sample Method	Limit	Grab	Grab	Grab	Grab
Sample Date		12/17/2018	12/17/2018	12/17/2018	12/17/2018
Comments			Field Duplicate		
INORG					
Chromium (total)	370	183 (3)	142 (2.4)	47.6 (1.7)	89.7 (2.5)

Notes:

- 1 All concentrations are presented in mg/kg (ppm).
- 2 All compounds analyzed for are shown.
- 3 Concentrations that exceed the Consent Order Specified Limit are **boldfaced**.

Abbreviations:

() -- Detection Limit.

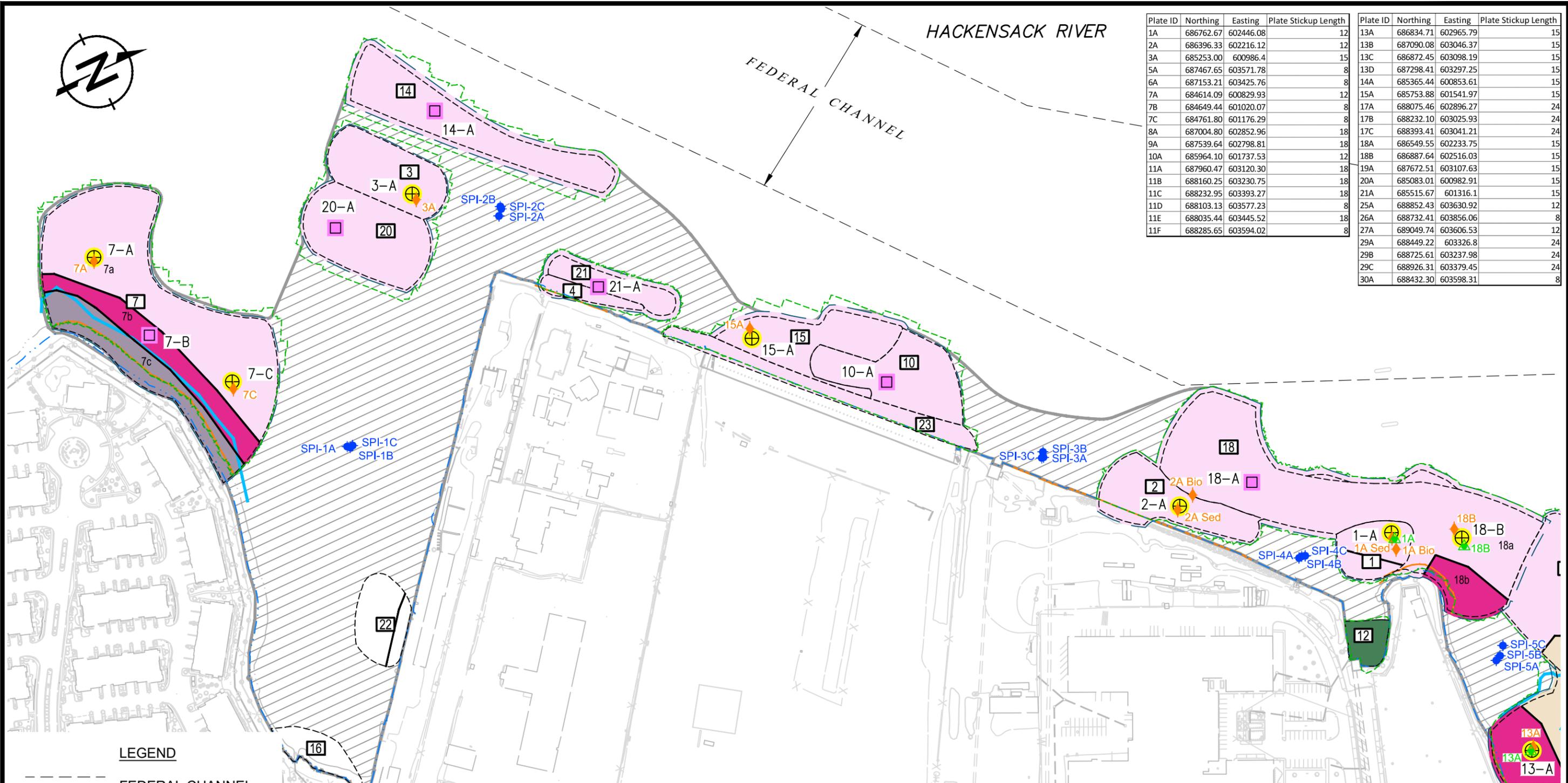
FIGURES



HACKENSACK RIVER

FEDERAL CHANNEL

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
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
- BIOLOGICAL AND SURFACE SEDIMENT 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
- SPI INVESTIGATION LOCATIONS
- CAP AREA
- SUB CAP AREAS
- PORE WATER SAMPLING LOCATION



YEAR 5 LONG TERM MONITORING SAMPLE LOCATIONS

STUDY AREA 7
JERSEY CITY, NEW JERSEY

FIGURE

1



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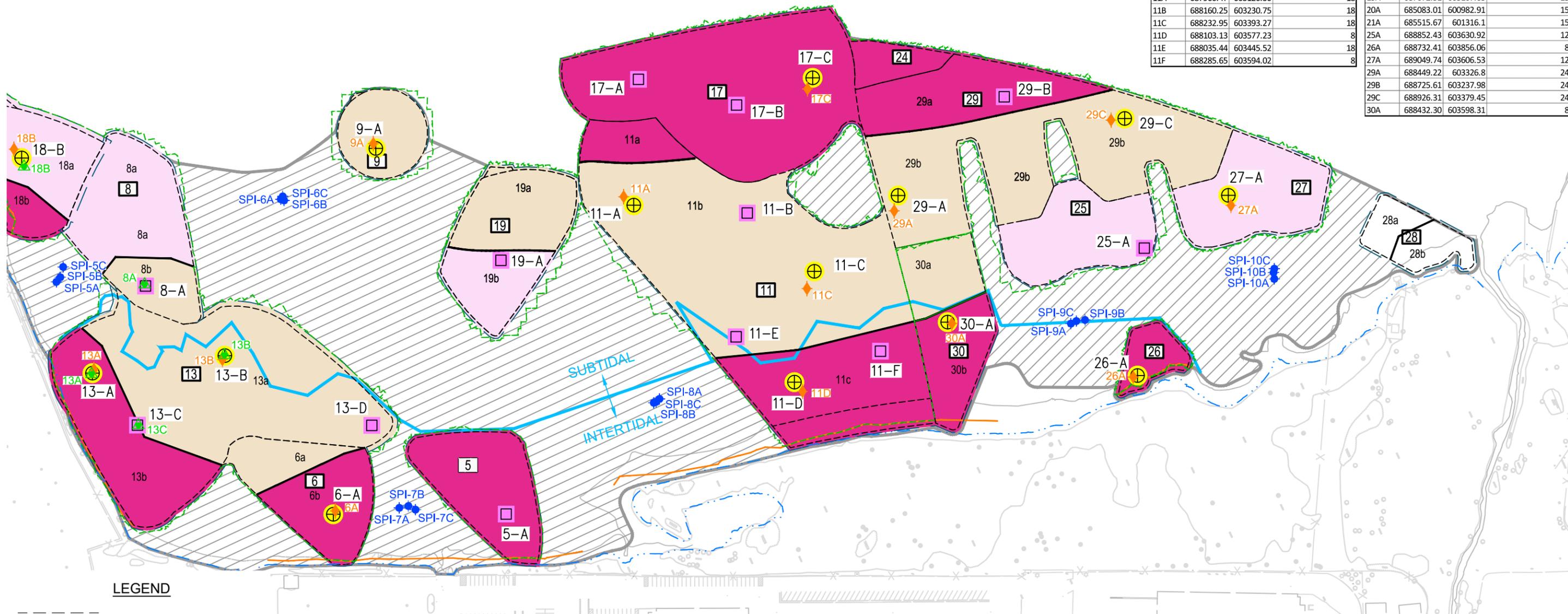
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FEDERAL CHANNEL

Plate ID	Northing	Easting	Plate Stickup Length	Plate ID	Northing	Easting	Plate Stickup Length
1A	686762.67	602446.08	12	13A	686834.71	602965.79	15
2A	686396.33	602216.12	12	13B	687090.08	603046.37	15
3A	685253.00	600986.4	15	13C	686872.45	603098.19	15
5A	687467.65	603571.78	8	13D	687298.41	603297.25	15
6A	687153.21	603425.76	8	14A	685365.44	600853.61	15
7A	684614.09	600829.93	12	15A	685753.88	601541.97	15
7B	684649.44	601020.07	8	17A	688075.46	602896.27	24
7C	684761.80	601176.29	8	17B	688232.10	603025.93	24
8A	687004.80	602852.96	18	17C	688393.41	603041.21	24
9A	687539.64	602798.81	18	18A	686549.55	602233.75	15
10A	685964.10	601737.53	12	18B	686887.64	602516.03	15
11A	687960.47	603120.30	18	19A	687672.51	603107.63	15
11B	688160.25	603230.75	18	20A	685083.01	600982.91	15
11C	688232.95	603393.27	18	21A	685515.67	601316.1	15
11D	688103.13	603577.23	8	25A	688852.43	603630.92	12
11E	688035.44	603445.52	18	26A	688732.41	603856.06	8
11F	688285.65	603594.02	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
- BIOLOGICAL AND SURFACE SEDIMENT 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
- SPI INVESTIGATION LOCATIONS
- CAP AREA
- 7a SUB CAP AREAS
- PORE WATER SAMPLING LOCATION



YEAR 5 LONG TERM MONITORING SAMPLE LOCATIONS

STUDY AREA 7
JERSEY CITY, NEW JERSEY



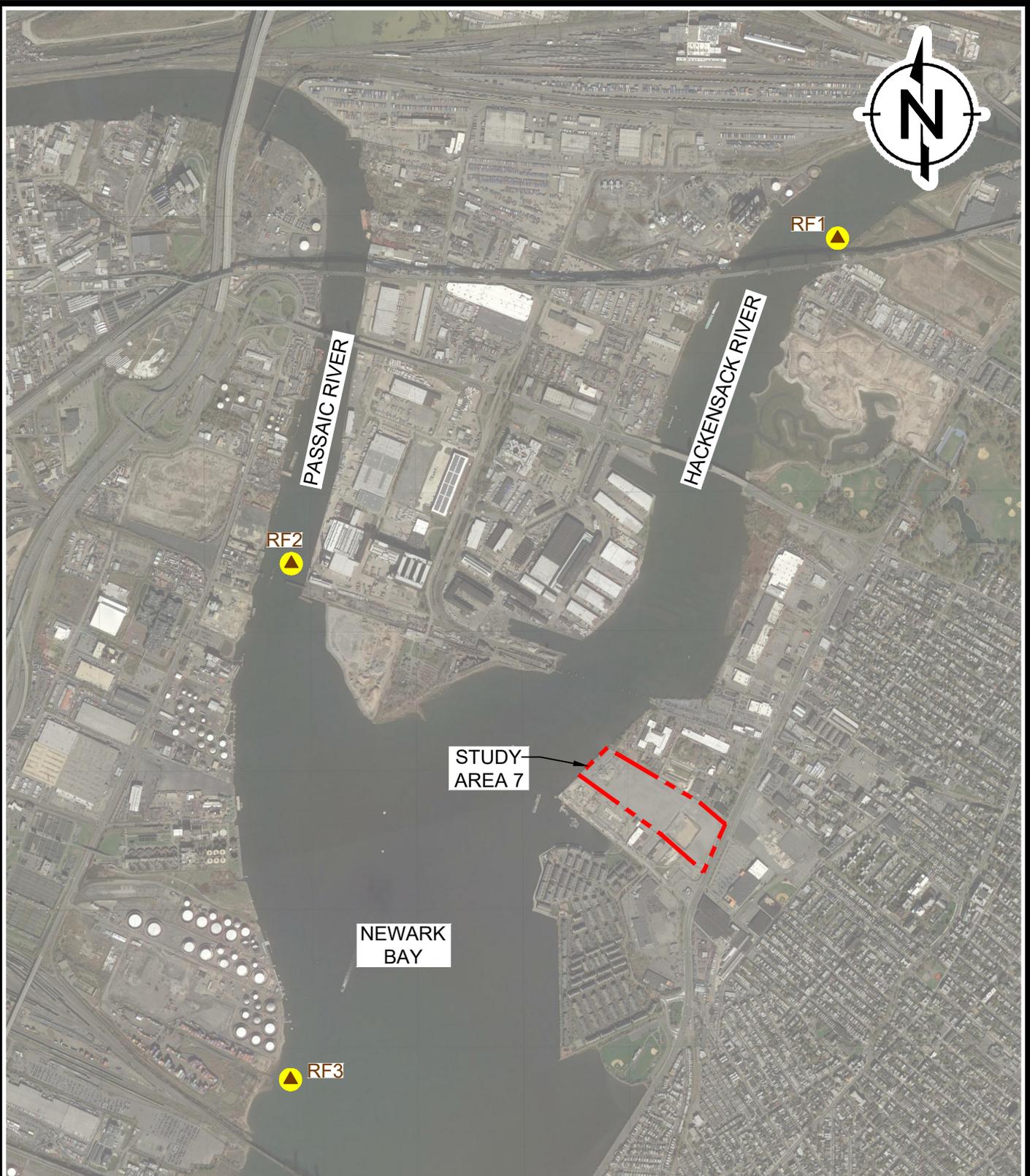
FIGURE 2

MBLE 1/7/19 [SMPL_YEAR 5 LTM] F:\169000484_SAT_WIP DRAFT

DRAFTED BY: BJK/MSB DATE: 01/07/2019

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LEGEND

 OFF-SITE BIOLOGICAL BACKGROUND LOCATIONS



SOURCE:
1. AERIAL IMAGE: Google Earth Pro™, IMAGERY DATED 11/03/2012.



**OFF-SITE BIOLOGICAL
BACKGROUND LOCATIONS**
STUDY AREA 7
JERSEY CITY, NEW JERSEY

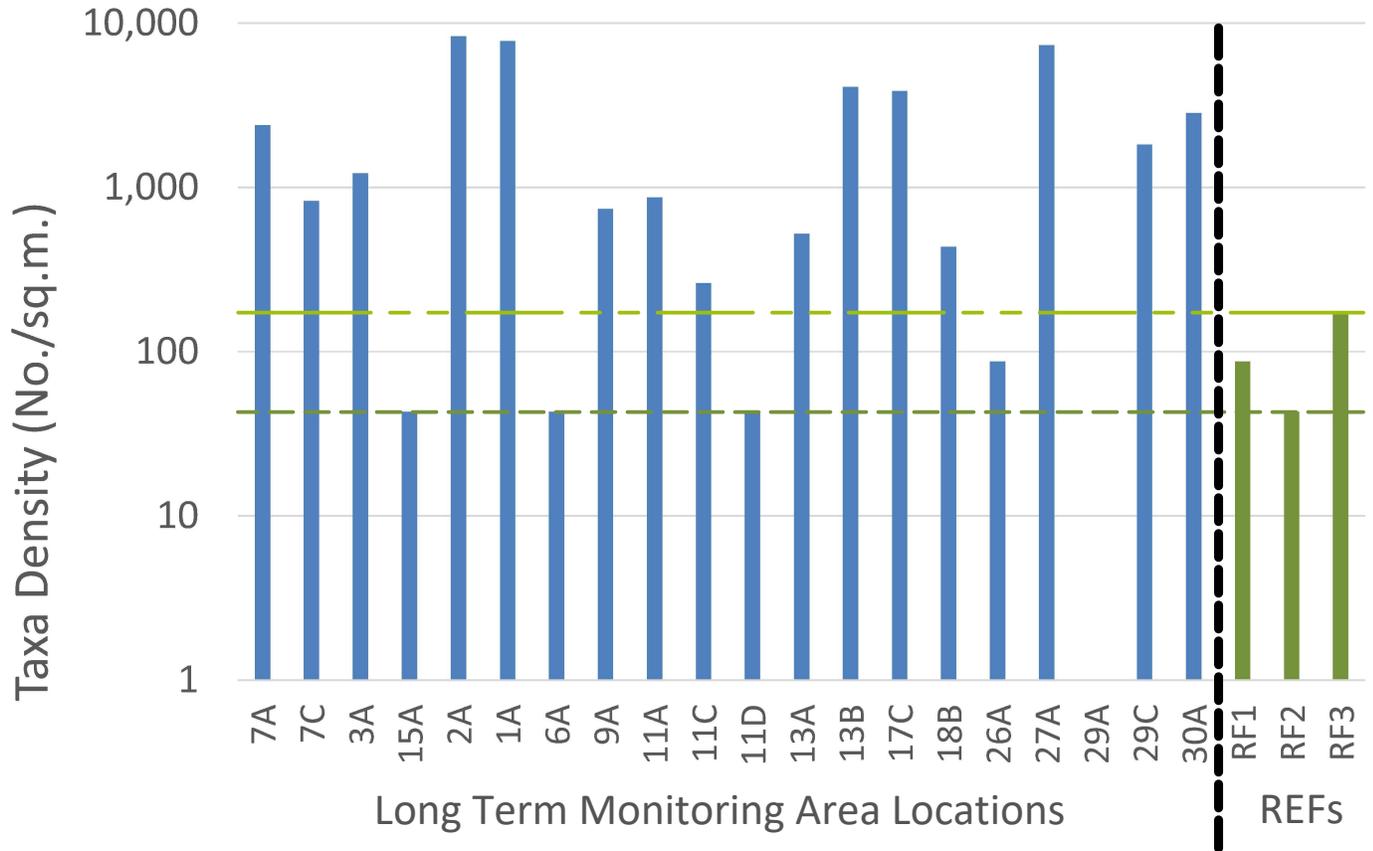
**FIGURE
3**

DRAFTED BY: MSB

DATE: 08/20/2018

1690000484

Taxa Density by Location



LEGEND:

- - - UPPER END OF DENSITY MEASUREMENTS FROM THE REFERENCE AREA MONITORED
- - - LOWER END OF DENSITY MEASUREMENTS FROM THE REFERENCE AREA MONITORED

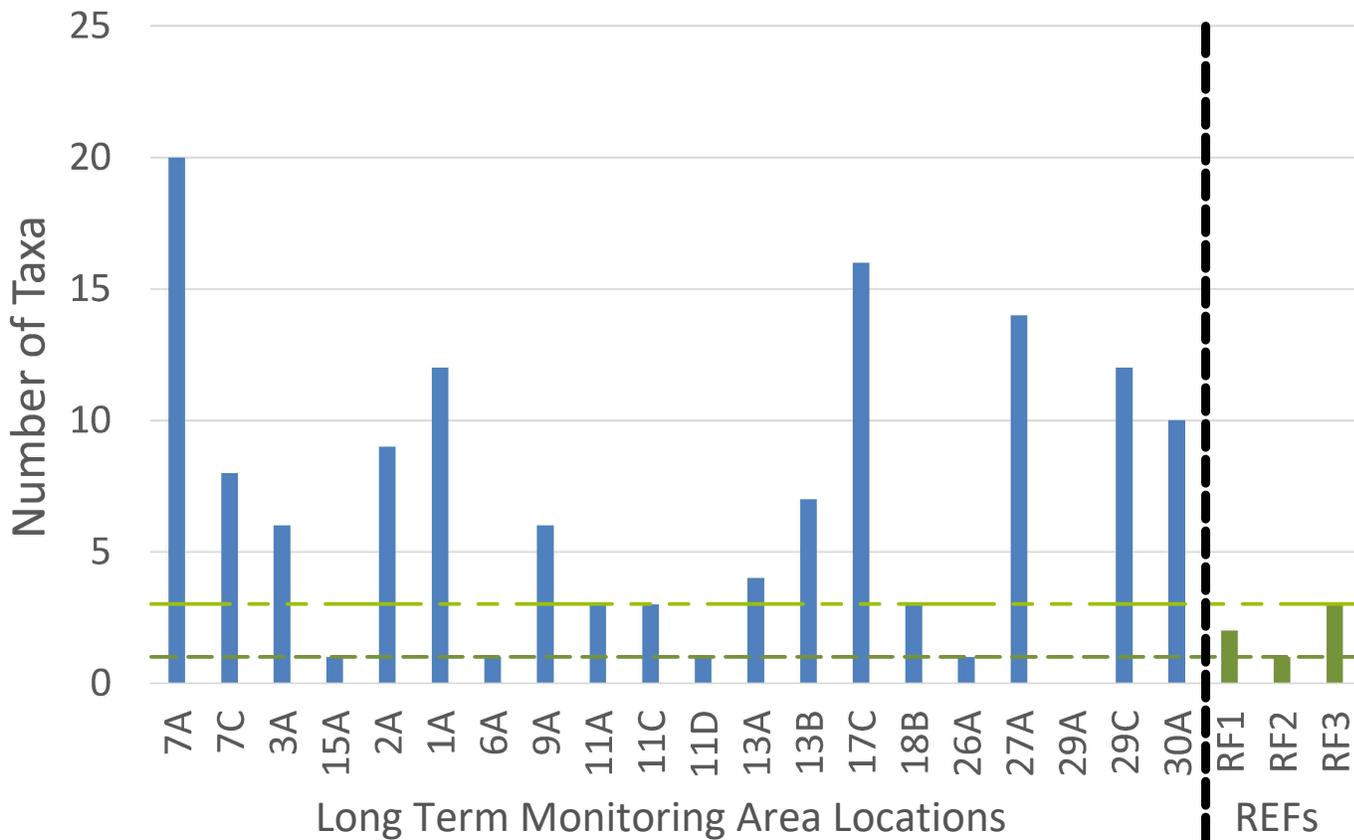
**BENTHIC COMMUNITY GRAB
SAMPLE DENSITY RESULTS**

STUDY AREA 7
JERSEY CITY, NEW JERSEY



**FIGURE
4**

Taxa Diversity By Station



LEGEND:

- - - - - UPPER END OF DIVERSITY MEASUREMENTS FROM THE REFERENCE AREA MONITORED
- - - - - LOWER END OF DIVERSITY MEASUREMENTS FROM THE REFERENCE AREA MONITORED

**BENTHIC COMMUNITY GRAB
SAMPLE DIVERSITY RESULTS**

STUDY AREA 7
JERSEY CITY, NEW JERSEY



**FIGURE
5**

**APPENDIX A
PHOTOGRAPHS**



Photo 1: SPI Camera staged on deck of ASI vessel (July 17, 2018).



Photo 2: Deploying the SPI Camera in subtidal MNR area (July 17, 2018).



Photo 3: Collecting pore water sample in intertidal cap area (July 18, 2018).

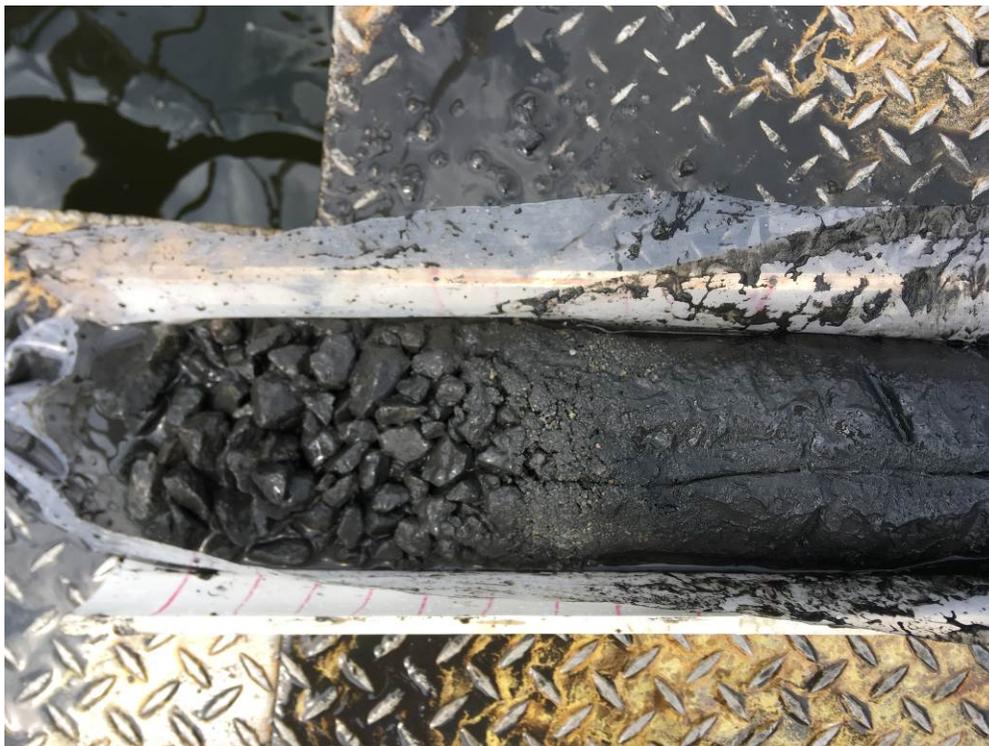


Photo 4: Sediment core from sample location 11C – 0.8 ft of cap material present (July 27, 2018).



Long Term Monitoring Program – Year 5

SA-7 Sediment Remedy
Jersey City, NJ
July 2018 – December 2018



Photo 5: Sediment core from sample location 13B – 1.4 ft of cap material present (July 27, 2018).



Photo 6: Sediment core from sample location 15A – 1.5 ft of cap material present (July 30, 2018).



Photo 7: Sediment core from sample location 18B – 1.5 ft of cap material present (July 30, 2018).



Photo 8: Sediment core from sample location 26A – 0.8 ft of cap material present (July 27, 2018).



Photo 9: Inspection of intertidal plate 5A in Cap Area 5 (December 7, 2018).



Photo 10: Inspection of intertidal plate 11F in Cap Area 11 (December 7, 2018).



Photo 11: Sediment deposition over sediment cap at intertidal plate 13C (December 7, 2018).



Photo 12: Biological growth and shells present on cap material in intertidal cap area (December 7, 2018).



Photo 13: Diver preparing to inspect subtidal Cap Area 1 (December 17, 2018).

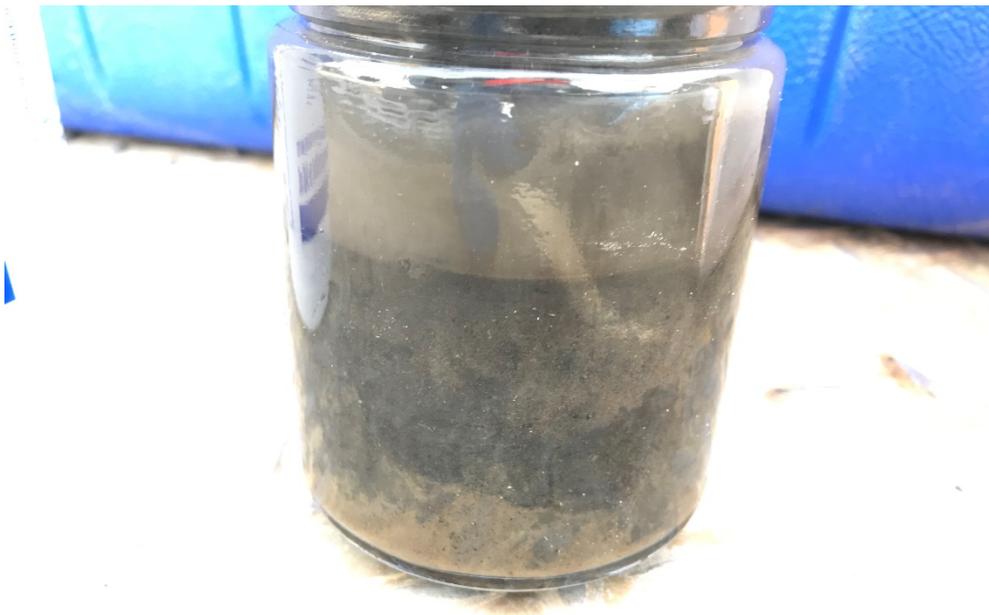


Photo 14: Sediment sample collected by diver from cap surface at location 1A (December 17, 2018).



Photo 15: Sediment sample collected by diver from cap surface at location 17C (December 17, 2018).



Photo 16: Sediment sample collected by diver from cap surface at location 29A (December 17, 2018).



Photo 17: Video recorder and monitor used for subtidal cap inspections (December 17, 2018).



Photo 18: Diver deployed to inspect subtidal cap area (December 19, 2018).



Long Term Monitoring Program – Year 5

SA-7 Sediment Remedy
Jersey City, NJ
July 2018 – December 2018



Photo 19: Approx. 1-inch thick, 18 inches wide, 12 inches tall debris observed sticking up from cap surface in LTM Plate 10A inspection area (December 19, 2018).



Photo 20: Fish observed during LTM Plate 17A inspection (December 19, 2018).



Long Term Monitoring Program – Year 5

SA-7 Sediment Remedy
Jersey City, NJ
July 2018 – December 2018



Photo 21: ¼- to ½-inch electrical cable observed on cap surface in LTM Plate 21A inspection area (December 19, 2018).



Photo 22: 32-inch long metal rod penetrating cap material at Sample Location 1A – approximately 2 inches of rod remain exposed above cap surface (December 19, 2018).



Long Term Monitoring Program – Year 5

SA-7 Sediment Remedy
Jersey City, NJ
July 2018 – December 2018



Photo 23: 32-inch long metal rod penetrating cap material at Sample Location 17C – full length of rod advanced through cap materials, soft sediments not encountered (December 19, 2018).



Photo 24: 32-inch long metal rod penetrating cap material at Sample Location 29A – approximately 10 inches of rod remain exposed above cap surface (December 19, 2018).



Long Term Monitoring Program – Year 5

SA-7 Sediment Remedy
Jersey City, NJ
July 2018 – December 2018

**APPENDIX B
YEAR 5 HYDRAULIC AND HYDRODYNAMIC
EVALUATION SUMMARIES**

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> Year 5 - October 2017 through December 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 3.86 Date: 10/29/2017 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 1.333 Date: 10/30/2017 Time: 3:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.763 Date: 10/27/2018 Time: 15:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO - for both events	NO
<u>Wind Event Data:</u> Max Wind (mph): 44 Date: 4/4/2018 Exceeds trigger criteria? YES Wind direction over 6-hr period: W OK (See Note 1) <u>Note:</u> (1) The averaged wind speed for the 6-hour period during which the maximum wind speed was recorded does not exceed the threshold criteria.	NO
<p><u>CRITERIA FROM LTMP:</u></p> <p>“Post-High Energy Event Monitoring Activities” will take place promptly following High Energy Events. The Consent Order defines “High Energy Events” as follows:</p> <p>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;</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p>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</p> <ul style="list-style-type: none"> • Note: Hurricane events are defined by NOAA. • See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750 <p>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.”</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p style="text-align: right;">CHECKED BY: <u> TEA </u></p>	

Weather History for KEWR - October, 2017

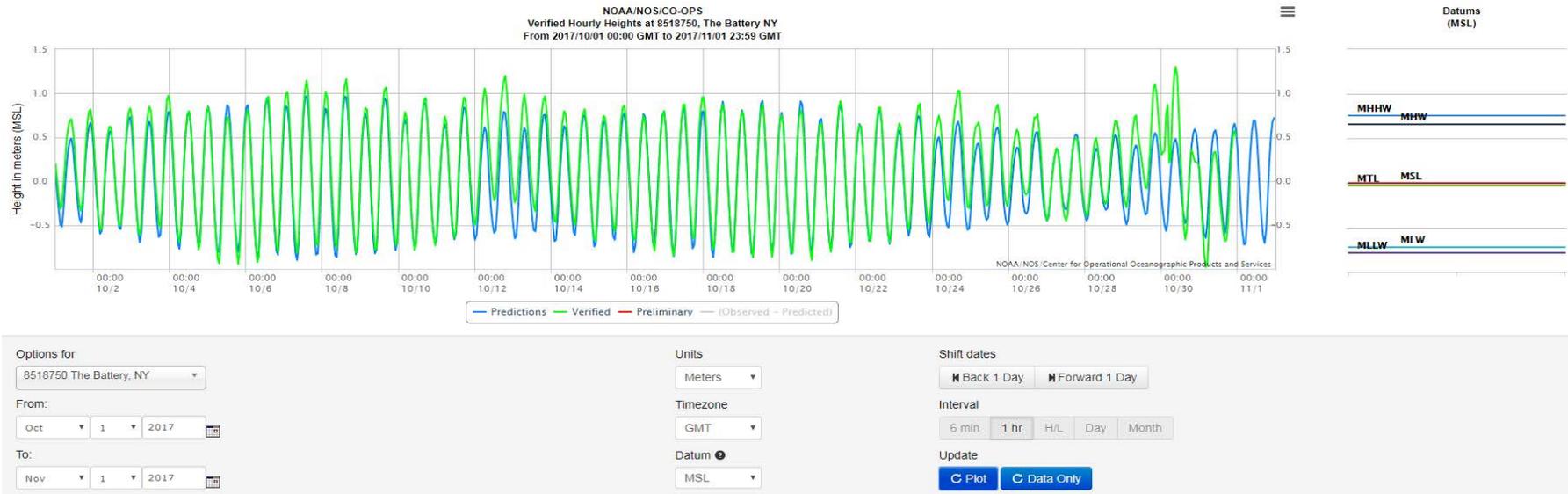
From:

To:

Get History

	Max	Avg	Min	Sum
Temperature				
Max Temperature	86 °F	73 °F	59 °F	
Mean Temperature	77 °F	64 °F	51 °F	
Min Temperature	73 °F	55 °F	40 °F	
Degree Days				
Heating Degree Days (base 65)	14	3	0	108
Cooling Degree Days (base 65)	12	3	0	86
Growing Degree Days (base 50)	26	13	0	415
Dew Point				
Dew Point	75 °F	51 °F	26 °F	
Precipitation				
Precipitation	3.86 in	0.19 in	0.00 in	4.94 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	39 mph	9 mph	0 mph	
Gust Wind	48 mph	23 mph	17 mph	
Sea Level Pressure				
Sea Level Pressure	30.64 in	30.10 in	28.90 in	

https://www.wunderground.com/history/airport/KEWR/2017/10/1/CustomHistory.html?dayend=31&monthend=10&yearend=2017&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20171001&edate=20171101&timezone=GMT&datum=MSL&interval=h&action=>

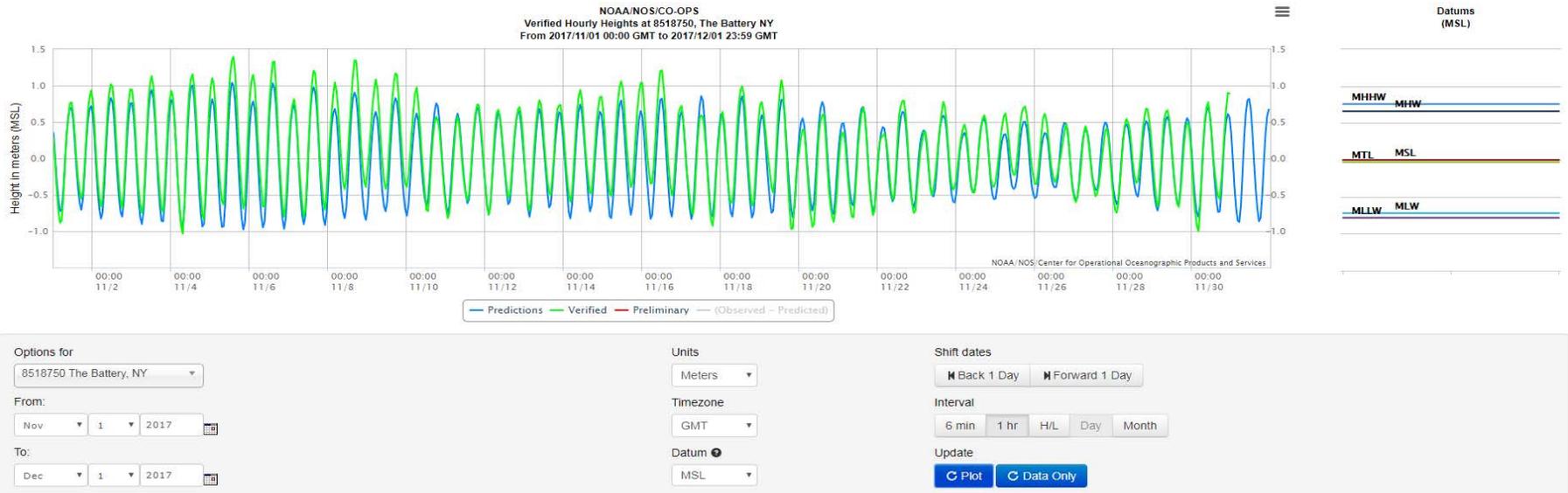
Weather History for KEWR - November, 2017

From: To:

[Get History](#)

Daily	Weekly	Monthly	Custom				
				Max	Avg	Min	Sum
Temperature							
Max Temperature				76 °F	55 °F	41 °F	
Mean Temperature				65 °F	46 °F	33 °F	
Min Temperature				55 °F	37 °F	24 °F	
Degree Days							
Heating Degree Days (base 65)				32	19	0	558
Cooling Degree Days (base 65)				0	0	0	0
Growing Degree Days (base 50)				14	2	0	48
Dew Point							
Dew Point				60 °F	33 °F	4 °F	
Precipitation							
Precipitation				0.69 in	0.06 in	0.00 in	1.51 in
Snowdepth				0.0 in	0.0 in	0.0 in	-
Wind							
Wind				38 mph	10 mph	0 mph	
Gust Wind				51 mph	25 mph	17 mph	
Sea Level Pressure							
Sea Level Pressure				30.58 in	30.12 in	29.22 in	

https://www.wunderground.com/history/airport/KEWR/2017/11/1/CustomHistory.html?dayend=30&monthend=11&yearend=2017&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20171101&edate=20171201&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> December 2017	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 0.51 Date: 12/23/2017 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.508 Date: 12/25/2017 Time: 7:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.406 Date: 12/5/2017 Time: 14:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 40 Date: 12/25/2017 Exceeds trigger criteria? YES Wind direction over 6-hr period: W OK (See Note 1) <u>Note:</u> (1) The averaged wind speed for the 6-hour period during which the maximum wind speed was recorded does not exceed the threshold criteria.	NO
<p><u>CRITERIA FROM LTMP:</u></p> <p>“Post-High Energy Event Monitoring Activities” will take place promptly following High Energy Events. The Consent Order defines “High Energy Events” as follows:</p> <p>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;</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p>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</p> <ul style="list-style-type: none"> • Note: Hurricane events are defined by NOAA. • See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750 <p>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.”</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p style="text-align: right;">CHECKED BY: <u>TEA</u></p>	

Weather History for KEWR - December, 2017

From: To:

[Get History](#)

Daily	Weekly	Monthly	Custom					
					Max	Avg	Min	Sum
Temperature								
					64 °F	41 °F	19 °F	
					57 °F	35 °F	14 °F	
					50 °F	28 °F	9 °F	
Degree Days								
					51	30	8	935
					0	0	0	0
					6	0	0	6
Dew Point								
					58 °F	22 °F	-9 °F	
Precipitation								
					0.51 in	0.06 in	0.00 in	1.64 in
					4.0 in	0.3 in	0.0 in	-
Wind								
					40 mph	10 mph	0 mph	
					51 mph	25 mph	16 mph	
Sea Level Pressure								
					30.59 in	30.07 in	29.43 in	

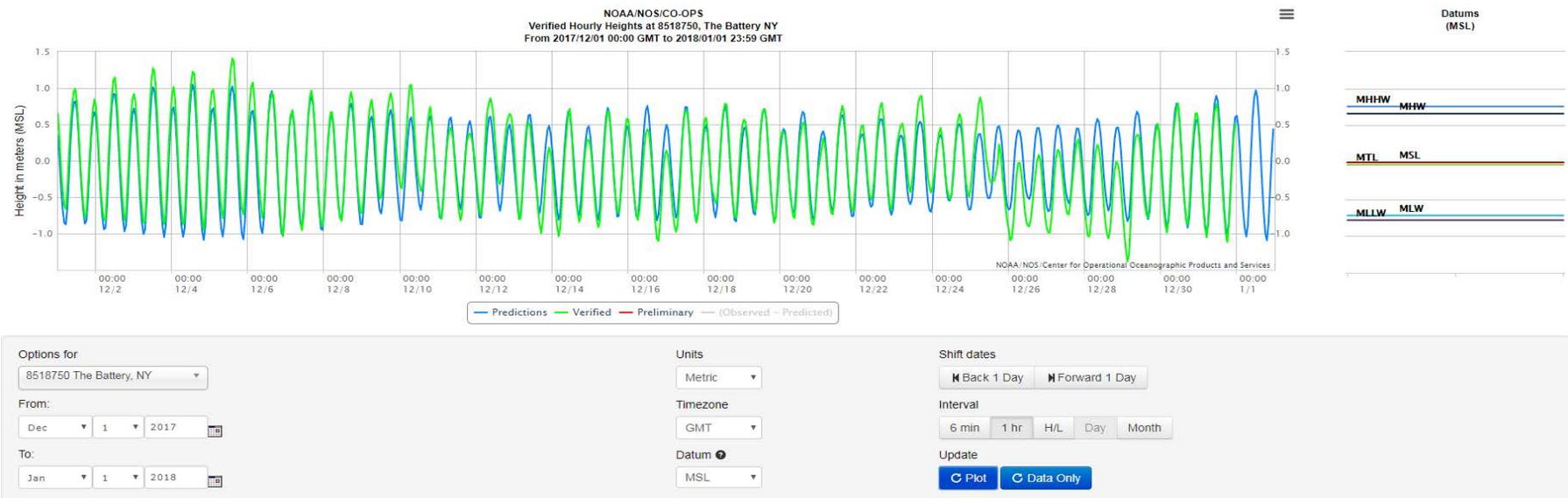
https://www.wunderground.com/history/airport/KEWR/2017/12/1/CustomHistory.html?dayend=31&monthend=12&yearend=2017&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

Hourly Weather History & Observations

Time (EST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
7:51 AM	36.0 °F	25.0 °F	33.1 °F	89%	29.73 in	10.0 mi	WSW	20.7 mph	27.6 mph	0.00 in		Scattered Clouds
	METAR KEWR 251251Z 25018G24KT 10SM FEW014 SCT040 SCT100 O2/01 A2973 RMK AO2 RAE23 SLP066 VCSH S P0000 T00220006 \$											
8:51 AM	37.0 °F	25.4 °F	26.1 °F	85%	29.76 in	10.0 mi	West	25.3 mph	41.4 mph	N/A		Partly Cloudy
	METAR KEWR 251351Z 26022G36KT 10SM FEW015 FEW040 FEW100 O3/M03 A2976 RMK AO2 PK WND 26088/1345 SLP078 T00281033 \$											
9:51 AM	37.0 °F	25.1 °F	21.0 °F	52%	29.82 in	9.0 mi	West	26.5 mph	44.9 mph	0.00 in	Snow	Light Snow
	METAR KEWR 251451Z 27023G39KT 9SM -SN FEW020 SCT040 O3/M05 A2982 RMK AO2 PK WND 28044/1437 SNB42 SLP067 P0000 80000 T00281061 53037 \$											
10:21 AM	37.0 °F	24.3 °F	19.9 °F	50%	29.84 in	10.0 mi	West	31.1 mph	41.4 mph	0.00 in		Scattered Clouds
	SPECI KEWR 251521Z 27027G36KT 10SM SCT047 O3/M07 A2984 RMK AO2 PK WND 27043/1501 SNED4 P0000 T00281067 \$											
10:51 AM	37.0 °F	23.5 °F	17.1 °F	44%	29.86 in	10.0 mi	West	35.7 mph	44.9 mph	0.00 in		Scattered Clouds
	METAR KEWR 251551Z 27031G39KT 10SM SCT049 O3/M08 A2986 RMK AO2 PK WND 27043/1501 SNED4 SLP110 VIRGA P0000 T00281083 \$											
11:51 AM	35.1 °F	22.5 °F	15.1 °F	44%	29.88 in	10.0 mi	West	26.5 mph	42.6 mph	N/A		Mostly Cloudy
	METAR KEWR 251651Z 26023G37KT 10SM BKN055 O2/M09 A2988 RMK AO2 PK WND 28037/1553 SLP117 T00171064 \$											
12:51 PM	37.9 °F	27.1 °F	14.0 °F	38%	29.90 in	10.0 mi	West	23.0 mph	31.1 mph	N/A		Mostly Cloudy
	METAR KEWR 251751Z 26020G27KT 10SM BKN055 O3/M10 A2990 RMK AO2 PK WND 28035/1712 SLP124 91000 60000 T00331100 10033 20017 51027 \$											
1:51 PM	36.0 °F	24.2 °F	12.0 °F	37%	29.92 in	10.0 mi	WSW	24.2 mph	36.8 mph	N/A		Mostly Cloudy
	METAR KEWR 251851Z 25021G32KT 10SM BKN055 O2/M11 A2992 RMK AO2 PK WND 25035/1823 SLP132 VIRGA NW T00221111 \$											

Averaged wind speed over the 6-hour period = **27 mph**

<https://www.wunderground.com/history/airport/KEWR/2017/12/25/DailyHistory.html>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20171201&edate=20180101&timezone=GMT&datum=MSL&interval=h&action=>

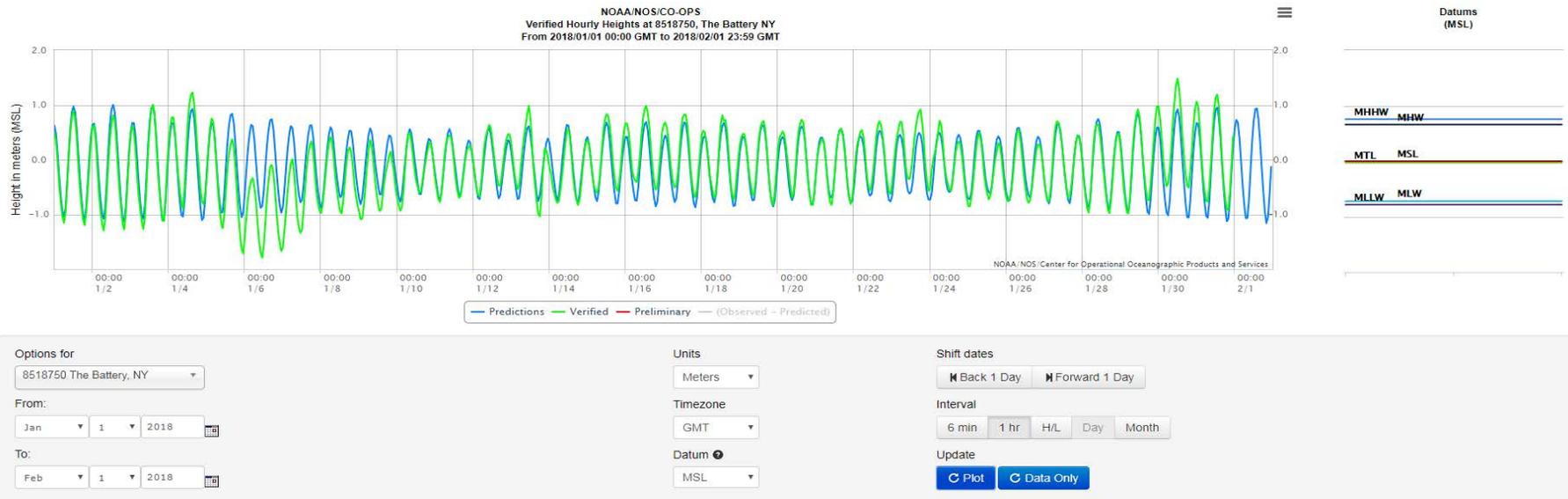
Weather History for KEWR - January, 2018

From: To:

Get History

Daily	Weekly	Monthly	Custom					
					Max	Avg	Min	Sum
Temperature								
					64 °F	39 °F	14 °F	
					53 °F	31 °F	10 °F	
					42 °F	22 °F	4 °F	
Degree Days								
					55	34	12	1048
					0	0	0	0
					2	0	0	2
Dew Point								
					62 °F	18 °F	-12 °F	
Precipitation								
					0.71 in	0.07 in	0.00 in	2.06 in
					7.0 in	1.2 in	0.0 in	-
Wind								
					33 mph	11 mph	0 mph	
					47 mph	25 mph	17 mph	
Sea Level Pressure								
					30.74 in	30.19 in	29.29 in	

https://www.wunderground.com/history/airport/KEWR/2018/1/1/CustomHistory.html?dayend=31&monthend=1&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20180101&edate=20180201&timezone=GMT&datum=MSL&interval=h&action=>

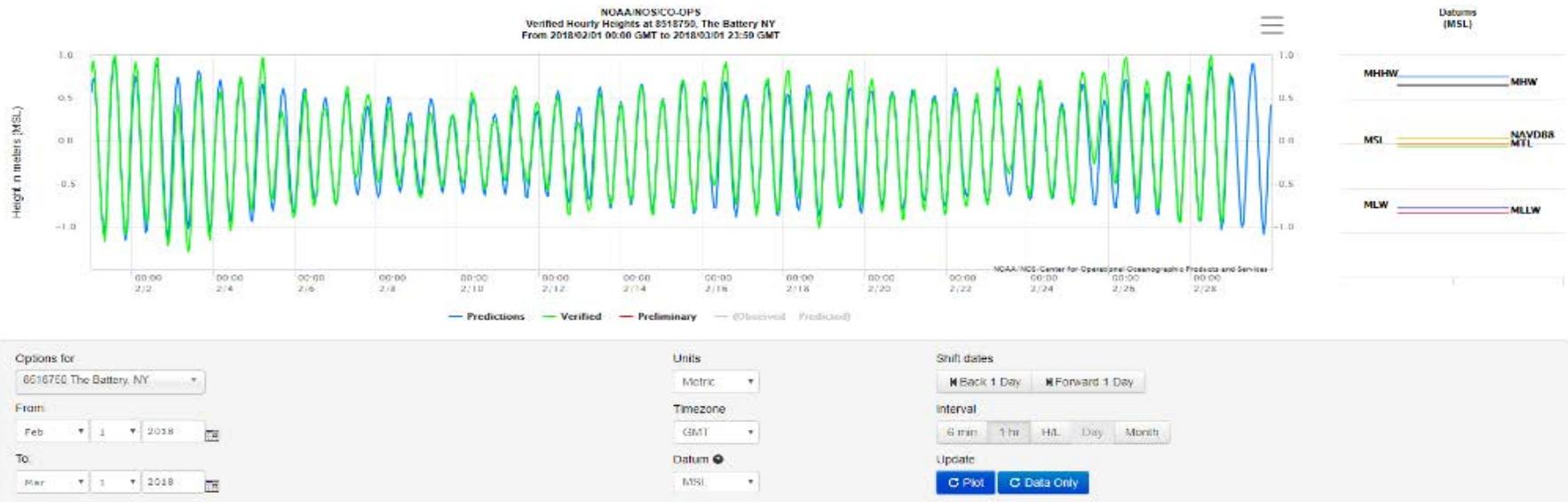
Weather History for KEWR - February, 2018

From: To:

Get History

Daily	Weekly	Monthly	Custom		Max	Avg	Min	Sum
Temperature								
					80 °F	50 °F	32 °F	
					68 °F	42 °F	23 °F	
					56 °F	33 °F	14 °F	
Degree Days								
					42	23	0	657
					3	0	0	3
					18	1	0	32
Dew Point								
					61 °F	31 °F	-3 °F	
Precipitation								
					1.19 in	0.25 in	0.00 in	5.74 in
					2.0 in	0.1 in	0.0 in	-
Wind								
					32 mph	9 mph	0 mph	
					45 mph	23 mph	17 mph	
Sea Level Pressure								
					30.84 in	30.22 in	29.57 in	

https://www.wunderground.com/history/airport/KEWR/2018/2/1/CustomHistory.html?dayend=28&monthend=2&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



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Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u>	March	2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u>			
Max Rainfall (in):	1.89	Date: 3/2/2018	
50-Year, 24-Hr event?	NO		NO
<u>Storm Surge Event Data:</u>			
Max Increase Above Predicted Normal Tidal Cycling (m):	0.888	Date: 3/7/2018	Time: 15:00
Exceeds event trigger criteria?	YES		
Max Tide Gauge Reading (m):	1.63	Date: 3/4/2018	Time: 3:00
Exceeds event trigger criteria?	YES		
10-year storm surge event defined as a hurricane?	NO		NO
<u>Wind Event Data:</u>			
Max Wind (mph):	39	Date: 3/2/2018	
Exceeds trigger criteria?	NO		
Wind direction over 6-hr period:	NNW	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

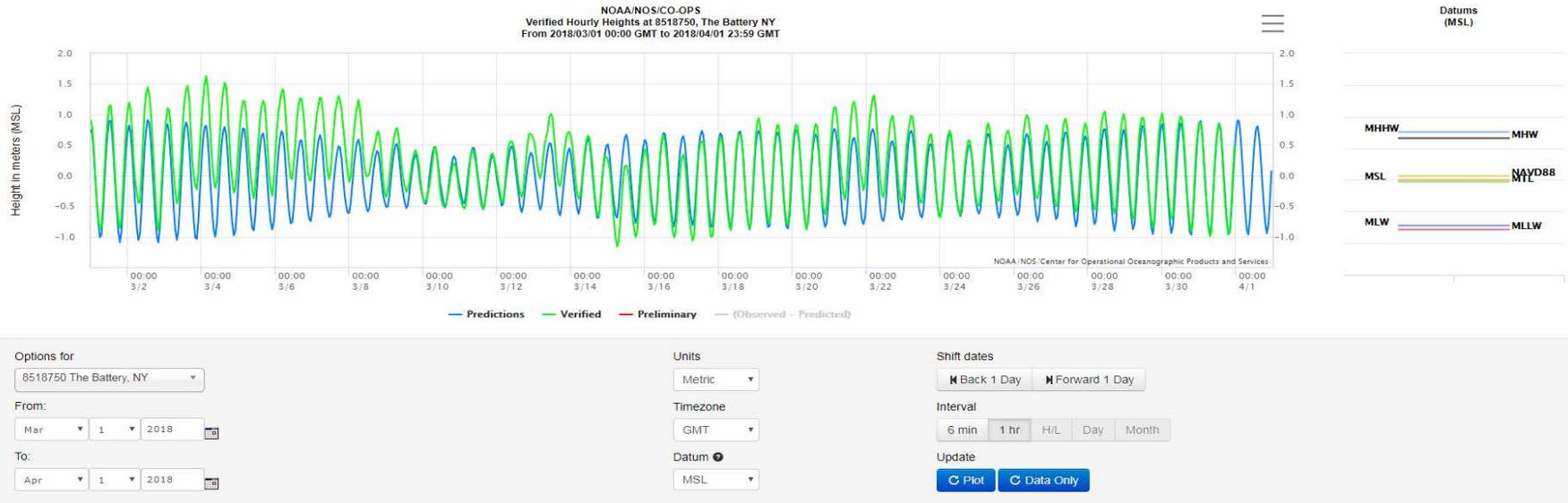
Weather History for KEWR - March, 2018

From: To:

Get History

Daily	Weekly	Monthly	Custom				
				Max	Avg	Min	Sum
Temperature							
Max Temperature				62 °F	47 °F	40 °F	
Mean Temperature				54 °F	41 °F	35 °F	
Min Temperature				46 °F	33 °F	27 °F	
Degree Days							
Heating Degree Days (base 65)				30	24	11	758
Cooling Degree Days (base 65)				0	0	0	0
Growing Degree Days (base 50)				4	0	0	8
Dew Point							
Dew Point				54 °F	24 °F	-10 °F	
Precipitation							
Precipitation				1.89 in	0.19 in	0.00 in	4.39 in
Snowdepth				8.0 in	0.4 in	0.0 in	-
Wind							
Wind				39 mph	13 mph	0 mph	
Gust Wind				53 mph	24 mph	16 mph	
Sea Level Pressure							
Sea Level Pressure				30.72 in	29.93 in	29.29 in	

https://www.wunderground.com/history/airport/KEWR/2018/3/1/CustomHistory.html?dayend=31&monthend=3&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=



SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> April 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 2.99 Date: 4/16/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.774 Date: 4/16/2018 Time: 16:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.464 Date: 4/16/2018 Time: 1:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 44 Date: 4/4/2018 Exceeds trigger criteria? YES Wind direction over 6-hr period: W OK (See Note 1) <u>Note:</u> (1) The averaged wind speed for the 6-hour period during which the maximum wind speed was recorded does not exceed the threshold criteria.	NO
<p><u>CRITERIA FROM LTMP:</u></p> <p>“Post-High Energy Event Monitoring Activities” will take place promptly following High Energy Events. The Consent Order defines “High Energy Events” as follows:</p> <p>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;</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p>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</p> <ul style="list-style-type: none"> • Note: Hurricane events are defined by NOAA. • See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750 <p>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.”</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p style="text-align: right;">CHECKED BY: <u>TEA</u></p>	

Weather History for KEWR - April, 2018

From:

April 1 2018

To:

April 30 2018

Get History

Daily	Weekly	Monthly	Custom				
				Max	Avg	Min	Sum
Temperature							
Max Temperature				84 °F	58 °F	43 °F	
Mean Temperature				71 °F	50 °F	39 °F	
Min Temperature				58 °F	41 °F	31 °F	
Degree Days							
Heating Degree Days (base 65)				26	16	0	465
Cooling Degree Days (base 65)				6	0	0	6
Growing Degree Days (base 50)				20	3	0	86
Dew Point							
Dew Point				58 °F	34 °F	9 °F	
Precipitation							
Precipitation				2.99 in	0.23 in	0.00 in	5.85 in
Snowdepth				4.0 in	0.2 in	0.0 in	-
Wind							
Wind				44 mph	11 mph	0 mph	
Gust Wind				54 mph	24 mph	16 mph	
Sea Level Pressure							
Sea Level Pressure				30.48 in	29.99 in	29.40 in	

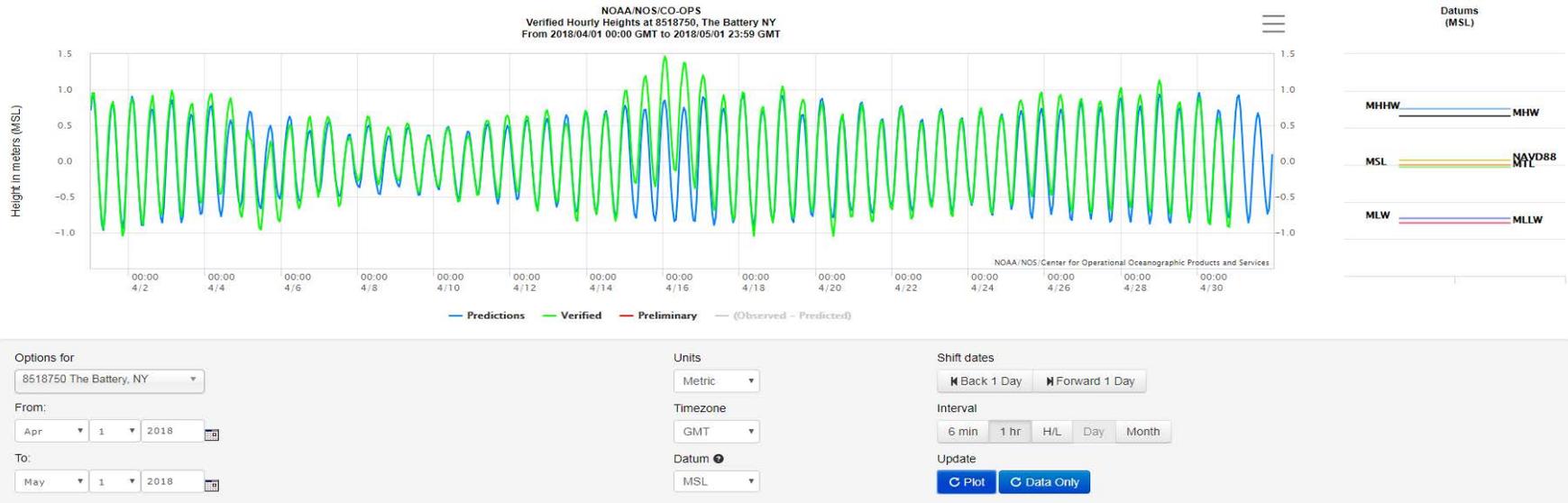
https://www.wunderground.com/history/airport/KEWR/2018/4/1/CustomHistory.html?dayend=30&monthend=4&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

Hourly Weather History & Observations

Time (EDT)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
1:51 PM	54.0 °F	-	48.9 °F	83%	29.46 in	2.0 mi	West	24.2 mph	33.4 mph	0.05 in	Rain	Light Rain
1:55 PM	54.0 °F	-	48.0 °F	80%	29.46 in	7.0 mi	WSW	24.2 mph	33.4 mph	0.00 in	Rain	Light Rain
2:51 PM	54.0 °F	-	41.0 °F	62%	29.47 in	10.0 mi	West	34.5 mph	44.9 mph	0.00 in		Overcast
3:51 PM	57.0 °F	-	33.1 °F	40%	29.49 in	10.0 mi	West	36.8 mph	48.3 mph	0.00 in		Mostly Cloudy
4:51 PM	55.9 °F	-	25.0 °F	30%	29.55 in	10.0 mi	West	36.8 mph	49.5 mph	N/A		Mostly Cloudy
5:51 PM	53.1 °F	-	21.9 °F	30%	29.60 in	10.0 mi	West	24.2 mph	50.6 mph	N/A		Mostly Cloudy
6:51 PM	48.9 °F	-	21.0 °F	33%	29.65 in	10.0 mi	West	26.5 mph	41.4 mph	N/A		Scattered Clouds
7:51 PM	46.9 °F	-	19.0 °F	33%	29.68 in	10.0 mi	West	25.3 mph	32.2 mph	N/A		Partly Cloudy

Averaged wind speed over the 6-hour period = 29 mph

<https://www.wunderground.com/history/airport/KEWR/2018/4/4/DailyHistory.html>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20180401&edate=20180501&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

Monitoring Period: May 2018	Assessment Required?
<u>Rainfall Event Data:</u> Max Rainfall (in): 0.87 Date: 5/27/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.393 Date: 5/18/2018 Time: 23:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.29 Date: 5/19/2018 Time: 4:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 43 Date: 5/15/2018 Exceeds trigger criteria? YES Wind direction over 6-hr period: W OK (See Note 1) <u>Note:</u> (1) The averaged wind speed for the 6-hour period during which the maximum wind speed was recorded does not exceed the threshold criteria.	NO
<p><u>CRITERIA FROM LTMP:</u></p> <p>“Post-High Energy Event Monitoring Activities” will take place promptly following High Energy Events. The Consent Order defines “High Energy Events” as follows:</p> <p>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;</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p>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</p> <ul style="list-style-type: none"> • Note: Hurricane events are defined by NOAA. • See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750 <p>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.”</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p style="text-align: right;">CHECKED BY: <u>TEA</u></p>	

Weather History for KEWR - May, 2018

From:

May 1 2018

To:

May 31 2018

[Get History](#)

	Max	Avg	Min	Sum
Temperature				
Max Temperature	94 °F	76 °F	54 °F	
Mean Temperature	81 °F	67 °F	53 °F	
Min Temperature	70 °F	58 °F	44 °F	
Degree Days				
Heating Degree Days (base 65)	12	2	0	57
Cooling Degree Days (base 65)	16	4	0	122
Growing Degree Days (base 50)	30	16	2	504
Dew Point				
Dew Point	69 °F	53 °F	20 °F	
Precipitation				
Precipitation	0.87 in	0.16 in	0.00 in	3.80 in
Snowdepth	0.0 in	0.0 in	0.0 in	-
Wind				
Wind	43 mph	8 mph	0 mph	
Gust Wind	53 mph	24 mph	17 mph	
Sea Level Pressure				
Sea Level Pressure	30.36 in	30.03 in	29.73 in	

https://www.wunderground.com/history/airport/KEWR/2018/5/1/CustomHistory.html?dayend=31&monthend=5&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

Hourly Weather History & Observations

Time (EDT)	Temp.	Heat Index	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
1:51 PM	88.0 °F	90.3 °F	66.0 °F	48%	29.78 in	10.0 mi	SW	16.1 mph	23.0 mph	N/A		Mostly Cloudy
2:51 PM	91.0 °F	93.8 °F	66.0 °F	44%	29.74 in	10.0 mi	SSW	17.3 mph	25.3 mph	N/A		Mostly Cloudy
3:51 PM	91.0 °F	94.3 °F	66.9 °F	45%	29.73 in	10.0 mi	SW	19.6 mph	29.9 mph	N/A		Mostly Cloudy
4:51 PM	88.0 °F	90.3 °F	66.0 °F	48%	29.75 in	10.0 mi	SW	20.7 mph	33.4 mph	N/A	Thunderstorm	Mostly Cloudy
4:55 PM	89.1 °F	91.3 °F	66.0 °F	46%	29.75 in	10.0 mi	SW	18.4 mph	33.4 mph	N/A	Thunderstorm	Thunderstorm
5:05 PM	84.9 °F	85.4 °F	62.1 °F	46%	29.81 in	10.0 mi	NNW	28.8 mph	49.5 mph	0.00 in	Rain , Thunderstorm	Light Thunderstorms and Rain
5:21 PM	73.9 °F	-	61.0 °F	64%	29.86 in	2.0 mi	West	25.3 mph	52.9 mph	0.00 in	Rain , Thunderstorm	Light Thunderstorms and Rain
5:32 PM	68.0 °F	-	64.0 °F	87%	29.87 in	1.2 mi	West	13.8 mph	36.8 mph	0.08 in	Rain , Thunderstorm	Heavy Thunderstorms and Rain
5:51 PM	68.0 °F	-	64.9 °F	90%	29.86 in	5.0 mi	WSW	11.5 mph	-	0.23 in	Rain , Thunderstorm	Thunderstorms and Rain
6:35 PM	68.0 °F	-	64.9 °F	90%	29.87 in	6.0 mi	SW	13.8 mph	-	0.06 in	Rain	Light Rain
6:51 PM	66.9 °F	-	64.9 °F	93%	29.88 in	5.0 mi	SW	8.1 mph	-	0.11 in	Rain	Rain
7:09 PM	68.0 °F	-	66.0 °F	93%	29.89 in	5.0 mi	WSW	4.6 mph	-	0.06 in	Rain , Thunderstorm	Thunderstorms and Rain
7:26 PM	66.9 °F	-	64.9 °F	93%	29.86 in	7.0 mi	East	3.5 mph	-	0.08 in	Rain	Light Rain
7:51 PM	68.0 °F	-	64.9 °F	90%	29.87 in	10.0 mi	NW	6.9 mph	-	0.09 in	Rain	Light Rain

Averaged wind speed over the 6-hour period = 15 mph

<https://www.wunderground.com/history/airport/KEWR/2018/5/15/DailyHistory.html>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20180501&edate=20180601&timezone=GMT&datum=MSL&interval=h&action=>

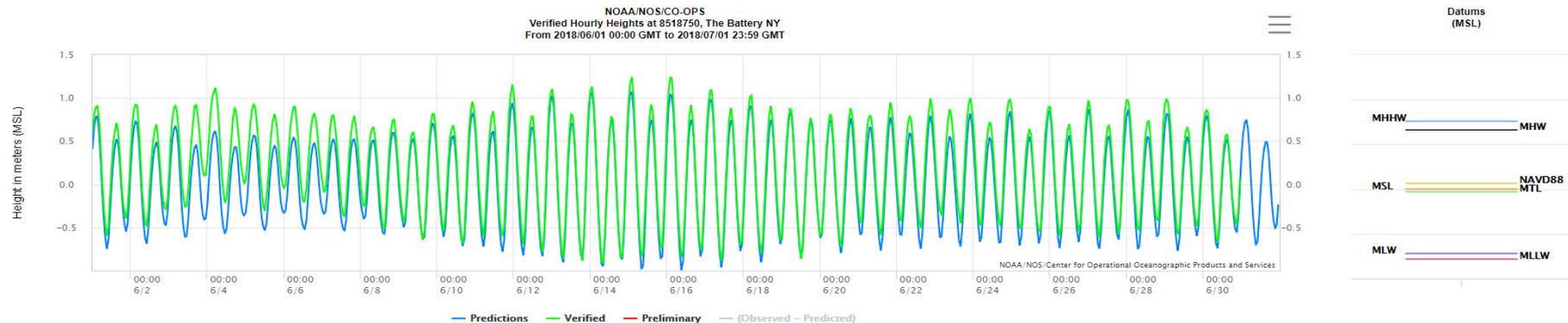
Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	96	83	74	-	
Avg Temperature	82	72	63	-	
Min Temperature	69	61	52	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	0.5	0.07	0	1.86	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	74	57	40	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation	
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Jun 1	82	73	63	70	67	63	100	-	69	15	-	0	29.88	-	29.73	-	0.20
2	87	78	68	72	69	64	97	-	51	28	-	0	29.88	-	29.71	-	0.05
3	69	61	52	61	53	49	89	-	65	18	-	7	30.03	-	29.9	-	0.20
4	72	62	52	57	54	50	100	-	57	15	-	0	29.9	-	29.68	-	0.11
5	77	67	57	56	50	45	84	-	41	24	-	0	29.74	-	29.62	-	0.00
6	71	64	57	55	50	46	72	-	44	12	-	0	30.02	-	29.72	-	0.00
7	70	65	60	56	54	52	84	-	57	16	-	4	30.16	-	30.01	-	0.00
8	85	71	56	64	58	54	93	-	37	17	-	4	30.17	-	30.06	-	0.00
9	83	75	66	64	56	51	73	-	34	14	-	0	30.14	-	30.04	-	0.00
10	73	65	57	57	51	47	80	-	44	13	-	0	30.09	-	30	-	0.06
11	71	64	57	56	49	42	93	-	40	15	-	0	30.21	-	29.98	-	0.07
12	75	65	54	54	50	46	77	-	41	18	-	0	30.25	-	30.09	-	0.00
13	80	71	62	69	63	52	84	-	67	24	-	5	30.09	-	29.73	-	0.04
14	87	76	65	70	53	43	81	-	22	28	-	8	29.89	-	29.74	-	0.00
15	81	73	64	55	50	47	61	-	33	25	-	0	29.99	-	29.88	-	0.00
16	87	73	59	56	49	42	78	-	21	16	-	0	30.06	-	29.97	-	0.00
17	91	76	61	59	53	47	73	-	24	15	-	0	30.09	-	30.03	-	0.00
18	96	83	70	73	68	61	94	-	42	31	-	6	30.06	-	29.77	-	0.14
19	90	82	74	74	62	47	94	-	24	28	-	4	29.86	-	29.73	-	0.17
20	86	78	69	68	56	47	84	-	36	13	-	0	29.91	-	29.77	-	0.07
21	87	77	66	69	61	49	100	-	27	18	-	0	29.85	-	29.74	-	0.11
22	74	69	63	66	61	56	93	-	57	15	-	4	30.03	-	29.86	-	0.14
23	69	67	64	62	59	52	87	-	63	16	-	0	29.97	-	29.81	-	0.00
24	89	78	66	69	65	62	90	-	43	20	-	0	29.84	-	29.75	-	0.00
25	84	75	65	66	52	40	84	-	24	24	-	6	30.17	-	29.82	-	0.00
26	77	69	61	61	54	46	78	-	46	14	-	4	30.27	-	30.17	-	0.00
27	75	69	63	66	60	55	84	-	47	13	-	4	30.16	-	29.9	-	0.00
28	88	79	70	73	70	66	93	-	51	18	-	4	29.88	-	29.73	-	0.50
29	93	81	69	0	0	0	79	-	30	20	-	0	0	-	0	-	0.00
30	96	83	69	0	0	0	66	-	27	16	-	0	0	-	0	-	0.00

https://www.wunderground.com/history/monthly/KEWR/date/2018-6?dayend=31&monthend=5&yearend=2018&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.



<p>Options for 8518750 The Battery, NY</p> <p>From: Jun 1 2018</p> <p>To: Jul 1 2018</p>	<p>Units Metric</p> <p>Timezone GMT</p> <p>Datum MSL</p>	<p>Shift dates Back 1 Day Forward 1 Day</p> <p>Interval 6 min 1 hr H/L Day Month</p> <p>Update Plot Data Only</p>
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<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20180601&edate=20180701&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

Monitoring Period: July 2018	Assessment Required?
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.16 Date: 7/27/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.618 Date: 7/22/2018 Time: 7:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.191 Date: 7/12/2018 Time: 0:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 35 Date: 7/17/2018 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 (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/>

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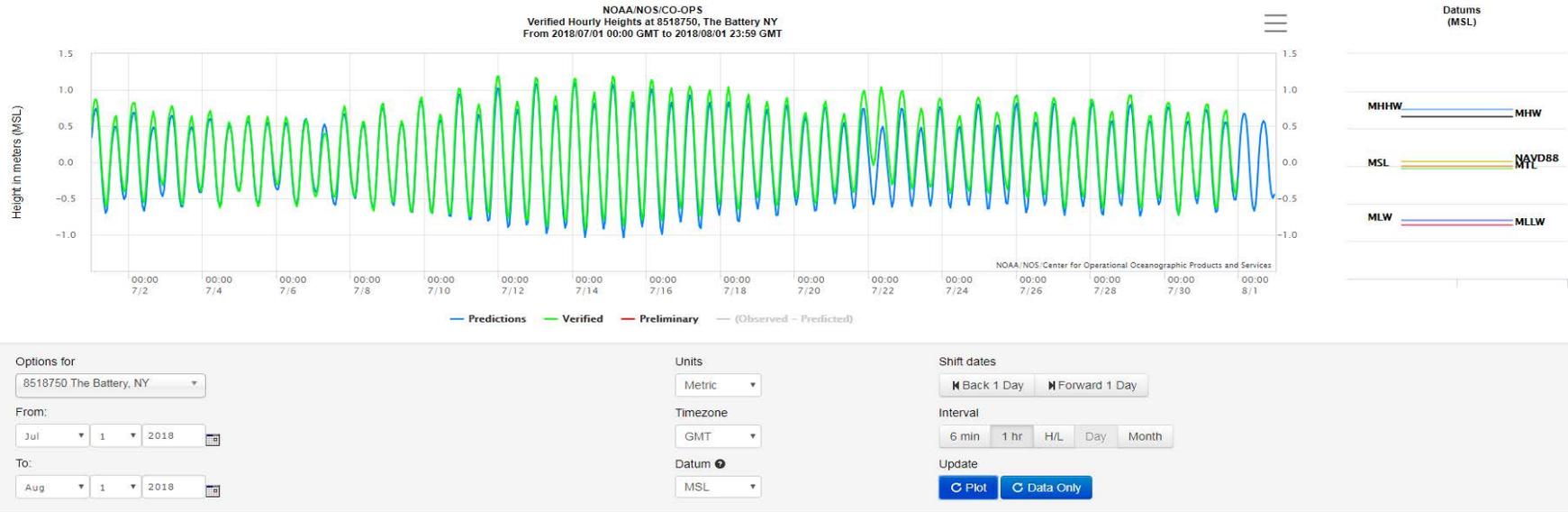
Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	98	88	77	-	
Avg Temperature	87	78	69	-	
Min Temperature	77	69	60	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	1.16	0.23	0	6.3	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	76	64	42	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation	
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1	98	88	77	71	68	65	67	-	35	13	-	0	30.05	-	29.97	-	0.00
2	96	86	75	74	70	67	79	-	39	15	-	0	30.09	-	30.01	-	0.00
3	94	86	77	76	74	71	91	-	60	17	-	0	30.23	-	30.08	-	0.13
4	89	83	76	74	72	67	94	-	47	13	-	0	30.31	-	30.22	-	0.00
5	91	83	75	75	73	70	94	-	49	20	-	0	30.31	-	30.13	-	0.00
6	84	77	69	75	68	52	94	-	42	21	-	9	30.16	-	30.01	-	0.27
7	77	69	61	53	48	42	67	-	31	23	-	5	30.35	-	30.18	-	0.00
8	84	72	60	55	52	49	73	-	34	14	-	0	30.38	-	30.27	-	0.00
9	91	77	63	61	55	51	72	-	28	15	-	4	30.27	-	30.04	-	0.00
10	96	83	69	64	58	52	73	-	22	18	-	0	30.04	-	29.82	-	0.00
11	89	81	72	67	62	58	84	-	36	20	-	4	30.07	-	29.85	-	0.00
12	86	78	70	66	56	46	84	-	27	14	-	0	30.24	-	30.07	-	0.00
13	86	77	67	60	58	54	73	-	34	16	-	0	30.25	-	30.15	-	0.00
14	93	80	67	62	59	57	73	-	32	31	-	5	30.17	-	29.99	-	0.06
15	86	78	69	71	68	60	82	-	48	18	-	0	30.07	-	29.94	-	1.14
16	94	83	72	73	71	69	87	-	46	16	-	5	29.99	-	29.88	-	0.00
17	93	82	71	73	71	69	93	-	52	35	-	0	29.91	-	29.75	-	1.12
18	88	79	69	68	56	48	90	-	28	21	-	5	29.99	-	29.81	-	0.00
19	83	73	62	64	52	45	79	-	28	14	-	4	30.13	-	29.99	-	0.00
20	82	75	67	66	60	49	90	-	33	16	-	0	30.17	-	30.12	-	0.00
21	77	72	66	68	60	55	100	-	50	20	-	4	30.11	-	29.87	-	0.98
22	81	76	71	74	71	69	100	-	74	28	-	7	30.02	-	29.76	-	0.60
23	83	78	72	75	73	72	100	-	74	21	-	6	30.18	-	30.01	-	0.17
24	83	79	74	73	73	73	94	-	74	21	-	8	30.19	-	30.11	-	0.00
25	79	75	71	74	73	71	100	-	85	17	-	5	30.09	-	29.87	-	0.66
26	88	79	70	71	70	67	100	-	53	15	-	4	29.94	-	29.82	-	0.01
27	89	80	70	73	68	63	93	-	53	21	-	0	30.02	-	29.94	-	1.16
28	88	77	66	71	67	62	100	-	50	16	-	0	30.01	-	29.92	-	0.00
29	85	78	70	62	60	58	68	-	43	15	-	4	30.11	-	30	-	0.00
30	81	74	66	69	62	58	79	-	45	12	-	0	30.15	-	30.09	-	0.00
31	82	75	67	68	65	61	93	-	54	13	-	0	30.14	-	30.09	-	0.00

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-7>



SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

Monitoring Period: August 2018	Assessment Required?
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.26 Date: 8/11/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.388 Date: 8/22/2018 Time: 7:00 Exceeds event trigger criteria? NO Max Tide Gauge Reading (m): 1.333 Date: 8/12/2018 Time: 1:00 Exceeds event trigger criteria? NO 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 30 Date: 8/7/2018 Exceeds trigger criteria? NO Wind direction over 6-hr period: NNW 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/>

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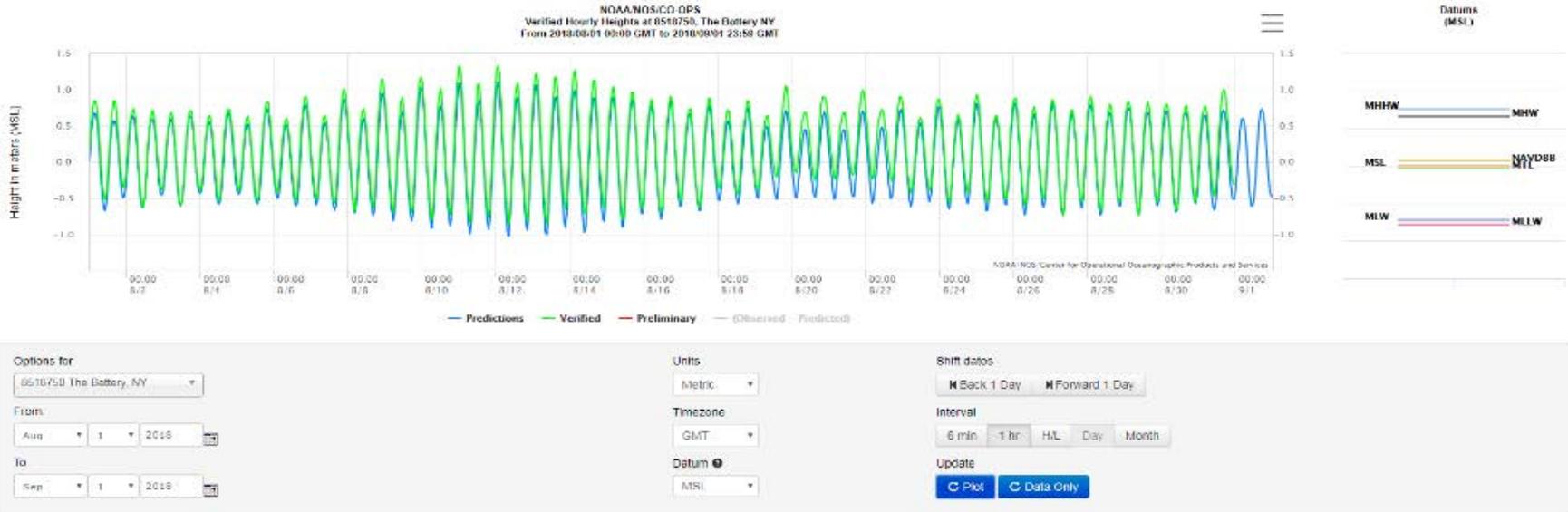
Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	96	87	78	-	
Avg Temperature	87	79	71	-	
Min Temperature	73	71	63	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	1.26	0.22	0	5.87	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	77	68	45	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Aug 1	89	82	75	77	73	69	94	-	52	23	-	4	30.09	-	29.98	-	0.09	-
2	88	82	75	75	71	66	94	-	57	23	-	0	30.13	-	30.04	-	0.40	-
3	87	80	72	75	73	70	100	-	69	23	-	4	30.16	-	30.1	-	0.54	-
4	89	81	72	73	71	65	100	-	46	16	-	0	30.13	-	30.04	-	0.69	-
5	94	83	71	71	67	64	90	-	39	14	-	0	30.17	-	30.08	-	0.00	-
6	95	85	75	72	69	65	87	-	39	15	-	0	30.1	-	29.99	-	0.00	-
7	93	85	76	75	72	68	88	-	49	30	-	4	30.01	-	29.88	-	0.13	-
8	94	85	75	73	71	68	87	-	46	16	-	0	29.92	-	29.78	-	0.00	-
9	91	84	76	73	68	59	85	-	42	21	-	5	29.86	-	29.77	-	0.01	-
10	91	81	71	68	64	59	68	-	43	15	-	0	29.9	-	29.85	-	0.00	-
11	80	76	71	74	71	68	87	-	67	25	-	0	29.96	-	29.88	-	1.26	-
12	85	77	69	73	71	68	100	-	61	17	-	0	30.05	-	29.96	-	0.00	-
13	77	74	70	72	71	70	100	-	82	16	-	0	30.05	-	29.88	-	0.72	-
14	83	75	67	71	68	64	100	-	62	22	-	0	29.9	-	29.82	-	0.40	-
15	90	80	69	69	67	65	97	-	44	18	-	6	29.97	-	29.84	-	0.00	-
16	92	83	73	70	68	64	87	-	41	16	-	0	30.06	-	29.96	-	0.00	-
17	90	82	73	76	72	68	93	-	56	28	-	4	30.08	-	29.91	-	0.61	-
18	90	80	70	74	71	64	94	-	53	25	-	0	29.94	-	29.76	-	0.11	-
19	73	71	68	66	64	61	84	-	68	18	-	6	30.09	-	29.86	-	0.00	-
20	75	72	68	66	63	59	79	-	66	17	-	4	30.15	-	30.08	-	0.00	-
21	77	73	69	70	65	61	84	-	64	15	-	4	30.14	-	29.87	-	0.11	-
22	86	79	71	73	68	58	100	-	44	23	-	6	29.85	-	29.69	-	0.75	-
23	81	74	66	61	54	45	73	-	30	23	-	7	30.11	-	29.81	-	0.00	-
24	85	74	63	57	56	53	84	-	37	14	-	0	30.25	-	30.12	-	0.00	-
25	80	73	66	62	59	55	73	-	45	13	-	0	30.31	-	30.21	-	0.00	-
26	87	77	66	67	64	60	81	-	48	17	-	0	30.22	-	30.04	-	0.00	-
27	92	82	71	72	69	67	90	-	52	14	-	0	30.1	-	30.03	-	0.00	-
28	96	86	76	75	72	69	88	-	42	22	-	5	30.06	-	29.98	-	0.00	-
29	96	87	78	75	72	68	85	-	42	21	-	6	30.02	-	29.91	-	0.00	-
30	92	85	77	74	67	61	79	-	40	21	-	7	30.13	-	29.93	-	0.00	-
31	79	76	72	69	65	63	87	-	62	16	-	6	30.3	-	30.14	-	0.05	-

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-8>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20180801&edate=20180901&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> September 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.89 Date: 9/25/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.825 Date: 9/10/2018 Time: 18:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.546 Date: 9/10/2018 Time: 14:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 29 Date: 9/6/2018 Exceeds trigger criteria? NO Wind direction over 6-hr period: NNW 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/>

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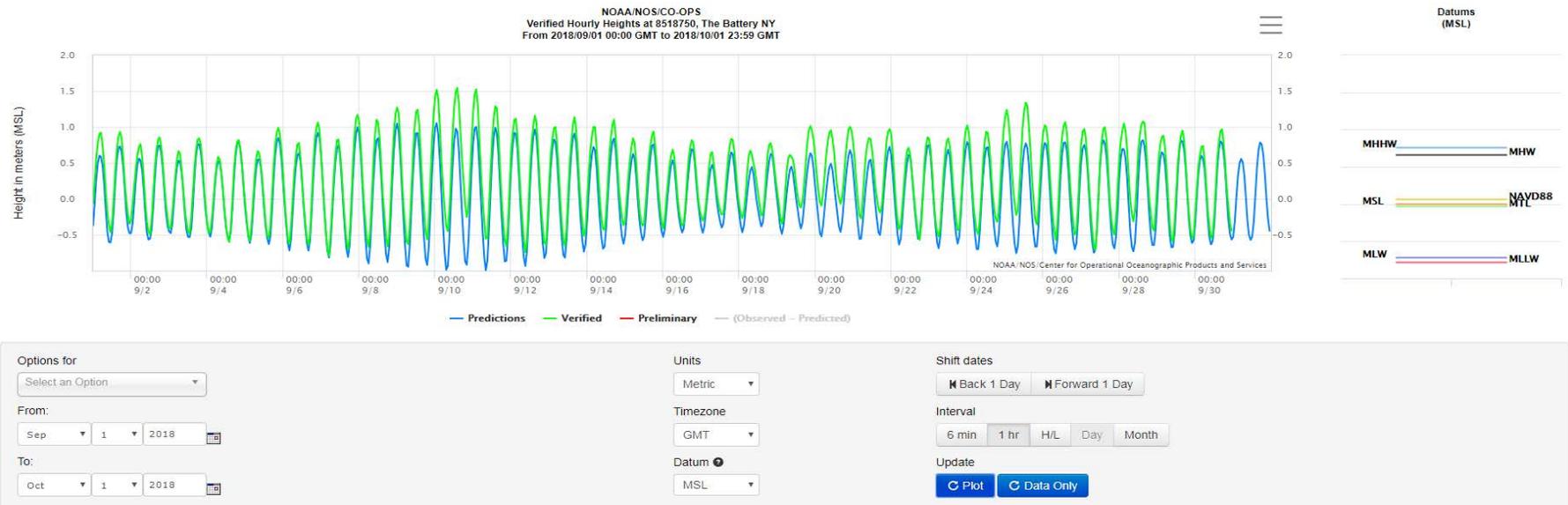
Summary

Temperature (° F)		Max	Average	Min	Sum	▲
Max Temperature		98	87	78	-	
Avg Temperature		78	72	65	-	
Min Temperature		61	59	53	-	
Precipitation (Inches)		Max	Average	Min	Sum	▲
Precipitation		1.89	0.25	0	5.64	
Dew Point (° F)		Max	Average	Min	Sum	▲
Dew Point		76	63	46	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Sep 1	78	74	70	64	62	61	79	-	60	14	-	0	30.32	-	30.26	-	0.00	-
2	82	75	68	71	67	64	87	-	62	12	-	0	30.28	-	30.19	-	0.00	-
3	95	86	76	76	72	70	94	-	46	16	-	4	30.27	-	30.17	-	0.00	-
4	95	87	78	72	69	67	79	-	44	13	-	4	30.25	-	30.16	-	0.00	-
5	91	85	78	74	73	71	85	-	56	15	-	0	30.25	-	30.15	-	0.00	-
6	98	87	76	75	72	67	91	-	39	29	-	0	30.18	-	30.02	-	0.07	-
7	79	75	71	72	68	64	87	-	69	14	-	7	30.16	-	30.1	-	0.00	-
8	72	66	59	65	57	47	84	-	49	21	-	8	30.18	-	30.06	-	0.01	-
9	61	59	56	57	54	49	93	-	64	18	-	9	30.26	-	30.17	-	0.51	-
10	63	59	55	62	58	50	100	-	77	21	-	9	30.25	-	30.1	-	0.69	-
11	76	67	58	70	65	58	100	-	79	13	-	0	30.16	-	30.08	-	0.01	-
12	79	75	71	74	72	70	100	-	79	10	-	4	30.24	-	30.16	-	0.23	-
13	77	74	70	72	69	67	100	-	76	14	-	4	30.27	-	30.22	-	0.47	-
14	76	73	69	69	66	63	90	-	68	12	-	0	30.25	-	30.19	-	0.05	-
15	81	74	66	67	65	64	93	-	62	12	-	0	30.23	-	30.17	-	0.00	-
16	84	74	64	66	64	62	93	-	55	13	-	0	30.22	-	30.16	-	0.00	-
17	79	73	67	73	69	63	93	-	74	13	-	0	30.19	-	29.91	-	0.00	-
18	81	76	71	75	72	69	94	-	82	20	-	4	29.88	-	29.72	-	0.46	-
19	83	75	67	68	66	62	90	-	51	16	-	0	30.06	-	29.78	-	0.00	-
20	74	70	66	64	59	56	81	-	57	10	-	0	30.26	-	30.06	-	0.01	-
21	74	71	67	66	62	59	84	-	68	22	-	6	30.26	-	29.99	-	0.00	-
22	75	68	61	69	56	47	93	-	46	24	-	7	30.2	-	29.94	-	0.00	-
23	66	62	58	57	53	49	78	-	63	13	-	0	30.3	-	30.2	-	0.00	-
24	71	64	56	57	53	51	93	-	53	21	-	7	30.49	-	30.3	-	0.00	-
25	75	67	59	72	65	52	100	-	78	17	-	0	30.47	-	30.12	-	1.89	-
26	84	77	69	74	71	65	100	-	61	28	-	0	30.12	-	29.85	-	0.02	-
27	74	68	61	64	54	46	73	-	44	23	-	5	30.15	-	29.97	-	0.01	-
28	65	60	55	62	56	53	100	-	67	23	-	0	30.13	-	29.93	-	1.21	-
29	76	65	53	57	53	50	100	-	46	17	-	0	30.26	-	30.13	-	0.00	-
30	70	62	53	58	52	47	89	-	45	15	-	0	30.38	-	30.26	-	0.00	-

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-9>



SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

Monitoring Period: October 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.09 Date: 10/27/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.898 Date: 10/27/2018 Time: 16:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.763 Date: 10/27/2018 Time: 15:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 35 Date: 10/21/2018 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 (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/>

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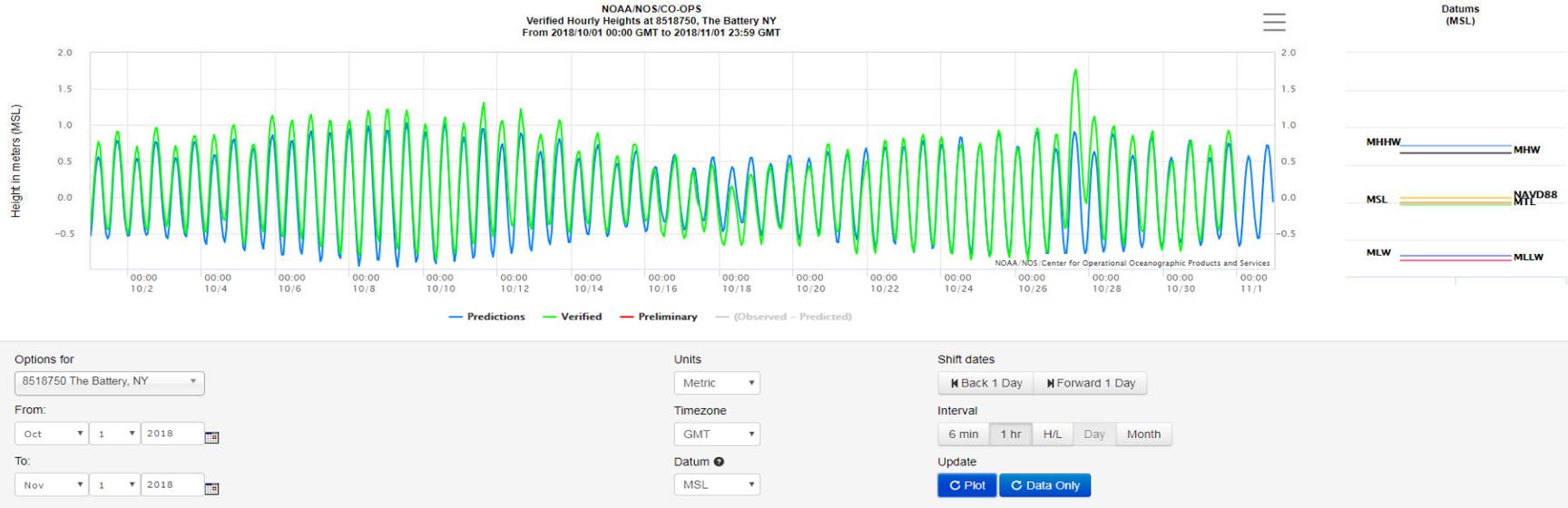
Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	82	76	70	-	
Avg Temperature	65	58	50	-	
Min Temperature	50	43	34	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	1.09	0.12	0	2.82	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	75	48	19	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Oct 1	79	69	59	67	63	57	97	-	64	16	-	0	30.31	-	30.22	-	0.00	-
2	79	72	64	68	65	63	100	-	67	24	-	0	30.23	-	29.98	-	0.46	-
3	76	68	60	64	60	56	100	-	54	20	-	0	30.09	-	29.99	-	0.00	-
4	79	69	58	69	63	57	100	-	67	15	-	0	30.07	-	29.92	-	0.00	-
5	71	65	59	63	55	50	84	-	51	20	-	0	30.19	-	30	-	0.00	-
6	67	65	63	65	62	58	100	-	78	14	-	0	30.23	-	30.16	-	0.01	-
7	82	75	67	71	69	65	100	-	69	13	-	0	30.26	-	30.14	-	0.00	-
8	71	68	64	69	65	62	100	-	84	13	-	4	30.43	-	30.27	-	0.00	-
9	78	72	65	70	68	65	100	-	74	10	-	0	30.38	-	30.22	-	0.00	-
10	81	76	70	71	69	67	100	-	62	14	-	0	30.21	-	29.92	-	0.00	-
11	81	75	68	75	70	68	100	-	76	21	-	0	29.92	-	29.53	-	0.72	-
12	68	60	51	65	47	37	90	-	39	32	-	8	29.8	-	29.49	-	0.33	-
13	59	53	47	45	42	38	93	-	55	21	-	0	30.11	-	29.77	-	0.07	-
14	58	51	43	45	42	40	89	-	51	13	-	0	30.27	-	30.13	-	0.00	-
15	68	61	53	64	57	46	93	-	77	25	-	0	30.21	-	29.86	-	0.04	-
16	59	52	45	54	36	27	80	-	41	24	-	8	30.18	-	29.94	-	0.00	-
17	64	53	42	40	37	27	89	-	39	29	-	5	30.14	-	29.87	-	0.00	-
18	53	47	40	30	24	19	57	-	28	25	-	4	30.36	-	30.16	-	0.00	-
19	61	48	35	44	35	30	85	-	32	21	-	4	30.34	-	29.92	-	0.00	-
20	63	56	49	54	48	41	93	-	52	20	-	5	29.87	-	29.61	-	0.06	-
21	50	44	37	45	32	21	86	-	38	35	-	0	30.19	-	29.6	-	0.00	-
22	54	44	34	36	32	27	82	-	48	15	-	6	30.27	-	30.17	-	0.00	-
23	66	55	44	45	39	33	82	-	29	24	-	0	30.17	-	29.9	-	0.00	-
24	56	50	44	36	33	30	65	-	38	28	-	0	30.18	-	30	-	0.00	-
25	53	45	36	32	29	27	76	-	38	20	-	5	30.18	-	30.04	-	0.00	-
26	50	43	36	40	33	27	76	-	50	16	-	0	30.16	-	30.02	-	0.01	-
27	50	48	45	48	45	39	100	-	76	26	-	9	30	-	29.49	-	1.09	-
28	54	50	45	46	43	40	100	-	59	17	-	6	29.81	-	29.63	-	0.02	-
29	59	52	44	48	43	36	93	-	51	23	-	4	29.97	-	29.66	-	0.01	-
30	58	49	39	37	31	23	86	-	25	22	-	4	30.14	-	29.98	-	0.00	-
31	68	53	37	49	41	32	85	-	39	18	-	0	30.15	-	29.91	-	0.00	-

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-10>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20181001&edate=20181101&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> November 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.23 Date: 11/24/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 1.21 Date: 11/16/2018 Time: 9:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.528 Date: 11/25/2018 Time: 15:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 37 Date: 11/3/2018 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/>

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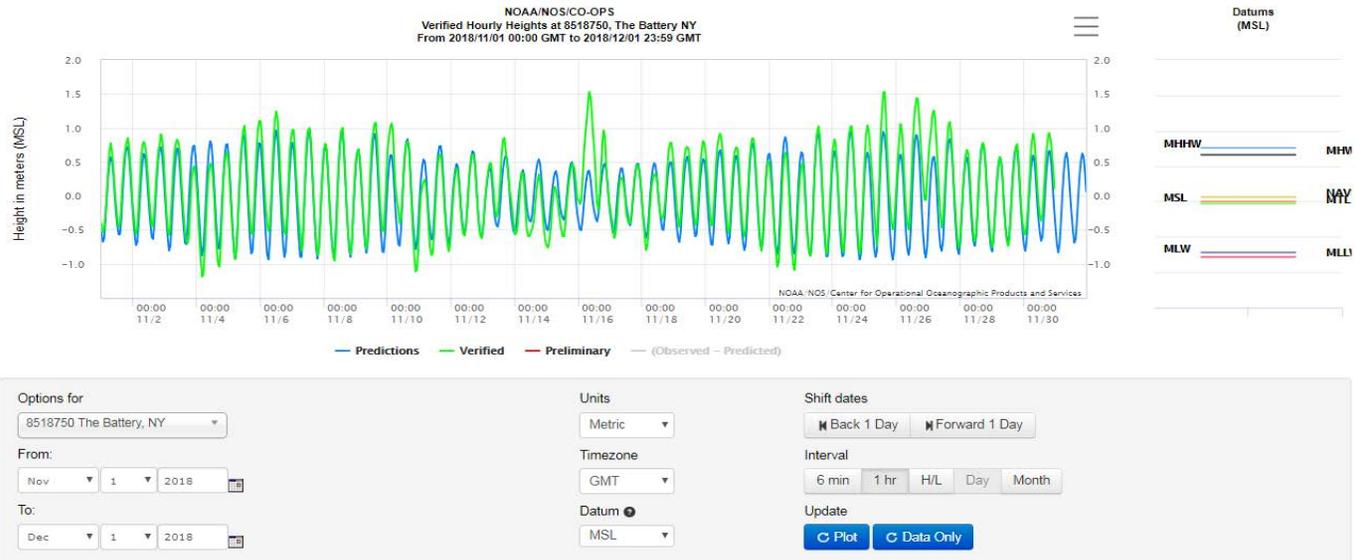
Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	73	69	65	-	
Avg Temperature	51	44	37	-	
Min Temperature	29	23	13	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	1.23	0.29	0	7.96	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	65	33	-6	-	

Daily Observations

Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)			Pressure (Hg)			Precipitation (in)		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Nov 1	73	63	52	58	54	49	93	-	57	18	-	0	29.91	-	29.76	-	0.00	-
2	73	69	65	65	63	60	100	-	73	22	-	6	29.74	-	29.59	-	0.07	-
3	67	57	46	64	47	32	100	-	37	37	-	0	30.32	-	29.56	-	0.43	-
4	56	48	39	39	34	30	79	-	38	15	-	4	30.54	-	30.35	-	0.00	-
5	54	52	49	50	46	40	89	-	66	17	-	5	30.48	-	30.06	-	0.29	-
6	59	54	49	58	54	48	100	-	93	22	-	0	30.05	-	29.78	-	0.68	-
7	63	54	45	53	41	37	100	-	42	23	-	8	30.11	-	29.86	-	0.00	-
8	58	49	40	33	31	29	62	-	36	18	-	0	30.36	-	30.13	-	0.00	-
9	52	44	36	50	41	29	100	-	54	17	-	4	30.36	-	29.77	-	0.97	-
10	49	41	32	48	28	12	92	-	30	32	-	7	30.25	-	29.77	-	0.03	-
11	48	38	28	26	22	19	72	-	37	18	-	0	30.4	-	30.27	-	0.00	-
12	49	40	30	42	31	25	85	-	42	9	-	0	30.45	-	30.27	-	0.06	-
13	50	47	43	48	41	29	100	-	57	22	-	6	30.25	-	29.83	-	0.90	-
14	43	37	31	23	16	12	62	-	30	26	-	7	30.61	-	30.17	-	0.00	-
15	40	34	28	36	24	13	100	-	47	30	-	8	30.61	-	29.76	-	1.06	-
16	46	40	34	39	33	29	100	-	62	30	-	8	29.98	-	29.44	-	0.33	-
17	49	42	34	32	31	29	82	-	50	22	-	7	30.3	-	30	-	0.00	-
18	44	41	37	35	29	23	70	-	50	14	-	0	30.4	-	30.2	-	0.00	-
19	52	45	37	40	37	33	89	-	63	10	-	0	30.19	-	29.92	-	0.00	-
20	49	44	39	39	35	27	89	-	45	24	-	7	30.07	-	29.86	-	0.00	-
21	47	37	27	30	23	5	69	-	43	28	-	5	30.25	-	30	-	0.00	-
22	29	23	17	6	0	-6	47	-	29	25	-	10	30.62	-	30.27	-	0.00	-
23	33	23	13	8	1	-2	53	-	23	14	-	0	30.64	-	30.36	-	0.00	-
24	48	37	25	47	29	8	100	-	46	23	-	0	30.34	-	29.63	-	1.23	-
25	58	52	45	47	42	37	93	-	51	28	-	0	29.95	-	29.62	-	0.77	-
26	53	48	42	48	44	38	93	-	66	21	-	0	29.94	-	29.35	-	1.12	-
27	45	40	35	43	31	24	100	-	53	32	-	10	29.49	-	29.37	-	0.02	-
28	42	39	35	26	25	24	64	-	49	33	-	13	29.73	-	29.46	-	0.00	-
29	47	42	37	27	26	24	59	-	45	26	-	7	30.03	-	29.75	-	0.00	-
30	42	39	36	35	30	25	85	-	55	12	-	0	30.12	-	30.02	-	0.00	-

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-11>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20181101&edate=20181201&timezone=GMT&datum=MSL&interval=h&action=>

SA-7 Sediment Remedy

Long-Term Monitoring Program

Hydrologic Data Review

<u>Monitoring Period:</u> December 2018	<i>Assessment Required?</i>
<u>Rainfall Event Data:</u> Max Rainfall (in): 1.47 Date: 12/16/2018 50-Year, 24-Hr event? NO	NO
<u>Storm Surge Event Data:</u> Max Increase Above Predicted Normal Tidal Cycling (m): 0.815 Date: 12/16/2018 Time: 22:00 Exceeds event trigger criteria? YES Max Tide Gauge Reading (m): 1.405 Date: 12/21/2018 Time: 12:00 Exceeds event trigger criteria? YES 10-year storm surge event defined as a hurricane? NO	NO
<u>Wind Event Data:</u> Max Wind (mph): 33 Date: 12/18/2018 Exceeds trigger criteria? NO Wind direction over 6-hr period: WNW OK	NO
<p><u>CRITERIA FROM LTMP:</u></p> <p>“Post-High Energy Event Monitoring Activities” will take place promptly following High Energy Events. The Consent Order defines “High Energy Events” as follows:</p> <p>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;</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p>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</p> <ul style="list-style-type: none"> • Note: Hurricane events are defined by NOAA. • See http://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750 <p>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.”</p> <ul style="list-style-type: none"> • See http://www.wunderground.com/history/ <p style="text-align: right;">CHECKED BY: <u>TEA</u></p>	

Summary

Temperature (° F)	Max	Average	Min	Sum	▲
Max Temperature	61	56	50	-	
Avg Temperature	46	40	33	-	
Min Temperature	36	30	23	-	
Precipitation (Inches)	Max	Average	Min	Sum	▲
Precipitation	1.47	0.28	0	7.09	
Dew Point (° F)	Max	Average	Min	Sum	▲
Dew Point	60	30	10	-	

Daily Observations

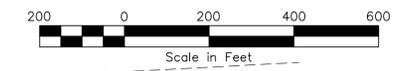
Time	Temperature (° F)			Dew Point (° F)			Humidity (%)			Wind Speed (mph)		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
1	46	39	32	41	34	30	89	-	58	10	-	0
2	55	49	42	54	49	42	100	-	93	16	-	0
3	55	50	45	54	43	33	100	-	46	24	-	6
4	45	36	27	30	19	13	65	-	30	26	-	8
5	37	31	24	19	17	15	74	-	44	16	-	4
6	40	32	24	23	21	17	75	-	44	23	-	4
7	40	33	26	24	16	10	69	-	30	22	-	6
8	37	30	23	18	15	12	68	-	43	20	-	4
9	36	31	25	20	17	14	68	-	49	9	-	0
10	41	32	23	21	18	15	74	-	41	16	-	4
11	42	33	23	25	20	17	75	-	46	14	-	0
12	41	36	31	25	23	21	69	-	50	20	-	0
13	38	35	32	35	29	21	92	-	56	15	-	7
14	50	44	37	48	42	35	100	-	71	12	-	0
15	51	49	47	49	46	38	100	-	66	23	-	0
16	47	42	36	39	37	33	100	-	65	26	-	10
17	49	44	38	37	31	23	92	-	45	33	-	6
18	40	34	27	23	15	13	53	-	38	33	-	7
19	44	35	25	26	19	14	70	-	38	14	-	0
20	53	42	30	51	35	24	100	-	62	10	-	0
21	61	56	50	60	56	49	100	-	93	25	-	4
22	53	47	40	51	36	23	96	-	51	31	-	0
23	45	41	36	30	24	22	64	-	45	23	-	4
24	44	39	34	37	31	23	92	-	49	20	-	0
25	42	36	29	23	21	19	72	-	41	20	-	6
26	44	38	31	29	23	20	75	-	41	15	-	4
27	45	40	34	36	28	22	76	-	40	15	-	0
28	59	51	43	59	51	38	100	-	76	17	-	0
29	56	48	39	54	37	26	100	-	44	25	-	6
30	41	37	33	32	28	23	82	-	54	14	-	0
31	46	39	32	46	37	28	100	-	70	15	-	0

<https://www.wunderground.com/history/monthly/us/nj/newark/KEWR/date/2018-12>



<https://tidesandcurrents.noaa.gov/waterlevels.html?id=8518750&units=metric&bdate=20181201&edate=20190101&timezone=GMT&datum=MSL&interval=h&action=>

APPENDIX C
BATHYMETRIC SURVEY



- 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 8.94 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 OCCUPANCY CONTROL POINT ASI-PA AVE. LOCATED NEAR THE WESTERN END OF PENNSYLVANIA AVENUE IN KEARNEY, NEW JERSEY.
 3. SURVEYED BATHYMETRIC CONTOURS WERE PROVIDED IN MLLW 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.

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

SOURCES:

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

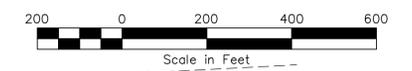
LOTS BASED ON A MAP SHOWING REMAINING STATE TIDELANDS CLAIMS, BLOCK 1290.1, LOT A1 & A2, BLOCK 1751, LOTS 10K1, 10K2, 11 & 12, CMX, 8/6/09.

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			
HONEYWELL INTERNATIONAL, INC. SA7 SEDIMENT REMEDIATION PROJECT JERSEY CITY, HUDSON COUNTY, NJ		PREPARED BY: EC/PRM DRAFTED BY: PRM APPROVED BY: JS/JMN	DATE: 04/24/2018 SCALE: AS SHOWN PROJECT: 169000484
			DRAWING 1

DATE: 04/24/2018
DRAWING: 1



LEGEND

- 2018 BATHYMETRIC CONTOUR ELEVATION
- - - AS-BUILT CAPPING LIMIT
- ⊕ 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-NAL" 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 MLW DATUM AND CONVERTED TO NAVD 29 DATUM BY PERFORMING AN ELEVATION ADJUSTMENT OF -1.94 FEET. THE ELEVATION ADJUSTMENT IS BASED ON THE DIFFERENCE IN ELEVATION DATUM BETWEEN MLW AND NAVD 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.

YEAR 5 SURVEY: 2018 BATHYMETRIC CONTOURS BASED ON A BATHYMETRIC SURVEY FOR HONEYWELL BY AQUA SURVEY INC., CONDUCTED 3/19/2018, 3/21/2018, AND 4/26/2018 AND DIGITALLY PROVIDED 05/09/2018.

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

2018 BATHYMETRIC BASE MAP			
HONEYWELL INTERNATIONAL, INC. SA7 SEDIMENT REMEDIATION PROJECT JERSEY CITY, HUDSON COUNTY, NJ		PREPARED BY: EC/PRM DATE: 09/05/2018	DRAWING 2
		DRAFTED BY: MSB APPROVED BY: JSJ/MN	SCALE: AS SHOWN PROJECT: 1690000484

WORLD 10/21/18 (L) 10/21/18 (R) 10/21/18 (B) 10/21/18 (G) 10/21/18 (Y) 10/21/18 (C) 10/21/18 (M) 10/21/18 (A) 10/21/18 (I) 10/21/18 (S) 10/21/18 (O) 10/21/18 (U) 10/21/18 (N) 10/21/18 (J) 10/21/18 (K) 10/21/18 (L) 10/21/18 (P) 10/21/18 (Q) 10/21/18 (R) 10/21/18 (S) 10/21/18 (T) 10/21/18 (V) 10/21/18 (W) 10/21/18 (X) 10/21/18 (Z)



CAP Areas			MNR Areas			MNR Areas			MNR Areas											
Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain	Grid Name	Grid Area	Net Loss/Gain
	(Square Feet)	(Inches)																		
1-1	6976.69	1.66	11A-1	2386.73	8.66	15-1	7685.85	9.77	25-1	10886.41	5.01	61MNR	6243.04	8.67	71MNR	7375.15	-0.32	101MNR	10513.03	20.07
1-2	7786.27	4.43	11A-2	6289.34	9.91	15-2	9968.47	9.86	25-2	10887.38	7.52	62MNR	7253.84	9.79	72MNR	7950.86	-1.16	102MNR	10888.92	9.78
2-1	5547.52	11.22	11B-1	10369.32	7.82	15-3	10802.38	3.63	25-3	10834.03	2.76	63MNR	5193.66	10.52	73MNR	5884.05	3.31	103MNR	10888.92	3.55
2-2	9854.38	10.92	11B-2	9341.93	5.81	17A-1	9130.55	6.28	25-4	10889.45	5.85	64MNR	10694.97	4.97	74MNR	8542.55	16.57	104MNR	10888.92	1.93
2-3	8085.63	11.69	11B-3	10241.08	5.65	17A-2	10755.48	6.91	26-1	4041.13	0.01	65MNR	10391.50	5.30	75MNR	10391.50	18.49	105MNR	10888.92	1.59
3-1	9888.19	0.73	11B-4	8967.65	6.32	17A-3	10532.40	8.11	26-2	4364.92	2.60	66MNR	8461.53	2.65	76MNR	10513.03	20.07	106MNR	10888.92	1.89
3-2	9557.30	0.13	11B-5	7093.74	6.79	17A-4	10842.36	6.94	27-1	10145.65	9.87	67MNR	7482.13	5.43	77MNR	10766.13	12.40	107MNR	10888.92	1.68
3-3	7791.11	-0.38	11B-6	10888.92	6.80	17A-5	10757.17	8.42	27-2	9720.15	7.99	68MNR	7365.23	6.96	78MNR	10189.85	7.26	108MNR	10888.92	1.06
4-1	4833.87	7.35	11B-7	10888.92	6.49	17A-6	10601.60	8.84	27-3	9556.33	5.60	69MNR	7315.76	5.90	79MNR	6202.07	11.84	109MNR	10888.92	1.68
5-1	10674.57	2.49	11B-8	10888.92	5.78	17A-7	10799.51	10.02	27-4	10396.69	4.10	70MNR	10515.53	2.90	80MNR	8594.91	9.53	110MNR	10888.92	1.68
5-2	10775.32	-0.12	11B-9	10120.85	5.53	17A-8	6603.19	8.44	27-5	6606.32	3.11	71MNR	7623.22	5.71	81MNR	7087.62	9.15	111MNR	10888.92	1.68
5-3	3612.18	0.19	11B-10	9594.19	4.95	17A-9	10340.97	8.99	29A-1	10340.97	8.99	72MNR	1235.87	7.16	82MNR	3871.80	9.37	112MNR	10888.92	1.68
5-4	10276.65	0.14	11B-11	8621.65	8.50	17A-10	10888.92	8.84	29A-2	10751.43	9.93	73MNR	10888.92	4.64	83MNR	6984.14	9.57	113MNR	10888.92	1.68
5-5	5760.84	0.94	11B-12	10888.92	7.92	17A-11	10888.92	7.90	29A-3	9766.71	12.21	74MNR	10888.92	3.12	84MNR	8635.24	9.19	114MNR	10888.92	1.68
6A-1	9898.13	2.68	11B-13	10888.92	7.97	17A-12	4662.45	9.62	29A-4	8156.62	11.62	75MNR	10888.92	9.53	85MNR	7126.33	4.47	115MNR	10888.92	1.68
6A-2	6360.60	1.63	11B-14	10888.92	4.27	17A-13	9474.69	8.44	29A-5	5649.17	8.43	76MNR	10888.92	7.68	86MNR	4800.79	4.28	116MNR	10888.92	1.68
6B-1	10675.93	0.74	11B-15	10651.11	2.23	17A-14	6461.97	9.67	29B-1	9404.02	8.23	77MNR	10888.92	7.79	87MNR	7091.05	4.01	117MNR	10888.92	1.68
6B-2	10485.00	-0.74	11B-16	10806.33	2.67	18A-1	9865.12	8.38	29B-10	8540.15	5.99	78MNR	10888.92	3.31	88MNR	6899.04	1.42	118MNR	10888.92	1.68
6B-3	9453.97	0.79	11B-17	8332.10	2.03	18A-2	8551.72	9.50	29B-11	10650.20	5.43	79MNR	10888.92	4.84	89MNR	10458.39	7.79	119MNR	10888.92	1.68
7A-1	9296.37	1.09	11C-1	9079.90	1.58	18A-3	9161.56	5.62	29B-12	9738.45	7.59	80MNR	10888.92	8.96	90MNR	10595.07	10.17	120MNR	10888.92	1.68
7A-2	10643.50	1.59	11C-2	10856.57	0.74	18A-4	9060.05	5.50	29B-20	9200.77	8.76	81MNR	9550.74	3.45	91MNR	10753.68	11.94	121MNR	10888.92	1.68
7A-3	10650.17	0.59	11C-3	10755.43	1.39	18A-5	9378.66	4.65	29B-21	8906.93	5.22	82MNR	10888.92	3.00	92MNR	10888.92	16.72	122MNR	10888.92	1.68
7A-4	10764.85	2.38	11C-4	7657.32	0.47	18A-6	10617.44	3.12	29B-22	9288.71	5.19	83MNR	10888.92	9.69	93MNR	6051.29	11.91	123MNR	10888.92	1.68
7A-5	10209.86	1.79	11C-5	7390.58	0.32	18A-7	10466.84	4.44	29B-23	10888.92	8.07	84MNR	7937.78	14.25	94MNR	10588.92	10.98	124MNR	10888.92	1.68
7A-6	10132.28	1.77	11C-6	841.71	-2.55	18A-8	10714.65	6.86	29B-24	8260.60	7.95	85MNR	10888.92	17.84	95MNR	10476.67	2.42	125MNR	10888.92	1.68
7A-7	10491.91	2.06	11C-7	246.64	-0.71	18A-9	10386.36	9.93	29B-25	10127.05	4.81	86MNR	10888.92	11.73	96MNR	5760.04	6.23	126MNR	10888.92	1.68
7A-8	10752.96	3.55	12-1	797.31	0.75	18A-10	8574.38	8.98	29B-26	10886.06	7.84	87MNR	10888.92	6.07	97MNR	7984.39	6.98	127MNR	10888.92	1.68
7B-1	6072.73	3.78	13A-1	10884.68	-0.93	18A-11	10502.08	9.67	29B-27	10678.16	7.41	88MNR	8127.54	3.88	98MNR	7984.39	6.98	128MNR	10888.92	1.68
7B-2	8466.24	1.78	13A-2	10710.96	1.04	18B-1	6356.55	11.73	30A-1	10837.09	3.16	89MNR	8536.80	5.94	99MNR	10812.61	21.21	129MNR	10888.92	1.68
7B-3	9143.45	5.56	13A-3	10764.41	2.44	18B-2	2603.56	7.95	30A-2	10175.73	3.82	90MNR	10888.92	9.38	100MNR	10888.92	24.68	130MNR	10888.92	1.68
7C-1	5200.95	5.17	13A-4	9293.67	0.57	19A-1	9375.24	8.80	30B-1	7786.37	-0.06	91MNR	10770.70	14.68	101MNR	10888.92	23.76	131MNR	10888.92	1.68
7C-2	3779.35	5.89	13A-5	10888.92	-0.07	19A-2	10638.74	9.01	30B-2	9544.75	2.85	92MNR	10888.92	21.35	102MNR	10888.92	13.98	132MNR	10888.92	1.68
7C-3	1009.15	8.73	13A-6	10888.92	1.78	19A-3	8148.37	7.42	30B-3	3431.11	-0.02	93MNR	8956.79	6.56	103MNR	10888.92	11.99	133MNR	10888.92	1.68
8A-1	5321.93	10.47	13A-7	10861.99	4.68	19A-4	5801.48	8.57	34MNR	9163.43	17.64	94MNR	10633.49	13.38	104MNR	10888.92	16.98	134MNR	10888.92	1.68
8A-2	10168.12	10.15	13A-8	9641.56	2.13	19B-1	10040.58	12.04	35MNR	9363.89	13.38	95MNR	10540.11	5.84	105MNR	10888.92	20.59	135MNR	10888.92	1.68
8A-3	9889.20	9.53	13A-9	10812.64	2.17	19B-2	8108.89	13.17	36MNR	10540.11	5.84	96MNR	10888.92	15.61	106MNR	10888.92	15.61	136MNR	10888.92	1.68
8A-4	11039.19	9.12	13A-10	10323.22	2.97	19B-3	5817.84	11.58	37MNR	7542.29	3.30	97MNR	10888.92	2.63	107MNR	10888.92	15.61	137MNR	10888.92	1.68
8A-5	10569.88	15.25	13A-11	9740.43	1.43	20-1	7071.05	1.15	38MNR	10348.98	2.63	98MNR	10888.92	11.30	108MNR	10888.92	11.30	138MNR	10888.92	1.68
8B-1	7513.52	2.86	13A-12	8438.85	2.86	20-2	9504.85	0.51	39MNR	8256.15	0.07	99MNR	10888.92	9.70	109MNR	10888.92	11.61	139MNR	10888.92	1.68
8B-2	10605.66	5.43	13B-1	8010.78	2.59	20-3	10011.35	1.24	40MNR	11966.63	9.70	100MNR	10888.92	10.10	110MNR	10888.92	4.15	140MNR	10888.92	1.68
9-1	6727.34	6.80	13B-2	6875.54	4.24	20-4	10441.14	6.44	41MNR	8256.15	0.73	101MNR	10888.92	11.99	111MNR	10888.92	11.99	141MNR	10888.92	1.68
9-2	11389.60	9.57	13B-3	6598.21	3.97	21-1	5754.80	8.30	42MNR	8256.15	0.73	102MNR	10888.92	5.77	112MNR	10888.92	5.77	142MNR	10888.92	1.68
9-3	7319.95	16.25	13B-4	4425.97	4.04	21-2	5276.55	8.78	43MNR	10376.52	-0.23	103MNR	10888.92	-0.23	113MNR	10888.92	-0.23	143MNR	10888.92	1.68
10-1	9785.14	2.32	13B-5	10721.25	8.00	23-1	6554.15	9.10	44MNR	10887.46	-1.11	104MNR	10888.92	1.01	114MNR	10888.92	1.01	144MNR	10888.92	1.68
10-2	7908.97	11.71	14-1	10869.50	4.30	23-2	8264.65	9.54	45MNR	10888.92	1.01	105MNR	10888.92	1.85	115MNR	10888.92	1.85	145MNR	10888.92	1.68
10-3	7171.59	11.23	14-2	9740.21	2.18	24-1	8939.90	10.77	46MNR	6762.11	1.85	106MNR	10888.92	-2.12	116MNR	10888.92	-2.12	146MNR	10888.92	1.68
10-4	6714.88	9.78	14-3	10133.25	3.15	24-2	3451.14	7.66	47MNR	7194.82	-2.12	107MNR	10888.92	-2.12	117MNR	10888.92	-2.12	147MNR	10888.92	1.68
			14-4	10013.68	3.20															



- NOTES:
- TOPOGRAPHY: TOPOGRAPHIC ELEVATIONS ARE IN FEET AND ARE REFERENCED TO NATIONAL GEODETIC VERTICAL DATUM 1929 (NGVD 29) BASED ON BENCHMARK "TK-NAL" 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.
 - 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 NOS 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.
 - 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".
 - 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.
 - 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

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.

YEAR 5 SURVEY: 2018 BATHYMETRIC CONTOURS BASED ON A BATHYMETRIC SURVEY FOR HONEYWELL BY AQUA SURVEY INC., CONDUCTED 3/19/2018, 3/21/2018, AND 4/26/2018 AND DIGITALLY PROVIDED 05/09/2018.

TOPOGRAPHIC CONTOURS BASED ON A SURVEY MAP FOR HONEYWELL ENTITLED "ALTA / ACSM LAND TITLE SURVEY BLOCK 1290.1 ~ LOTS 20, 2E, & 16A.99", BY CMX, DATED 5/23/08 & REVISED THROUGH 11/07/08

APPENDIX D
SEDIMENT PROFILE IMAGERY REPORT

Hackensack River Study Area 7 Sediment Profile Imaging Monitoring, Summer 2018

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INTRODUCTION

Sediments in and around Study Area 7 in the Hackensack River are known to contain elevated levels of chromium, partly attributable to historical disposal of chromite ore processing residue and from combined storm water/sewer outfalls, and other industrial activities that operated up to the mid-1900s (Magar et al. 2008). The Hackensack River is part of the greater Newark Bay estuarine ecosystem. The ecology of this ecosystem has been severely affected for over a century from the intense industrialization and urbanization that has occurred throughout the region. As a result there has been a significant loss of natural habitat. However, in the past two decades sediment and water quality improvements have been documented, indicating pollution control measures and reduction of other environmental stressors have produced a gradual improvement in the ecosystem (Crawford et al. 1994).

Following shoreline restoration of a former Honeywell facility (Study Area 7) in the lower Hackensack River a series of sediment profile imaging (SPI) surveys were conducted to assess benthic habitat conditions at Study Area 7 (Figure 1). Part of the restoration included capping of contaminated sediments. The sediment profile camera was developed by Rhoads and Cande (1971) to investigate processes structuring the sediment-water interface and as a means of obtaining in situ data on benthic habitat conditions. The technology of Sediment Profile Imaging (SPI) or remote ecological monitoring of the sea floor (REMOTS) has allowed for the development of a better understanding of the complexity of sediment dynamics, from both a biological and physical point of view (Solan et al. 2004, Germano et al. 2011).

The first SPI survey occurred at the end of October 2014 one year after restoration efforts (NewFields, 2014). The second survey was at the beginning of November 2015 (Germano and Associates 2015). This report evaluates SPI images collected about five years post restoration in mid July 2018 and compares change between all three collections.

MATERIALS AND METHODS

On 17 July 2018 sediment profile images were collected at ten stations in the lower Hackensack River (Figure 1). These were the same station locations occupied 29 October 2014 (NewFields 2014) and 2 November 2015 (Germano and Associates 2015). At each station three replicate SPI were collected.

The profile camera used a Canon 7D digital single lens reflex camera and captured 18-megapixel images onto internal memory card using Canon's raw image format. The profile camera prism window was 15.5 cm wide and 30 cm tall. The profile camera was controlled from the surface vessel via a cable that supplied power and allowed monitoring of the Canon 7D operation and image capture in real-time. The camera was triggered from the surface about 1-sec after bottom contact and after the prism stopped penetrating the sediment. One hundred pounds of lead was added to the camera frame to increase prism penetration. More detail on sediment profile camera operation can be found in Rhoads and Cande (1971) and Germano et al. (2011). As SPI images were collected, they were downloaded onto a laptop computer and assessed for quality while still on site.

IMAGE ANALYSIS

All SPI were evaluated visually with data of all features recorded in a formatted spreadsheet file. Images were digitally processed using histogram equalization and 0.1 to 1% histogram clipping to enhance contrast and color for determination of the aRPD layer depth with Adobe PhotoShop®. Prior to making image adjustments, excess water column space above the sediment-water-interface was cropped from the image to improve contrast between red-green-blue pixel layers of the sediment portion of the image.

Pixel size, used to measure linear distance and area, was calibrated for the SPI images by measuring 1-cm gradations from the Kodak® Color Separation Guide. This

calibration information was applied to all the SPI images analyzed. Linear and area measurements were recorded as number of pixels and converted to scientific units by using calibration information. All measured parameters were recorded to Microsoft® Excel© spreadsheets. Senior Scientist, Dr. Robert Diaz, conducted the image analysis. Details of how these data were obtained can be found in Diaz and Schaffner (1988), NewFields (2014), and Germano and Associates (2015). A brief description of parameter follows.

Sediment Grain-Size - An important parameter for determining the nature of the physical forces acting on the bottom and is one of the major factors in determining benthic community composition and benthic habitat value (Rhoads 1974, Snelgrove and Butman 1994). The sediment size classes used for SPI analysis follow the Wentworth classification as described in Folk (1974) and represent the modal Phi class for each image. Maximum and minimum grain-size were also estimated. Grain-size was determined by comparison of collected images with a set of standard images for which mean grain-size had been determined in the laboratory. The Phi scale sizes corresponding to sediment grain-size estimated from images are in Table 1.

Prism Penetration Depth - Prism penetration provides a geotechnical estimate of sediment compaction with the profile camera prism acting as a dead-weight penetrometer. The further the prism entered into the sediment the less compact the sediments. Prism penetration was measured as the distance the sediment moved up the length of the prism faceplate. Because the weight added to the camera frame was the same for all stations, penetration depth provides an estimate of relative sediment compaction between stations. Linear maximum and minimum depths of penetration were also measured.

Surface Relief or Boundary Roughness - Surface relief is an important parameter for predicting sediment transport and in determining processes that dominate surface sediment dynamics (Rhoads et al. 1978). The origin of surface relief can be determined from visual analysis of SPI and plan-view images. Small-scale surface relief or boundary roughness on the order of the prism faceplate width (about 15 cm) was

measured as the difference between the maximum and minimum distance the prism penetrated, which represent the highest and lowest points of the sediment-water-interface. In physically dominated habitats, features such as ripples or bedforms, and sediment granularity cause bed roughness. In biologically dominated habitats, bed roughness is a result of biogenic activity such as tube structures, defecation mounds, or feeding pits.

Apparent Redox Potential Discontinuity Layer Depth - The depth of the apparent Redox Potential Discontinuity (aRPD) layer provides information on the oxidation state of the sediment and is an important parameter for estimating benthic habitat conditions that relate directly to benthic habitat quality (Pearson and Rosenberg 1978, Rosenberg et al. 2001, Diaz et al. 2008). The term apparent is used in describing these parameters because no actual measurement was made of oxygen or redox potential. Oxidation-reduction reactions in marine sediments are related to a complex biogeochemistry that is controlled by a combination of factors ranging from sediment grain-size, organic content, microbial communities, bioturbation, and oxygen availability. Biogeochemical reactions follow a consistent pattern with chemical substrates consumed in order of decreasing energy production per mole of organic carbon oxidized (Oxygen > manganese oxides and nitrate > iron oxides > sulfate) (Froelich et al. 1979).

Typically, oxidation and reduction (redox) are measured using Eh or redox potential profiles. Sediments with Eh above 225 to 250 mvolts likely contain free oxygen and all substrates are in an oxic chemical state, from 225 to 50 mvolts there is likely no free oxygen and sediments are considered to be suboxic with most substrates still in an oxic chemical state but no free oxygen present, below 50 mvolts sediments are considered anoxic and substrates are in a reduced chemical state. These three biogeochemical states are relatively colorful, oxic sediments being brown to reddish-brown, suboxic sediments being olive-brown to light-gray, and anoxic sediments being dark-gray to black. This is the basis for the well-known qualitative relationship between sediment color and redox state (Bull and Williamson 2001). It is assumed that given the complexities of manganese, iron, and sulfate oxidation-reduction chemistry the reddish-

brown sediment color tones indicate sediments contain oxygen and are in an oxidative geochemical state, or at least are not intensely reducing (Fenchel 1969, Bull and Williamson 2001, Diaz and Trefry 2006).

Estimation of the aRPD layer depth was done by including both the oxic light-brown color tones and the suboxic light-gray color tones (Lyle 1983, Haese et al. 1998, Rosenberg et al. 2001). The number of pixels in the user-defined aRPD layers was counted and converted to linear measurement by dividing by the width of the image used in the analysis. In some images, the layer of oxidized sediment was assumed to be deeper than prism penetration depth and penetration depth was assigned as the aRPD depth and expressed with a “greater than” sign to indicate that it was a minimal or conservative estimate of the actual aRPD depth.

Subsurface Features - Subsurface features include a wide variety of structures (such as infaunal organisms, burrows, water filled voids, gas voids, or sediment layering) that reveal the importance of physical and biological processes influencing the bottom. For example, layered sediment or homogeneous sediment is generally dominated by physical processes while sediment with burrows, infaunal feeding voids, and/or visible infaunal organisms is generally dominated by biological processes (Rhoads and Germano 1986, Diaz and Schaffner 1988, Nilsson and Rosenberg 2000). Active burrows can be identified in the images by the oxidation state of their walls. Typically the walls of a burrow, and also the lumen of feeding voids, become oxidized with time as the fauna actively or passively pump oxygenated water (Aller 1982). This oxidation results in browner colored sediment as minerals (primarily those of iron and manganese) change oxidation state. After the fauna abandon burrows and voids the sediment lining these structures typically become reduced within hours or days and change in color toward grayish tones (Diaz and Cutter 2001). Subsurface features were visually evaluated from each image and compiled by type and frequency of occurrence. Minimum and maximum depth of infauna and voids was also recorded.

Infaunal Successional Stage - Sediment profile data have also been used to estimate the successional stage of the fauna (Rhoads and Germano 1986). Characteristics

associated with pioneering or colonizing (Stage I) assemblages (in the sense of Odum, 1969), such as dense aggregations of small polychaete tubes at the surface and shallow aRPD layers, are easily seen in SPI. Advanced or equilibrium (Stage III) assemblages also have characteristics that are easily seen in SPI, such as deep aRPD layers, large infauna, and subsurface feeding voids. Stage II is intermediate to Stages I and III, and has characteristics of both (Rosenberg 2001). A set of SPI parameters was evaluated to estimate successional stage of each image (Table 2-2). These are broad relative indicators of association between successional stage and benthic physical/biological parameters as typically applied in SPI investigations.

Organism-Sediment Index - Rhoads and Germano (1986) developed the multi-parameter organism-sediment index (OSI) from data provided by SPI to characterize benthic habitat quality in soft-bottom estuarine and coastal embayments. The OSI defines quality of benthic habitats by evaluating the depth of the aRPD layer, successional stage of macrofaunal organisms, the presence of gas bubbles in the sediment (an indication of high rates of methanogenesis that are associated with high carbon inputs to the sediment), and visual signs of the presence of low dissolved oxygen conditions (sulfide covered tubes, anaerobic sediment at the interface, bacterial mats) at the sediment-water interface. The parameter scores that are used in the calculation of the OSI are in Rhoads and Germano (1986). The OSI ranges from -10 for poorest quality habitats to +11 for highest quality habitats. The formulation of the OSI and contribution of each component are scaled to reflect the increasing importance of bioturbation, sediment mixing mediated by organisms, and other biogenic activity, such as structure building, in defining good benthic habitat quality. For estuarine and coastal bay benthic habitats in the northeastern United States, OSI values >6 indicate good habitat conditions and are generally associated with bottoms that are not heavily influenced by stress, either physical or anthropogenic (Rhoads and Germano 1986).

BIOLOGICAL MIXING DEPTH

The depth of biologically mediated sediment mixing was inferred from SPI images based on the maximum depth of either of three parameters: 1-Thickness of the aRPD and extent to which oxic sediment appeared to extend below the sediment surface, measured as the maximum extend of the aRPD layer (aRPD Max); 2-Maximum depth to which infauna occurred (Infauna Max); or 3-Maximum depth to which feeding voids occurred (Oxic Void Max).

Figure 2 shows the relationship between SPI defined biological mixing depth and the mixing compartments defined by Swift et al. (1996) and François et al. (2002). The base of the mixing depth being the zone of transition in the Swift model or tube bottom zone in the François model. The biological mixing depth was considered to be the maximum depth of either the aRPD or biogenic structures.

COMPARISONS BETWEEN YEARS

To compare 2014 (NewFields 2014) and 2015 (Germano and Associates 2015) images with 2018, original high resolution images from those years were image processes using the same steps and algorithms applied to the 2018 images.

When making data comparisons between years, data were summarized from appendices found in NewFields (2014) and Germano and Associates (2015). The only exception was with the 2014 aRPD layer depths. For 2014, the reanalysis by Germano and Associates (2015) of the 2014 images was used as the station means for 2014 aRPD layer depths.

Estimates of biological mixing depths for 2014 were assumed to be represented by the greater of either of two SPI parameter (Infaunal Depth of Activity and Max Apparent RPD Thickness) in Appendix A of NewFields (2014). For 2015, biological mixing depth was assumed to be represented by the maximum depth of feeding voids (Void Maximum Depth) when present and by aRPD layer depth (Mean RPD) when no voids were present (Germano and Associates 2015, Appendix A).

RESULTS

All SPI data for 2018 are in Appendix A and a summary in Table 3. High resolution SPI images are in Appendix B and medium resolution images in Figures 3 and 5. Spatial mosaics of SPI images from 2014 (NewFields 2014), 2015 (Germano and Associates 2015), and 2018 (This Report) are in Figures 6 to 15. Medium resolution images from three years are in Appendix C.

Sediments

Study Area 7 surficial sediments were all unconsolidated, silt-clay, flocculent sediments that appeared to have a high water content. Even Station 02 with the coarsest modal grain-size of all stations consisting of fine-medium-sand (3 to 2 Phi) had a thin layer of silt-clay at the surface (Figure 3). Modal grain-size ranged from silt-clay (>4 Phi) at six stations to silty fine-sand (4 to 3 Phi) at two stations, and silty fine-medium-sand (3 to 2 Phi) at one station (Table 3). Station 07 was the only station where the three replicate images were not all the same grain-size (Figure 5). One replicate had a modal grain-size of silty fine-sand (4 to 3 Phi) and the other two silt-clay (>4 Phi). Spatially, the silty fine-sand replicate A was separated from B and C by about 18 m and 32 m, respectively (Figure 12). Other than Station 07, there was little between replicate variation in sediment modal grain-size at a station.

Prism penetration was related to modal grain-size and ranged from 2.1 cm at silty fine-sand Station 08 to 24.8 cm at silt-clay Station 06 (Figure 5). Penetration was higher for sediments that appeared to have a higher silt-clay fraction, based on minimum modal Phi, (two-tail t-test, $t = 3.52$, $df = 8$, $p = 0.008$). Penetration averaged 14.0 cm (SD = 6.5 cm) and tended to be deeper as water depth increased (one-tail t-test, $t = 1.91$, $df = 8$, $p = 0.046$).

Grain-size layering was observed at Stations 04 and 07. At Station 04 there was a 4 to 5 cm layer of what appeared to be high organic content silty-clay (>4 Phi) over clayey (>8 Phi) sediments (Figure 4). At Station 07 replicate C there was an 8 cm layer of what appeared to be high organic content silt-clay over silty sand (Figure 5). Color layering

of what appeared to be similar grain-size sediments occurred at most silt-clay stations. These layers alternated between shades of gray, for example, going from lighter-gray to darker-gray at Station 03 and from darker- to lighter- to darker-gray at Station 06 (Figures 3 and 4).

Surface sediments at the majority of stations appeared to be shaped by a combination of physical and biological processes with biological processes being slightly more dominant at Stations 01, 05, 09, and 10, and physical processes slightly more dominant at Stations 03, 06, and 08. Physical processes predominated at Stations 02, 04, and 05 (Table 3, Figures 3 to 5).

Tube structures, and feeding pits or mound, which are common features in marine soft-sediment (Zajac 2004), were the most common biogenic features to occur.

Unconsolidated sediment surfaces appeared to be bioturbated to varying degrees across Study Area 7. However, physical processes appeared to exert sufficient influence to keep the surficial sediments from being categorized as highly biologically dominated.

Apparent Redox Potential Discontinuity Layer Depth

Penetration was sufficient at all but two replicates, which were compact fine-sands (Station 08-B and 08-C), to allow measurement of the apparent redox potential discontinuity (aRPD) layer depth. aRPD layer depths averaged by station ranged from 0.0 cm at Station 04 to 3.3 cm at Station 02 (Table 3).

Stations 04, 07, and two replicates from Station 06 appeared to have diffusion limited aRPD layers that were <1 cm thick. In finer sediment composed mostly of silts and clays, physical diffusion limits oxygen penetration to <1 cm (Jørgensen and Revsbech 1985). For Station 04 there did not appear to be any aRPD layer with just a trace of light gray sediment on the surface. It appeared that before or during sampling, all replicates from Station 04 and two replicates from Station 07 were exposed to hypoxic water. Hypoxia effected replicates B and C from Station 07 had 0.2 to 0.3 cm thick aRPD layers and were at about 18 to 32 m northeast of replicate A, which had a 0.6 cm

thick aRPD layer. Replicate images from all other stations did have signs that bioturbation by infauna contributed to increasing the depth of aRPD layers when they were deeper than 1 cm. Station averaged aRPD layer depths were not significantly related to water depth or grain-size.

Infaunal burrows convoluted the plane of the aRPD layer and projected oxidized sediment below the average aRPD layer depth at Stations 01, 03, 05, 09, and 10. Feeding voids also extended the depth to which oxidized sediments appeared to reach below the sediment surface at Stations 01, 03, and 05. The halo of oxidized sediment around these types of biogenic structures greatly increases the total volume of oxidized sediment and surface area of the aRPD layer (Aller and Aller, 1998). At Stations 04, 06, and 07 there was little evidence bioturbation contributed to aRPD layer depth. The deep mean aRPD at fine-medium-sand Station 02 appeared driven by pore-water pumping (Huettel and Gust 1992) and not bioturbation. Penetration was too shallow at Station 08 to assess bioturbation. At Stations 03 and 04 there were anaerobic voids 12.9 cm and 16.0 cm below the sediment surface that were likely either relic remnants of oxic feeding voids or possibly tracks from the ebullition of methane gas (Martens and Val Klump 1980).

Infaunal Successional Stage and Biogenic Activity

Estimated successional stage ranged from pioneering Stage I, which represents recently recruited or disturbed sites, to Stage I on equilibrium Stage III, which is representative of benthic communities that are advanced and well on their way to being mature (Rosenberg 2001). Evidence of Stage I communities (Table 2) representing early stages of community development with high abundances of small colonizing or pioneering species (Zajac et al. 1998) occurred at all stations. But at Station 04 and one replicate from Station 03 there was only evidence of Stage I fauna. This represented 4 of 30 image replicates. Stage II, intermediate between pioneering and equilibrium stages, was determined to be present at 21 of 30 replicate images. Stage III fauna appeared to be present at 5 of 30 replicates.

Stage I on III designation was based on the presence of a combination of biogenic factors that included: lower numbers of small (<1 mm in diameter), large short or long tubes (>2 mm in diameter), infauna, biogenic feeding pits or mounds, and the presence of oxic feeding voids (Table 3). Tubes that appeared to be constructed by a variety of polychaete species were common and occurred at all stations. Density of tubes ranged from 1 to 4 per image to 25 to 50 at most stations with no pattern across the study area. Tubes were even present at replicate C from Station 04 that had just a trace of oxic sediment on the surface (Figure 4). Microalgal mats appeared to cover surface sediments at Stations 01 and 08 (Figures 3 and 5). What appeared to be a small bacterial patch, a key indicator of hypoxia (Rosenberg and Diaz 1993), was present at Station 07 replicate B (Figure 5).

The most common subsurface biogenic feature observed was infauna that occurred at all stations except 04 and 07. Oxic feeding voids formed by head down deposit feeders (Rhoads 1974) occurred at Stations 01, 03, and 05 (Table 3). High levels of microbial activity was evident in the formation of gas voids containing methane, a byproduct of anaerobic metabolism (Boudreau et al. 2001), at Stations 02, 04, 05, 07, 09, and 10.

Organism Sediment Index

The Organism Sediment Index (OSI) calculated from a combination of aRPD layer depth, estimated successional stage, gas voids, and apparent dissolved oxygen condition provides a relative estimate of benthic habitat conditions (Rhoads and Germano 1986). The two variables that point to degraded benthic conditions, gas voids and apparent low dissolved oxygen, occurred. Stations 04 and 07 appeared to have both low dissolved oxygen water present and gas voids. Station 06 may also have been exposed to lower dissolved oxygen as the aRPD layer depth ranged from 0.4 cm to 1.1 cm for the three replicates. Four other stations had gas voids (02, 05, 09, and 10).

Station averaged OSI ranged from -5.0 at Station 04 to 7.7 at Station 03, indicating a wide range of variation in benthic habitat conditions over Study Area 7. OSI variation

was due primarily to presence of low dissolved oxygen and gas voids. OSI values <6 , indicative of stressful conditions for infaunal communities (Rhoads and Germano 1986), occurred at 7 of 10 stations (Table 3). Only Stations 01, 02, and 03, at the northern end of Study Area 7, had OSI values indicative of less stressed, higher habitat quality.

Stress being defined in the sense of Menge and Sutherland (1987) as a factor that prevents an organism from operating at its optimal level due to either physical forces (e.g. strong currents or sediment instability) or through inducing physiological responses in the organism (e.g. salinity or hypoxia). OSI on its own cannot identify the cause of the stressful conditions. Diaz et al. (2003) found OSI to be significantly correlated to benthic habitat quality as measured by salinity, sediment type, dissolved oxygen, and sediment contamination. Valente et al. (1992) also found the OSI related to sediment organic content.

Biological Mixing Depth

Station averaged biological mixing depth, the depth to which organisms appeared to mix sediments also known as bioturbation, was 6.5 cm (SD = 3.8 cm). The range was from 0.0 cm at Station 04 to 10.7 cm at Station 05 (Table 3). The deepest mixing depth for a single replicate was 13.8 cm (Station 06-C). For four replicates (Station 08-A,B,C and Station 09-C) penetration was too shallow for reliable estimation of mixed layer depth.

Biological mixing depth was positively correlated with benthic habitat quality as measured by OSI ($r = 0.80$, $N = 9$, $p = 0.010$). This supports the importance of advanced successional stage fauna to sediment mixing at Study Area 7. For the 26 of 30 replicate images which had mixing depth estimates, 16 were based on maximum extent of the aRPD layer from the sediment surface, eight were based on maximum depth of observed infauna, and two were based on the maximum depth of oxic feeding voids.

The depth of biological mixing or bioturbation was highly location-specific, varying by 10.7 cm across the ten stations, with a high degree of within station variability. There was a 13 cm difference mixing depth between the three replicates at Station 06. This

was likely due to spatial variability in benthic abundance and differences in life-histories of organisms, and their interaction with the environment (Clarke et al. 2001).

DISCUSSION

The quality of habitats within the Newark Bay ecosystem, of which the Hackensack River is part, have been reduced since the late 1800s due to the intense industrialization and urbanization. Since the mid 1970s, pollution control measures and the reduction or control of other environmental stressors have produced a gradual improvement in the Newark Bay ecosystem (Crawford et al. 1994). Benthic habitat quality in Study Area 7, located in the lower Hackensack River, reflects these improvements.

In 2014 NewFields (2014) classified the benthic habitats at the ten Study Area 7 stations as either unconsolidated soft bottom or hard fine-sand bottom. In 2015 and 2018, the ten stations would fall into the same classifications as there were no major changes in sediment characteristics even though there was some spatial variability between replicates within a year and also between years (Table 4, Figures 6 to 15, and Appendix C). Modal grain-size remained the same for most stations at the observed scales of spatial variability. Station 02 appeared to get slightly coarser in 2015 (Figure 7) and by 2018 so did Stations 08 and 09 (Figures 13 and 14). Station 07 was the only station that appeared to have finer sediments in 2018 (Figure 12). Prism penetration and boundary roughness had more within station variability but when averaged there was no significant difference between years.

Based on July 2018 sediment profile image (SPI) data, Study Area 7 appeared to have a wide range in benthic habitat quality at the ten stations sampled. Based on the organism sediment index (OSI), severely degraded habitat was documented at Stations 04 and 07, and 'healthy' habitat at Stations 01 and 03. The other six stations were in between these endpoints. The factor that appeared to be causing habitat degradation was hypoxia, a common factor degrading benthic habitat in many eutrophic urban systems in summer months (Diaz and Rosenberg 2008). While there are no accounts of hypoxia in the lower Hackensack River or Newark Bay, the Upper reaches of the Hackensack do experience seasonal hypoxia (Neuman et al. 2004), as does the

Passaic River, the other major tributary in the Newark Bay system (Bengraïne and Marhaba 2003).

For the 2014 and 2015 autumn SPI surveys, no low dissolved oxygen condition were detected (NewFields 2014, Germano and Associates 2015). In both 2014 and 2015, Stations 04 and 07 were found to have better habitat quality and advanced successional stage fauna than in 2018. It is likely that benthic habitats within Study Area 7 that were exposed to summertime hypoxia, if it occurred in 2014 and 2015, recovered with the onset of autumn. Quick seasonal recovery from summertime hypoxia is common feature of eutrophic systems (Diaz and Rosenberg 2008). High quality benthic habitat was consistently found at Station 01 and 03 from 2014 to 2018.

Gas voids, assumed to be from microbial anaerobic metabolism (Boudreau et al. 2001), occurred all three years but at twice as many stations in summer compared to autumn likely due to higher summer temperatures (Table 4). The presence of gas voids does point to higher levels of labile organic matter in the sediments, but within Study Area 7 it does not appear that organic content is high enough to severely effect benthic habitat quality. Degradation of benthos is usually high at organic sediment content >3.5 % (Hyland et al. 2005). However, when higher organic content is combined with hypoxia, habitat quality is severely affected (Pearson and Rosenberg 1978). This can be seen at Stations 04 and 07 in 2018. In autumn 2015, gas voids were observed at these two stations but habitat quality did not appear to be effected (Germano and Associates 2015).

For all three years SPI was sampled, processes controlling surficial sediments tended to be biological. This is supported by the consistently advanced estimated successional stage found at most all stations. Exceptions were Stations 04 and 06 in 2018, which declined in successional stage from Stage I on III to Stage I. Station 07 also declined to Stage I in 2018 from Stage I to II in 2015.

The depth of the Redox Potential Discontinuity (RPD) layer, and by proxy the apparent color RPD (aRPD) derived from SPI, is primarily a function of bioturbation, which is

associated with successional stage (Rhoads 1974). Deeper RPD layers tend to indicate higher levels of infaunal activity and point to the importance of bioturbation in mixing sediments and reducing fluxes of nutrient to the water column (Tucker et al. 2014). When levels of bioturbation are not sufficient to keep up with microbial activity or geochemical fluxes from sediments, RPD layers tend to shallow which leads to increased nutrient fluxes to the water column (Rozan et al 2002). These changes in RPD can be seen in SPI aRPDs as either increases or reductions in the area of reddish-brown surficial sediment.

The differences in mean aRPD layer depths in Study Area 7 between years was barely significant, largely due to high variability between stations (Welch ANOVA testing mean Year with SD not equal, $F = 3.7$, $df = 2$, $p = 0.047$). Nonparametric analysis pointed to larger differences between years in the rank sums of aRPD layer depths (Kruskal-Wallis Test, $ChiSq = 7.9$, $df = 2$, $p = 0.019$).

There was evidence of seasonality in that summer aRPD layers tended to be shallower than those in autumn (Figure 16). Autumn means were 2.5 cm (SD = 1.0 cm) and 2.1 cm (SD = 1.1 cm), 2014 and 2015 respectively, with a summer mean of 1.7 cm (SD = 1.1 cm). Between 2014 and 2018, the overall range in aRPD layer depths was 0.0 cm (Station 04 in 2018) to 4.6 cm (Station 06 in 2015), which fell within the aRPD range of 0.0 cm to 6.2 cm that Martello et al. (2007) found in the autumn of 2006 in and around Study Area 7. The mean aRPD layer depth for the 167 stations sampled by Martello et al. (2007) 2006 was 1.7 cm (no SD given). Shallower aRPD layers at Study Area 7 in summer fit the pattern for other marine sediments with low to moderate bioturbation levels that tend to be more anaerobic during summer months because of increase microbial activity (Kristensen 2000).

Estimated biological mixing or bioturbation depths for Study Area 7, based on biogenic structures observed in SPI, were different between years (ANOVA, $F = 5.4$, $df = 2$, $p = 0.013$), but the relationship between years was not straight forward (Figure 17).

Biological mixing depth in autumn 2015 was highest at 14.0 cm (SD = 1.7 cm) and lowest in summer 2018 at 6.5 cm (SD = 1.5 cm). Autumn 2014 mixing depth was not

significantly different from either 2015 or 2018 (based on comparisons for all mean pairs using Tukey's HSD test). Within a year, mixing depths ranged from 4.2 cm to 14.3 cm in 2014, 0.9 cm to 19.3 cm in 2015, and 0.0 cm to 10.7 cm in 2018 (Table 4). These ranges match SPI derived bioturbation depths estimated in and near Study Area 7 by Martello et al. (2007). They found a range of 0.0 cm to approximately 15.5 cm, with an average of 7.8 cm (no SD given) in the autumn of 2006 (Martello et al. 2007). In Newark Bay proper, biological mixing depths derived from SPI ranged from 9.4 cm to 18.6 cm in autumn 2005 (Diaz and ARCADIS 2008). The large overlap in the range of biological mixing depth from these regional studies indicates a broad distribution of 'healthy' benthic habitat. But the low end of the mixing depth range points to the existence of pockets of stressed habitat. An example would be the hypoxia stress Station 04 in 2018 (Figure 4) where bioturbation is severely impaired but not necessarily eliminated (Sturdivant et al. 2012).

Overall, benthic habitat quality, as assessed by SPI parameters, in Study Area 7 appeared to be similar to other portions of the Newark Bay ecosystem (Diaz and ARCADIS 2008). Estimates of successional Stage III infauna observed at the majority of stations and active biological mixing of sediments suggested that benthic habitats in Study Area 7 currently are not greatly impacted.

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Table 1. Wentworth sediment Phi classes and descriptors used for modal grain-size estimation.

Phi Class	Sediment Description
< -6	cobble
-2 to -6	pebble
-1 to -2	gravel
1 to 0	coarse sand
2 to 1	medium sand
3 to 2	fine sand
4 to 3	very fine sand
> 4	silt-clay
>8	clay

Table 2. General weight given to SPI data used to assess successional stage.

Parameter	Successional Stage		
	I - Pioneering	II - Intermediate	III - Equilibrium
aRPD Layer Depth (cm)	<1	1-3	>2-3
Maximum aRPD Depth (cm)	<2	>2	>3-4
Small Tubes (<1 mm dia.)	+++	++	+
Large Tubes (>2 mm dia.)	-	++	+++
Burrows	-	++	+++
Feeding Voids	-	++	+++
Small Infauna	+++	++	+
Large Infauna	-	+	++
Epifauna	+	++	++
- = Not Associated With	+ = Associated With	++ = Moderately Associated With	+++ = Strongly Associated With

Table 3. Study Area 7 summary of SPI data for July 2018.

Stat	Penetration Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Source	aRPD Max (cm)	aRPD Mean (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Biological Mixing Depth (cm)	
01	15.4	0.6	Biological	5.4	2.8	>4	>8	8 to 4	9.1	
02	13.1	0.6	Physical	4.3	3.3	3 to 2	>4	2 to 1	4.3	
03	19.2	0.6	Bio/Phy	6.1	2.8	>4	>8	8 to 4	8.3	
04	12.9	1.0	Physical	0.0	0.0	>4	>8	8 to 4	0.0	
05	17.7	1.1	Biological	5.8	1.8	>4	>8	8 to 4	10.7	
06	24.8	0.6	Physical	1.3	0.7	>4	>8	8 to 4	9.1	
07	9.2	1.7	Physical	1.3	0.4	4 to 3, >4	>4	2 to 1	1.3	
08	2.1	1.4	Bio/Phy	IND	1.3	4 to 3	>4	4 to 3	IND	
09	7.5	1.6	Biological	6.0	2.3	4 to 3	>4	4 to 3	6.0	
10	17.9	0.9	Biological	7.1	2.0	>4	>8	8 to 4	9.5	
Stat	Surface Tubes Max (#/image)	Infauna (#/image)	Infauna Max Depth (cm)	Oxic Voids (#/image)	Oxic Voids Max Depth (cm)	Anaerobic Voids (#/image)	Anaerobic Voids Max Depth (cm)	Gas Voids Max (#/image)	Successional Stage Max	OSI Mean
01	1 to 4	1.3	11.6	0.3	10.4	0.0		0	I on III	7.3
02	25 to 50	0.7	3.7	0.0		0.0		>50	I to II	6.3
03	15 to 24	2.0	10.4	1.3	4.8	0.3	12.9	0	I on III	7.7
04	5 to 14	0.0		0.0		0.3	16.0	10 to 19	I	-5.0
05	25 to 50	1.7	13.3	0.3	12.6	0.0		1 to 4	I on III	5.3
06	15 to 24	1.7	13.8	0.0		0.0		0	I to II	3.0
07	15 to 24	0.0		0.0		0.0		25 to 50	I	-2.0
08	25 to 50	1.7	1.7	0.0		0.0		0	I to II	4.0
09	25 to 50	1.0	5.0	0.0		0.0		1 to 4	I to II	4.7
10	25 to 50	3.7	11.3	0.0		0.0		1 to 4	I on III	5.7

Table 4. Study Area 7 summary of SPI data for 2014, 2015, and 2018.

Station Year	01			02			03			04			05		
	2014	2015	2018	2014	2015	2018	2014	2015	2018	2014	2015	2018	2014	2015	2018
Grain Size Major Mode (phi)	>4	>4	>4	4 to 3	3 to 2	3 to 2	>4	>4	>4	>4	>4	>4	>4	>4	>4
Mean Penetration (cm)	16.5	20.1	15.4	6.7	3.2	13.1	19.0	20.5	19.2	12.8	19.5	12.9	13.4	18.0	17.7
Boundary Roughness Type	Bio	Bio	Bio	Bio	Phy	Phy	Bio	Bio	Bio/Phy	Bio	Bio	Phy	Bio	Bio	Bio
Mean aRPD (cm)	1.5	1.1	2.8	2.8	2.0	3.3	4.4	3.0	2.8	1.6	1.3	0.0	2.5	2.4	1.8
Gas Voids	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes
Feeding Voids	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Biological Mixing Depth (cm)	14.3	17.9	9.1	0.7	IND	4.3	12.7	19.3	8.3	7.5	15.8	0.0	10.8	13.2	10.7
Succ. Stage Max	III	I on III	I on III	I	I on III	I to II	III	III	I on III	I on III	I on III	I	III	I on III	I on III
Mean OSI	6.7		7.3	5.3		6.3	10.3		7.7	5.3		-5.0	9.3		5.3
Station Year	06			07			08			09			10		
	2014	2015	2018	2014	2015	2018	2014	2015	2018	2014	2015	2018	2014	2015	2018
Grain Size Major Mode (phi)	>4	>4	>4	4 to 3	3 to 2	>4	>4	>4	4 to 3	>4	>4	4 to 3	>4	>4	>4
Mean Penetration (cm)	19.9	17.6	24.8	10.0	6.1	9.2	4.2	4.7	2.1	7.1	5.0	7.5	14.3	15.6	17.9
Boundary Roughness Type	Bio	Bio	Phy	Bio	Bio	Phy	Bio	Bio	Bio/Phy	Bio	Bio	Bio	Bio	Bio	Bio
Mean aRPD (cm)	3.9	4.6	0.7	1.2	0.9	0.4	1.7	1.6	1.3	2.6	2.1	2.3	2.9	2.0	2.0
Gas Voids	Yes	No	No	No	Yes	Yes	No	No	No	No	No	Yes	No	No	Yes
Feeding Voids	No	Yes	No	No	No	No	Yes	No	No	No	No	No	Yes	Yes	No
Biological Mixing Depth (cm)	14.2	16.8	9.1	7.7	0.9	1.3	IND	IND	IND	5.5	IND	6.0	11.1	14.1	9.5
Succ. Stage Max	III	I on III	I to II	II	I to II	I	I on III	II to III	I to II	II	II to III	I to II	I on III	I on III	I on III
Mean OSI	7.0		3.0	4.3		-2.0	5.0		4.0	6.3		4.7	10.0		5.7

Bio = Biological Phy = Physical IND = Indeterminate



Figure 1. Lower Hackensack River, Study Area 7 station locations for SPI monitoring (From Germano and Associates 2015).

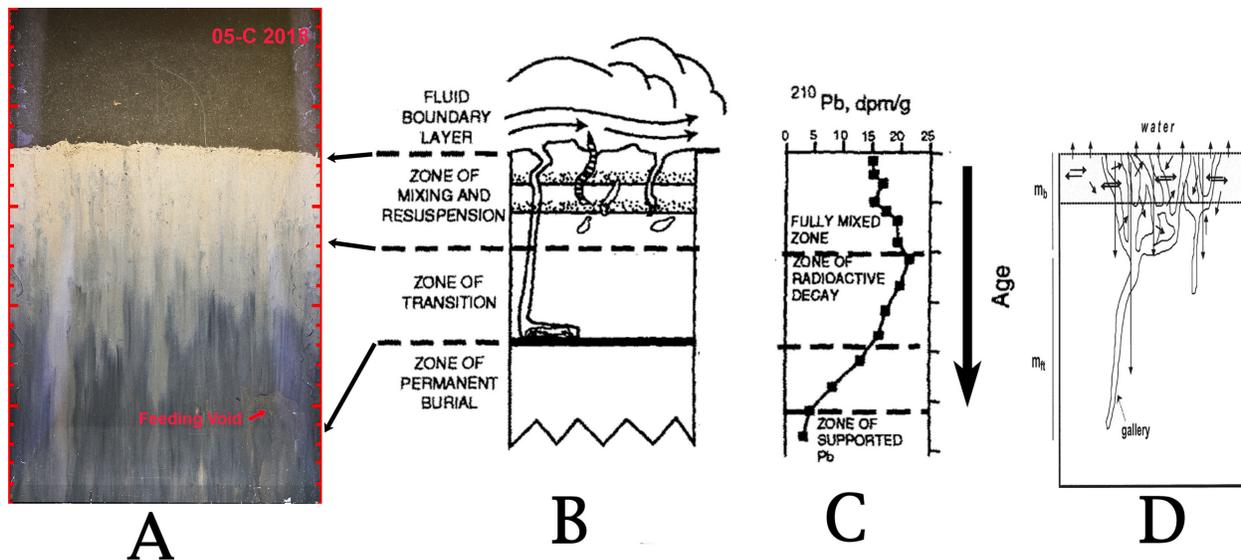


Figure 2. Relationship between SPI derived biological mixing and biological mixing models: A – SPI image from Station 05 replicate C. B – Biogenic mixing zone model of Swift et al. (1996). C – Example of a ^{210}Pb profile that matches Swift model. D – Two part mixing model of François et al. (2002), m_b is the biodiffusion zone and m_{ft} is the tube bottom zone. Arrows from B to A point to sediment-water-interface, maximum extent of aRPD at about 5 cm considered the bottom of the resuspension zone, and the level of the deepest observed infaunal activity at about 13 cm. B and C are modified from Swift et al. (1996) and D from François et al. (2002). Scale alongside of image is in cm.

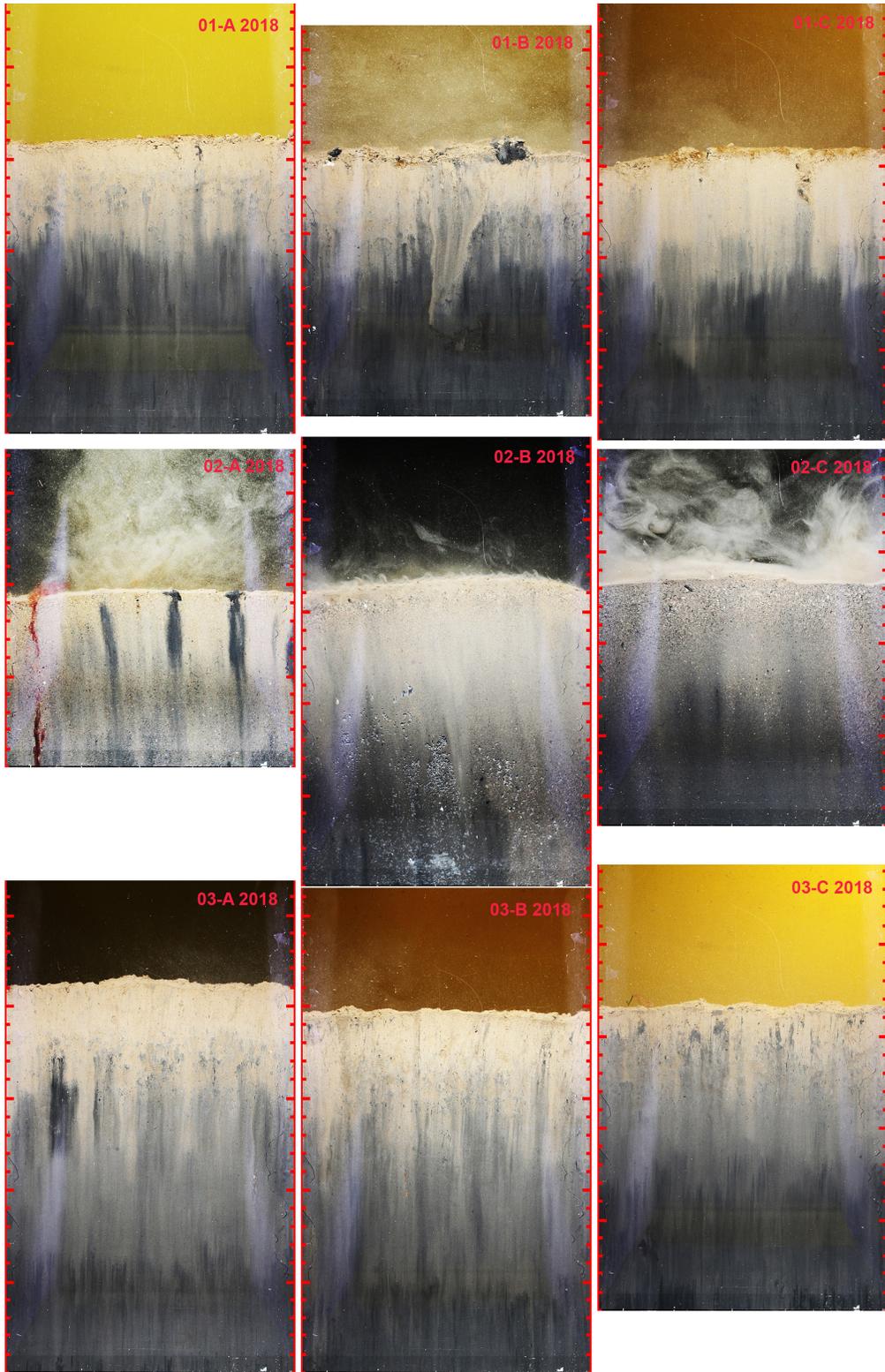


Figure 3. Study Area 7, Stations 01 to 03, replicate images for summer 2018. Scale on side of images is in cm.

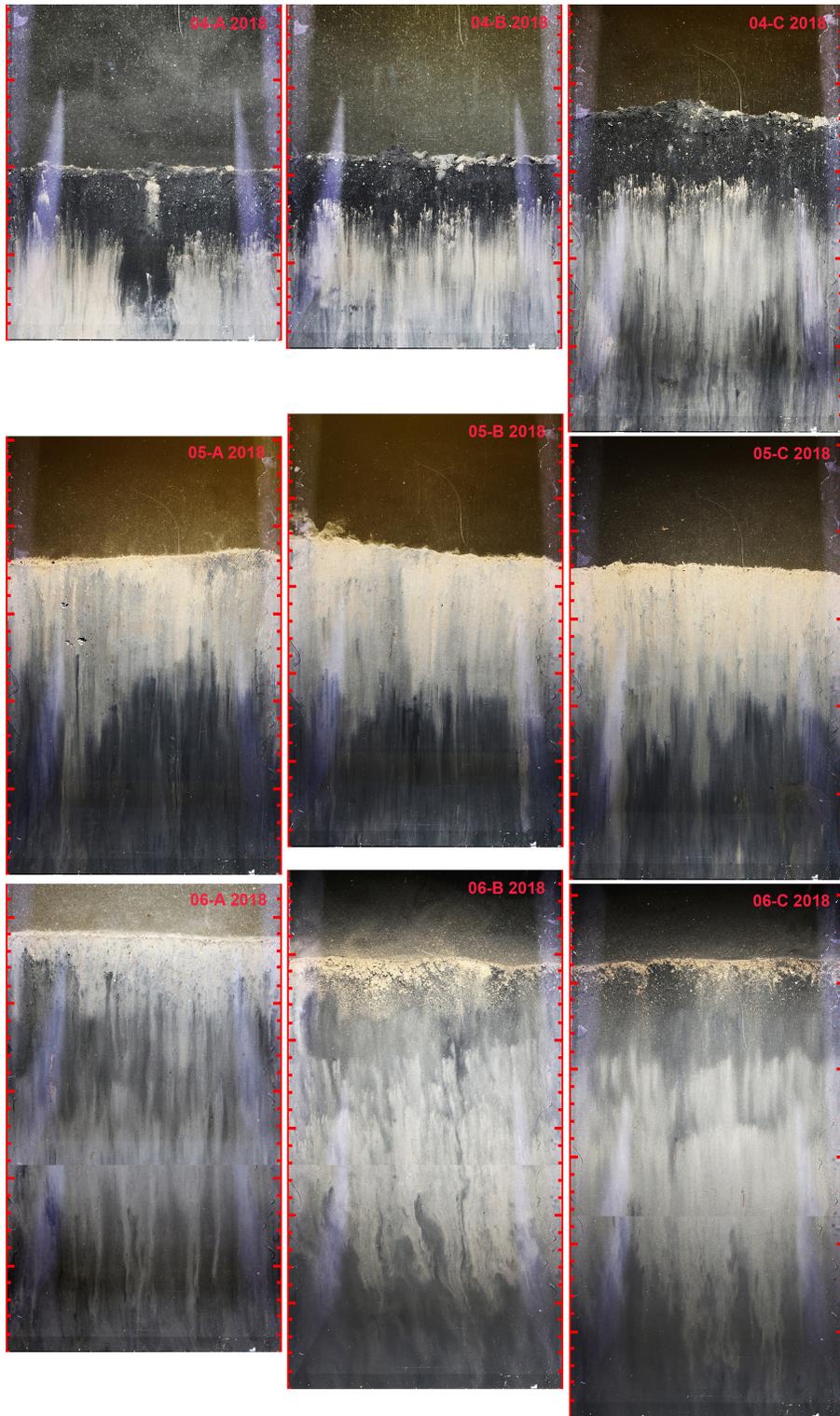


Figure 4. Study Area 7, Stations 04 to 06, replicate images for summer 2018. Scale on side of images is in cm.

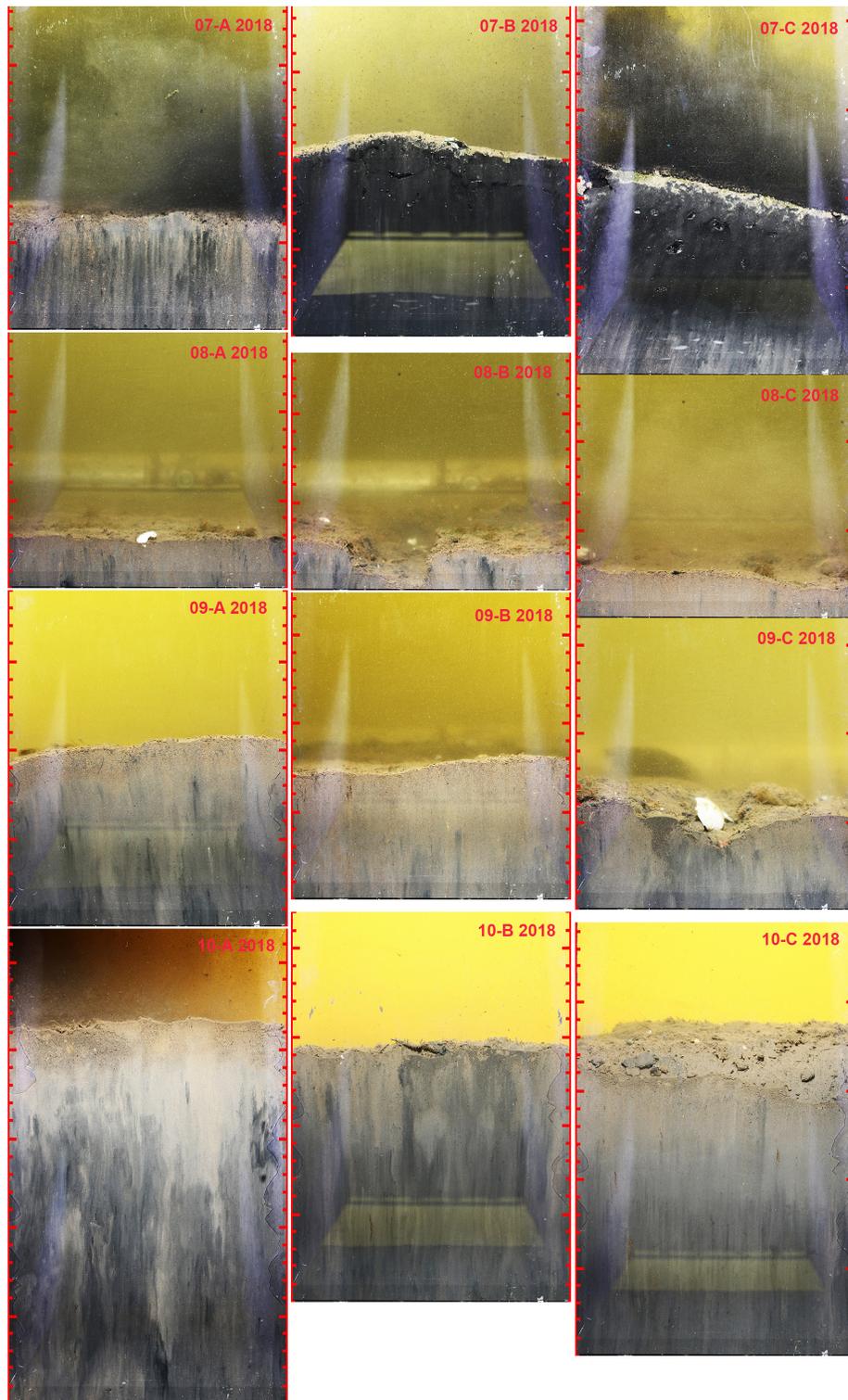


Figure 5. Study Area 7, Stations 07 to 01, replicate images for summer 2018. Scale on side of images is in cm.

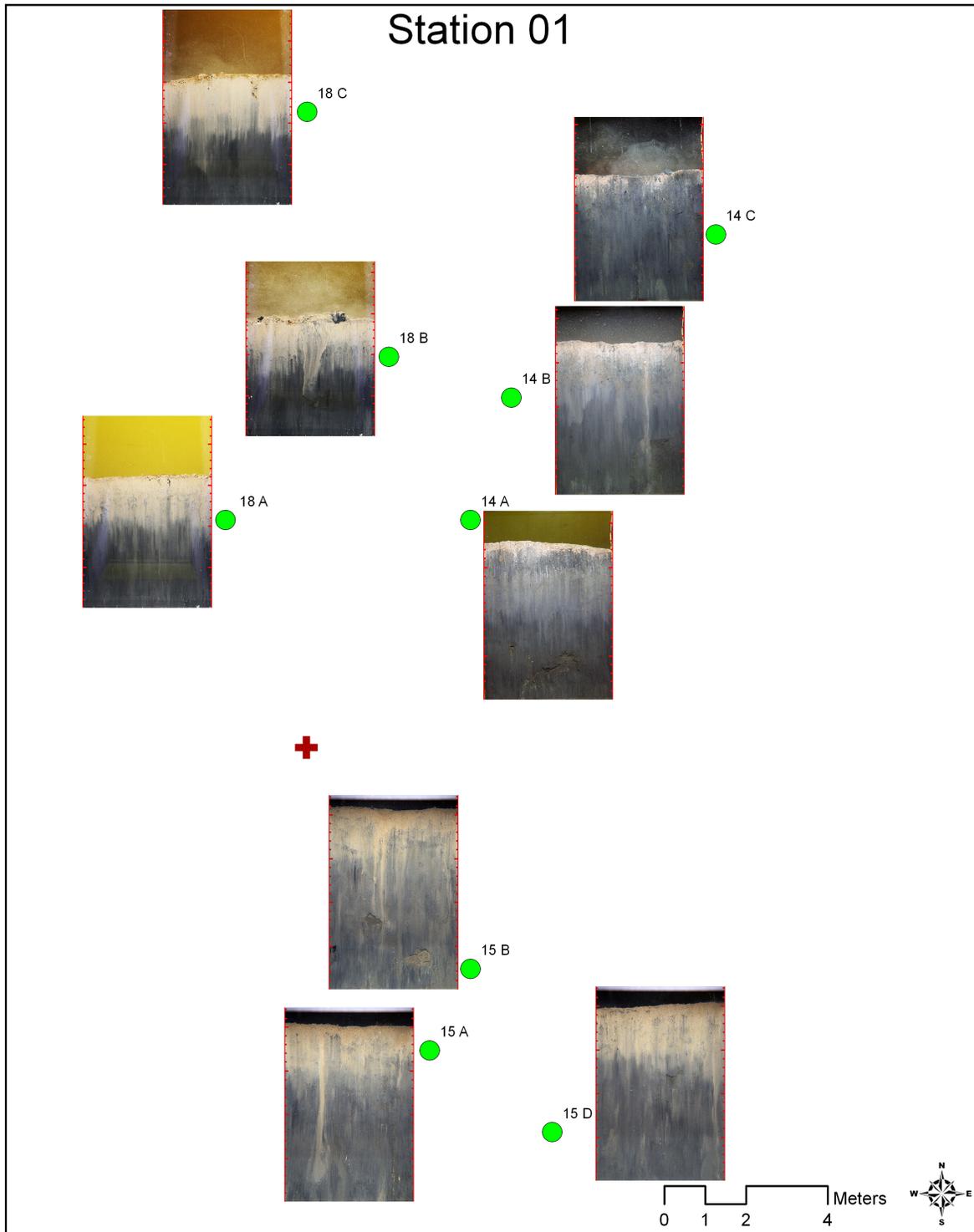


Figure 6. Study Area 7, Station 01 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm..

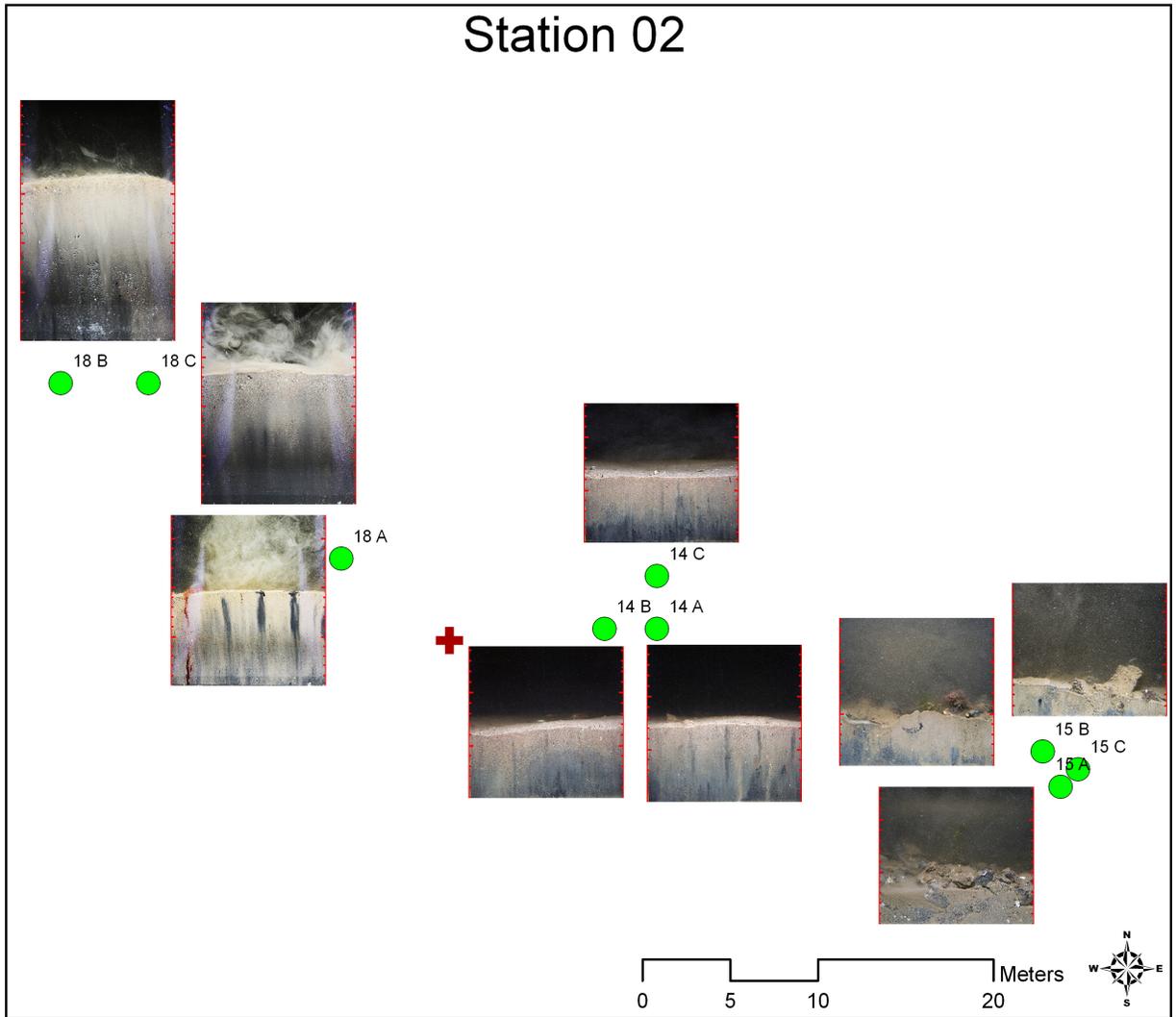


Figure 7. Study Area 7, Station 02 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

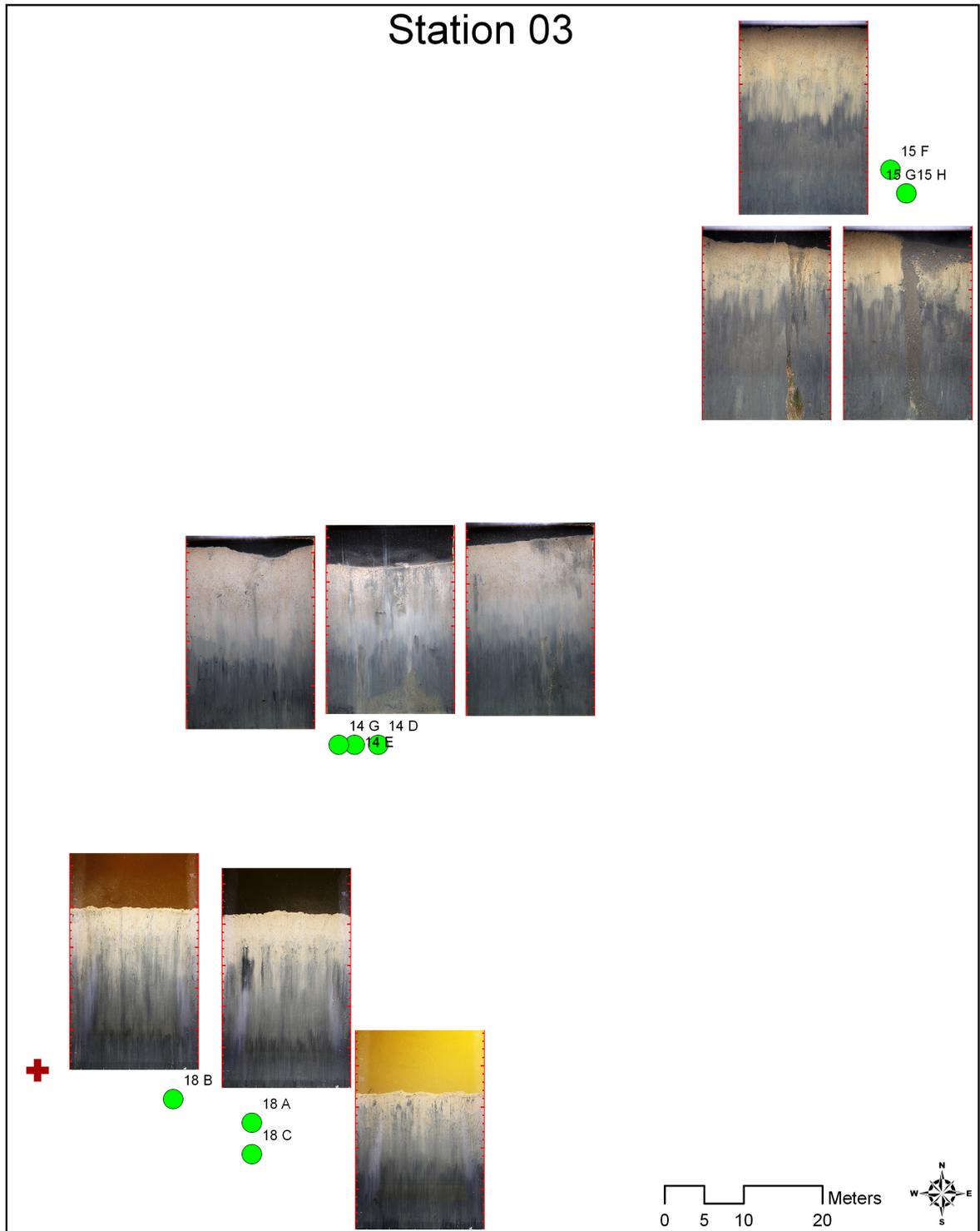


Figure 8. Study Area 7, Station 03 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

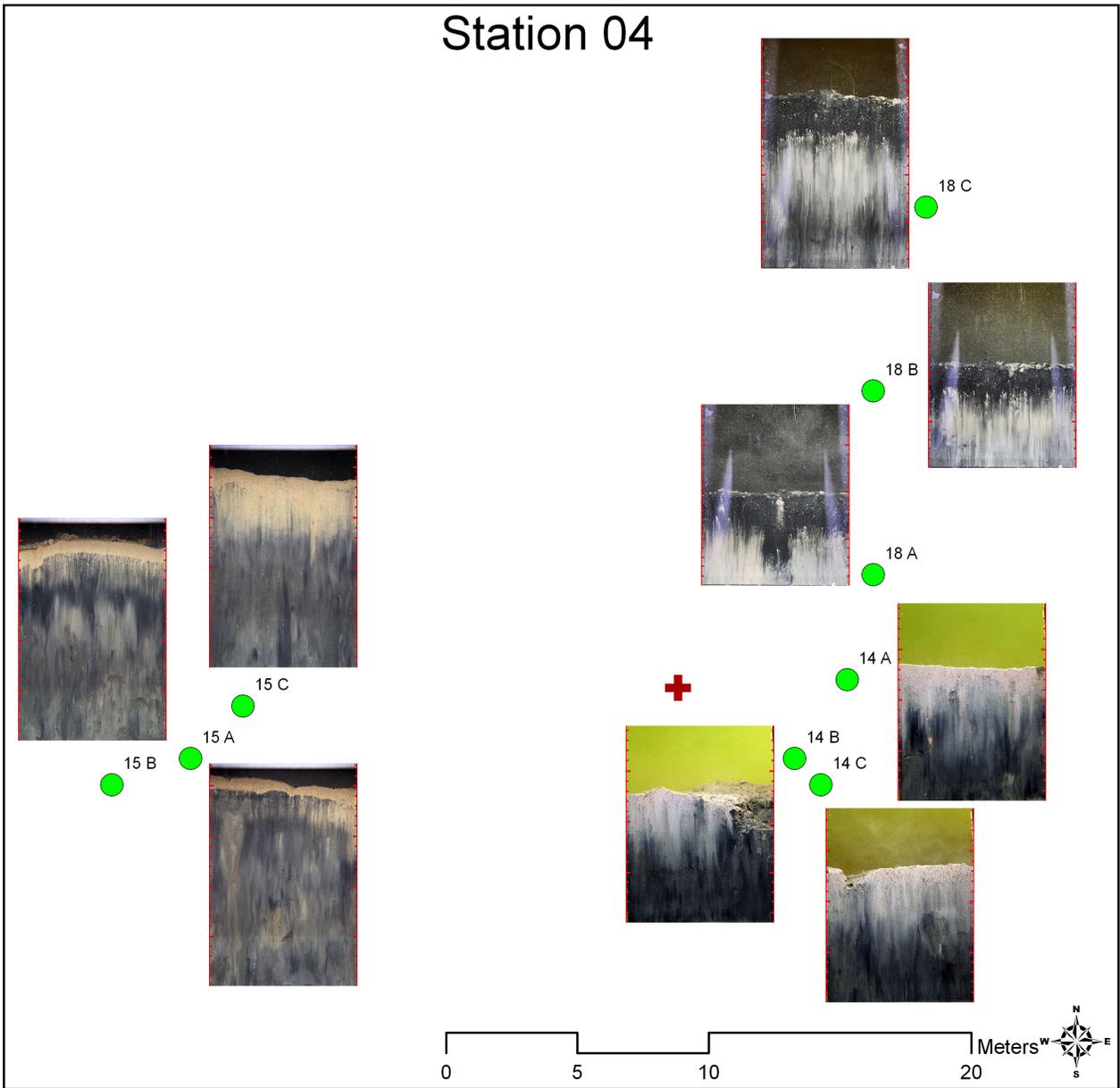


Figure 9. Study Area 7, Station 04 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

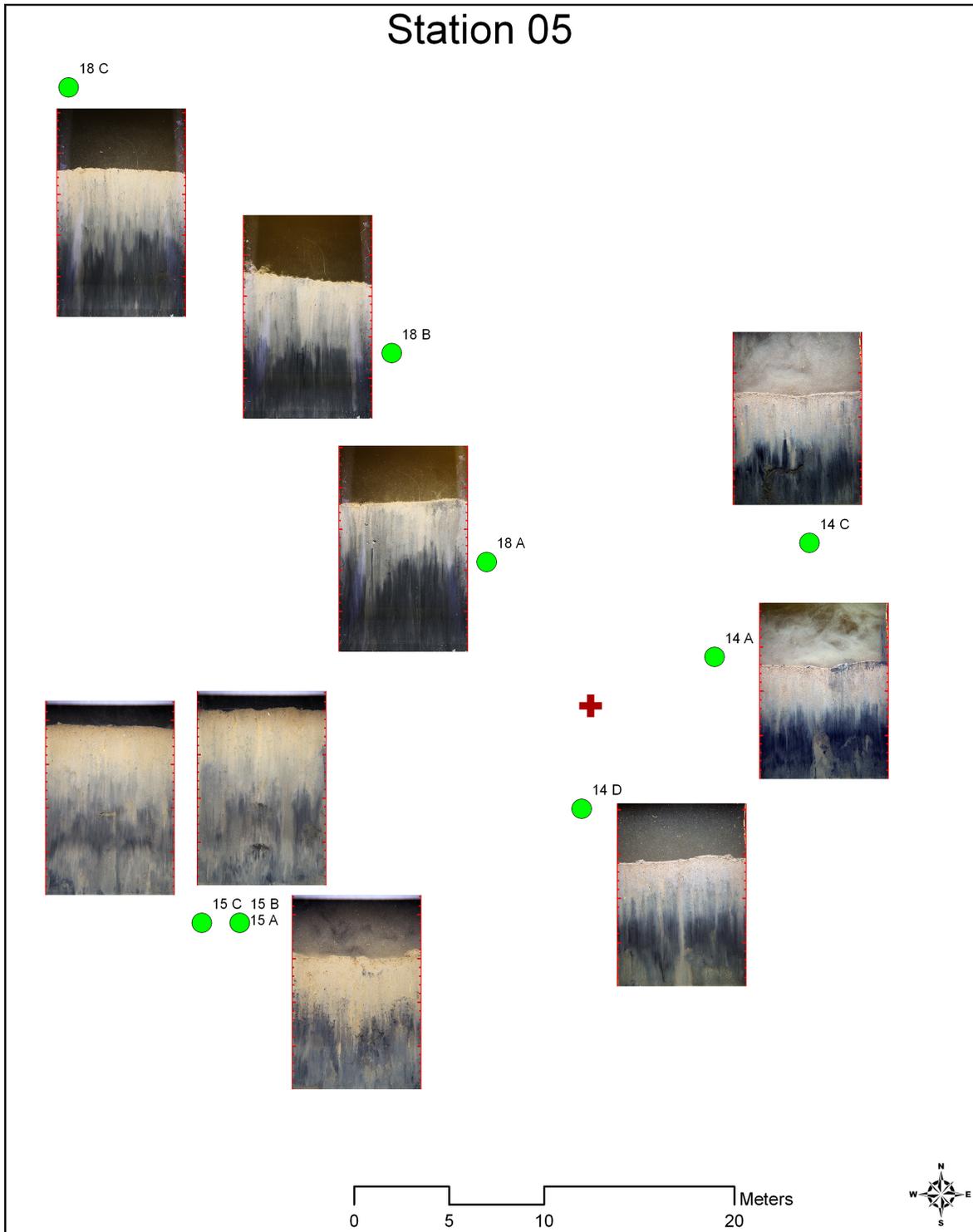


Figure 10. Study Area 7, Station 05 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

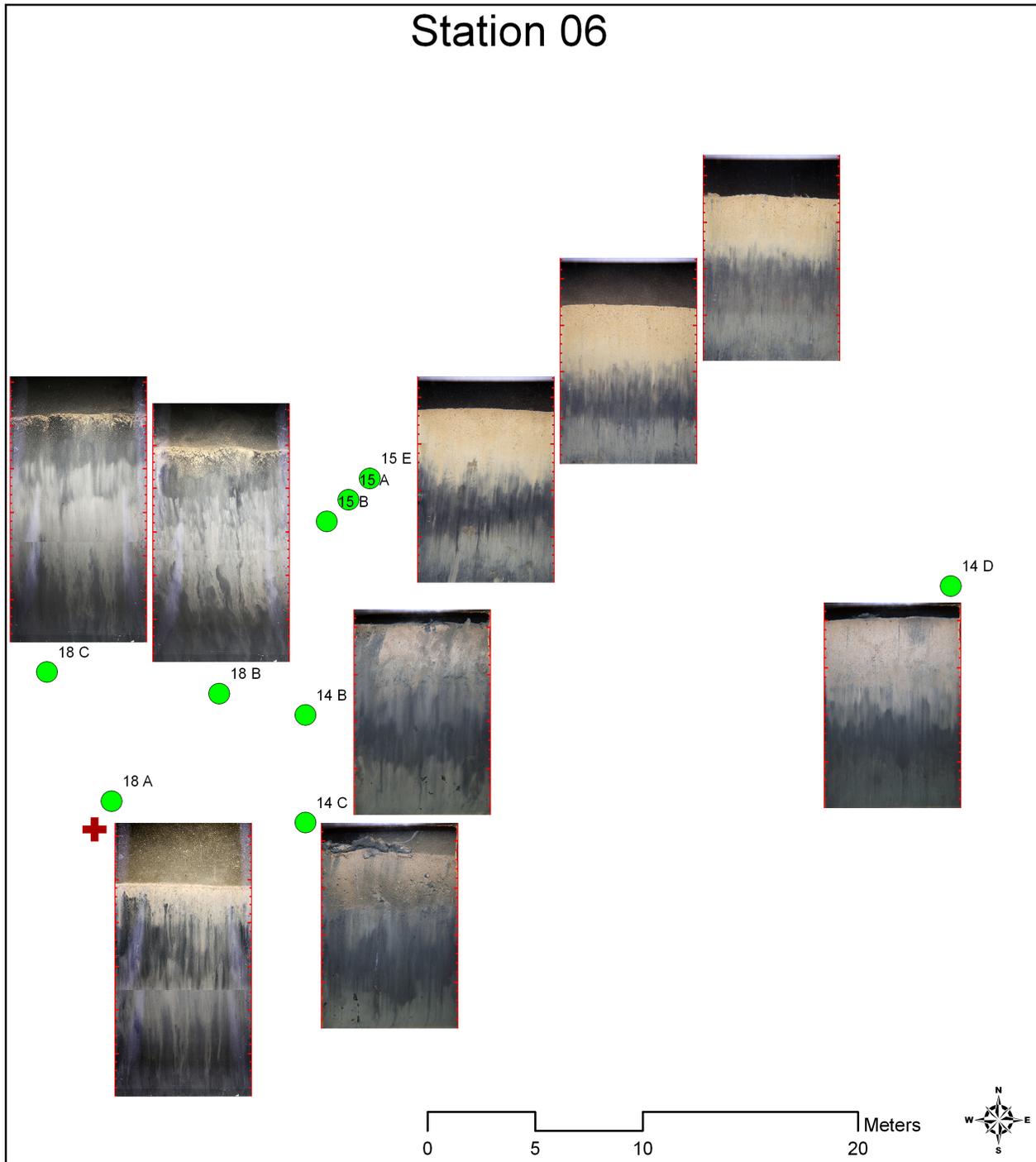


Figure 11. Study Area 7, Station 06 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

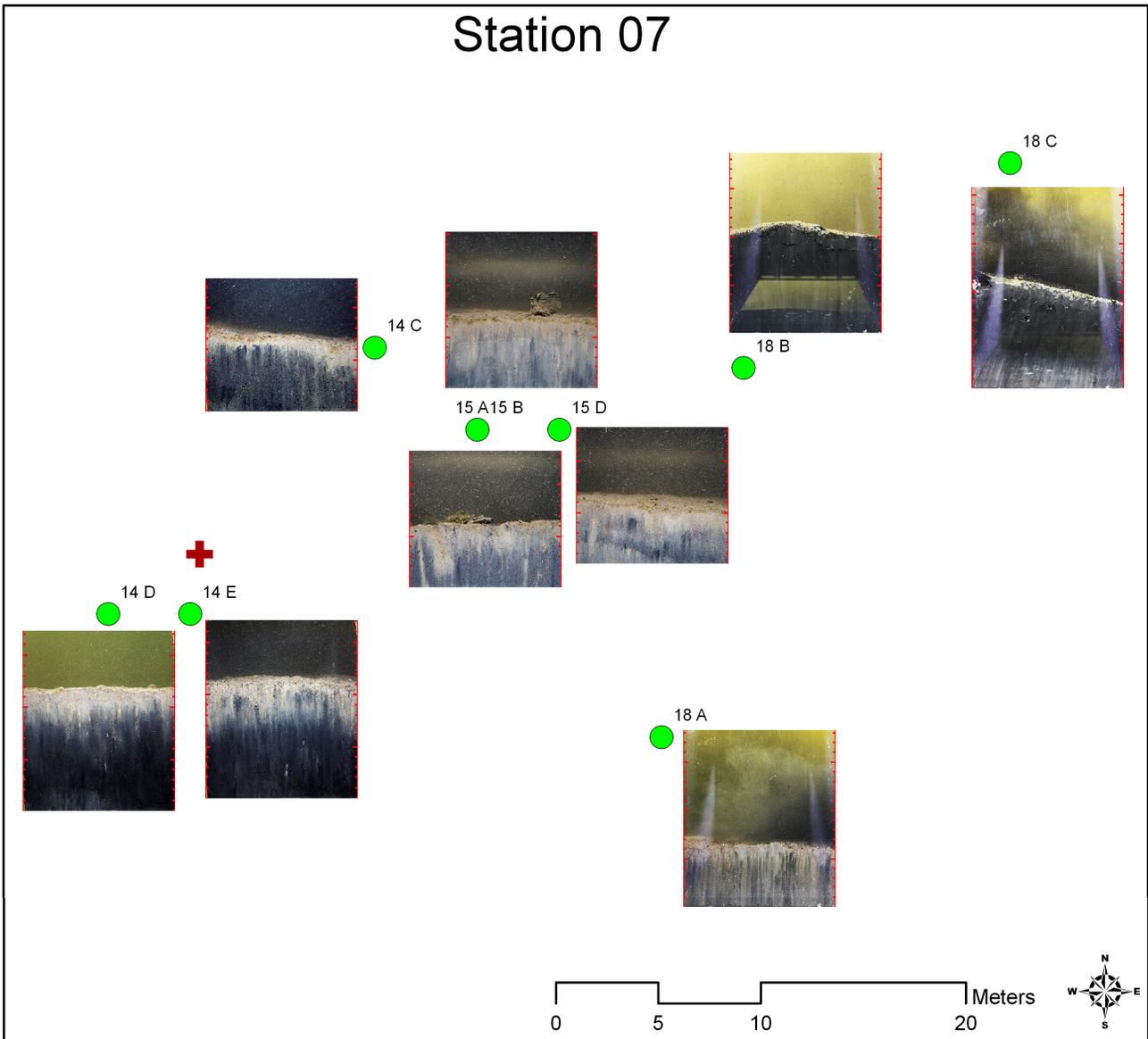


Figure 12. Study Area 7, Station 07 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.



Figure 13. Study Area 7, Station 08 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

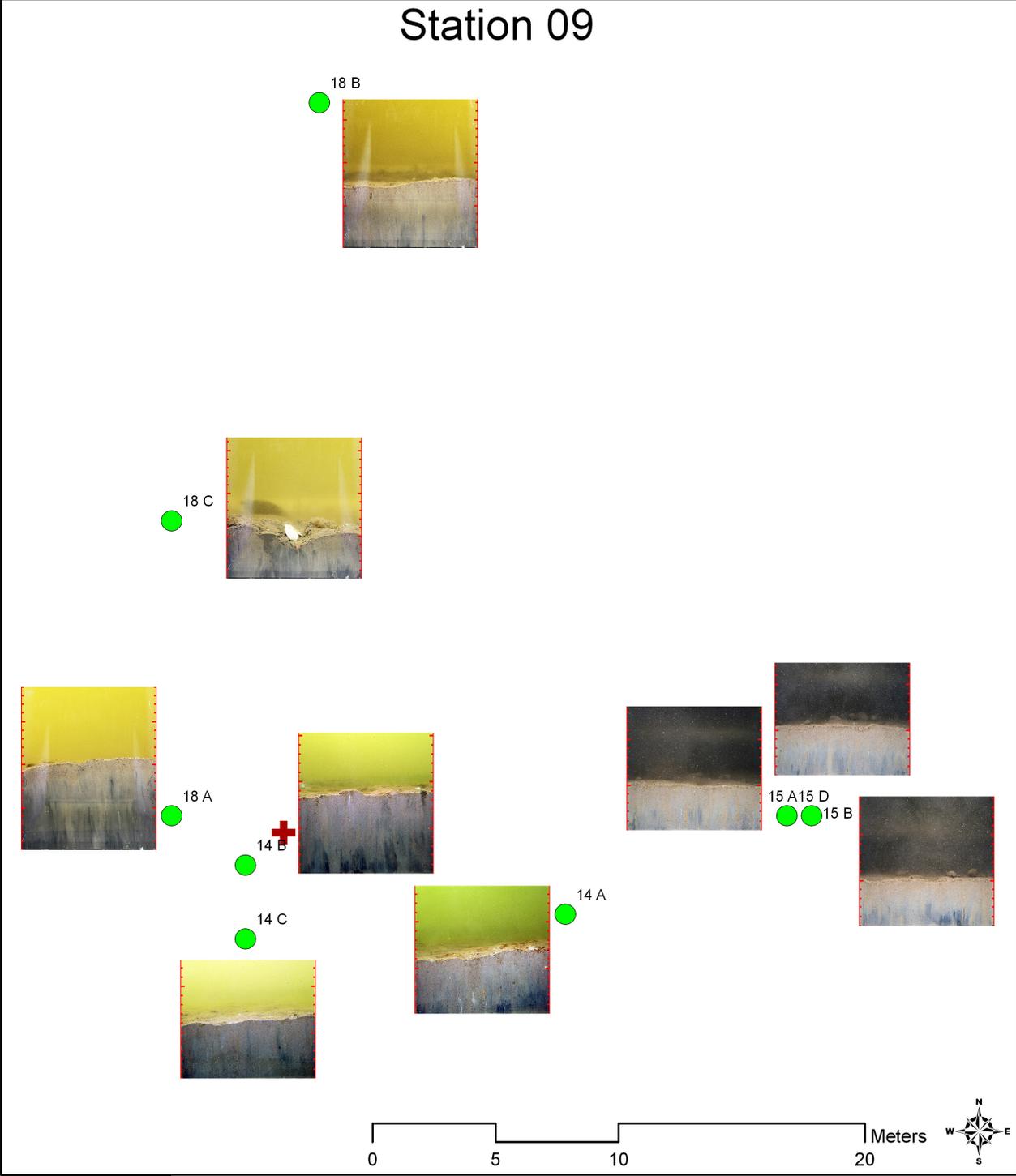


Figure 14 Study Area 7, Station 09 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

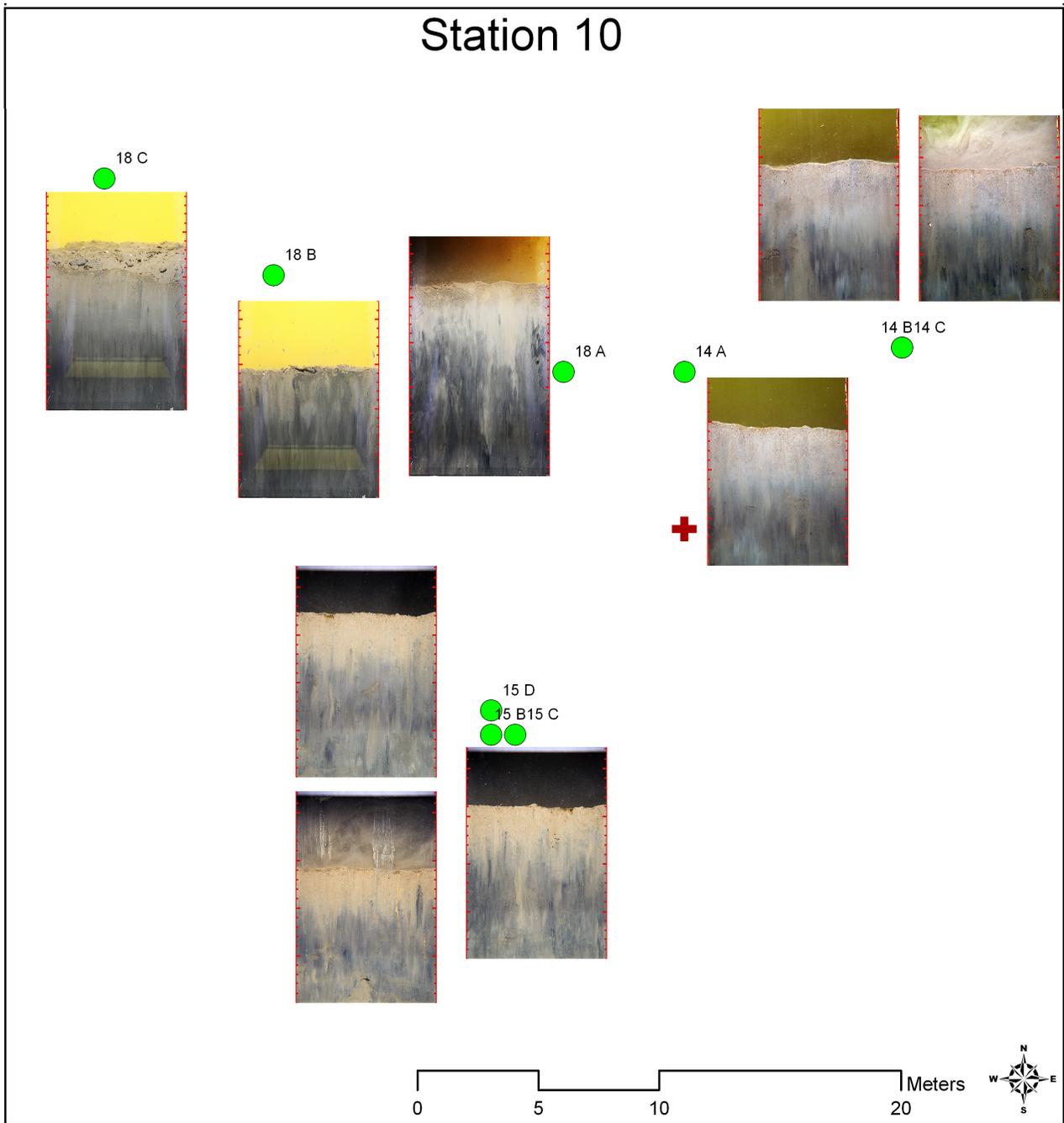


Figure 15. Study Area 7, Station 10 spatial mosaic of images from 2014 to 2018. Cross is station target. Scale on side of images is in cm.

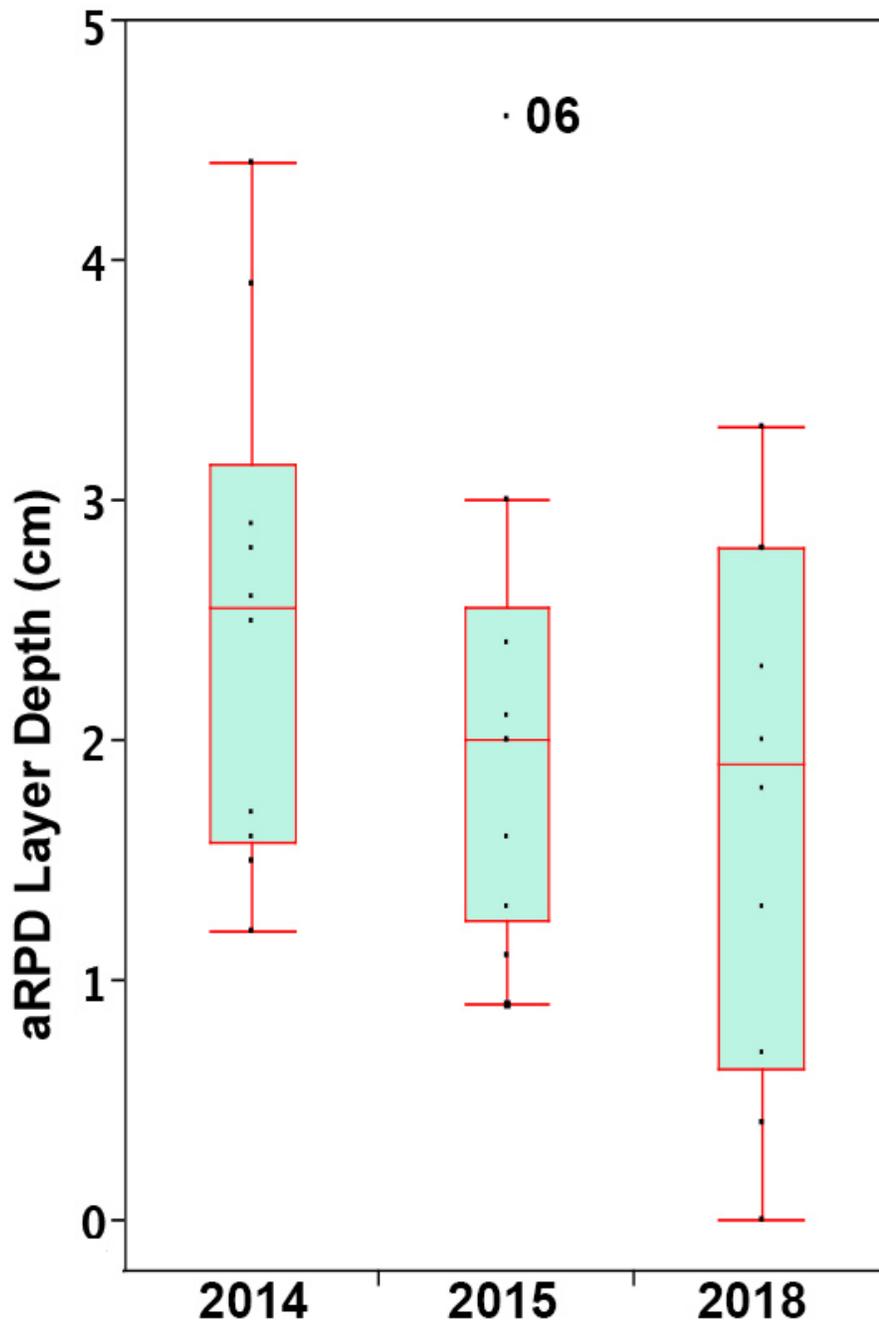


Figure 16. Study Area 7 box plot of aRPD layer depth. Box is interquartile range (IR), whiskers are ranges, bar in box is median, dots are individual data points, box width is proportional to sample size. Station 06 was an outlier ($>2 \times IR$) in 2015.

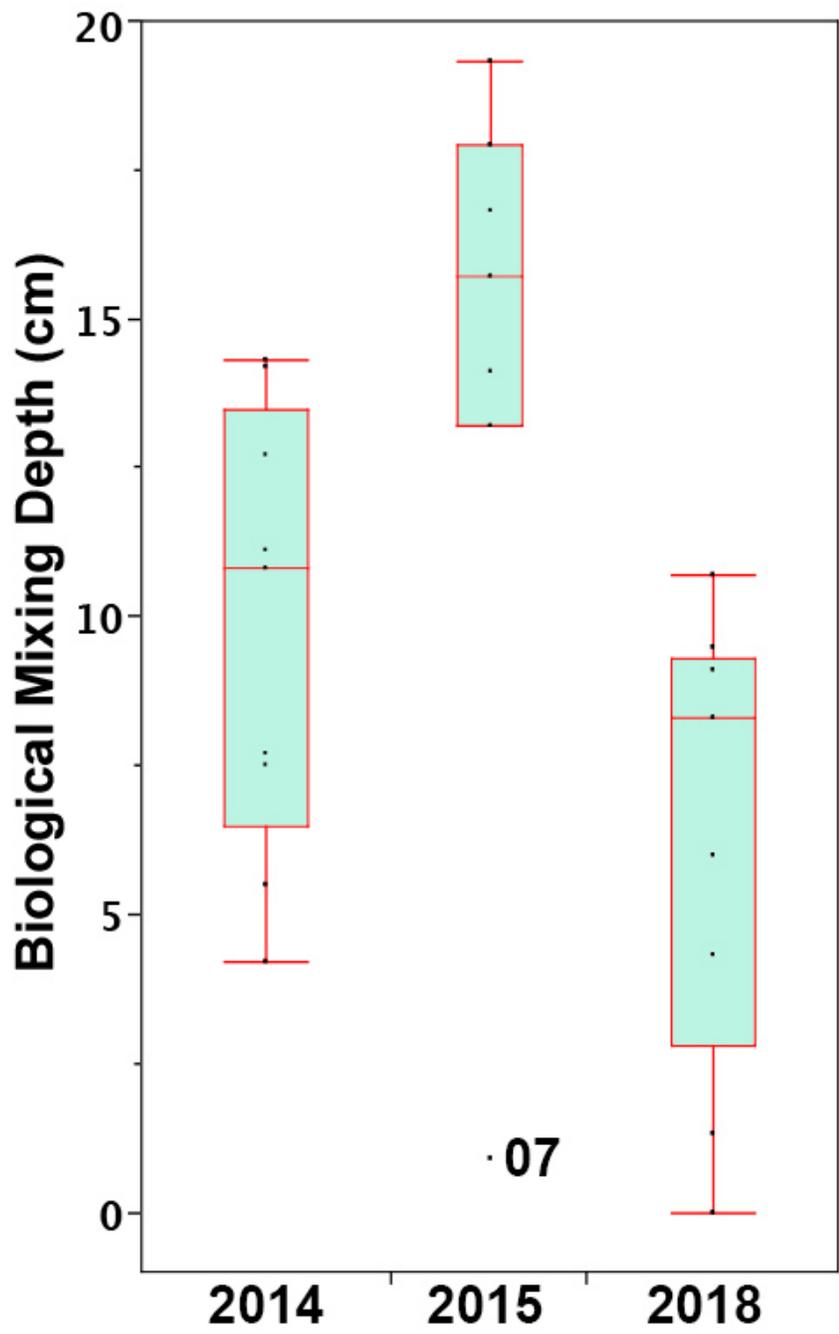


Figure 17. Study Area 7 box plot of biological mixing depth. Box is interquartile range (IR), whiskers are ranges, bar in box is median, dots are individual data points, box width is proportional to sample size. Station 07 was an outlier ($>2 \times IR$) in 2015.

APPENDIX A

Hackensack River, Study Area 7, July 2018, Sediment Profile Image Data

Station	Replicate	Penetration Min (cm)	Penetration Max (cm)	Penetration Mean (cm)	Boundary Roughness (cm)	Boundary Roughness Source	aRPD Max (cm)	aRPD Mean (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Sediment Comment	Biological Comments
01	A	15.9	16.3	16.07	0.4	Biological	5.5	2.5	>4	>8	8 to 4	Silt-clay	Microalgal mat on sediment surface
01	B	14.1	14.5	14.49	0.4	Biological	4.6	2.4	>4	>8	8 to 4	Silt-clay	Microalgal mat on sediment surface
01	C	14.9	15.8	15.55	0.9	Biological	6.0	3.4	>4	>8	8 to 4	Silt-clay	Microalgal mat on sediment surface
02	A	9.0	9.6	9.40	0.5	Physical	3.7	3.2	3 to 2	>4	2 to 1	Silty fine-medium sand	Red macro algae on sediment surface
02	B	15.9	16.6	16.41	0.7	Physical	3.9	3.3	3 to 2	>4	2 to 1	Silty fine-medium sand	Tubes are small about 3 mm long and <1 mm diameter, Many small gas voids in sandy layer below 8 to 9 cm layer of silty sand
02	C	13.1	13.6	13.51	0.5	Physical	5.3	3.4	3 to 2	>4	2 to 1	Silty fine-medium sand	One tube about 10 mm long and 2 mm diameter
03	A	20.8	21.4	21.33	0.6	Bio/Phy	6.2	3.0	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
03	B	19.3	19.7	19.71	0.5	Bio/Phy	7.1	3.4	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
03	C	16.1	16.7	16.58	0.7	Bio/Phy	5.0	1.9	>4	>8	8 to 4	Silt-clay	Red macroalgae on sediment surface, Tubes are small <3 mm long and 0.1 mm diameter
04	A	9.3	9.9	9.66	0.6	Physical	0.0	0.0	>4	>8	8 to 4	5 cm layer of high organic content silty-clay over clayey sediment	Top layer of sediment appears to be highly anoxic with virtually no oxidized sediment on the surface, Low dissolved oxygen present
04	B	10.0	11.2	10.74	1.2	Physical	0.0	0.0	>4	>8	8 to 4	4 cm layer of high organic content silty-clay over clayey sediment	Top layer of sediment appears to be highly anoxic with virtually no oxidized sediment on the surface, Low dissolved oxygen present
04	C	17.4	18.7	18.27	1.3	Physical	0.0	0.0	>4	>8	8 to 4	5 cm layer of high organic content silty-clay over clayey sediment	Top layer of sediment appears to be highly anoxic with virtually no oxidized sediment on the surface, Low dissolved oxygen present
05	A	17.5	18.4	18.15	0.9	Biological	4.9	1.5	>4	>8	8 to 4	Silt-clay	Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 mm diameter
05	B	16.2	17.6	17.07	1.4	Biological	6.1	1.2	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
05	C	17.1	18.0	17.75	0.9	Biological	6.4	2.5	>4	>8	8 to 4	Silt-clay	Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 mm diameter
06	A	23.2	23.7	23.74	0.5	Physical	2.4	1.1	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
06	B	23.9	24.6	24.52	0.6	Physical	0.8	0.7	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
06	C	25.6	26.2	26.20	0.6	Physical	0.9	0.4	>4	>8	8 to 4	Silt-clay	Tubes are small about 3 mm long and <1 mm diameter
07	A	6.0	6.6	6.34	0.6	Biological	4.0	0.6	4 to 3	>4	2 to 1	Silty sand, mostly fine-sand with some medium-sand	Tubes are small about 3 mm long and <1 mm diameter
07	B	9.9	11.4	10.75	1.4	Physical	0.0	0.2	>4	>4	4 to 3	High organic content silty sand	Small patches of bacterial mat on sediment surface, Low dissolved oxygen present
07	C	8.9	11.9	10.49	3.0	Physical	0.0	0.3	>4	>4	4 to 3	8 cm layer of high organic content silty sand over silty sand	Low dissolved oxygen present
08	A	2.5	3.0	2.79	0.4	Bio/Phy	IND	1.3	4 to 3	>4	4 to 3	Fine sand with some silt-clay	Microalgae, macroalgae and colonial epifauna on sediment surface
08	B	0.2	2.7	1.43	2.5	Bio/Phy	IND	>1.4	4 to 3	>4	4 to 3	Fine sand with some silt-clay	Microalgae, macroalgae and colonial epifauna on sediment surface
08	C	1.5	2.7	2.16	1.2	Bio/Phy	IND	>2.2	4 to 3	>4	4 to 3	Fine sand with some silt-clay	Microalgae, macroalgae and colonial epifauna on sediment surface
09	A	9.1	10.6	9.95	1.4	Biological	5.8	2.1	4 to 3	>4	4 to 3	Silty fine-sand	Macroalgae on sediment surface, Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 mm diameter
09	B	6.9	8.0	7.54	1.0	Biological	6.2	2.5	4 to 3	>4	4 to 3	Silty fine-sand	Macroalgae on sediment surface, Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 mm diameter
09	C	3.9	6.1	5.05	2.3	Bio/Phy	IND	2.2	4 to 3	>4	4 to 3	Silty fine-sand	Most tubes are about 10 mm long and 1 to 2 mm diameter
10	A	20.8	21.6	21.44	0.8	Biological	6.9	1.8	>4	>8	8 to 4	Silt-clay	Most tubes are about 10 mm long and 1 to 2 mm diameter
10	B	13.7	14.5	14.30	0.8	Bio/Phy	8.5	1.9	>4	>8	8 to 4	Silt-clay	Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 to 3 mm diameter
10	C	17.2	18.3	17.93	1.0	Biological	6.0	2.4	>4	>8	8 to 4	Silt-clay	Most tubes are small about 3 mm long and <1 mm diameter, a few are about 2 mm diameter

Station	Replicate	Surface Tubes (#/image)	Infauna (#/image)	Infauna Min Depth (cm)	Infauna Max Depth (cm)	Oxic Voids (#/image)	Oxic Voids Min Depth (cm)	Oxic Voids Max Depth (cm)	Anaerobic Voids (#/image)	Anaerobic Voids Min Depth (cm)	Anaerobic Voids Max Depth (cm)	Gas Voids (#/image)	Successional Stage	OSI	Biol Mix Depth (cm)	Biol Mix Depth Bases
01	A	1 to 4	0			0			0			0	I to II	6	5.5	aRPD Max
01	B	1 to 4	3	0.9	9.0	1	10.4	10.4	0			0	I on III	9	10.4	Oxic Voids Max
01	C	1 to 4	1	11.6	11.6	0			0			0	I to II	7	11.6	Infauna Max
02	A	0	0			0			0			0	I to II	7	3.7	aRPD Max
02	B	25 to 50	2	3.0	3.7	0			0			>50	I to II	5	3.9	aRPD Max
02	C	1 to 4	0			0			0			0	I to II	7	5.3	aRPD Max
03	A	15 to 24	2	1.9	10.4	2	2.1	4.8	0			0	I on III	9	10.4	Infauna Max
03	B	5 to 14	1	9.3	9.3	2	2.3	3.8	0			0	I on III	10	9.3	Infauna Max
03	C	5 to 14	3	1.6	4.7	0			1	12.9	12.9	0	I	4	5.0	aRPD Max
04	A	0	0			0			0			10 to 19	I	-5	0.0	aRPD Max
04	B	0	0			0			0			1 to 4	I	-5	0.0	aRPD Max
04	C	5 to 14	0			0			1	16.0	16.0	10 to 19	I	-5	0.0	aRPD Max
05	A	25 to 50	2	5.1	13.3	0			0			1 to 4	I to II	3	13.3	Infauna Max
05	B	15 to 24	1	5.7	5.7	0			0			0	I to II	4	6.1	aRPD Max
05	C	25 to 50	2	5.9	6.2	1	12.6	12.6	0			0	I on III	9	12.6	Oxic Voids Max
06	A	15 to 24	2	8.5	12.6	0			0			0	I to II	4	12.6	Infauna Max
06	B	1 to 4	0			0			0			0	I	2	0.8	aRPD Max
06	C	1 to 4	3	9.4	13.8	0			0			0	I to II	3	13.8	Infauna Max
07	A	15 to 24	0			0			0			0	I	2	4.0	aRPD Max
07	B	0	0			0			0			25 to 50	I	-4	0.0	aRPD Max
07	C	0	0			0			0			10 to 19	I	-4	0.0	aRPD Max
08	A	5 to 14	4	0.5	1.7	0			0			0	I to II	4	IND	IND
08	B	25 to 50	1	1.5	1.5	0			0			0	I to II	IND	IND	IND
08	C	25 to 50	0			0			0			0	I to II	IND	IND	IND
09	A	25 to 50	0			0			0			1 to 4	I to II	3	5.8	aRPD Max
09	B	25 to 50	2	1.7	5.0	0			0			0	I to II	6	6.2	aRPD Max
09	C	25 to 50	1	1.8	1.8	0			0			0	I to II	5	IND	IND
10	A	15 to 24	1	4.6	4.6	0			0			1 to 4	I on III	6	6.9	aRPD Max
10	B	25 to 50	2	1.9	10.2	0			0			0	I to II	5	10.2	Infauna Max
10	C	25 to 50	8	5.1	11.3	0			0			0	I to II	6	11.3	Infauna Max

APPENDIX B

Hackensack River, Study Area 7, July 2018, SPI images

(provided on CD-ROM)

APPENDIX C

Hackensack River, Study Area 7, Medium resolution images

from 2014, 2015, and 2018



01 A 2014



01 B 2014



01 C 2014



01 A 2015



01 B 2015



01 D 2015



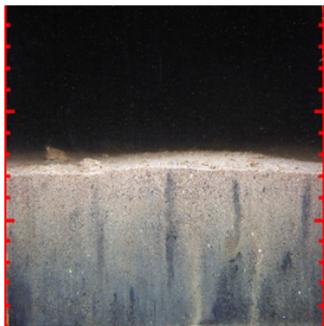
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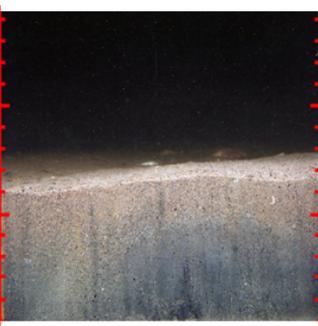
01-B 2018



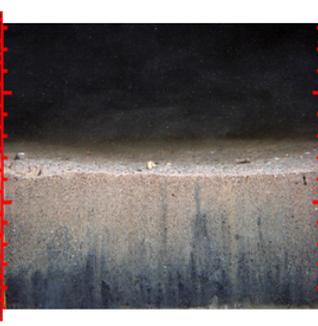
01-C 2018



02 A 2014



02 B 2014



02 C 2014



02 A 2015



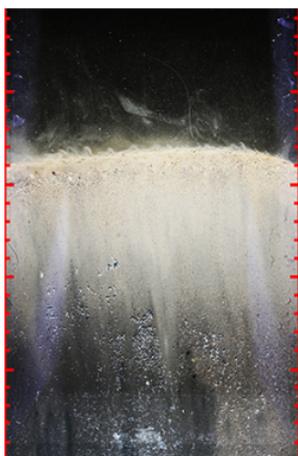
02 B 2015



02 C 2015



02-A 2018



02-B 2018



02-C 2018



03 D 2014



03 E 2014



03 G 2014



03 F 2015



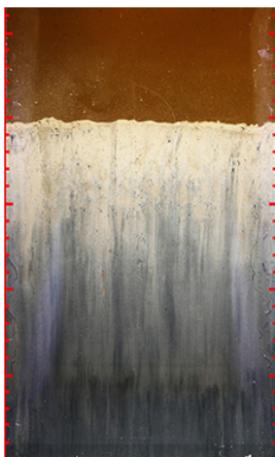
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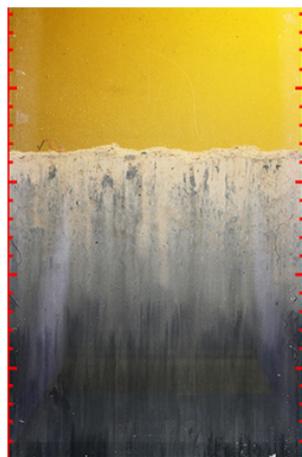
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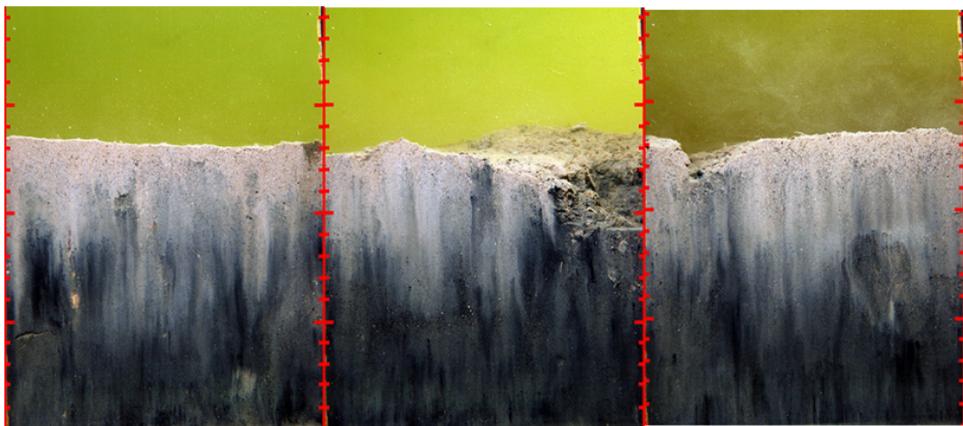
03-A 2018



03-B 2018



03-C 2018



04 A 2014

04 B 2014

04 C 2014



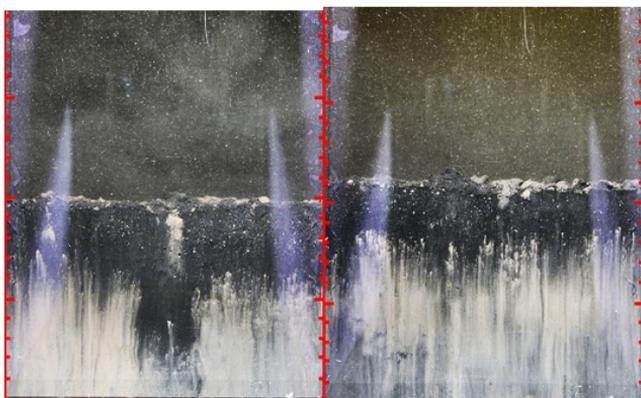
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04 B 2015



04 C 2015



04-A 2018

04-B 2018



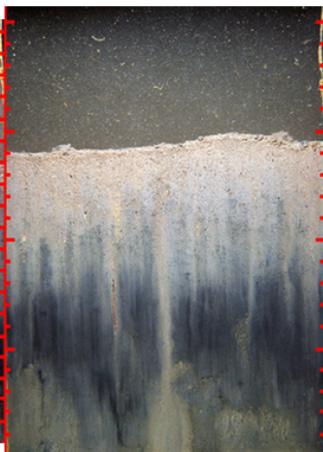
04-C 2018



05 A 2014



05 C 2014



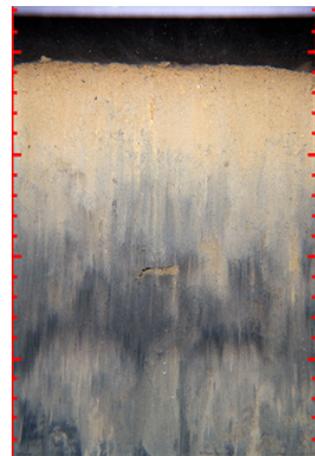
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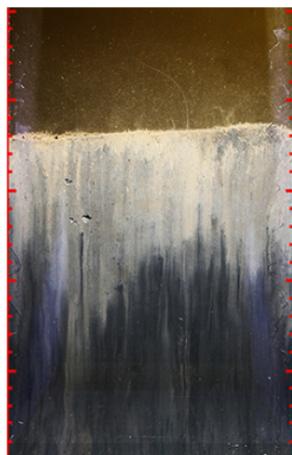
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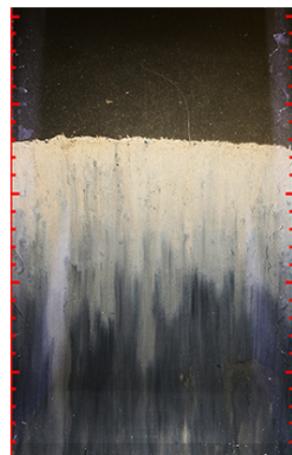
05 C 2015



05-A 2018



05-B 2018



05-C 2018



06 B 2014



06 C 2014



06 D 2014



06 A 2015



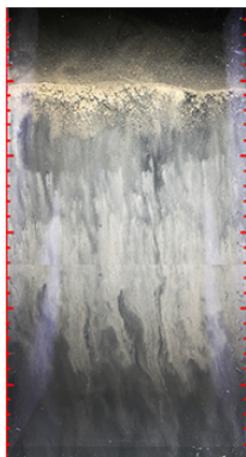
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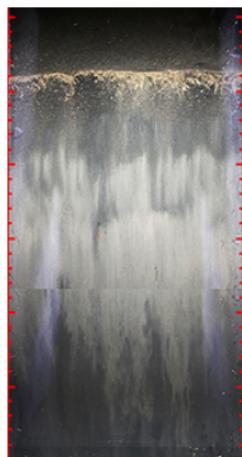
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06-A 2018



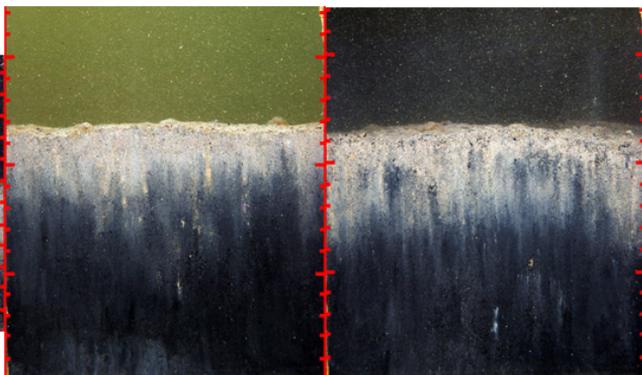
06-B 2018



06-C 2018



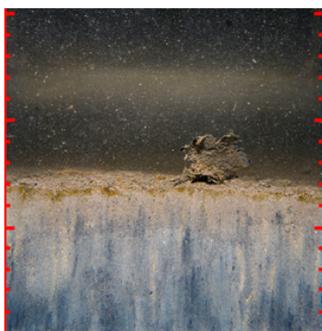
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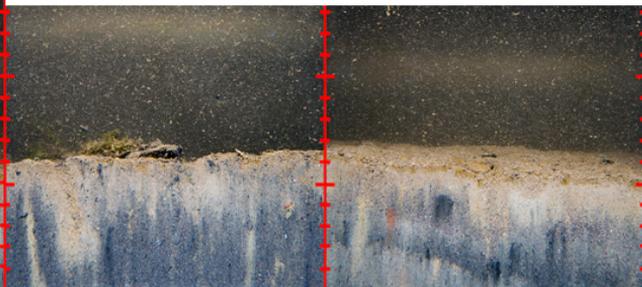
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07 E 2014



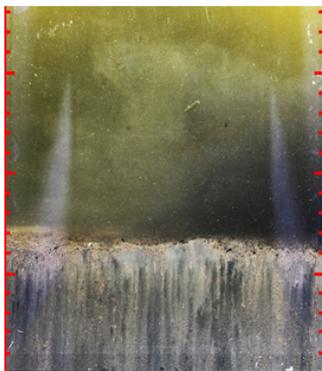
07 A 2015



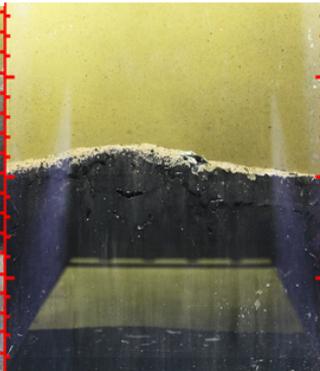
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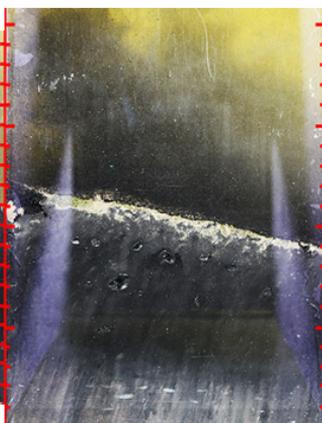
07 D 2015



07-A 2018



07-B 2018



07-C 2018



08 A 2014

08 B 2014

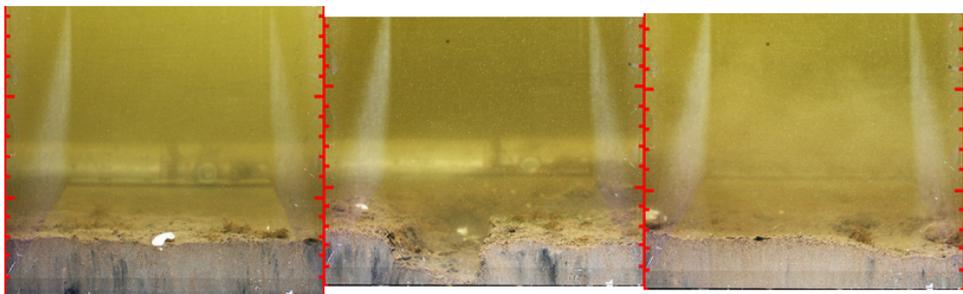
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08 A 2015

08 B 2015

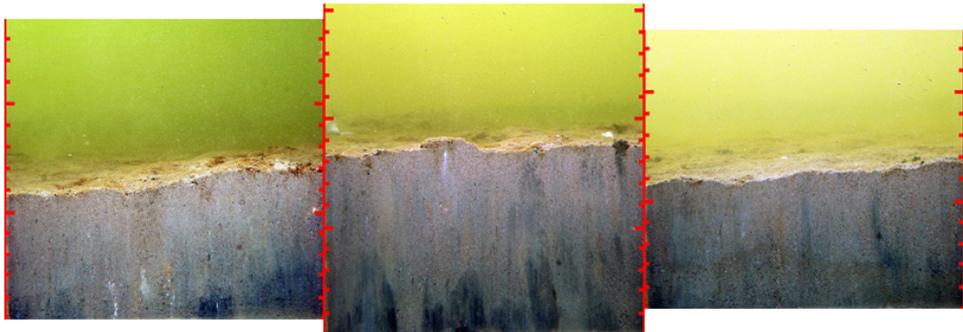
08 D 2015



08-A 2018

08-B 2018

08-C 2018



09 A 2014

09 B 2014

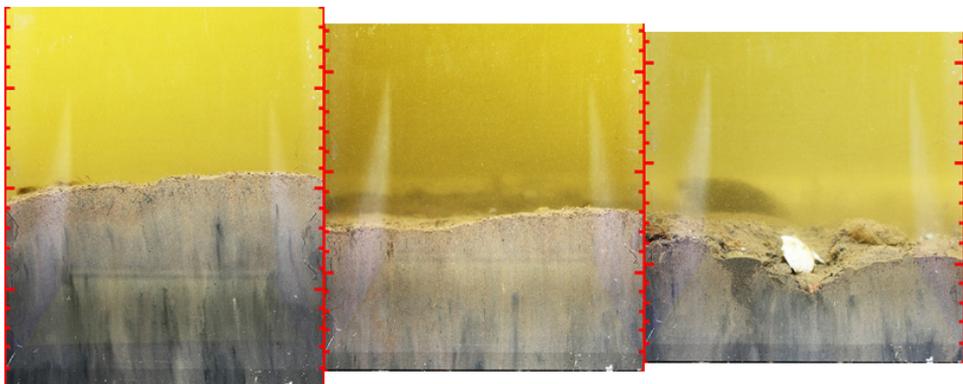
09 C 2014



09 A 2015

09 B 2015

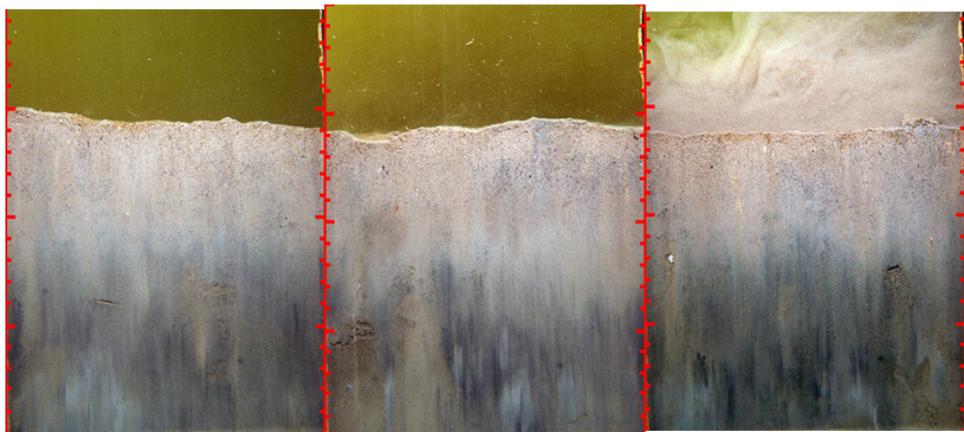
09 D 2015



09-A 2018

09-B 2018

09-C 2018



10 A 2014

10 B 2014

10 C 2014



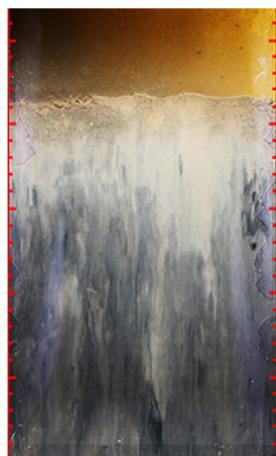
10 B 2015



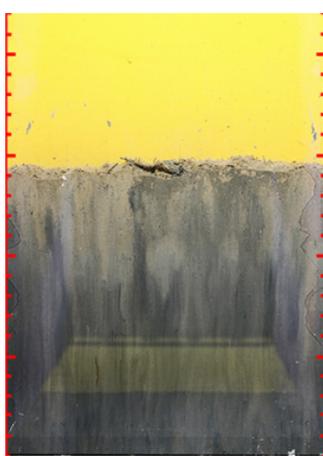
10 C 2015



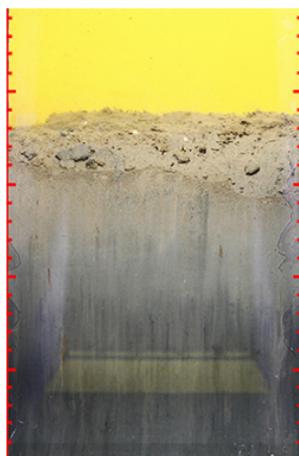
10 D 2015



10-A 2018



10-B 2018



10-C 2018

**APPENDIX E
TAXONOMIC IDENTIFICATION OF BENTHIC
MACROINVERTEBRATES TECHNICAL REPORT**

Aqua Survey, Inc.

Technical Report

Taxonomic Identification of Benthic Macroinvertebrates

Hackensack River, Hudson County, New Jersey

**Ramboll Environ, Inc.
214 Carnegie Center
Princeton, NJ 08540**

**September 13, 2018
REVISED September 20, 2018**

ASI Job No. 38-005

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Signature Page

Taxonomic Identification of Benthic Macroinvertebrates

Hackensack River, Hudson County, New Jersey

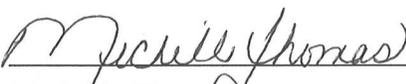
The report as well as all records and raw data were audited and found to be an accurate reflection of the study. Copies of the raw data will be maintained by Aqua Survey, Inc., 469 Point Breeze Road, Flemington, New Jersey, 08822.



Cheryl Hall
Quality Assurance Officer

9/20/18

Date



Michelle Thomas
Laboratory Manager

9/20/18

Date



Jon Doi, Ph.D.
Executive Vice President

9-20-18

Date

Technical Report
Taxonomic Identification of Benthic Macroinvertebrates
Hackensack River, Hudson County, New Jersey

Study Initiation Date

July 24, 2018

Study Completion Date

September 13, 2018
REVISED September 20, 2018
(% Dominant Taxa in Table 2 corrected)

Performing Laboratory

Aqua Survey, Inc.
469 Point Breeze Road
Flemington, New Jersey 08822

Sponsor

Ramboll Environ, Inc.
214 Carnegie Center
Princeton, NJ 08540

Laboratory Project ID

ASI Job No. 38-005

I. INTRODUCTION

The objective of this task was to isolate, identify, and count the organisms in samples of benthic substrate from the Hackensack River, Hudson County, New Jersey.

II. TEST ADMINISTRATION

A. Sponsor

Ramboll Environ, Inc.
214 Carnegie Center
Princeton, NJ 08540

B. Testing Facilities

Aqua Survey, Inc.
469 Point Breeze Road
Flemington, New Jersey 08822

EcoAnalysts
1420 S. Blaine St., Suite 14
Moscow, ID 83843

C. Dates of Study

Date of Study Initiation: July 24, 2018
Date of Study Completion: September 13, 2018
Revised on: September 20, 2018

D. Study Participants

Jon Doi, Ph.D.	Executive Vice-President
Tom Dolce	Field Operations Manager
Cheryl Hall	Quality Assurance Officer
Liz Horn	Scientist
Michael Bowman	Field Operations
Matt Shappell	Field Operations
Kevin Sondag	Field Operations
Michelle Thomas	Laboratory Manager

III. MATERIALS AND METHODS

A. Sampling

Twenty-three (23) grab samples were collected by ASI personnel on July 24, 26, 27 and 30, 2018 from the Hackensack River, Hudson County, New Jersey. All samples were received at ASI in Flemington, New Jersey under chain of custody. Upon arrival at ASI, the samples were logged in and assigned unique sample numbers. Sample positioning was performed using a Trimble SPS 855 Differential Global Positioning System. The (DGPS) coordinates and identification numbers are listed in Table 1. Site maps are presented in Figures 1 and 2.

Table 1 DGPS Coordinates and Sample Identification

Sample	Northings	Eastings	ASI ID #
1A	686759.4	602456.5	20180457
2A	686389.6	602221.1	20180458
3A	685255.5	601000.2	20180459
6A	687159.8	603421.2	20180466
7A	684610.7	600837.2	20180460
7C	684757.8	601190.4	20180461
9A	687539.2	602788.1	20180462
11A	687949.4	603096.4	20180475
11C	688204.9	603418.4	20180469
11D	688110.0	603600.9	20180465
13A	686840.4	602960.3	20180467
13B	687082.4	603051.4	20180468
15A	685758.3	601522.4	20180473
17C	688374.6	603057.1	20180476
18B	686881.3	602493.4	20180474
26A	688723.5	603855.1	20180463
27A	689046.0	603627.0	20180471
29A	688429.3	603351.4	20180470
29C	688700.2	603370.7	20180472
30A	688439.0	603604.3	20180464
REF 1	693370.9	605232.2	20180479
REF 2	688704.1	597405.3	20180477
REF 3	681306.1	597394.0	20180478

B. Sample Preparation

Upon receipt at the laboratory, the benthic sediment samples were stored prior to sorting. Once sorting commenced, the samples were rinsed with tap water and sieved through a 500- μ m sieve to remove the formalin and debris prior to picking. Benthic samples were completely picked to remove all invertebrates from the substrate and the organisms were stored in individual containers with 70% methanol. No

organisms were found in sample number 20180470, from location 29A.

All organisms were stored in separately labeled vials filled with clean 70% ethanol. The samples will be archived at Aqua Survey, Inc. for a minimum of five years, after which the samples will be returned to the client or properly disposed.

C. Taxonomic Identification

The total and estimated number of organisms present and the number of taxa are presented in the summary tables. Density of each taxon was calculated by dividing the number of organisms by the approximate volume of sediment. Calculations for percent abundance (relative abundance) were done for each organism in each sample.

Organisms were sorted by taxon and keyed to the family level or lower using one or more of the following keys:

Abbott, R.T. 1974. *American Seashells, The Marine Mollusca of the Atlantic and Pacific Coasts of North America*. Van Nostrand Reinhold Co. New York, NY. 663 pp.

Bousfield, E.L. 1973. *Shallow-water Gammaridean Amphipoda of New England*. Cornell University Press. Ithaca, NY. 312 pp.

Burch, J. B., 1972. *Freshwater Sphaeriacean clams (Mollusca: Pelecypoda) of North America*. U. S. Environmental Protection Agency Biota of Freshwater Ecosystems Identification Manual No. 3. 31 pp.

Fauchald, K. 1977. *The Polychaete Worms, Definitions and Keys to the Orders, Families, and Genera*. Natural History Museum of Los Angeles County, Science Series 28:1-190.

Gosner, K.L. 1971. *Guide to identification of marine and estuarine invertebrates: Cape Hatteras to the Bay of Fundy*. John Wiley & Sons, Inc. 693 p

Kathman, R.D., and R.O. Brinkhurst. 1998. *Guide to the freshwater oligochaetes of North America*. Aquatic Resources Center, College Grove, TN. 264 pp.

Merritt, R. W., K. W. Cummins, and M. B. Berg (eds). 2008. *An Introduction to the Aquatic Insects of North America* (4th ed.). Kendall/Hunt Publ. Co., Dubuque, IA 1158 pp.

NOAA Technical Report. *New Polychaeta from Beaufort, with a key to all species recorded from North Carolina*. NMFS CIRC. 375: 1-140.

Pettibone, M.H. 1963. *Marine Polychaete Worms of the New England Region, Aphroditidae through Trochochaetidae*. U.S. Nat. Mus., Bull.

227:1-356.

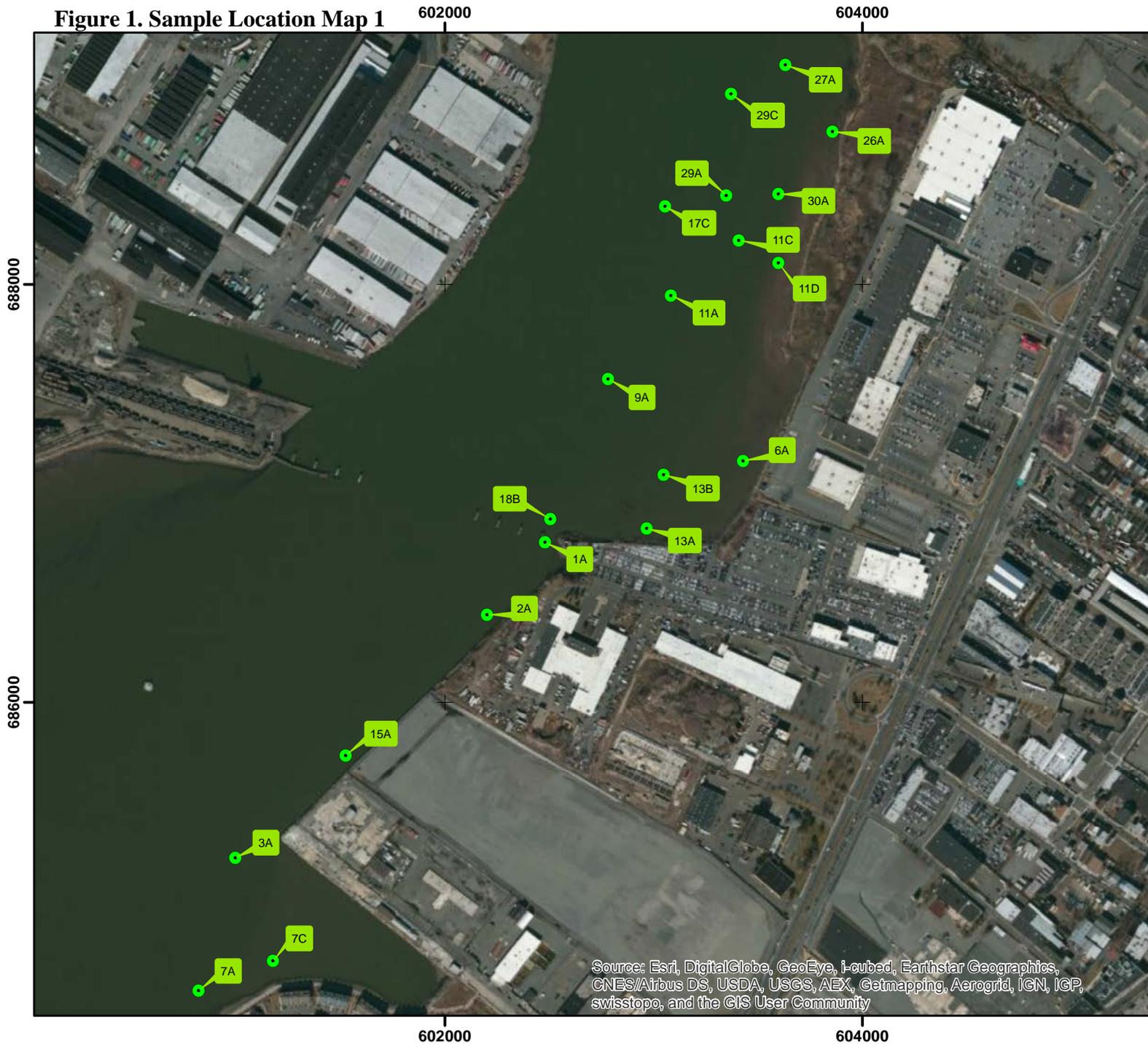
Rogers, D. C. and M. Hill, 2008. Key to the Freshwater Malacostraca (Crustacea) of the Mid-Atlantic Region. EPA-230-R-08-017. US Environmental Protection Agency, Office of Environmental Information, Environmental Analysis Division, Washington, DC.

Williams, A.B. 1984. Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution Press. Washington D.C. 550 pp.

IV. RESULTS

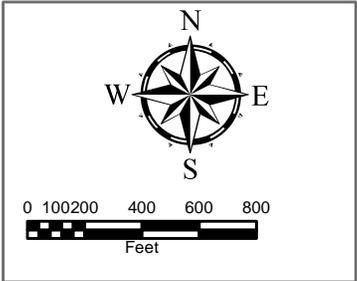
Results of the benthic taxonomic enumeration for the 23 samples are presented in Tables 2 and 3. Table 2 provides density, richness and dominant taxa data for each sample. Table 3 provides benthic analysis data for each individual species found in each sample.

Figure 1. Sample Location Map 1



Ramboll Environ
Lower Hackensack River
Sample Location Map 1

ASI Project: 38-005
Coordinate System:
State Plane NAD 83
New Jersey US Survey Foot



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



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Figure 2. Sample Location Map 2: Reference Samples

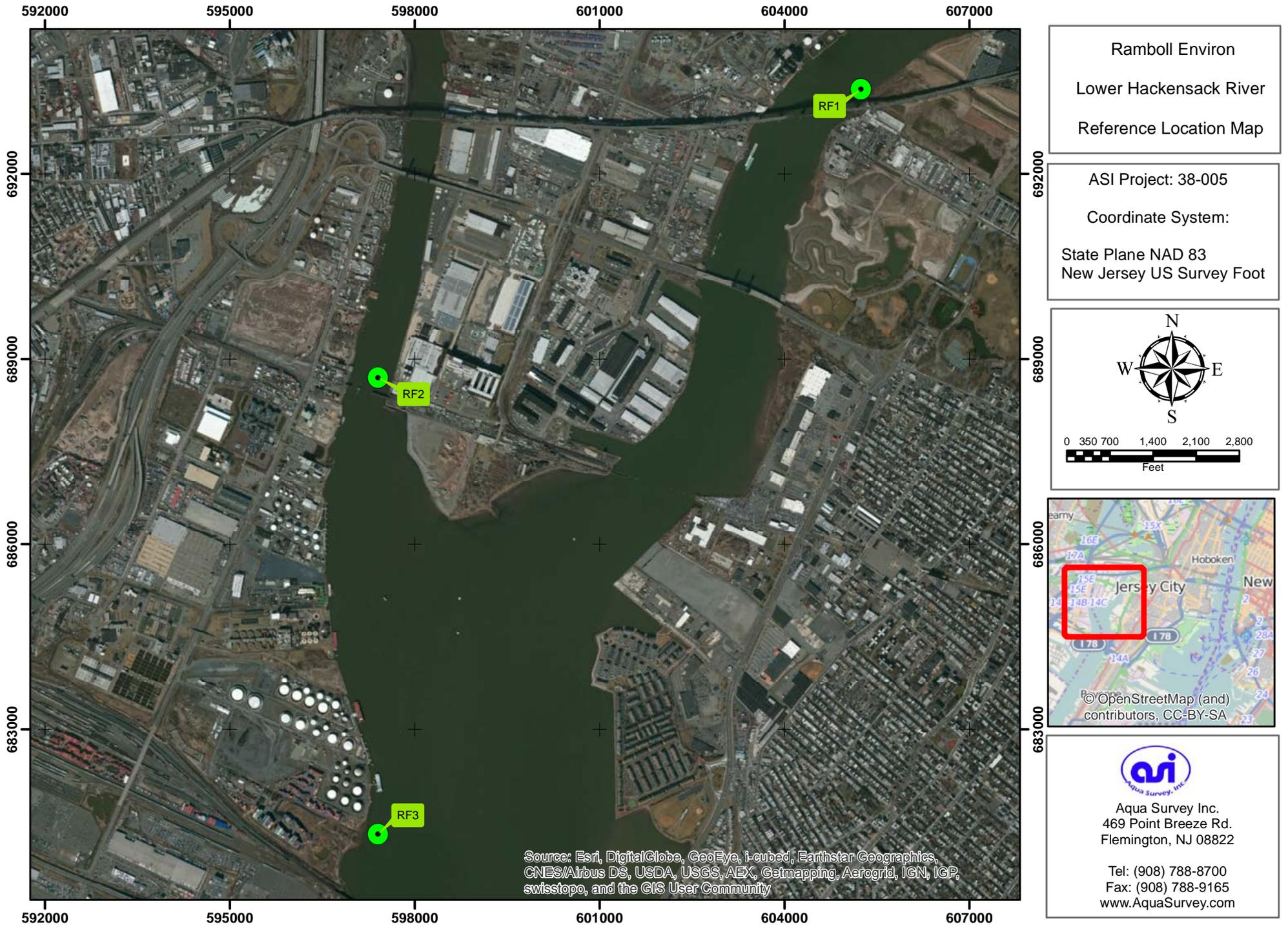


Table 2. Summary of Benthic Analysis, Lower Hackensack River, 2018

Location	SAMPLE	SAMPLE COUNT	DENSITY (No./m ²)	TAXONOMIC RICHNESS	DOMINANT TAXA	% DOMINANT TAXA	H'	J'
1A	20180457	179	7783	12	<i>Streblospio benedicti</i>	55.3	1.43	0.58
2A	20180458	191	8304	9	<i>Streblospio benedicti</i>	68.6	1.00	0.46
3A	20180459	28	1217	6	<i>Leitoscoloplos fragilis</i>	82.1	0.76	0.42
6A	20180466	1	43	1	<i>Edotea triloba</i>	100	0.00	N/A
7A	20180460	55	2391	20	<i>Streblospio benedicti</i>	38.2	2.37	0.79
7C	20180461	19	826	8	<i>Leitoscoloplos fragilis</i>	57.9	1.48	0.71
9A	20180462	17	739	6	<i>Leitoscoloplos fragilis</i>	64.7	1.20	0.67
11A	20180475	20	870	3	<i>Leitoscoloplos fragilis</i>	85.0	0.52	0.47
11C	20180469	6	261	3	<i>Amphibalanus improvisus</i>	66.7	0.87	0.79
11D	20180465	1	43	1	<i>Cyathura polita</i>	100	0.00	N/A
13A	20180467	12	522	4	<i>Streblospio benedicti</i>	33.3	1.36	0.98
13B	20180468	94	4087	7	<i>Streblospio benedicti</i>	88.3	0.55	0.28
15A	20180473	1	43	1	<i>Molgulidae</i>	100	0.00	N/A
17C	20180476	89	3870	16	<i>Streblospio benedicti</i>	59.6	1.62	0.59
18B	20180474	10	435	3	<i>Molgulidae</i>	70.0	0.80	0.73
26A	20180463	2	87	1	<i>Oligochaeta</i>	100	0.00	0.00
27A	20180471	169	7348	14	<i>Streblospio benedicti</i>	59.2	1.54	0.58
29A	20180470	0	0	N/A	No organisms found	N/A	N/A	N/A
29C	20180472	42	1826	12	<i>Streblospio benedicti</i>	31.0	1.93	0.78
30A	20180464	65	2826	10	<i>Streblospio benedicti</i>	35.4	1.76	0.76
REF 1	20180479	2	87	2	<i>Kirsteueriella biocellatus</i>	50.0	0.69	1.00
REF 2	20180477	1	43	1	<i>Streblospio benedicti</i>	100	0.00	N/A
REF 3	20180478	4	174	3	<i>Streblospio benedicti</i>	50.0	1.04	0.95

H' = Shannon-Weaver H' (log e)

J' = Pielou's J'

Table 3. Benthic Analysis, Lower Hackensack River, 2018

SAMPLE	SPECIES NAME	SAMPLE COUNT	DENSITY (No./m ²)	RELATIVE ABUNDANCE
20180457	<i>Oligochaeta</i>	1	43	0.6
20180457	<i>Leucon americanus</i>	1	43	0.6
20180457	<i>Crangon septemspinosa</i>	2	87	1.1
20180457	<i>Heteromastus filiformis</i>	1	43	0.6
20180457	<i>Glycinde multidentis</i>	1	43	0.6
20180457	<i>Alitta succinea</i>	7	304	3.9
20180457	<i>Hypereteone foliosa</i>	1	43	0.6
20180457	<i>Hypereteone heteropoda</i>	19	826	10.6
20180457	<i>Tharyx sp. A sensu MWRA 2007</i>	3	130	1.7
20180457	<i>Marenzelleria viridis</i>	10	435	5.6
20180457	<i>Streblospio benedicti</i>	99	4304	55.3
20180457	<i>Leitoscoloplos fragilis</i>	34	1478	19.0
20180458	<i>Tritia obsoleta</i>	1	43	0.5
20180458	<i>Mediomastus sp.</i>	8	348	4.2
20180458	<i>Glycinde multidentis</i>	2	87	1.0
20180458	<i>Hypereteone heteropoda</i>	3	130	1.6
20180458	<i>Tharyx sp. A sensu MWRA 2007</i>	2	87	1.0
20180458	<i>Marenzelleria viridis</i>	2	87	1.0
20180458	<i>Polydora cornuta</i>	2	87	1.0
20180458	<i>Streblospio benedicti</i>	131	5696	68.6
20180458	<i>Leitoscoloplos fragilis</i>	40	1739	20.9
20180459	<i>Mediomastus sp.</i>	1	43	3.6
20180459	<i>Glycera americana</i>	1	43	3.6
20180459	<i>Glycinde multidentis</i>	1	43	3.6
20180459	<i>Hypereteone foliosa</i>	1	43	3.6
20180459	<i>Ampharete oculata</i>	1	43	3.6
20180459	<i>Leitoscoloplos fragilis</i>	23	1000	82.1

Table 3. Benthic Analysis, Lower Hackensack River, 2018, continued

SAMPLE	SPECIES NAME	SAMPLE COUNT	DENSITY (No./m ²)	RELATIVE ABUNDANCE
20180460	<i>Actiniaria</i>	3	130	5.5
20180460	<i>Molgula manhattensis</i>	1	43	1.8
20180460	<i>Bivalvia</i>	1	43	1.8
20180460	<i>Amphiporus sp.</i>	1	43	1.8
20180460	<i>Kirsteueriella biocellatus</i>	1	43	1.8
20180460	<i>Ampelisca abdita</i>	1	43	1.8
20180460	<i>Grandierella bonnieroides</i>	4	174	7.3
20180460	<i>Monocorophium insidiosum</i>	3	130	5.5
20180460	<i>Melita nitida</i>	1	43	1.8
20180460	<i>Paracaprella tenuis</i>	1	43	1.8
20180460	<i>Mediomastus sp.</i>	1	43	1.8
20180460	<i>Glycera americana</i>	1	43	1.8
20180460	<i>Alitta succinea</i>	3	130	5.5
20180460	<i>Salvatoria clavata</i>	2	87	3.6
20180460	<i>Cirratulidae</i>	1	43	1.8
20180460	<i>Sabellaria vulgaris</i>	1	43	1.8
20180460	<i>Potamilla neglecta</i>	1	43	1.8
20180460	<i>Polydora cornuta</i>	5	217	9.1
20180460	<i>Streblospio benedicti</i>	21	913	38.2
20180460	<i>Leitoscoloplos fragilis</i>	2	87	3.6
20180461	<i>Cephalaspidea</i>	1	43	5.3
20180461	<i>Ameroculodes edwardsi</i>	1	43	5.3
20180461	<i>Glycinde multidentis</i>	1	43	5.3
20180461	<i>Laeonereis culveri</i>	2	87	10.5
20180461	<i>Hypereteone heteropoda</i>	1	43	5.3
20180461	<i>Marenzelleria viridis</i>	1	43	5.3
20180461	<i>Streblospio benedicti</i>	1	43	5.3
20180461	<i>Leitoscoloplos fragilis</i>	11	478	57.9

Table 3. Benthic Analysis, Lower Hackensack River, 2018, continued

SAMPLE	SPECIES NAME	SAMPLE COUNT	DENSITY (No./m ²)	RELATIVE ABUNDANCE
20180462	<i>Molgula manhattensis</i>	1	43	5.9
20180462	<i>Mya arenaria</i>	1	43	5.9
20180462	<i>Gammarus mucronatus</i>	1	43	5.9
20180462	<i>Neomysis americana</i>	2	87	11.8
20180462	<i>Pectinaria gouldii</i>	1	43	5.9
20180462	<i>Leitoscoloplos fragilis</i>	11	478	64.7
20180463	<i>Oligochaeta</i>	2	87	100.0
20180464	<i>Oligochaeta</i>	1	43	1.5
20180464	<i>Elasmopus levis</i>	1	43	1.5
20180464	<i>Cyathura polita</i>	1	43	1.5
20180464	<i>Edotea triloba</i>	1	43	1.5
20180464	<i>Heteromastus filiformis</i>	3	130	4.6
20180464	<i>Alitta succinea</i>	12	522	18.5
20180464	<i>Hypereteone heteropoda</i>	15	652	23.1
20180464	<i>Hobsonia florida</i>	3	130	4.6
20180464	<i>Streblospio benedicti</i>	23	1000	35.4
20180464	<i>Leitoscoloplos fragilis</i>	5	217	7.7
20180465	<i>Cyathura polita</i>	1	43	100.0
20180466	<i>Edotea triloba</i>	1	43	100.0
20180467	<i>Laeonereis culveri</i>	3	130	25.0
20180467	<i>Hypereteone heteropoda</i>	2	87	16.7
20180467	<i>Hobsonia florida</i>	3	130	25.0
20180467	<i>Streblospio benedicti</i>	4	174	33.3
20180468	<i>Grandierella bonnieroides</i>	3	130	3.2
20180468	<i>Gammarus mucronatus</i>	1	43	1.1
20180468	<i>Edotea triloba</i>	1	43	1.1
20180468	<i>Alitta succinea</i>	4	174	4.3
20180468	<i>Hypereteone foliosa</i>	1	43	1.1
20180468	<i>Ampharete oculata</i>	1	43	1.1
20180468	<i>Streblospio benedicti</i>	83	3609	88.3
20180469	<i>Grandierella bonnieroides</i>	1	43	16.7
20180469	<i>Leucon americanus</i>	1	43	16.7
20180469	<i>Amphibalanus improvisus</i>	4	174	66.7

Table 3. Benthic Analysis, Lower Hackensack River, 2018, continued

SAMPLE	SPECIES NAME	SAMPLE COUNT	DENSITY (No./m ²)	RELATIVE ABUNDANCE
20180470	No organisms found	0	N/A	N/A
20180471	<i>Enopla</i>	1	43	0.5
20180471	<i>Kirsteueriella biocellatus</i>	1	43	0.5
20180471	<i>Grandidierella bonnieroides</i>	4	174	2.1
20180471	<i>Heteromastus filiformis</i>	3	130	1.6
20180471	<i>Mediomastus sp.</i>	1	43	0.5
20180471	<i>Alitta succinea</i>	5	217	2.6
20180471	<i>Hypereteone foliosa</i>	1	43	0.5
20180471	<i>Hypereteone heteropoda</i>	16	696	8.4
20180471	<i>Hobsonia florida</i>	1	43	0.5
20180471	<i>Cirratulidae</i>	9	391	4.7
20180471	<i>Marenzelleria viridis</i>	5	217	2.6
20180471	<i>Polydora cornuta</i>	4	174	2.1
20180471	<i>Streblospio benedicti</i>	100	4348	52.6
20180471	<i>Leitoscoloplos fragilis</i>	18	783	9.5
20180472	<i>Nemertea</i>	1	43	0.5
20180472	<i>Grandidierella bonnieroides</i>	5	217	2.4
20180472	<i>Mediomastus sp.</i>	3	130	1.4
20180472	<i>Glycera americana</i>	1	43	0.5
20180472	<i>Alitta succinea</i>	1	43	0.5
20180472	<i>Hypereteone heteropoda</i>	2	87	1.0
20180472	<i>Hobsonia florida</i>	1	43	0.5
20180472	<i>Cirratulidae</i>	1	43	0.5
20180472	<i>Sabellaria vulgaris</i>	1	43	0.5
20180472	<i>Polydora cornuta</i>	1	43	0.5
20180472	<i>Streblospio benedicti</i>	13	565	6.3
20180472	<i>Leitoscoloplos fragilis</i>	12	522	5.8

Table 3. Benthic Analysis, Lower Hackensack River, 2018, continued

SAMPLE	SPECIES NAME	SAMPLE COUNT	DENSITY (No./m ²)	RELATIVE ABUNDANCE
20180473	<i>Molgulidae</i>	1	43	33.3
20180474	<i>Molgulidae</i>	7	304	233.3
20180474	<i>Grandidierella bonnieroides</i>	1	43	33.3
20180474	<i>Sabellaria vulgaris</i>	2	87	66.7
20180475	<i>Glycinde multidentis</i>	2	87	33.3
20180475	<i>Streblospio benedicti</i>	1	43	16.7
20180475	<i>Leitoscoloplos fragilis</i>	17	739	283.3
20180476	<i>Diadumene lineata</i>	1	43	2.2
20180476	<i>Oligochaeta</i>	1	43	2.2
20180476	<i>Kirsteueriella biocellatus</i>	1	43	2.2
20180476	<i>Ampelisca abdita</i>	1	43	2.2
20180476	<i>Grandidierella bonnieroides</i>	2	87	4.3
20180476	<i>Apocorophium simile</i>	1	43	2.2
20180476	<i>Pleustidae</i>	1	43	2.2
20180476	<i>Mediomastus sp.</i>	7	304	15.2
20180476	<i>Glycinde multidentis</i>	1	43	2.2
20180476	<i>Hypereteone heteropoda</i>	1	43	2.2
20180476	<i>Ampharete oculata</i>	1	43	2.2
20180476	<i>Tharyx sp. A sensu MWRA 2007</i>	1	43	2.2
20180476	<i>Sabellaria vulgaris</i>	6	261	13.0
20180476	<i>Polydora cornuta</i>	5	217	10.9
20180476	<i>Streblospio benedicti</i>	53	2304	115.2
20180476	<i>Leitoscoloplos fragilis</i>	6	261	13.0
20180477	<i>Streblospio benedicti</i>	1	43	50.0
20180478	<i>Neomysis americana</i>	1	43	33.3
20180478	<i>Mediomastus sp.</i>	1	43	33.3
20180478	<i>Streblospio benedicti</i>	2	87	66.7
20180479	<i>Kirsteueriella biocellatus</i>	1	43	8.3
20180479	<i>Leitoscoloplos fragilis</i>	1	43	8.3

Appendix A
Chains of Custody

10 + 6



CHAIN OF CUSTODY RECORD

AQUA SURVEY, INC.

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(908) 788-9165 FAX

www.aquasurvey.com

SAMPLE NUMBER	SAMPLING LOCATION AND DESCRIPTION (# of org.)	DATE	TIME	SAMPLE TYPE			NO. CNT.	ANALYSES REQUIRED *	SEE WORK ORD.
				SED	WTR	COM			
20180457	Loc # 1A (~170)	7/24/18	1013				1	1	8/7/18
20180458	Loc # 2A (~207)	7/24/18	1100				1	1	8/7/18
20180459	Loc # 3A (~40)	7/26/18	1440				1	1	8/7/18
20180460	Loc # 7A (~74)	7/26/18	1527				1	1	8/7/18
20180461	Loc # 7C (~20)	7/26/18	1613				1	1	8/7/18
20180462	Loc # 9A (~23)	7/26/18	1701				1	1	8/7/18
20180463	Loc # 26A (~2)	7/27/18	0844				1	1	8/7/18
20180464	Loc # 30A (~81)	7/27/18	0915				1	1	8/7/18
20180465	Loc # 11D (~1)	7/27/18	0931				1	1	8/7/18
20180466	Loc # 6A (~2)	7/27/18	0955				1	1	8/7/18
20180467	Loc # 13A (~14)	7/27/18	1018				1	1	8/7/18
EXACT SAMPLING LOCATION: Hackensack River - Jersey City, NJ									
SAMPLE COLLECTED BY: ASI		DATE	TIME	SAMPLE RECEIVED BY:		DATE	TIME		
		8/7/18	1415	Tom Dike					
SAMPLE RELINQUISHED BY:				SAMPLE RECEIVED BY:					
SAMPLE RELINQUISHED BY:				SAMPLE RECEIVED BY:					
SAMPLE RELINQUISHED BY:				SAMPLE RECEIVED BY:					
SPECIAL INSTRUCTIONS:									

* Attach Separate Sheet If Necessary

102412

2012

469 POINT BREEZE ROAD
FLEMINGTON, NJ 08822
(908) 788-8700 OFFICE
(908) 788-9165 FAX

CHAIN OF CUSTODY RECORD
AQUA SURVEY, INC.



www.aquasurvey.com

CLIENT: Aqua Survey, Inc. METHOD OF SHIPMENT: UPS
 PROJECT/SITE NAME: Jersey City SA-7 SITE in NJ TO: ECOA ANALYSTS - MASSCO, ID
 ASI JOB NUMBER: 38-005 FROM: Aqua survey - Flemington, NJ

SAMPLING & ANALYSIS AUTHORIZED BY: ASI DATE: 8/7/18 SEE WORK ORD.

SAMPLE NUMBER	SAMPLING LOCATION AND DESCRIPTION (w/ # of org.)	DATE	TIME	SAMPLE TYPE			NO. CNT.	ANALYSES REQUIRED *	SEE WORK ORD.
				SED	WTR	COM GRB			
20180468	LOC #13B (~106)	7/27/18	1050			X	1	Taxonomy	
20180469	LOC #11C (~6)	7/27/18	1120			X	1		
20180471	LOC #27A (~181)	7/27/18	1302			X	1		
20180472	LOC #29C (~64)	7/27/18	1325			X	1		
20180473	LOC #15A (~2)	7/30/18	0936			X	1		
20180474	LOC #18B (~10)	7/30/18	1002			X	1		
20180475	LOC #11A (~29)	7/30/18	1024			X	1		
20180476	LOC #17C (~95)	7/30/18	1042			X	1		
20180477	LOC # REF 2 (~5)	7/30/18	1128			X	1		
20180478	LOC # REF 3 (~7)	7/30/18	1142			X	1		
20180479	LOC # REF 1 (~5)	7/30/18	1159			X	1		

EXACT SAMPLING LOCATION: Hackensack River - Jersey City, NJ
 SAMPLE COLLECTED BY: ASI
 SAMPLE RELINQUISHED BY: Tom Doh DATE: 8/7/18 TIME: 1415
 SAMPLE RELINQUISHED BY: _____ DATE: _____ TIME: _____
 SAMPLE RELINQUISHED BY: _____ DATE: _____ TIME: _____

SPECIAL INSTRUCTIONS:

* Attach Separate Sheet If Necessary 102412

CHAIN OF CUSTODY RECORD

469 POINT BREEZE ROAD
FLEMINGTON, NJ 08822
(908) 788-8700 OFFICE
(908) 788-9165 FAX

AQUA SURVEY, INC.



www.aquasurvey.com

CLIENT: RAMBOLL ENVIRON METHOD OF SHIPMENT: ASI TRUCK
 PROJECT/SITE NAME: SA-7 SITE, JERSEY CITY, NJ
 TO: ASI - FLEMINGTON, NJ
 FROM: KEARNY, NJ

ASI JOB NUMBER: 38-005 DATE: 7-30-18

SAMPLING & ANALYSIS AUTHORIZED BY:

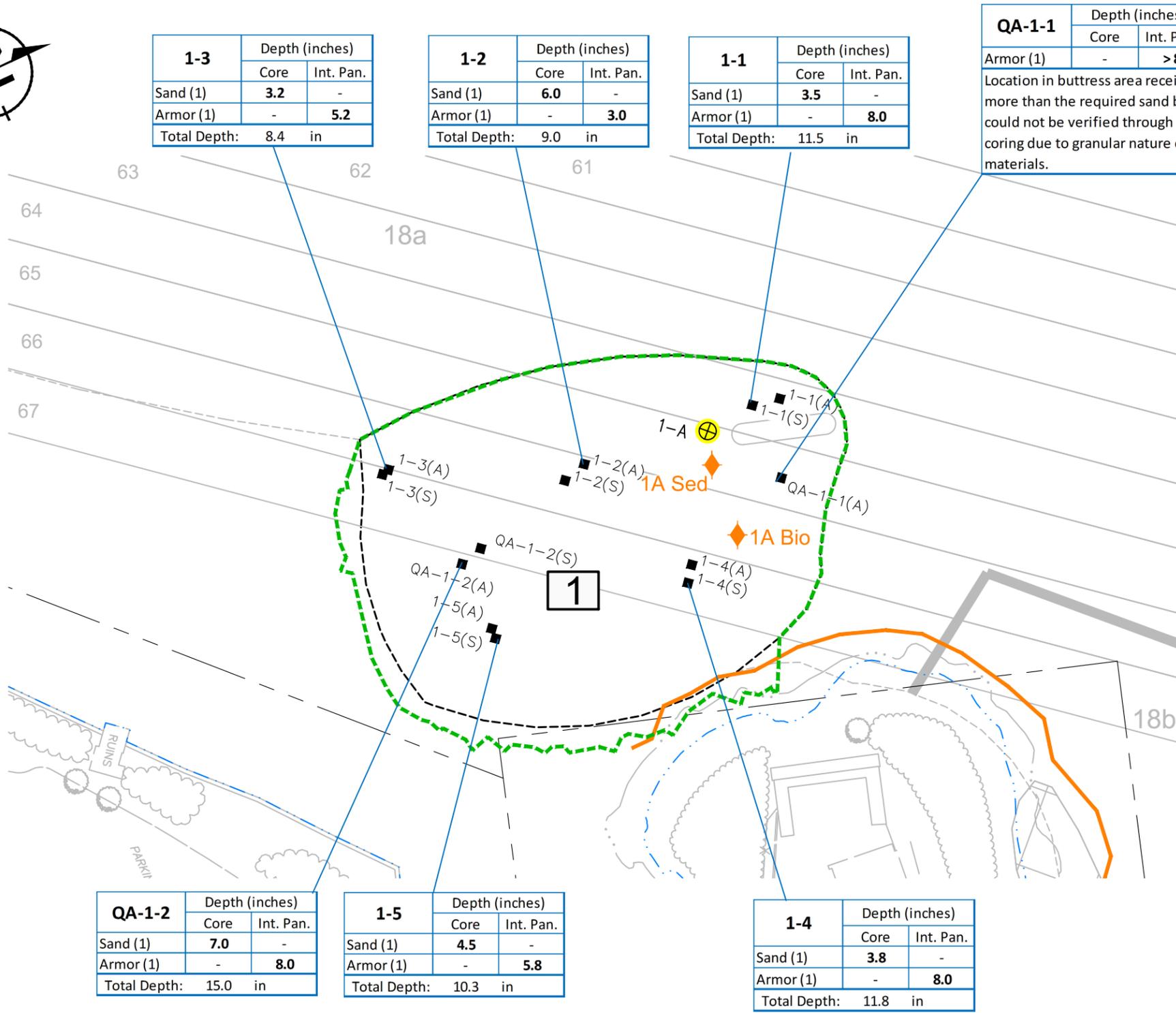
SAMPLE NUMBER	SAMPLING LOCATION AND DESCRIPTION	DATE	TIME	SAMPLE TYPE			NO. ANALYSES REQUIRED *	SEE WORK ORD.
				SED	WTR	COM GRB		
20180473	15A	7-30-18	0936			✓	1	
20180474	18B	7-30-18	1002			✓	1	
20180475	11A	7-30-18	1024			✓	1	
20180476	17C	7-30-18	1042			✓	1	
20180477	RF2	7-30-18	1128			✓	1	
20180478	RF3	7-30-18	1142			✓	1	
20180479	RF1	7-30-18	1159			✓	1	

EXACT SAMPLING LOCATION: Hackensack River - Kearny Point SA-7
 SAMPLE COLLECTED BY: ASI - MATTHEW SHARPEL
MICHAEL BOWMAN
 DATE: 7-30-18 TIME: 1500
 SAMPLE RELINQUISHED BY: MICHAEL BOWMAN
 SAMPLE RECEIVED BY: 7-30-18 DATE: 7/30/18 TIME: 1600
 SAMPLE RELINQUISHED BY: SAMPLE RECEIVED BY: DATE: DATE: TIME: TIME

SPECIAL INSTRUCTIONS:

* Attach Separate Sheet If Necessary

APPENDIX F
QC VERIFICATION DATA FIGURES



1-3	Depth (inches)	
	Core	Int. Pan.
Sand (1)	3.2	-
Armor (1)	-	5.2
Total Depth: 8.4 in		

1-2	Depth (inches)	
	Core	Int. Pan.
Sand (1)	6.0	-
Armor (1)	-	3.0
Total Depth: 9.0 in		

1-1	Depth (inches)	
	Core	Int. Pan.
Sand (1)	3.5	-
Armor (1)	-	8.0
Total Depth: 11.5 in		

QA-1-1	Depth (inches)	
	Core	Int. Pan.
Armor (1)	-	> 8
Location in buttress area received more than the required sand but could not be verified through coring due to granular nature of materials.		

QA-1-2	Depth (inches)	
	Core	Int. Pan.
Sand (1)	7.0	-
Armor (1)	-	8.0
Total Depth: 15.0 in		

1-5	Depth (inches)	
	Core	Int. Pan.
Sand (1)	4.5	-
Armor (1)	-	5.8
Total Depth: 10.3 in		

1-4	Depth (inches)	
	Core	Int. Pan.
Sand (1)	3.8	-
Armor (1)	-	8.0
Total Depth: 11.8 in		

Cap Area	1
Target C.O. Thickness (in)	6
Armor Size (in)	0.75

LEGEND

- CAPPING AREA LIMIT REQUIRED BY CONSENT ORDER
- AS-BUILT CAPPING AREA LIMIT
- 67 [] CAP LANE AND IDENTIFICATION
- 1-1(S) AS-BUILT CAP THICKNESS VERIFICATION LOCATION AND ID (SAND)
- 1-1(A) AS-BUILT CAP THICKNESS VERIFICATION LOCATION AND ID (ARMOR)
- MEAN HIGH WATER LINE (3.52 FT NGVD'29)
- EXISTING SHORELINE PROTECTION LIMITS (AS SURVEYED BY SEVENSON ENVIRONMENTAL SERVICES, INC. ON 11/30/2012)
- [] BRIDGE ABUTMENT
- ◆ BIOLOGICAL AND SURFACE SEDIMENT SAMPLE LOCATION

NOTES:

1. THE NUMBER NEXT TO THE MATERIAL TYPE IN THE DATABOXES REPRESENTS THE NUMBER OF MATERIAL PLACEMENT PASSES.
2. THE TOTAL THICKNESS MEASUREMENT IS DEFINED AS THE SUM OF THE BEST MEASUREMENTS FOR EACH MATERIAL TYPE (BOLD). MEASUREMENTS ARE TAKEN, IN ORDER OF PREFERENCE: 1) CORES, 2) INTERMEDIATE PANS, 3) FULL DEPTH PANS, AND 4) VIBRA-CORES. SHADED CELLS INDICATE DUPLICATE MEASUREMENTS; THE AVERAGE OF THESE VALUES ARE USED TO COMPUTE THE TOTAL THICKNESS. MULTIPLE VALUES FOR A GIVEN MATERIAL LAYER SHOWN ON SEPARATE ROWS INDICATE SEQUENTIAL MEASUREMENTS; EACH VALUE IS USED TO COMPUTE THE TOTAL THICKNESS. NOTE, IN CERTAIN CASES A CORE OR VIBRA-CORE MEASUREMENT CAPTURED MULTIPLE CAP LAYERS. IN THESE CASES, THE CORE MEASUREMENT IS USED TO REPRESENT THE COMBINED THICKNESS OF THESE LAYERS.
3. ACTUAL LANDWARD LIMITS OF CONSTRUCTED CAP AREAS ALONG THE SHORELINE AND BULKHEAD WERE VERIFIED IN THE FIELD AS SPECIFIED ON FINAL DESIGN DRAWINGS C-6 AND C-13; CAP LIMITS WERE ADJUSTED IN THE FIELD AS FOLLOWS:
 1. AT MEAN HIGHER HIGH WATER LINE (EL. 3.84-FT);
 2. AT THE EXISTING BULKHEAD; OR
 3. AT THE LIMIT OF WETLANDS



MBLEI 8/23/18 [DATA_AREA_1]
F:\69000484_SAT7\MP DRAFT



DRAFTED BY: BJK DATE: 08/23/2018

CAP AREA 1 DATA
HONEYWELL
STUDY AREA 7
JERSEY CITY, NEW JERSEY

FIGURE F.1

169000484

