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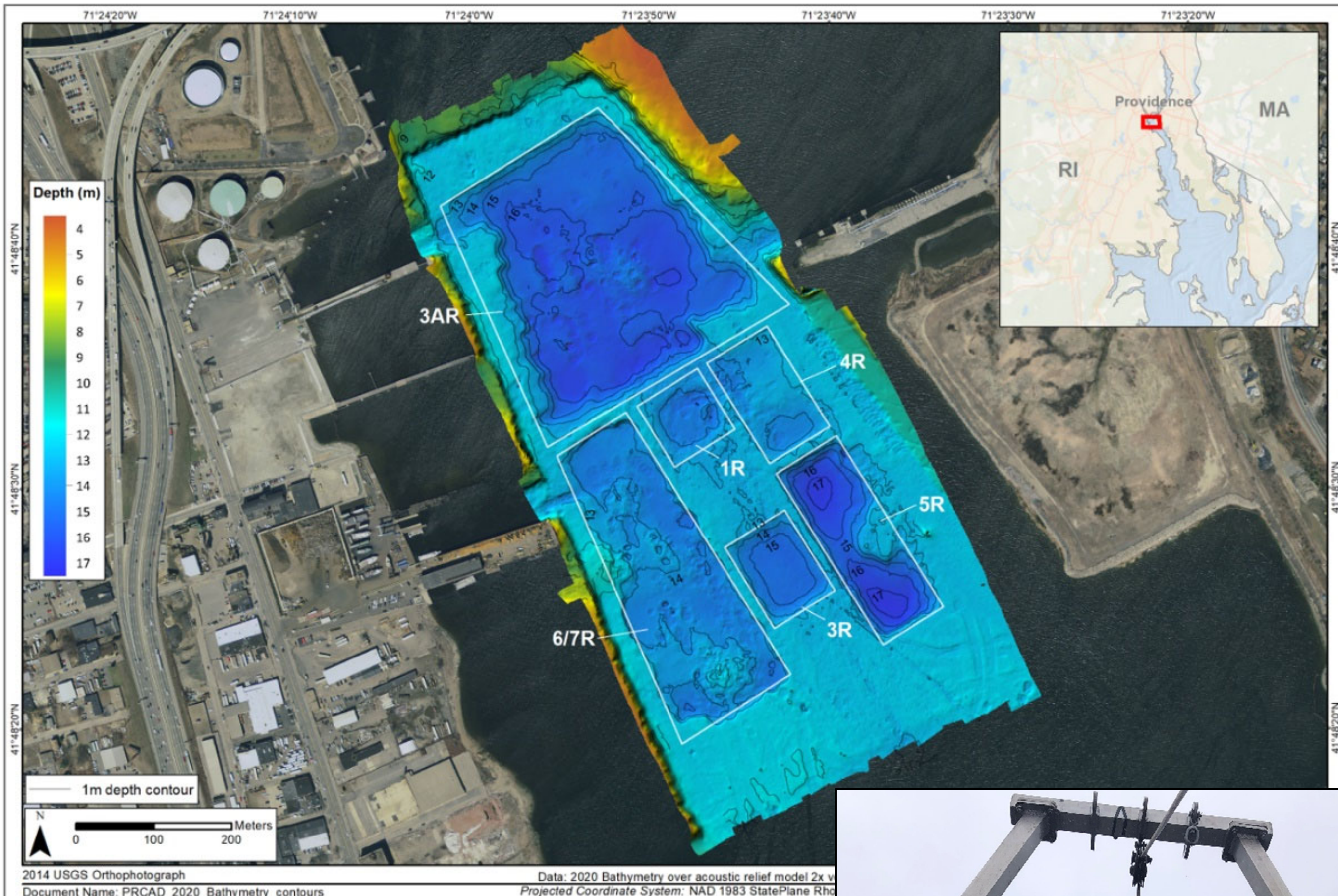
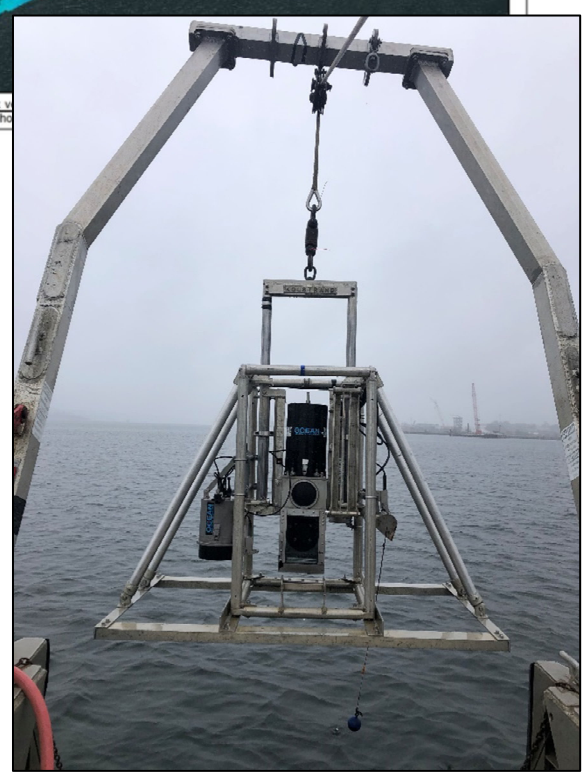
Monitoring Survey at the Providence River Confined Aquatic Disposal Cells September/October 2020

Disposal Area Monitoring System – DAMOS





US Army Corps of Engineers®
New England District

D A M O S
DISPOSAL AREA MONITORING SYSTEM

Contribution 211
October 2021

REPORT DOCUMENTATION PAGE

form approved
OMB No. 0704-0188

1. AGENCY USE ONLY (LEAVE BLANK)

2. REPORT DATE
October 2021

3. REPORT TYPE AND DATES COVERED
Contribution, September/October 2020

4. TITLE AND SUBTITLE
Monitoring Survey at the Providence River Confined Aquatic Disposal Cells, September/October 2020

5. FUNDING NUMBERS
Contract No. W912WJ-19-D-0010

6. AUTHOR(S)
USACE

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers-New England District
696 Virginia Rd
Concord, MA 01742-2751

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Contribution No. 211

11. SUPPLEMENTARY NOTES
Available from DAMOS Program Manager, Environmental Branch
USACE-NAE, 696 Virginia Rd, Concord, MA 01742-2751

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT

The Providence River Confined Aquatic Disposal Cells (PRCAD) were constructed between 2003 and 2004 to isolate dredged material not suitable for open ocean disposal generated from the Providence River and Harbor Maintenance Dredging Project (PRHMDP) and other private dredging projects. The last Disposal Area Monitoring System (DAMOS) survey of the cells was conducted in 2015. Since then, 12 private dredging projects placed dredged material into the PRCAD cells, under State of Rhode Island management. The 2020 survey characterized the topography and surficial features of all six CAD cells and assessed the benthic recolonization status at five CAD cells (excluding Cell 3R) and the associated reference areas.

The 2020 PRCAD survey included collection of high-resolution acoustic data and Sediment Profile and Plan View imaging (SPI/PV). The acoustic survey collected bathymetric, backscatter, and side-scan sonar measurements over the entire PRCAD. SPI/PV imagery was collected at a total of 30 stations, which included five stations at each of Cells 4R, 5R, and 6/7R, six stations at Cell 3AR, one station at Cell 1R, and four stations at each of the two reference areas (REF-North and REF-South).

The acoustic data showed consistent bathymetric distinctions between the PRCAD cells, the surrounding navigation channel, and edges of the shoals flanking the channel. The Providence River in the survey area was approximately 12.5 m deep with shallow plateaus flanking the navigation channel. The six PRCAD cells were readily distinguishable from the navigation channel as topographic depressions that were generally 0.5 to 4.5 m below the surrounding channel. CAD Cells 3AR, 5R, and 3R were the deepest of the cells while Cells 6/7R, 1R, and 4R were shallower and approached the depth of the surrounding channel. Since 2015, the elevation of the cells increased primarily in Cells 3AR and 6/7R. In Cell 1R, Cell 3AR, and adjacent to three piers, there was relatively stronger backscatter returns and topographic roughness and heterogeneity in the side-scan sonar data, which suggested vessel activity may have resulted in scouring of the surficial sediments in these areas. The 2020 bathymetric measurements were used to calculate the remaining capacity of all six CAD cells. Remaining cell capacity ranged from less than 15,000 yd^3 (Cell 1R) to 290,000 yd^3 (Cell 3AR) relative to a 12.8 m (42 ft) depth datum.

The biological attributes observed in the 2020 SPI and PV images showed that the benthic communities at both PRCAD and the reference areas were generally stressed or disturbed in this urbanized portion of the Providence River estuary. Across the PRCAD cells and both reference areas, high sediment oxygen demand was inferred by dark sediments, very shallow apparent redox potential discontinuity (aRPD) depths, frequent occurrences of sulfide-oxidizing bacteria (*Beggiatoa*) on the sediment surface, and limited evidence of bioturbation (voids and burrows). The surveyed area is located within a highly urban environment with high vessel traffic and urban runoff, which contribute to the overall stressed benthic environment. The biological communities were generally similar between the PRCAD cells and the reference areas. However, the communities at Cell 6/7R and Cell 5R were less advanced, likely due to physical disturbance from recent disposal activity and vessel-induced sediment scour (Cell 6/7R) and generally deep topography, which may result in reduced water circulation and less oxygen delivery to the sediments (Cell 5R).

The results of the 2020 survey led to the following recommendations:

R1: Future dredged material placement should be targeted to the southwest corner and the deeper pockets along the southern boundary of Cell 3AR and the two deep basins in the northern and southern areas of Cell 5R. Lesser volumes of dredged material may be placed in other PRCAD cell areas.
R2: Due to potential scouring from vessel activity, additional placement of unsuitable dredged material in Cell 1R and the northern portion of Cell 6/7R should be avoided.
R3: At this time, SPI and PV data suggest the biological community is recolonizing at PRCAD, with similar communities present compared with the reference areas. As a result, capping the cells does not appear to be necessary to provide suitable habitat conditions.
R4: More detailed documentation of dredged material placement including the origins, quantity, and disposal locations (i.e., cell) should be recorded.
R5: Future monitoring surveys should ensure that sampling at the REF-North area is conducted within the dredged navigation channel but not along the steep slope at the northern boundary of the channel.

14. SUBJECT TERMS DAMOS, dredged material, PRCAD, Providence River Confined Aquatic Disposal Cells, acoustic, multibeam, Sediment Profile Imaging, Plan View Imaging, SPI, PV, MBES

15. NUMBER OF TEXT PAGES:
50 plus Figures and Appendices

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

MONITORING SURVEY AT THE PROVIDENCE RIVER CONFINED AQUATIC DISPOSAL CELLS (PRCAD) SEPTEMBER/OCTOBER 2020

CONTRIBUTION #211

October 2021

Contract No. W912WJ-19-D-0010
Delivery Order W912WJ19F0126

Funded and Managed by:
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

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This report should be cited as:

USACE. 2021. Monitoring Survey at the Providence River Confined Aquatic Disposal Cells, September/October 2020. DAMOS Contribution No. 211. Prepared by INSPIRE Environmental. Prepared for the U.S. Army Corps of Engineers, New England District, Concord, MA, 50 pp. plus Figures and Appendices.

__Note on units of this report__: As a scientific data summary, information and data are presented in the metric system. However, given the prevalence of English units in the dredging industry of the United States, conversions to English units are provided for general information in Section 1.0. A table of common conversions can be found in Appendix A.

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LIST OF ACRONYMS

aRPD	Apparent redox potential discontinuity
ASCII	American Standard Code for Information Interchange
CAD	Confined aquatic disposal
CCOM/JHC	NOAA’s Center for Coastal and Ocean Mapping Joint Hydrographic Center
CI	Confidence interval
CLT	Central Limit Theorem
CTD	Conductivity-Temperature-Depth (sensor)
DAMOS	Disposal Area Monitoring System
DGPS	Differential Global Positioning System
GIS	Geographic information system
GPS	Global Positioning System
GRD	Gridded data
INSPIRE	INSPIRE Environmental
MBES	Multibeam echosounder
MLLW	Mean Lower Low Water
NAD83	North American Datum of 1983
NAE	USACE, New England Division
NEF	Nikon Electronic Format
NOAA	National Oceanic and Atmospheric Association
NOS	National Ocean Service
OPUS	NOAA’s Online Positioning User Service
PRCAD	Providence River Confined Aquatic Disposal Cells
PRHMDP	Providence River and Harbor Maintenance Dredging Project

LIST OF ACRONYMS (CONTINUED)

PSD	Photoshop Document
PV	Plan View
QAPP	Quality Assurance Project Plan
RTK	Real time kinematic GPS
R/V	Research vessel
SD	Standard deviation
SOP	Standard Operating Procedures
SPI	Sediment Profile Imaging
SSS	Side-scan sonar
TIF	Tagged image file
USACE	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY

The Providence River Confined Aquatic Disposal Cells (PRCAD) were constructed between 2003 and 2004 to isolate dredged material not suitable for open ocean disposal generated from the Providence River and Harbor Maintenance Dredging Project (PRHMDP) and other private dredging projects. The last Disposal Area Monitoring System (DAMOS) survey of the cells was conducted in 2015. Since then, 12 private dredging projects placed dredged material into the PRCAD cells, under State of Rhode Island management. The 2020 survey characterized the topography and surficial features of all six CAD cells and assessed the benthic recolonization status at five CAD cells (excluding Cell 3R) and the associated reference areas.

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The biological attributes observed in the 2020 SPI and PV images showed that the benthic communities at both PRCAD and the reference areas were generally stressed or disturbed in this urbanized portion of the Providence River estuary. Across the PRCAD cells and both reference areas, high sediment oxygen demand was inferred by dark sediments, very shallow apparent redox potential discontinuity (aRPD) depths, frequent occurrences of

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R3: At this time, SPI and PV data suggest the biological community is recolonizing at PRCAD, with similar communities present compared with the reference areas. As a result, capping the cells does not appear to be necessary to provide suitable habitat conditions.

R4: More detailed documentation of dredged material placement including the origins, quantity, and disposal locations (i.e., cell) should be recorded.

R5: Future monitoring surveys should ensure that sampling at the REF-North area is conducted within the dredged navigation channel but not along the steep slope at the northern boundary of the channel.

1.0 INTRODUCTION

INSPIRE Environmental (INSPIRE) conducted acoustic and Sediment Profile and Plan View Imaging (SPI/PV) monitoring surveys at the Providence River Confined Aquatic Disposal Cells (PRCAD) in September and October 2020 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and PRCAD, including brief descriptions of previous dredged material disposal and site monitoring activities, is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Germano et al. 1994). For over 40 years, the DAMOS Program has collected and evaluated dredged material disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented (Fredette and French 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. The data collected and evaluated during these studies provide answers to strategic questions in determining next steps in the disposal site management process. DAMOS monitoring results guide the management of disposal activities at existing sites, support planning for use of future sites, and evaluate the long-term status of historical sites (Wolf et al. 2012).

Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential acoustic monitoring surveys (including bathymetric, acoustic backscatter, and side-scan sonar data collection) are performed to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal cells.

SPI and PV imaging surveys are performed in confirmatory studies to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites, and the conditions found after a defined period of disposal activity are compared with the long-term data set at specific sites to determine the next step in the disposal site management process (Germano et al. 1994).

Focused studies are periodically undertaken within the DAMOS Program to evaluate candidate sites, as baseline surveys at new sites, to evaluate inactive or historical disposal sites, and to contribute to the development of dredged material management and monitoring techniques. Focused DAMOS monitoring surveys may also feature additional types of data collection activities as deemed appropriate to achieve specific survey objectives, such as grab or core sampling of sediment for physical/chemical/biological analyses, sub-bottom profiling, or video image files.

The 2020 PRCAD survey was a confirmatory survey of the site designed to assess material placement and benthic recolonization status of PRCAD cells through acoustic and SPI/PV data collection and analysis.

1.2 Introduction to the Providence River Confined Aquatic Disposal Cells (PRCAD)

PRCAD is located in Providence Harbor, just south of Fox Point at the confluence of the Providence and Seekonk Rivers, in Providence, Rhode Island (Figure 1-1). The study area consists of six confined aquatic disposal (CAD) cells and is located 460 m (1,500 ft) downstream from the Fox Point Hurricane Barrier in the Providence River (Figure 1-1). The CAD cells were constructed between May 2003 and January 2004 beneath the Providence Harbor Federal Navigation Project and were designed to contain dredged material not suitable for open ocean disposal generated from the Providence River and Harbor Maintenance Dredging Project (PRHMDP; ENSR 2008) as per the findings of the PRHMDP Final Environmental Impact Statement (USACE 2001).

A total of six cells were constructed as rectangular pits (or slightly trapezoidal in the cases of Cells 3AR and 6/7R) with dimensions at the sediment–water interface ranging from approximately 91 m × 91 m (300 ft × 300 ft) for Cell 1R to 340 m × 347 m (1,111 ft × 1,118 ft) for Cell 3AR, with depths of 20.7 to 30.2 m (70 ft to 100 ft) Mean Lower Low Water (MLLW) (Figure 1-2). The side slopes of the CAD cells generally range from slightly steeper than 2:1 (horizontal:vertical) to slightly flatter than 3:1 (USACE 2012). The original plan was for the CAD cells to be capped at the conclusion of the PRHMDP in 2005, however a bathymetric survey showed that the surface of each of the six cells remained well-depressed below the surrounding floor of the Providence River, with substantial additional capacity remaining in Cells 5R and 6/7R (ENSR 2008).

The State of Rhode Island assumed management responsibility for the PRCAD cells with a plan to make full use of the remaining cell capacity for other, non-federal dredging projects (USACE 2012). With the PRCAD cells nearing capacity, the 2020 survey was designed to quantify the remaining volume and characterize physical and benthic habitat conditions within the cells and in the surrounding area.

1.3 Historical Dredged Material Disposal Activity

During the PRHMDP and construction of the PRCAD cells, sediments to be dredged were evaluated in accordance with the requirements of the Marine Protection, Research, and Sanctuaries Act (MPRSA) to determine suitability for unconfined open water disposal at the Rhode Island Sound Disposal Site (RISDS). The smaller CAD cells (1R, 3R, 4R, and 5R) were filled with unsuitable surficial material generated from the construction of the larger CAD cells (3AR and 6/7R). Cell 3AR, the largest CAD cell, was used primarily for disposal of unsuitable maintenance material from the Fox Point Reach (outside of the CAD cell footprint). The second largest cell, Cell 6/7R, was used for disposal of unsuitable material from state and private dredging projects (e.g., marinas and berths) in the vicinity of Providence Harbor since the PRHMDP (Table 1-1; ENSR 2008; USACE 2012; Carey et al. 2017). Underlying parent material generated from the construction of the CAD cells was found suitable for unconfined open water disposal and was placed at RISDS.

Between 2003 and 2005, approximately 1,382,800 m^3 (1,809,000 yd^3) of dredged material were placed in the PRCAD cells. Since 2005, the State of Rhode Island has been using available PRCAD capacity for placement of dredged material from non-federal dredging projects. Between 2005 and 2015, the State of Rhode Island managed the placement of approximately 244,000 m^3 (319,000 yd^3) of dredged material in the PRCAD cells. Between 2015 and 2020, the State of Rhode Island reported that several private projects utilized the PRCAD cells for dredged material disposal, but the dredged material volumes were not available for this report. In general, PRCAD was used for relatively high-volume disposal during a period shortly after construction and for relatively low-volume disposal during the following 15-year period.

1.4 Previous PRCAD Monitoring Events

During PRCAD construction and the high-volume disposal period immediately following construction (2003-2005) several bathymetric and plume/water quality monitoring surveys were conducted to characterize and assess site conditions (Table 1-2). Later, in 2009 and in 2015, bathymetric surveys were conducted to support physical characterization of the PRCAD cells over time. In 2009, a SPI/PV survey was also conducted to support characterization of the ecological health of the sediment in the PRCAD cells and surrounding area as part of a broader survey effort across CAD cells in New England.

The 2009 bathymetric survey was conducted at PRCAD as a baseline for longer term study and documented the elevation of each CAD cell below the harbor bottom at that time (USACE 2012). The October 2015 survey was designed to monitor long-term stability and consolidation and found that the PRCAD cells were distinguished from the surrounding channel as topographic depressions, generally 4 to 6 m (13 to 20 ft) below the channel depth of 12.5 m (41 ft). PRCAD Cells 3AR and 5R were the deepest, roughly 6 m (20 ft) below channel depth (Figure 1-2; Carey et al. 2017).

1.5 Recent Dredged Material Disposal Activity

Since the most recent DAMOS survey in October 2015, dredged material from private dredging projects, under management of the State of Rhode Island, was placed within the PRCAD cells to utilize the remaining capacity. A total of 12 separate private dredging projects placed dredged material at PRCAD between 2016 and 2020 (Table 1-3).

1.6 2020 Survey Objectives

The overall objective of the 2020 PRCAD survey were to:

- Characterize the topography and surficial features over all six CAD cells by conducting a high-resolution acoustic survey and calculate remaining cell capacity.
- Further define the physical characteristics of surficial sediments and assess benthic recolonization status over five CAD cells (excluding Cell 3R) and the associated reference areas by conducting a SPI/PV survey.

Table 1-1.

Estimated Volume of Historical Dredged Material Placed at PRCAD

Cell	Dredged Material Placement Time Frame	Origin of Dredged Material	Volume (m^3)	Volume (yd^3)	Reference
1R	2003-2005	Surficial material generated from the construction of the larger CAD cells	55,000	72,000	USACE 2012
3R	2003-2005	Surficial material generated from the construction of the larger CAD cells	55,000	72,000	USACE 2012
3AR	2003-2005	Unsuitable maintenance material from Fox Point Reach	873,000	1,142,000	USACE 2012
4R	2003-2005	Surficial material generated from the construction of the larger CAD cells	88,000	115,000	USACE 2012
5R	2003-2005	Surficial material generated from the construction of the larger CAD cells	113,000	148,000	USACE 2012
6/7R	2003-2005	Private projects	198,800	260,000	USACE 2012
	2005 - 2010	Private projects	117,000	153,000	USACE 2012
	2010-2015	State and private projects	127,000	166,000	Carey et al. 2017
	2015-2020	See Table 1-3 for a list of completed dredging projects			
All	**2003-2005**	**Total**	**1,382,800**	**1,809,000**	
All	**2005-2015**	**Total**	**244,000**	**319,000**	

Table 1-2.

Summary of Previous Investigations at PRCAD

Date	Cell Phase	Study Type	Reference
September 2003	Construction	Plume monitoring	Reine and Clarke, unpublished
May-September 2003	High-Volume Disposal	Plume and water quality monitoring	USACE submittals to RI Dept. of Environmental Management
2003-2005	High-Volume Disposal	Bathymetric surveys	ENSR 2008
May 2005	Post-High-Volume Disposal	Bathymetric surveys	ENSR 2008
October 2009	Low-Volume Disposal	Bathymetric and SPI/PV surveys	USACE 2012
October 2015	Low-Volume Disposal	Bathymetric survey	Carey et al. 2017

Table 1-3.

Summary of Recent Dredging Projects that Placed Dredged Material at PRCAD*

Year	Location	Town
2016	Bella Vista Marina	Warwick
2016	Cowessett Marina	Warwick
2016	Pawtuxet By The Sea	Cranston
2016	Rhode Island Yacht Club	Cranston
2016	Wickford Yacht Club	North Kingstown
2017	Brown and Howard Wharf	Newport
2017	Greenwich Bay Marina East	Warwick
2017	Carnegie Marina	Portsmouth
2018	Pawtuxet Cove Marina	Cranston
2019	Safe Harbor Marina	Warwick
2019	Westerly Yacht Club	Westerly
2020	Walkers Cove	Bristol

* Estimated volumes of dredged material placed at the PRCAD during this time period were not available

2.0 METHODS

Due to health and safety restrictions associated with the SARS COVID19 pandemic, the 2020 PRCAD survey data collection was conducted as two separate survey efforts. The acoustic data collection survey was conducted by Substructure onboard the 31-foot *R/V Orion* on 25-26 September and 22 October 2020. The SPI/PV survey was conducted by INSPIRE onboard the 26-foot *R/V Lophius* on 26-28 October 2020.

2.1 Navigation and Onboard Data Acquisition

During the acoustic survey, navigation onboard the *R/V Orion* was accomplished using a Trimble R10 dual-frequency Global Navigation Satellite System (GNSS) receiver configured to log continuous dual-frequency GNSS data and to transmit real-time kinematic (RTK) differential GNSS (DGNSS) correctors to the Applanix 320 POSMV vessel motion and navigation reference system via a dedicated NTRIP caster network. During survey operations, the POSMV vessel navigation, heading, and motion data were logged within the QPS QINSy hydrographic survey software. In addition, the raw POSMV observables were continuously recorded throughout the survey period to enable post-processing using the Applanix POSPac Mobile Mapping Suite (MMS) software.

For the SPI/PV survey, navigation onboard the *R/V Lophius* was accomplished using a Hemisphere V-104 submeter Differential Global Positioning System (DGPS) and heading receiver. The GPS system was interfaced to a laptop computer running HYPACK 2014 hydrographic survey software. HYPACK continually recorded vessel position and GPS satellite quality and provided a steering display for the vessel captain allowing accurate positioning of the vessel at the pre-established SPI/PV station coordinates. Once the vessel was within 7.5 m of the target location, the SPI/PV camera system was deployed to the seafloor. As soon as the camera system made contact with the seafloor, the navigator recorded the time and position of the camera electronically in HYPACK and in the written field log. This process was repeated for at least five SPI/PV replicate “drops” of the SPI/PV camera system at each sampling station. After all stations were surveyed the navigator exported all recorded positional data into an Excel sheet.

2.2 Acoustic Survey

The acoustic survey included bathymetric, backscatter, and side-scan sonar (SSS) data collection and processing. The bathymetric data provided measurements of water depth that, when processed, were used to map the seafloor topography. The processed data were also compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool of the DAMOS Program for mapping the distribution of dredged material at disposal sites. The methodology for acoustic data acquisition is described in detail in the Project QAPP (INSPIRE 2020a) and INSPIRE acoustic standard operating procedures (SOP); INSPIRE 2020b).

Multibeam backscatter and side-scan sonar data provided images that supported characterization of surficial topography, sediment texture, and roughness. Backscatter data are processed into a seamless image with corrections for topography (depth-normalized) while side-scan sonar data retains a higher resolution image without correction for topography. Comparison of synoptic acoustic data types is very useful for assessing dredged material placed on the seafloor.

2.2.1 Acoustic Survey Planning

Two acoustic surveys were planned to collect multibeam and side-scan sonar data separately over all six CAD cells at PRCAD and the surrounding channel immediately adjacent to the cells (Figures 2-1 and 2-2). A certified hydrographer obtained site coordinates from USACE NAE, imported them to QPS QINSy and MMS software, and created maps to guide survey activities. The proposed PRCAD survey design was then reviewed and approved by NAE scientists.

A 500-m × 1,000-m acoustic survey was conducted to cover the entire PRCAD seafloor. Multibeam echosounder (MBES) survey lines were spaced 25 m apart and cross lines were spaced 150 m apart, which ensured greater than 100-percent coverage of PRCAD (Figure 2-1). Side-scan sonar survey lines were spaced 60 m apart to ensure proper coverage of the survey area (Figure 2-2).

2.2.2 Bathymetric and Backscatter Data Collection

The 2020 multibeam bathymetric survey of PRCAD was conducted on 25-26 September 2020. Bathymetric and acoustic backscatter data were collected using an R2Sonic 2024 MBES as detailed in the Program Quality Assurance Project Plan (QAPP;

INSPIRE 2020a). This 200-450 kHz system forms 256, 0.5-1° beams (frequency dependent) distributed equiangularly or equidistantly across up to a 160° swath. For this survey, the sonar frequency was set to 250 kHz (to be consistent with previous site surveys) and a sonar swath opening of 110-degrees was used, resulting in swath coverage approximately 2.8 times the water depth. The acoustic survey was executed to provide greater than 100-percent coverage of the seafloor based on a continuous review of the 50-cm real-time sounding grid. After the first survey line was run along the western edge of the survey area, each subsequent line working toward the east was run along the outer extent of the previous line, providing approximately 50% swath overlap on each line. This resulted in survey lines spaced at approximately 25-m intervals and provided 200% swath overlap across the survey area. In addition, five cross-check sounding lines spaced at 150-m intervals were acquired perpendicular to the main scheme lines at different times during the survey period.

Prior to the start of the survey, the NOAA Providence tidal benchmark station (Stamping: "845 4000 K TIDAL"; PID: LW5205) located on a pier at the Simms Metal facility and immediately adjacent to the float well was established. The horizontal and vertical offsets between the locations of the various critical sensors (e.g., POSMV IMU and GNSS antennas, and 2024 hull mount transducer phase center location) have been measured for *Orion* using survey laser measuring instruments over short ranges. In addition, the POSMV IMU was mounted directly above the 2024 multibeam transducer within *Orion's* rigid moon pool sonar plug, and the physical offsets between these two critical sensors have been precisely measured in an engineering laboratory. These precise physical measurements were used to create an accurate vessel reference frame for *Orion* that was entered into the QINSy survey configuration files and applied during data acquisition. In addition, the minor roll, pitch, and heading offsets between the POSMV and the 2024 multibeam array were determined during patch test calibrations that were conducted on *Orion* before the start of the survey. Because of the rigid and repeatable sensor mounting systems employed on *Orion*, the patch test results have remained very consistent over time.

During the multibeam survey operations, periodic water column speed of sound profiles were acquired throughout the survey area with a YSI Castaway Conductivity-Temperature-Depth (CTD) sensor and entered directly into the QINSy data acquisition package. The R2Sonic 2024 also included a Valeport Mini sound velocity sensor (SVS) that provided a continuous speed of sound measurement near the multibeam sonar head that was also logged in the QINSy raw data files. At the beginning and end of the survey operations, a series of lead-line depths were manually recorded adjacent to the sonar transducer location, reduced for the local NOAA tidal values, and then directly compared to the near nadir multibeam data logged during this same period.

2.2.3 Side-scan Sonar Data Collection

The 2020 side-scan sonar survey of PRCAD was conducted on 22 October 2020. The side-scan sonar data were acquired as a separate, supplemental survey operation using a Klein 3500 (Hydroscan) side-scan sonar system. The Klein 3500 is a simultaneous dual-frequency, SSS system operating at 445 and 900 kHz with a nominal horizontal beam width of 0.34º and a wideband frequency-modulated chirp pulse width of 1 to 8 msec. For this survey, the sonar towfish was mounted to a rigid over-the-side fairing at a fixed depth below the water-surface and with known, fixed offsets to the primary POSMV navigation reference point. The precisely measured horizontal and vertical offsets between the POSMV reference point and the SSS towfish phase center were entered into the QINSy and SonarPro survey configuration files and applied during data acquisition. The SSS range-scale was set to 75 meters throughout the survey, and the towfish height generally remained between 11 to 15 meters above the bottom, except in the shallow areas outside of the PRCAD boundaries. Based on the 75-meter range setting, a series of seven survey lines spaced at 60-m intervals were established over the PRCAD survey area that provided 200% SSS imagery coverage (Figure 2-2). Both high- and low-frequency SSS sonar data were acquired, though post-processing focused primarily on the lower frequency (445 kHz) data.

2.2.4 Bathymetric Data Processing

Bathymetric data were processed using Applanix POSPac Mobile Mapping Suite (MMS), QPS Qimera, and HYPACK HYSWEEP® software. Processing components are described below and included:

- Post-processing of real-time POSMV solution with POSPac MMS using POSMV raw observables and local base station Trimble R10 GNSS data;
- Application of POSPac SBET (Smoothed Best Estimate of Trajectory) file to raw multibeam data files;
- Conversion of the SBET ellipsoidal height reference to MLLW via Geoid Model 12B and published NAVD88 to MLLW offset for the NOAA Providence tide station;
- Comparison of SBET height reference to the NOAA Providence tide observations;

- Application of speed of sound profiles to account for differences in the water-column during the survey period;
- Removal of spurious points associated with water column interference or system errors;
- Development of a grid surface representing depth solutions;
- Statistical estimation of sounding solution uncertainty; and
- Generation of data visualization products.

Corrections of sounding depth and position (range and azimuth) for refraction due to water column speed of sound differences were applied using a series of eight CTD profiles acquired during the survey operations. The water column was only lightly stratified during the survey, with an approximately 5 m/s difference between the surface and bottom, due primarily to warmer near-surface water temperatures. The CTD profiles were consistent across the survey period, and the profiles were applied directly within the survey program during data acquisition. The speed of sound differences resulted in very minor outer beam differences that had no effect on the useable swath of the multibeam data.

Bathymetric data were filtered to accept only beams falling within an angular limit of 55° to minimize refraction artifacts. Spurious sounding solutions were flagged or rejected based on the careful examination of data in sweep and profile views.

The R2Sonics 2024 MBES system was operated at 250 kHz. At this frequency, the system has a published beam width of 1.0° with a resulting nadir beam footprint of around 0.12 m^2. Based on a review of various grid cell data densities using the full edited dataset, the data were eventually reduced to a cell (grid) size of 0.5 × 0.5 m, acknowledging the system's fine range resolution while accommodating beam position uncertainty. This data reduction was accomplished by calculating and exporting the average elevation for each cell in accordance with USACE recommendations (USACE 2013). Prior to gridding, spurious sounding solutions were flagged as rejected based on the careful examination of all data in sweep and profile views, as well as a review of the grid cell standard deviation surface.

The combined uncertainties associated with all system elements, including calibrations, tide corrections, and refraction caused by water column stratification were quantified by comparing primary survey transects with perpendicular "cross-line" transects.

Comparisons were made using the Qimera Cross Check program to show the observed differences by beam angle between the 0.5-m grid surface (computed from the primary survey transects) and the cross-line survey point data. This comparison used the full 55° swath opening for both main and cross lines and resulted in 4.8 million comparison points. The mean difference between the mainstay reference surface and cross-line data was 0.009 m, with a standard deviation of 0.039 m, and a mean 95% RMS (2-sigma) confidence limit uncertainty of 0.087 m. Mean elevation differences across the swaths ranged from 0.0 m to 0.08 m with the greatest difference at the maximum beam angle (55°) from nadir. This comparison indicates negligible tide bias and minor outer swath uncertainty associated with refraction. This analysis shows compliance with USACE accuracy recommendations and National Ocean Service (NOS) standards. Note that the NOS standard for this project depth (Special Order 1A) would call for a 95th percentile confidence interval (95% CI) of 0.34 m at the maximum site depth (31.6 m) and at the mean site depth (30.1 m).

Reduced data were exported in ASCII text format with fields for Easting, Northing, and MLLW elevation (meters). All data were projected to the NAD 1983 Rhode Island State Plane Coordinate System meters. A variety of data visualizations were generated using a combination of Hypack, QPS Fledermaus, and ESRI ArcGIS Pro. Visualizations and data products included:

- ASCII data files of all processed soundings including MLLW depths and elevations,
- Contours of seabed elevation (25-cm, 50-cm, and 1.0-m intervals) in SHP format suitable for plotting using GIS and CAD software,
- 3-dimensional surface maps of the seabed created using 2× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers (delivered in grid and TIF formats), and,
- An acoustic relief map of the survey area created using 2× vertical exaggeration, delivered in georeferenced TIF format.

2.2.5 Backscatter Data Processing

MBES backscatter data were processed using QPS FMGT implementation of GeoCoder software developed by NOAA’s Center for Coastal and Ocean Mapping Joint Hydrographic Center (CCOM/JHC). GeoCoder was used to create a mosaic best suited for substratum characterization through the use of innovative beam-angle correction algorithms. Data acquired were processed using R2Sonics’ full snippet beam time series data. A trendadaptive angle-varying gain function in Geocoder was applied to minimize artifacts associated with substrate variation within survey transects.

Backscatter data for PRCAD were next exported in ASCII format with fields for Easting, Northing, and backscatter (in dB units) using a 0.5 × 0.5 m resolution. Data were exported in grid format. This grid was used to generate a seamless mosaic of backscatter in GeoTIF format. A Gaussian filter was next applied to backscatter data to minimize nadir artifacts and the filtered data were used to develop a backscatter model using a 3.0-m × 3.0-m grid. The grid was exported to an ESRI binary GRD format to facilitate comparison with other data layers.

2.2.6 Side-Scan Sonar Data Processing

The Klein 3500 side-scan sonar data were processed using Chesapeake Technology SonarWiz software. The Klein 3500 recorded both 455 and 900 kHz acoustic data, though only the 455 kHz data were post-processed. The data were first bottom-tracked to ensure accurate towfish height values and then various automatic and time-varied gain adjustments were applied to normalize the imagery across each swath and between lines. Since side-scan sonar imagery was acquired with 200% coverage across the site, two separate imagery mosaics were constructed using the root-mean squared intensity value to represent overlapping pixels. The mosaics were exported in GeoTIF format using a resolution of 0.25 m per pixel.

2.2.7 Acoustic Data Analysis

The processed bathymetric grids were converted to rasters, and bathymetric contour lines and acoustic relief models were generated and displayed using GIS. The backscatter mosaics and filtered backscatter grid were combined with acoustic relief models in GIS to facilitate visualization of relationships between acoustic datasets. This was done by rendering images and color-coded grids with sufficient transparency to allow the three-dimensional acoustic relief model to be visible underneath.

Golder Software Surfer software was used to calculate elevation difference grids between the 2020 bathymetric dataset and the DAMOS survey conducted in 2015 (Carey and Sturdivant 2017). Elevation difference grids (0.5 m cells) were calculated by subtracting the earlier survey depth estimates from the 2020 survey depth estimates at each point throughout the grid. The resulting elevation differences were contoured and displayed using GIS.

2.3 Sediment Profile and Plan View Imaging Survey

Sediment profile and plan view (SPI/PV) imaging are monitoring techniques used to provide data on the physical characteristics of the seafloor and the status of the benthic biological community.

2.3.1 SPI and PV Survey Planning

The PRCAD SPI/PV survey featured image collection at 30 stations located over five of the six CAD cells and at four stations to the north of PRCAD (REF-North) and another four stations to the south of PRCAD (REF-South) (Figure 2-3). SPI/PV target station locations are provided in Table 2-1 and actual SPI/PV station replicate locations are provided in Appendix B. The methodology for data acquisition and analysis for these images was consistent with the sampling methods described in detail in the Project QAPP (INSPIRE 2020a) and INSPIRE SPI/PV standard operating procedures (INSPIRE 2019).

2.3.2 Sediment Profile Imaging

Sediment profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor and the status of the benthic biological community. The technique involves deploying an underwater camera system to photograph a cross section of the sediment–water interface. In the 2020 survey at PRCAD, high-resolution SPI images were acquired using a Nikon® D7100 digital single-lens reflex camera mounted inside an Ocean Imaging® Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped steel prism with a plexiglass front faceplate and a back mirror. The mirror was mounted at a 45° angle to reflect the profile of the sediment–water interface. The camera lens looked down at the mirror, which reflected the image from the faceplate. The prism had an internal strobe mounted inside at the back of the wedge to provide illumination for the image; this chamber was filled with distilled water, so the camera always had an optically clear path. The descent of the prism into the sediment was controlled by a hydraulic piston. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired an internal strobe to obtain a cross-sectional image of the upper 15-20 cm of the sediment column (Figure 2-4). The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained.

Test exposures of a Color Calibration Target were made on deck at the beginning and end of the 2020 survey to verify that all internal electronic systems consistently met design specifications and to provide a color standard against which final images could be checked to ensure proper color balance. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 640, shutter speed was 1/250, f-stop was f11, and storage was in compressed raw Nikon Electronic Format (NEF) files (approximately 30 MB each). All camera settings and any setting changes were recorded in the field log (INSPIRE 2020c).

Each time the camera system was brought onboard, the frame counter was checked to ensure that the requisite number of replicates had been obtained. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth. If images were missed or the penetration depth was insufficient, the camera frame stop collars were adjusted and/or weights were added or removed, and additional replicate images were taken. Frame counts, time of image acquisition, frame stop-collar position, and the number of weights used were recorded in the field log for each replicate image.

Each image was assigned a unique time stamp in the digital file attributes by the camera's data logger and cross-checked with the time stamp in the navigational system's computer data file. In addition, the field crew kept redundant written sample logs. Images were downloaded periodically to verify successful sample acquisition and/or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were renamed with the appropriate station names after downloading as a further quality assurance step.

2.3.3 Plan View Imaging

An Ocean Imaging® Model DSC24000 plan view underwater camera (PV) system with two Ocean Imaging® Model 400-37 Deep Sea Scaling lasers was attached to the sediment profile camera frame and used to collect plan view images of the seafloor surface. Both SPI and PV images were collected during each "drop" of the system. The PV system consisted of a Nikon D-7200 encased in an aluminum housing, a 24 VDC autonomous power pack, a 500 W strobe, and a bounce trigger. A weight was attached to the bounce trigger with a stainless-steel cable so that the weight hung below the camera frame; the scaling lasers projected two red dots that are separated by a constant distance (26 cm) regardless of the field-of-view of the PV system. The field-of-view can be varied by increasing or decreasing the length of the trigger wire and, thereby, the camera height above the bottom when the picture is taken. As the SPI/PV camera system was lowered to the seafloor, the weight attached to the bounce trigger contacted the seafloor prior to the camera frame reaching the seafloor and triggered the PV camera (Figure 2-4).

During set-up and testing of the PV camera, the positions of lasers on the PV camera were checked and calibrated to ensure separation of 26 cm. Test images were also captured to confirm proper camera settings for site conditions. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file; for this survey, the ISO-equivalent was set at 250. The additional camera settings used were as follows: shutter speed 1/15, f18, white balance set to flash, color mode set to Adobe RGB, sharpening set to none, noise reduction off, and storage in compressed JPG files (approximately 6 MB each). Images were checked periodically throughout the survey to confirm that the initial camera settings were still resulting in the highest quality images possible. All camera settings and any setting changes were recorded in the field log.

Prior to field operations, the internal clock in the digital PV system was synchronized with the GPS navigation system and the SPI camera. For each PV image, a time stamp was recorded in the digital file and redundant time notes were made in the field and navigation logs. Throughout the survey, PV images were downloaded at the same time as the SPI images and evaluated to confirm image acquisition and image clarity.

The ability of the PV system to collect usable images was dependent on the clarity of the water column. Water conditions at PRCAD allowed use of a 1.0-m trigger wire, resulting in a mean image width of 0.7 m and a mean field-of-view of 0.3 m^2.

2.3.4 SPI/PV Data Acquisition

The SPI/PV survey was conducted at PRCAD and reference area stations on 26-28 October 2020 onboard the *R/V Lophius*. At each station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 15 m. At least five replicate SPI and PV images were collected at each station. The three replicate images with the best quality (adequate prism penetration, no or minimal sampling artifacts) at each station were selected for analysis (Appendices C and D).

The DGPS described above was interfaced to HYPACK® software via laptop serial ports to provide a method to locate target coordinates and record actual sampling locations. Throughout the survey, the HYPACK® data acquisition system received DGPS data. The incoming data stream was digitally integrated and stored on the PC's hard drive. Actual SPI/PV sampling locations were recorded using this system.

2.3.5 Image Conversion and Calibration

Following completion of field operations, quality control checks were conducted of filenames, date/time stamps, and the field log. After these procedures, the raw image files were color calibrated in Adobe Camera Raw® by synchronizing the raw color profiles to the Color Calibration Target that was photographed prior to field operations with the SPI camera. The raw SPI and PV images were then converted to high-resolution Photoshop Document (PSD) format files, using a lossless conversion file process and maintaining an Adobe RGB (1998) color profile. The PSD images were then calibrated and analyzed in Adobe Photoshop®. Length and area measurements were recorded as number of pixels and converted to scientific units using the calibration information. Detailed results of all SPI and PV image analyses are presented in Appendices C and D.

2.3.6 SPI and PV Data Analysis

Computer-aided analysis of the resulting images provided a set of standard measurements to allow comparisons between different locations and different surveys. The DAMOS Program has successfully used this technique for over 30 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites (Germano et al. 2011).

Measured parameters for SPI and PV images were recorded in Microsoft Excel© spreadsheets. These data were subsequently checked by one of INSPIRE's senior scientists as an independent quality assurance/quality control review before final interpretation was performed. Spatial distributions of SPI and PV parameters were mapped using ESRI ArcGIS 10.5.

2.3.6.1 Sediment Profile Image Analysis Parameters

The parameters discussed below were assessed and/or measured and recorded for each replicate SPI image selected for analysis (Appendix C). Descriptive comments were also recorded for each. Many variables can be seen and annotated in context in SPI images from soft bottom coastal and estuarine environments (Figure 2-5).

Sediment Type – The sediment grain size major mode and range were estimated visually from the images using a grain size comparator at a similar scale. Results were reported using the phi scale. Conversion to other grain size scales is provided in Appendix E. The presence and thickness of disposed dredged material were also assessed as described below.

Penetration Depth – The depth to which the camera penetrated into the seafloor was measured to provide an indication of the sediment density and bearing capacity. The penetration depth can range from a minimum of 0 cm (i.e., no penetration on hard substrata) to a maximum of 20 cm (full penetration on very soft substrata).

Surface Boundary Roughness – Surface boundary roughness is a measure of the vertical relief of features at the sediment–water interface in the sediment profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment–water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbation activities.

Apparent Redox Potential Discontinuity (aRPD) Depth – The aRPD depth provides a measure of the integrated time history of the balance between near-surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light gray. As the particles are buried or moved down by biological activity, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark gray or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases. The aRPD depth was measured by assessing color and reflectance boundaries within the images.

Mud Clasts – When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging) intact clumps of sediment are often scattered across the seafloor. The number of clasts observed at the sediment–water interface was counted and their oxidation state assessed. The detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin (Germano 1983). Mud clasts that are artifacts of SPI sampling (mud clots can fall off the back of the prism or wiper blade) are not recorded in the analysis sheet but may be noted in the "Comments" field.

Distinguishable Dredged Material Layer Depth and Thickness – The depth below the sediment–water interface of any dredged material layer, distinguishable from other sediment layers, was measured. Additionally, the thickness of any distinguishable dredged material layer, from 1 mm to 20 cm (the height of the SPI optical window) was measured. If the layer extended below the depth of prism penetration this was noted. Notably, the lack of a distinct dredged material layer is not an indication that dredged material was not present as non-native material may have very similar characteristics as the native material.

Biological Mixing – The depth to which sediments are bioturbated, or the biological mixing depth, can be an important parameter for studying nutrient or contaminant flux, as well as organic enrichment, in sediments. In this study, the minimum and maximum linear distances from the sediment surface to subsurface voids were measured. The latter parameter represents the maximum observed particle mixing depth of head-down feeders, mainly polychaetes. The number of subsurface voids were counted for each SPI replicate.

Infaunal Successional Stage – Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism–sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (e.g., dredged material disposal) (Pearson and Rosenberg 1978; Rhoads and Germano 1982; Rhoads and Boyer 1982). This continuum has been divided subjectively into four stages: Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source; Stage 1 is the initial recolonizing tiny, densely populated polychaete assemblages; Stage 2 is the start of the transition to head-down deposit feeders; and Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders (Figure 2-6). Successional stage was assigned by assessing the types of species and related activities (e.g., feeding voids) apparent in the images. Biogenic particle mixing depths can be estimated by measuring the maximum and minimum depths of imaged fauna, burrows, or feeding voids in the sediment column.

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping of means of replicate values from each station.

Station means were calculated from three replicates from each station and used in statistical analysis.

2.3.6.2 Plan View Image Analysis Parameters

The PV images provided a much larger field-of-view than the SPI images and provided valuable information about the landscape ecology and sediment topography in the area where the pinpoint "optical core" of the sediment profile was taken (Figure 2-7). Unusual surface sediment layers, textures, or structures detected in any of the sediment profile images can be interpreted within the larger context of surface sediment features. For example, if a surface layer or topographic feature is a regularly occurring feature and typical of the bottom in this general vicinity or just an isolated anomaly. The scale information provided by the underwater lasers allows for accurate density counts (number per square meter) of attached epifaunal colonies, sediment burrow openings, or larger macrofauna or fish which may have been missed in the sediment profile cross section. Information on sediment transport dynamics and bedform wavelength were also available from PV image analysis.

For each replicate PV image selected for analysis, analysts calculated the image size and field-of-view and the following were recorded: sediment type; oxidation state of the surface sediment; presence and type of bedforms; presence of *Beggiatoa* and estimates of cover extent; dredged material presence; presence of burrows, tubes, tracks/trails, and debris; types of epifauna and flora; number of fish; and descriptive comments (Appendix D).

2.3.7 Data Quality Assurance and Quality Control

Measures were taken both during field data collection and during post-collection analysis for data quality assurance and control in alignment with the project QAPP (INSPIRE 2020a). These included but were not limited to:

- Systems were tested prior to and during survey activities to ensure calibration and operation,
- A full backup system (including tools, parts, and electronics) was carried in the field, and
- Image data collected was time stamped both digitally and in hand-written logs to ensure proper identification and synchronization with navigational data.

2.4 Statistical Analyses on aRPD and Successional Stage

One of the objectives of the 2020 SPI/PV survey at PRCAD was to assess the benthic colonization status within the CAD cells and associated reference areas. Statistical analyses were conducted to compare key SPI parameter values between individual CAD cells and the reference areas. The aRPD depth and successional stage measured in each image are the best indicators of infaunal activity measured by SPI and were, therefore, used in this comparative analysis. Standard boxplots were generated for visual assessment of the central tendency and variation in each of these parameters within the disposal areas and the reference areas. Inequivalence tests between the reference and disposal areas were conducted, as described in detail below.

Traditionally, the objective of this study would be addressed using point null hypotheses of the form "There is no difference in benthic conditions between the reference areas and the disposal target areas." However, in this instance, an approach using bioequivalence or interval testing was considered to be more informative than the point null hypothesis test of "no difference" (Germano 1999). One reason is that there is always some small difference, and the statistical significance of this difference may or may not be ecologically meaningful. Without an associated power analysis, the results of traditional point null hypothesis testing often provide an inadequate ecological assessment.

In this application of bioequivalence (interval) testing the null hypothesis is chosen as one that presumes the difference is great, i.e., an <u>inequivalence</u> hypothesis (e.g., McBride 1999). This is recognized as a "proof of safety" approach because rejection of this inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested were:

H_0: $d \leq -\delta$ or $d \geq \delta$ (presumes the difference is great)

H_A: $-\delta < d < \delta$ (requires proof that the difference is small)

where d is the difference between a reference mean and a CAD cell site mean. If the null hypothesis is rejected, then it can be concluded that the two means are equivalent to one another within $\pm\delta$ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful. Previously established δ values of 1 for aRPD, and 0.5 for successional stage rank on the 0-3 scale were used.

A successional stage rank variable, on a 0-3 scale, was applied to each image to evaluate successional stages numerically. A value of 3 was assigned to Stage 3, 2 on 3, and 1 on 3 designations, a value of 2 was applied to Stage 2 and 1 on 2, a value of 1 was applied to Stage 1, a value of 0 was applied to Stage 0, and intermediate ranks were assigned to the transitional assemblages (2.5 for Stage 2 transitioning to Stage 3, and 1.5 for Stage 1 transitioning to Stage 2). Images from which the stage could not be determined were excluded from calculations. The maximum successional stage rank among replicates was used to represent the station value.

The test of this interval hypothesis can be broken down into two one-sided tests (TOST) (McBride 1999 after Schuirmann 1987) which are based on the normal distribution, or on Student's *t*-distribution when sample sizes are small and variances must be estimated from the data (the typical case in the majority of environmental monitoring projects). The statistics used to test the interval hypotheses shown here are based on such statistical foundations as the Central Limit Theorem (CLT) and basic statistical properties of random variables. A simplification of the CLT says that the mean of any random variable is normally distributed. Linear combinations of normal random variables are also normal so a linear function of means is also normally distributed. When a linear function of means is divided by its standard error, the ratio follows a *t*-distribution with degrees of freedom associated with the variance estimate. Hence, the *t*-distribution can be used to construct a confidence interval around any linear function of means.

In this 2020 survey sampling design, there were seven distinct sampling areas, two of which were categorized as reference areas (REF-North, REF-South) and five were CAD cells (1R, 3AR, 4R, 5R, and 6/7R). A single reconnaissance station was sampled within CAD cell 1R, and thus, no statistical analyses were planned for this area. The difference equations for the comparisons of interest were the linear contrast of the mean of the two reference means minus the mean each CAD cell area mean, or

$$\hat{d} = ½\,(\text{Mean}_{\text{REF-North}} + \text{Mean}_{\text{REF-South}}) - \text{Mean}_{\text{CAD}} \qquad \text{[Eq. 1]}$$

where Mean_{CAD} was the mean for one of the sampled CAD cells (3AR, 4R, 5R, or 6/7R).

The two reference areas collectively represented ambient conditions, but if the means were different among these three areas, then pooling them into a single reference group would inflate the variance estimate because it would include the variability between areas, rather than only the variability between stations within each single homogeneous area. The effect of keeping the two reference areas separate had no effect on the reference mean when sample size was equal among these areas, but it ensured that the variance is truly the residual variance within a single population with a constant mean.

The standard errors of each difference equation were calculated from the fact that the variance of a sum is the sum of the variances for independent variables, or

$$se(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j\right)} \qquad \text{[Eq. 2]}$$

Where:

$se(\hat{d})$ standard error of the difference equation

$\hat{d}$ observed difference in means between the reference and the CAD cell area

c_j coefficients for the j means in the difference equation, $\hat{d}$ (i.e., for [Eq. 1] shown above, the coefficients were ½ for each of the three reference locations, and -1 for each of the CAD cell areas

S_j^2 variance for the j^{th} area. If we can assume equal variances, a single pooled residual variance estimate can be substituted for each group, equal to the mean square error from an ANOVA.

n_j number of stations for the jth area.

The inequivalence null hypothesis was rejected (and equivalence was concluded) if the confidence interval on the difference of means, $\hat{d}$, was fully contained within the interval [–δ, +δ].

Thus, the decision rule was to reject H_0 if

$$D_L = \hat{d} - t_{\alpha,\upsilon} se(\hat{d}) > -\delta \text{ and } \qquad D_U = \hat{d} + t_{\alpha,\upsilon} se(\hat{d}) < \delta \qquad \text{[Eq. 3]}$$

where:

$t_{\alpha,\upsilon}$ upper (1-α)*100th percentile of a Student's t-distribution with υ degrees of freedom (α = 0.05)

υ degrees of freedom for the standard error. If a pooled residual variance estimate was used, it was the residual degrees of freedom from an ANOVA on all groups (total number of samples minus the number of groups); if separate variance estimates were used, degrees of freedom were calculated based on the Welch-Satterthwaite estimation (Satterthwaite 1946).

Validity of the normality and equal variance assumptions was tested using Shapiro-Wilk's test for normality on the area residuals (α=0.05) and Levene's test for equality of variances among the six areas (α =0.05). If normality was not rejected but equality of variances was, then the variance for the difference equation was based on separate variances for each group. If systematic deviations from normality were identified, then a nonparametric bootstrapped interval were used (Appendix F). Bootstrapping is a statistical resampling procedure that uses the sample data to represent the entire population to construct confidence limits around population parameters. Bootstrapping does not make assumptions about the distribution of the data; it assumes only that the sample data are representative of the underlying population, so random sampling is a prerequisite for appropriate application of this method. Bootstrapping procedures entail resampling, with replacement, from the observed sample of size n. Each time the sample is resampled, a summary statistic (e.g., mean or standard deviation) of the bootstrapped sample is computed and stored. After repeating this procedure many times, a summary of the bootstrapped statistics is used to construct the confidence limit.

Table 2-1.

PRCAD 2020 Survey Target SPI/PV Station Locations

Station ID	Latitude (NAD83)	Longitude (NAD83)	X (RI State Plane meters)	Y (RI State Plane meters)
1	41.810740	-71.398968	108395.3	80792.0
2	41.811175	-71.397567	108511.7	80840.5
3	41.811513	-71.397013	108557.6	80878.1
4	41.810023	-71.398613	108424.9	80712.5
5	41.810707	-71.397542	108513.8	80788.5
6	41.810890	-71.397038	108555.7	80808.9
7	41.808622	-71.397951	108480.1	80556.9
8	41.807826	-71.397223	108540.7	80468.6
9	41.807291	-71.396201	108625.7	80409.3
10	41.806886	-71.396263	108620.5	80364.3
11	41.806267	-71.396051	108638.3	80295.5
12	41.809837	-71.395812	108657.6	80692.1
13	41.809651	-71.395582	108676.8	80671.4
14	41.809493	-71.395166	108711.4	80654.0
15	41.809174	-71.395147	108713.0	80618.5
16	41.808847	-71.395286	108701.5	80582.2
17	41.808370	-71.394982	108726.8	80529.2
18	41.808283	-71.394017	108807.0	80519.6
19	41.807721	-71.394031	108805.9	80457.3
20	41.807375	-71.393206	108874.5	80418.9
21	41.806933	-71.393120	108881.8	80369.9
22	41.809308	-71.396409	108608.1	80633.3
01R	41.803067	-71.394367	108778.7	79940.3
02R	41.803600	-71.393483	108852.0	79999.6
03R	41.803617	-71.392367	108944.8	80001.6
05R	41.804300	-71.390367	109110.9	80077.7
07R	41.812917	-71.398517	108432.5	81033.9
08R	41.812617	-71.399133	108381.3	81000.5
09R	41.812583	-71.399750	108330.1	80996.7
10R	41.812267	-71.400667	108253.9	80961.5

Notes
1. Grid coordinates are NAD_1983_StatePlane_Rhode_Island_FIPS_3800_Meters
2. Geographic coordinates are NAD83 decimal degrees

3.0 RESULTS

3.1 Acoustic Survey

Substructure conducted an acoustic survey in September and October 2020 to characterize the topography and surficial features over the PRCAD survey area.

3.1.1 Bathymetry

The 2020 multibeam bathymetric data were rendered as an acoustic relief model (color scale with hillshading) to provide a detailed representation of the surface of the survey area (Figure 3-1). The Providence River in the survey area was approximately 12.5 m deep with shallow plateaus to the east, west, and north of the PRCAD cells flanking the navigation channel. The six PRCAD cells were readily distinguishable from the navigation channel as topographic depressions that were generally 0.5 to 4.5 m below the surrounding channel depth of 12.5 m.

CAD Cells 3AR, 5R, and 3R were the deepest of the six CAD cells. Cell 3AR, the largest cell (350 × 300 m), was approximately 16 m deep throughout most of the cell but reached 17 m in depth in some areas. Thus, the depth of Cell 3AR was approximately 3.5 m below the surrounding channel depth of 12.5 m. Cell 5R was also relatively deep, reaching 17 m in the northern and southern portions with shallower depths in the middle of the cell. The sides of Cell 5R were steep, dropping from 12.5 m to 17 m over a distance of approximately 15 m along the western boundary. The northern and southern portions of Cell 5R were approximately 4.5 m below the surrounding channel depth. Cell 3R was observed to have a flat surface at approximately 2 m below the surrounding channel depth.

CAD Cells 6/7R, 1R, and 4R were shallower than the other three cells, and approached the depth of the surrounding channel. In the southeast corner of the site, water depths in CAD Cell 6/7R averaged 13.8 m throughout the cell, which was 1.3 m below the surrounding channel. CAD Cells 1R and 4R were the shallowest cells and were typically about 1 to 2 m deeper than the surrounding floor of the Providence River (Figure 3-1).

3.1.2 Acoustic Backscatter and Side-Scan Sonar

Acoustic backscatter provided an indication of the nature of surficial sediment present in the survey area. Unfiltered backscatter imagery of the PRCAD survey area revealed stronger returns near the center of the survey area and at the end of piers (Figure 3-2). Filtered backscatter over acoustic hillshaded relief presented an assessment of surficial sediment characteristics independent of slope effects and provided a more readily interpreted map (Figure 3-3).

Acoustic backscatter imagery of the PRCAD cells indicated variable patterns of acoustic returns throughout the survey area (Figure 3-3). Strong backscatter returns indicated relatively coarser-grained, rougher, or harder sediment and were observed in CAD Cell 1R, in the center of Cell 3AR, and adjacent to three piers, two along the western side and one on the eastern side of the Providence River. Weaker returns were observed in Cell 6/7R and in portions of other cells. Most of the survey area, including both the topographic depressions of the CAD cells and ambient channel bottom had moderate backscatter returns.

Side-scan sonar results depicted the surface relief and texture of the Providence River channel (Figure 3-4) and confirmed the observations from the backscatter results, but with additional information including identifiable small-scale surficial features on the sediment surface. The side-scan sonar results showed topographical roughness or heterogeneous sediments in Cells 1R and 3AR and adjacent to the three piers. Features of increased topographic relief were observed in these areas as indicated by blips of high side-scan sonar return accompanied by "shadows" created by objects blocking signal return. Rocky substrate and pier pilings were observed along the banks of the channels to the east and west of PRCAD. Coarser-grained, rougher, or harder bottom observed in the backscatter and side-scan sonar returns adjacent to the three piers and in Cell 1R may be due to vessel activity and is discussed further in Section 4.0.

3.1.3 Comparison with Previous Bathymetry

Quantitative comparisons between bathymetric measurements collected over time can provide verification of dredged material placement and enhance understanding of the CAD cell filling sequence. Bathymetric change was analyzed over two time periods, 2009-2015 and 2015-2020, to support assessment of the PRCAD cells. These analyses spanned the three most recent PRCAD bathymetric surveys conducted in 2009, 2015, and 2020.

The multibeam bathymetric survey data collected in 2015 (Figure 1-2) was compared with the multibeam bathymetric survey data collected in 2009 (USACE 2012). Bathymetric data collected in 2015 were subtracted from 2009 bathymetry to capture any substantial elevation changes that occurred over that time period (Figure 3-5). Comparison of 2009-

2015 bathymetric data revealed that the majority of positive elevation change (i.e., filling of CAD cells) occurred throughout Cell 6/7R, with accumulation reaching a maximum of 5.1 m increase between 2009 and 2015. Less accumulation (~0.5 m) was observed in Cell 3R, and in parts of Cells 5R and 3AR during this time period. Decreased elevation (i.e., potential deepening of CAD cells likely due to loss of material, as discussed below) was observed in and around CAD Cell 1R (indicated in blue in Figure 3-5).

The multibeam bathymetric data collected in 2020 (Figure 3-1) was also compared with the multibeam bathymetric data collected in 2015 (Figure 1-2). Bathymetric data collected in 2020 were subtracted from 2015 bathymetry to capture any substantial elevation changes that may have occurred over that time period (Figure 3-6). Overall, substantially less elevation increase (i.e., CAD cell filling) was observed during the 2015-2020 period than during the previous period (2009-2015). Elevation increases were observed in the center of Cell 3AR, where a maximum increase of 2.0 m was observed and, to a lesser extent, in Cell 6/7R, where a maximum increase of 1.3 m was observed. Decreased elevation (i.e., deepening) ranging from 0.2 to 1.0 m was observed in and around Cell 1R. This deepening may be due to vessel activity and is discussed further in Section 4.0.

The depth of all six CAD cells was below the surrounding channel in 2020, indicating additional remaining capacity, which is evaluated in Section 4.0.

3.2 Sediment Profile and Plan View Imaging

The primary purpose of the SPI/PV survey at PRCAD was to characterize the physical features of surficial sediments and assess the status of benthic colonization at PRCAD and compare results with conditions at the two reference areas. Station summaries of selected physical and biological parameters derived from the SPI/PV images can be found in Tables 3-1 and 3-2, and a complete set of SPI/PV results is provided in Appendices C and D.

3.2.1 Reference Area Stations

In October 2020, a total of eight SPI/PV stations were sampled at two reference areas. This included SPI and PV image collection in triplicate at four stations to the north of PRCAD (REF-North) and another four stations to the south of PRCAD (REF-South) (Figure 3-7). These reference areas were used to represent nearby Providence River channel sediment conditions relative to PRCAD cells. Notably, the REF-North stations were located adjacent to the northern terminus of the Providence River channel, where water depths decrease rapidly over a short distance north, which may increase the within-station variability at these stations.

3.2.1.1 Physical Sediment Characteristics

Sediment at all reference stations was predominantly composed of silt/clay (Table 3-1; Figure 3-8) with little variation in physical characteristics observed across reference stations (Figure 3-9). Sediments at both reference areas were very soft with low load-bearing capacity as evident from the generally deep sediment prism penetrations. The weights and stops were consistent during the entire survey (INSPIRE 2020c) and thus, comparisons of prism penetration across stations provided insight into the relative load-bearing capacity of the sediments in the surveyed area. Mean station prism penetration ranged from a minimum of 6.6 cm at Station 03R (REF-South) to a maximum of 19.2 cm at Station 07R (REF-North), but generally was between 13 and 16 cm across the rest of the reference stations (Figure 3-10; Appendix C).

Small-scale boundary roughness measurements were generally low across all reference stations, ranging from 0.4 cm at Station 02R (REF-South) to 1.7 cm at Station 05R (REF-South) (Appendix C). Small-scale boundary roughness at all reference stations was between 0.0 and 2.5 cm (Figure 3-11) and appeared to be biogenic in origin (e.g., burrow openings, fecal mounds and fecal stacks) (Figure 3-9; Appendices C and D).

3.2.1.2 Biological Conditions and Benthic Recolonization

In general, there was little variation in biological characteristics observed across the reference areas, with both the REF-North and REF-South showing evidence of overall high sediment respiration rates. A qualitative assessment of sediment oxygen demand was documented as “High” for all reference stations, with the exception of Station 10R (REF-North), which had “Medium” sediment oxygen demand (Table 3-2; Appendix C). This qualitative sediment oxygen demand assessment considers several SPI and PV parameters related to sediment respiration. High sediment oxygen demand was inferred from very shallow aRPD depths and generally reduced state of the sediments based on dark coloration. The presence of methane and *Beggiatoa* sp. were also indications of high sediment oxygen demand.

Mean aRPD depths were generally shallow and similar between REF-South and REF-North areas (Figure 3-12). Station mean aRPD depths at the reference areas ranged from a minimum of 0.0 cm at Station 07R (REF-North) to a maximum of 0.9 cm at Station 01R (Ref-South) (Appendix C).

Methane was observed in SPI at one reference station in the REF-North area (Station 07R) (Table 3-2; Figure 3-13). Evidence of low oxygen conditions in the overlying water was observed at Station 07R (REF-North), where a continuous mat of *Beggiatoa* sp. was observed. *Beggiatoa* sp. was observed in the PV images at several other reference stations, but were characterized as trace levels (Stations 08R, 10R, 01R, and 02R) or patches (Station 05R) (Figure 3-14).

Infaunal successional stage was variable across reference stations (Figure 3-15). Deep subsurface voids, indicating the presence of Stage 3 infauna, were observed in at least one replicate at all but one reference station (no voids were documented at Station 10R) (Figures 3-15, 3-16, and 3-17A). High densities of Stage 2 tubicolous surface fauna were observed at all stations in REF-North, with the exception of Station 07R (Table 3-2; Figure 3-17B). Successional Stage 1 was documented at two replicate images at Station 07R within REF-North, where there was limited evidence of macrofaunal activity, although a subsurface void was observed at one replicate image at this station and was designated at Stage 1->3 (Table 3-2; Appendices C and D). Relatively large, symmetrically circular burrows were frequently observed in PV images at the reference stations (Figure 3-17). Given the characteristics of these burrows, it is possible they were formed by eels. Overall, the biological condition of the reference areas was considered stressed, with high respiration rates and low abundances of Stage 3 infauna.

3.2.2 PRCAD Cell Stations

In October 2020, a total of 22 SPI/PV stations were sampled across five cells within PRCAD. This included SPI and PV images collected in triplicate at five stations at each of Cells 4R, 5R, and 6/7R, six stations at Cell 3AR, and one station at Cell 1R (Figure 3-7). The survey was designed to provide sufficient station density to allow for comparisons between each individual cell and the reference areas, except for the single reconnaissance station at Cell 1R.

3.2.2.1 Physical Sediment Characteristics

The predominant grain size major mode observed across the majority of PRCAD stations was silt/clay. The only exceptions were two stations within 3AR that consisted of a surficial layer of silt/clay overlying very fine sand (Stations 02 and 06) (Figures 3-8 and 3-18A).

The load-bearing capacity of the sediments across PRCAD was generally low as indicated by the deep sediment prism penetrations (Figure 3-10). Since the weights and stops were consistent (INSPIRE 2020c), variation in prism penetration across stations is due to differences in the relative sediment load-bearing capacity across stations. Mean prism penetration depth by CAD cell ranged from 9.8 cm at 1R to 15.8 cm at 5R (Table 3-1). At the majority of PRCAD stations, mean station prism penetration depths were between 10 and 16 cm (Figures 3-10 and 3-18B).

Small-scale boundary roughness measurements were between 0 and 1.5 cm at all stations within PRCAD, with the exception of Station 08 (Cell 6/7R) (Figure 3-11). At Station 08, a large burrow was observed that was transected by the SPI camera prism and resulted in a larger boundary roughness, averaging 2.2 cm at that station (Figures 3-11 and 3-18C; Appendix C). Small-scale boundary roughness was biogenic in origin at all stations within PRCAD (e.g., burrow openings, fecal mounds, and fecal stacks) (Appendices C and D).

Several physical features observed in SPI across PRCAD stations were indicative of dredged material. Evidence of dredged material observed in SPI included subsurface layers with abrupt horizons indicative of depositional events and patches of mottled white and light gray clay (Figure 3-19). Notably, the lack of distinct dredged material is not an indication that dredged material was not present; dredged material placed at PRCAD was generally similar in sediment composition and physical characteristics as the ambient sediments in this area, therefore a clear distinction between dredged material and native sediments was not expected.

3.2.2.2 Biological Conditions and Benthic Recolonization

Sediments at PRCAD were characterized by evidence of generally high sediment respiration rates. A qualitative assessment of sediment oxygen demand was documented as “High” for all PRCAD stations, with the exception of Station 02 (Cell 3AR), which had

"Medium" sediment oxygen demand (Table 3-2; Appendix C). This qualitative assessment of sediment oxygen demand considers several SPI and PV parameters related to sediment respiration. Shallow aRPD depths, methane presence, *Beggiatoa* sp. presence, and generally reduced state of the sediments based on dark optical color were evidence of high sediment oxygen demand at PRCAD stations.

Mean aRPD depths were generally shallow and similar across the CAD cells (Figure 3-12). Station mean aRPD depths at PRCAD ranged from a minimum of 0.0 cm at two stations in Cell 5R (Stations 18 and 20) and one station in Cell 6/7R (Station 09) to a maximum of 0.78 cm at Station 04 in Cell 3AR (Appendix C). The majority of PRCAD stations had mean aRPD depths between 0 and 0.5 cm, with the exception of three stations within Cell 3AR where aRPD depths measured greater than 0.6 cm (Table 3-2; Figure 3-12).

Methane was observed in SPI at nine stations at PRCAD, with the most frequent observations occurring in Cell 4R (three out of five stations had methane) and Cell 5R (four out of five stations had methane) (Table 3-2; Figure 3-13). *Beggiatoa* sp. was observed in the PV images collected at the majority of PRCAD stations, including all but three stations (Figure 3-14). The three stations where *Beggiatoa* sp. was not observed were grouped within the vicinity of each other in the central portion of Cell 3AR. *Beggiatoa* sp. was observed as continuous mats across the sediment surface (Stations 16 and 20), discrete patches on the sediment (all stations in Cell 6/7R), or as trace levels on the surface of the sediment (central area of PRCAD, Cell 4R and 1R). *Beggiatoa* sp. was also observed within the sediment column (observed in SPI) as distinctive small white threads at nine PRCAD stations (Appendix C). There were no instances where *Beggiatoa* sp. was observed in SPI but not in the associated PV (Appendices C and D).

Infaunal successional stage was variable across the PRCAD stations (Figure 3-15). Generally, infaunal successional stage was more advanced in Cells 3AR and 4R and less advanced in Cells 5R and 6/7R. Infaunal successional Stage 1 on 3 occurred mainly at stations located in 5R and 4R (Stations 16, 17, and 18), where either very small tubes or no tubes were observed at the sediment–water interface concurrent with subsurface voids. These voids were generally small with no oxic layer around them (Figure 3-20A). Infaunal successional Stage 2 on 3 was frequently observed in Cells 3AR and 4R, as denoted by the presence of Stage 2 tubicolous surface fauna at the sediment–water interface and typically small subsurface voids at depth (Figure 3-20B). The presence of large burrows observed in PV images were generally an indication that Stage 3 deep burrowing infauna were present, likely in low abundances, even if subsurface voids were not observed in the SPI; these stations were classified as Stage 2 -> 3. Similar to several reference stations, very large symmetrical burrows were observed at some stations at the CAD cells; given the symmetry, size, and lack of excavated material surround the burrows, these features were likely not derived from infaunal species and more likely from eels.

3.2.3 Statistical Comparisons

3.2.3.1 aRPD Depth Comparisons

Reference areas REF-North and REF-South were similar in their distribution of aRPD depth values (Table 3-2; Figure 3-21); average aRPD depth values were 0.48 cm and 0.55 cm at REF-North and REF-South, respectively. At the CAD cell areas, the deepest aRPD depth was at Cell 3AR, which had an area mean aRPD depth of 0.53 cm. The shallowest aRPD depths occurred at CAD Cell 5R, which averaged 0.17 cm, although aRPD depths were variable within this cell (Table 3-2; Figure 3-21).

An inequivalence test was performed to determine whether the differences observed between the grand mean of aRPD depths of the two reference areas (0.52 cm ± 0.35 SD) and each of the four CAD cells were statistically significant. Using the data from these six locations, the results for the normality test indicated that the area residuals (i.e., each observation minus the area mean) were not significantly different from a normal distribution (Shapiro-Wilk's test p-value = 0.55). Levene's test for equality of variances was not rejected ($p = 0.25$). The confidence intervals for these aRPD difference equations were constructed using parametric estimates and pooled variance estimates.

The confidence regions for the differences between the grand reference mean versus each CAD cell area mean were all contained within the interval [-1.0, 1.0] (Table 3-3). The conclusion was that all four CAD cells had similar aRPD depths to the two reference areas in the 2020 survey.

3.2.3.2 Successional Stage Comparisons

A statistical comparison was made to examine the difference between the maximum successional stage ranks at the reference areas and each CAD cell area sampled in 2020. The mean maximum successional stage rank among reference areas was 2.94; the mean among all disposal areas was 2.67 (Tables 3-2 and 3-4; Figure 3-22). The results for the normality test indicated that the area residuals were different from a normal distribution (Shapiro-Wilk's test p-value = 0.0003). However, Levene's test for equality of variances was not rejected (p = 0.15). Consequently, the confidence intervals for these successional stage difference equations were constructed with bootstrapped non-parametric estimates using pooled variance estimates for each group.

The confidence regions for the differences between the mean maximum successional stage rank of the pooled reference areas (2.94) versus Cell 3AR (2.92) and versus Cell 4R (2.90) were both contained within the interval [-0.5, +0.5] (Tables 3-2 and 3-4), indicating that the maximum successional stage ranks at Cells 3AR and 4R were statistically equivalent to the pooled reference areas. The confidence regions for the differences between the mean maximum successional stage rank of the reference areas (2.94) versus Cell 5R (2.60) and versus Cell 6/7R (2.20) were not fully contained within the interval [-0.5, +0.5] (Tables 3-2 and 3-4), indicating the successional stage ranks at these two cells were statistically inequivalent from the reference areas. The conclusion was that the maximum successional stage ranks at Cells 3AR and 4R were similar to the reference areas, while Cells 5R and 6/7R were significantly different from the reference areas.

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Table 3-1.

Summary of PRCAD and Reference Area Sediment Profile and Plan View Imaging Physical Results, October 2020

	PRCAD Cells					Reference Areas	
	1R	**3AR**	**4R**	**5R**	**6/7R**	**REF-North**	**REF-South**
Number of Stations	1	6	5	5	5	4	4
Mean Water Depth (m)	15.1	15.9	13.1	15.1	14.2	12.8	13.6
Sediment Type (SPI) (# stations)	Silt/clay (1)	Silt/clay over very fine sand (2); Silt/clay (4)	Silt/clay (5)	Silt/clay (5)	Silt/clay (5)	Silt/clay (4)	Silt/clay (4)
Mean Prism Penetration (Std Dev) (cm)	9.8[1]	12.3 (3.0)	15.3 (0.5)	15.7 (0.9)	15.5 (0.8)	15.8 (2.4)	12.9 (4.3)
Mean Boundary Roughness (Std Dev) (cm)	0.7[1]	1.0 (0.3)	0.8 (0.2)	0.8 (0.2)	1.3 (0.6)	1.2 (0.3)	1.1 (0.6)

N/A=Not Applicable
[1]No standard deviation (n=1)

Table 3-2.

Summary of PRCAD Reference Area Sediment Profile and Plan View Imaging Biological Results, October 2020

	PRCAD Cells					Reference Areas	
	1R	**3AR**	**4R**	**5R**	**6/7R**	**REF-North**	**REF-South**
Number of Stations	1	6	5	5	5	4	4
Stations with Low Dissolved Oxygen (%)	100%	17%	40%	100%	60%	25%	0%
Sediment Oxygen Demand Level (# stations)	High (1)	Medium (1); High (5)	High (5)	High (5)	High (5)	Medium (1); High (3)	High (4)
Mean aRPD Depth (Std Dev) (cm)	0.29[1]	0.53 (0.16)	0.28 (0.07)	0.17 (0.22)	0.23 (0.19)	0.48 (0. 36)[2]	0.55 (0.39)[2]
Stations with Methane Present (SPI) (%)	100%	0%	60%	80%	20%	25%	0%
Stations with *Beggiatoa* (SPI and/or PV) (%)	100%	50%	100%	100%	100%	75%	75%
Beggiatoa Extent (PV) (# stations)	Trace (1)	Trace (2); Patches(1)	Trace (4); Mat (1)	Trace (2); Patches (2); Mat (1)	Patches (5)	Trace (2); Mat (1)	Trace (2); Patches (1)
Mean Number of Subsurface Feeding Voids (Std Dev)	0.0[1]	0.7 (0.5)	1.1 (0.7)	1.7 (1.5)	0.5 (0.7)	0.5 (0.4)	1.3 (1.0)
Mean Minimum Void Depth (Std Dev) (cm)	N/A[1]	6.5 (1.2)	5.5 (1.8)	5.7 (1.9)	5.9 (2.8)	6.5 (1.7)	4.1 (2.5)

	PRCAD Cells					Reference Areas	
	1R	**3AR**	**4R**	**5R**	**6/7R**	**REF-North**	**REF-South**
Mean Maximum Void Depth (Std Dev) (cm)	N/A[1]	12.1 (7.1)	9.7 (2.4)	9.5 (1.4)	7.7 (4.8)	9.1 (4.2)	6.3 (2.7)
Predominant Successional Stage (SPI) (# stations)[3]	2 (1)	2 -> 3 (1); 2 on 3 (3); Varies (2)	2 (2); 2 -> 3 (1); 2 on 3 (1); Varies (1)	2 (2); 1 on 3 (2); 1 -> 2 (1)	1 (2); 2 (1); 2 on 3 (1); Varies (1)	1 (1); 2 -> 3 (1); 2 on 3 (1); Varies (1)	2 -> 3 (1); 2 (1); 1 on 3 (1); Varies (1)
Mean of Maximum Successional Stage Rank (Std Dev)	2.00[1]	2.92 (0.20)	2.90 (0.22)	2.60 (0.65)	2.20 (1.10)	2.88 (0.25)[4]	3.00 (0.00)[4]

N/A=Not Applicable
Std Dev = Standard Deviation
[1]No standard deviation (n=1)
[2]Reference areas aRPD grand mean of 0.52 (0.25) used in the statistical inequivalence test
[3]Successional Stage: "on" indicates one Stage is found on top of another Stage (i.e. 1 on 3); "->" indicates one Stage is progressing to another Stage (i.e., 2 -> 3)
[4]Reference areas Maximum Successional Stage Rank grand mean of 2.94 (0.18) used in the statistical inequivalence test

Table 3-3.

Summary Statistics and Results of Inequivalence Hypothesis Testing for aRPD Values

Difference Equation	Observed Difference ($\hat{d}$)	SE $\hat{d}$	*df* for SE	Confidence Bounds (D_L to D_U)[1]	Results[2]	n (REF)	n (CAD)
$Mean_{REF} - Mean_{CAD3AR}$	-0.02	0.09	12	-0.18 to 0.14	s	8	6
$Mean_{REF} - Mean_{CAD4R}$	0.23	0.07	11	0.11 to 0.36	s	8	5
$Mean_{REF} - Mean_{CAD5R}$	0.35	0.12	11	0.14 to 0.56	s	8	5
$Mean_{REF} - Mean_{CAD6/7R}$	0.29	0.10	11	0.10 to 0.47	s	8	5

[1] D_L and D_U as defined in [Eq. 3]
[2] s = Reject the null hypothesis of inequivalence: the two group means are significantly equivalent, within ± 1 cm.
d = Fail to reject the null hypothesis of inequivalence between the two group means, the two group means are different.

Table 3-4.

Summary Statistics and Results of Inequivalence Hypothesis Testing for Maximum Successional Stage Rank Values

Difference Equation	**Observed Difference ($\hat{d}$)**	**SE $\hat{d}$**	***Number of Bootstrap Replicates***	**Confidence Bounds (D_L to D_U)[1]**	**Results[2]**	**n (REF)**	**n (CAD)**
$Mean_{REF} - Mean_{CAD3AR}$	0.02	0.10	10000	0.00 to 0.15	s	8	6
$Mean_{REF} - Mean_{CAD4R}$	0.04	0.11	10000	0.00 to 0.18	s	8	5
$Mean_{REF} - Mean_{CAD5R}$	0.34	0.27	10000	-3.11 to 0.75	d	8	5
$Mean_{REF} - Mean_{CAD6/7R}$	0.74	0.44	10000	-10.61 to 1.62	d	8	5

[1] D_L and D_U as defined in [Eq. 3]
[2] s = Reject the null hypothesis of inequivalence: the two group means are significantly equivalent, within ± 1 cm.
d = Fail to reject the null hypothesis of inequivalence between the two group means, the two group means are different.

4.0 DISCUSSION

The objectives of the 2020 PRCAD survey were to characterize the topography and surficial features over all six CAD cells and to assess benthic recolonization status at PRCAD relative to the two reference areas. The topography and surficial features were characterized using high-resolution acoustic data. Finer-scale physical characteristics of the surficial sediments and the benthic recolonization status were assessed using SPI/PV imagery.

4.1 Remaining Capacity

The 2020 bathymetric measurements were used to calculate the remaining capacity of all six CAD cells under two scenarios: (1) filling to a depth of 12.8 m (42 ft) and (2) filling to a depth of 13.7 m (45 ft) (Figure 4-1 table inset). The current management strategy for PRCAD is to continue to fill the cells with unsuitable dredged material to a depth of 45 ft and then potentially cover the cells with a three-foot-thick cap layer of suitable dredged material to a final depth of 42 ft. A final depth of 42 ft allows for future dredging efforts above the cells to maintain the authorized channel depth of 40 ft plus two feet of allowable overdepth. Figure 4-1 provides remaining capacity (unsuitable material plus cap material) relative to a 42 ft depth and contains an inset of remaining capacity volumes in cubic yards for each cell to both depths.

Cell 3AR has the greatest remaining capacity with approximately 290,000 yd^3 remaining when filled to 42-ft depth and 190,000 yd^3 of that volume available for unsuitable material. The deepest areas of Cell 3AR, and therefore where future dredged material placement is recommended, are generally in the southwest corner, as well as in pockets along the southern boundary and eastern portion of the cell. Cell 5R has ~78,000 yd^3 of remaining capacity when filled to 42-ft depth with 53,000 yd^3 available for unsuitable material. Specifically, discrete areas in the northern and southern portions of Cell 5R, have the greatest capacity and are recommended for future disposal placement. Cell 6/7R has a remaining capacity of ~74,000 yd^3 but with existing depths extending just 3 to 4 ft below the target depth of 42 ft only 22,000 yd^3 of this capacity is available for unsuitable material. Cell 3R is consistently about 5 ft below the target depth of 42 ft, with a remaining capacity of ~26,000 yd^3 and approximately half of this volume available for unsuitable material. Cells 1R and 4R each have less than ~5,000 yd^3 of capacity remaining for unsuitable material, so additional dredged material placement in these cells should be limited to suitable material only.

4.2 Topography

The bathymetric data collected at PRCAD in 2020 showed clear distinction between the cells, the surrounding navigation channel, and edges of the shoals flanking the channel. There were several features of interest on the sediment surface revealed in the acoustic data, as discussed below.

Evidence of vessel-related scouring near the pier located on the western flank of the PRCAD survey area can be seen in various acoustic data layers (Figure 4-2). Stronger backscatter returns extended from the north side of this pier in a linear pattern through the northern portion of Cell 6/7R and continued into Cell 1R and the area between this cell and Cell 3R (Figure 4-2A). These stronger backscatter returns suggest coarser and/or more compact surficial sediment. Rough textures seen in the side-scan sonar mosaic further indicate relatively coarser material in these regions (Figure 4-2B). Decreases in elevation in and around Cell 1R are another line of evidence that indicates scouring of finer surficial sediment in this area (Figure 4-2C). Within Cell 1R, arcing depressions can be seen in the bathymetry and elevation change model which may be associated with vessels turning in this location. Taken together, the evidence suggests large vessel propellor related hydrodynamic forces have resulted in scouring soft sediments from the sediment surface in this specific area. Similar backscatter returns and trends in acoustic data were observed within the vicinity of other large piers flanking the PRCAD study area. Specifically, potential sediment scour related to vessel activity was also observed at the pier adjacent to the northwest corner of Cell 3AR and at the pier on the eastern side of Cell 3AR just north of the land-based dewatering site (Figure 3-3).

A small volcano-shaped mound was observed in the bathymetry to the east of Cell 5R (Figure 4-3). The steep mound formation rose nearly 2 m above the surrounding channel peaking at 10.1 m depth. A linear feature on the seabed traversing from the east of the mound terminated at the large crater in the middle of the mound. This feature appears to have been created by a dewatering discharge pipe that terminates at the volcano-shaped mound. The dewatering pipe was detected in side-scan sonar returns (Figure 4-3) and originates in a shore-side dredged material dewatering area situated immediately to the east.

4.3 Physical Sediment Characteristics at PRCAD Cells and the Surrounding Channel

The sediments within PRCAD were generally similar in physical characteristics to the sediments in the two reference areas. Both PRCAD and reference sediments were predominantly composed of silt/clay with very low load-bearing capacity. The characteristics of these soft sediments are typical of shallow estuarine environments within an urban setting. Previous surveys in this area have documented similar observations, including the 2009 and 2015 PRCAD surveys (USACE 2012; Carey and Sturdivant 2017).

Despite the historical dredged material placement events throughout PRCAD, SPI and PV revealed little evidence of distinct non-native material at the cells.

Unlike offshore DAMOS disposal sites, dredged material placed at PRCAD was indistinguishable from subsurface sediments and reference area sediments, likely due to the origins of the material. The dredged material that has been placed in these cells has largely been sourced from either the PRCAD construction itself, or from other areas within the Providence River and Providence Harbor. As such, the dredged material placed at this site generally has similar sediment characteristics as those of the surrounding background sediments documented at the reference areas.

4.4 Benthic Recolonization and Community Composition

The biological attributes observed in the SPI and PV images in 2020 suggest the benthic communities at both PRCAD and the reference areas were generally stressed or disturbed. High sediment oxygen demand was noted across the disposal site as well as at both reference areas. This was inferred by the very dark colored sediments, very shallow aRPD depths, prevalence of methane in the sediment column, frequent occurrences of sulfide-oxidizing bacteria (*Beggiatoa*) on the sediment surface, and limited evidence of bioturbation (voids and burrows). Given the similarities in these biological features at PRCAD and the reference areas, the stressors on the benthic communities are likely sourced from several factors, and not solely due to the disturbance created through dredged material placement activity.

The surveyed area is located within a highly urban environment with high vessel traffic and urban runoff, which contribute to the overall stressed benthic environment. Within this urban context, high densities of tube-building surface fauna, particularly

Ampelisca sp. were commonly observed across the surveyed area. An increase in the prevalence (>5-fold increase from 1988 to 2008) of these tubicolous amphipods within Narragansett Bay, particularly in the more urban, anthropogenically-stressed Providence River estuary were recently documented (Shumchenia et al. 2016).

The maximum infaunal successional stages averaged by survey area revealed some differences in the recolonization patterns of the benthic communities at PRCAD relative to the reference stations. Maximum infaunal successional stage ranks documented at Cell 3AR and Cell 4R were similar to the reference areas, with Stage 3 taxa frequently observed across these areas (generally observed as Stage 2 on 3) (Figures 3-15 and 3-22). While at Cell 5R and Cell 6/7R, the maximum successional stage ranks were significantly lower than the reference areas. Cell 6/7R received dredged material within the past five years, as revealed by the elevation difference between 2015 and 2020 bathymetry (Figure 3-6), which may have contributed to the lower successional stage ranks in this cell. Additionally, evidence of frequent vessel-induced sediment scour was observed in the northern portion of Cell 6/7R, and may contribute to the lower successional stage in this area, particularly at Station 07. Cell 5R did not receive dredged material in the past five years, with no elevation change observed since 2015 (Figure 3-6). This cell is one of the deepest at PRCAD, ranging from 15 to 17 m deep. Water circulation near the sediment surface within Cell 5R, particularly in the two deep basins (17 m), may be limited due to its depth below the surrounding area, which may lead to stagnant water and reduced oxygen levels, locally. This lack of flushing may be contributing to the low colonization of Stage 3 fauna in Cell 5R.

In summary, the physical and benthic conditions within the cells at PRCAD were generally similar to the reference areas. The benthic habitat across the surveyed area, at both the PRCAD and reference areas, appeared stressed, with high sediment oxygen demand and patchy Stage 3 infauna. The highly urban setting likely contributed to these conditions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The October 2020 SPI/PV survey and September/October acoustic multibeam survey were conducted to collect data about the status of the surficial sediments and the health of the benthic communities at PRCAD. The overall findings were:

- Cell 3AR has the greatest remaining capacity with approximately 290,000 yd^3, followed by Cells 5R and 6/7R that have 78,000 and 74,000 yd^3 remaining, respectively. Cells 3R, 1R and 4R have little remaining capacity.
- The benthic habitat at both the PRCAD cells and the reference areas was characteristic of an urban estuarine environment, with high sediment oxygen demand and limited bioturbation.
- The biological communities were generally similar between PRCAD and the reference areas, although the communities at Cell 5R and Cell 6/7R were less advanced.

The results of the 2020 survey led to the following recommendations:

R1: Future dredged material placement should be targeted to the southwest corner and the deeper pockets along the southern boundary of Cell 3AR, and the two deep basins in the northern and southern areas of Cell 5R. Lesser volumes of dredged material may be placed in other PRCAD cell areas.

R2: Due to potential scouring from vessel activity, additional placement of unsuitable dredged material in Cell 1R and the northern portion of Cell 6/7R should be avoided.

R3: At this time, the SPI and PV data suggest that the biological community is recolonizing at PRCAD, with similar communities present compared with the reference areas. As a result, capping the cells does not appear to be necessary to provide suitable habitat conditions.

R4: More detailed documentation of dredged material placement including the origins, quantity, and disposal locations (i.e., cell) should be recorded.

R5: Future monitoring surveys should ensure that sampling at the REF-North area is conducted within the dredged navigation channel but not along the steep slope at the northern boundary of the channel.

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CONTRIBUTION #211

October 2021

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Contract No. W912WJ-19-D-0010
Delivery Order W912WJ19F0126

Funded and Managed by:
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Prepared by:
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Newport, RI 02840

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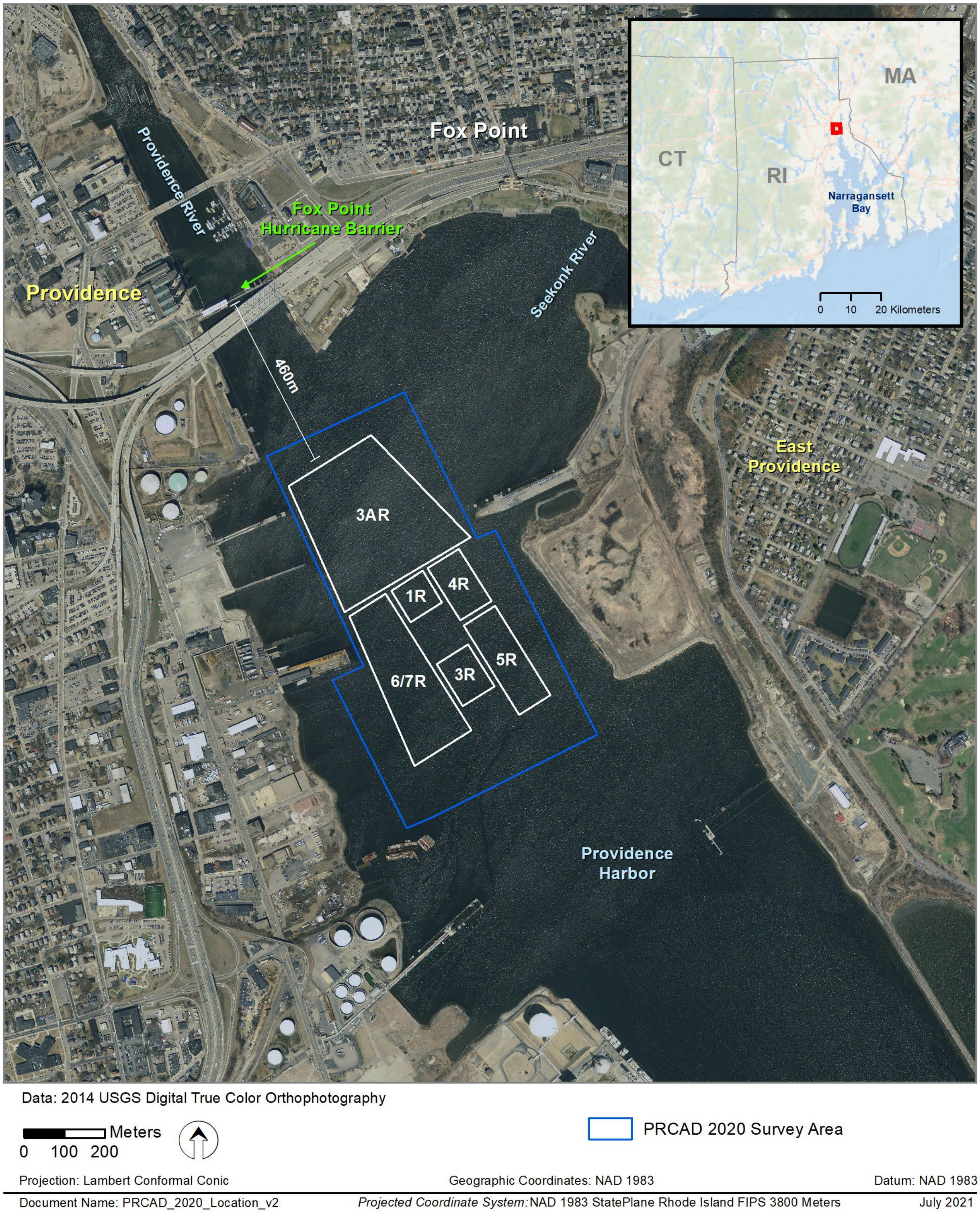

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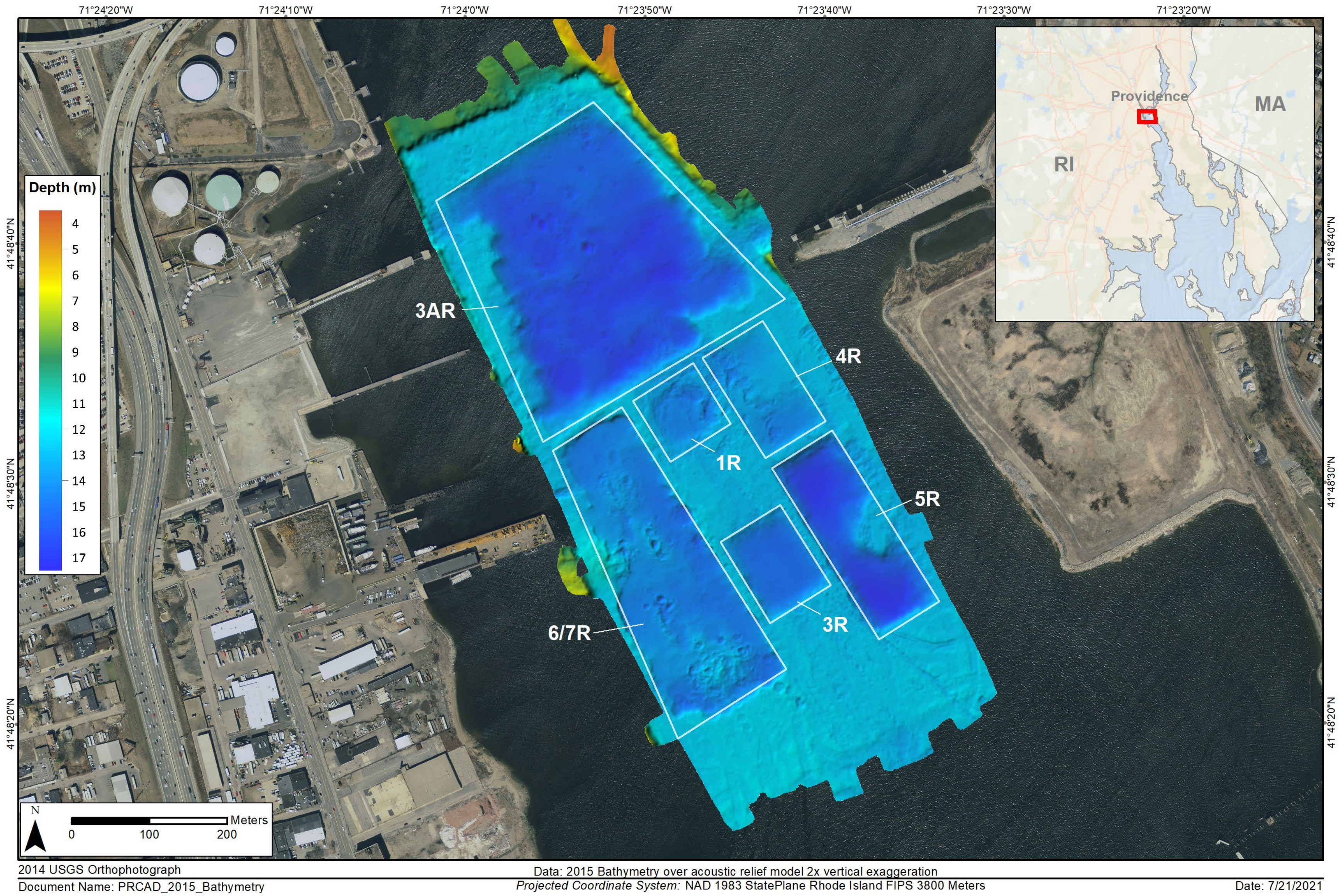

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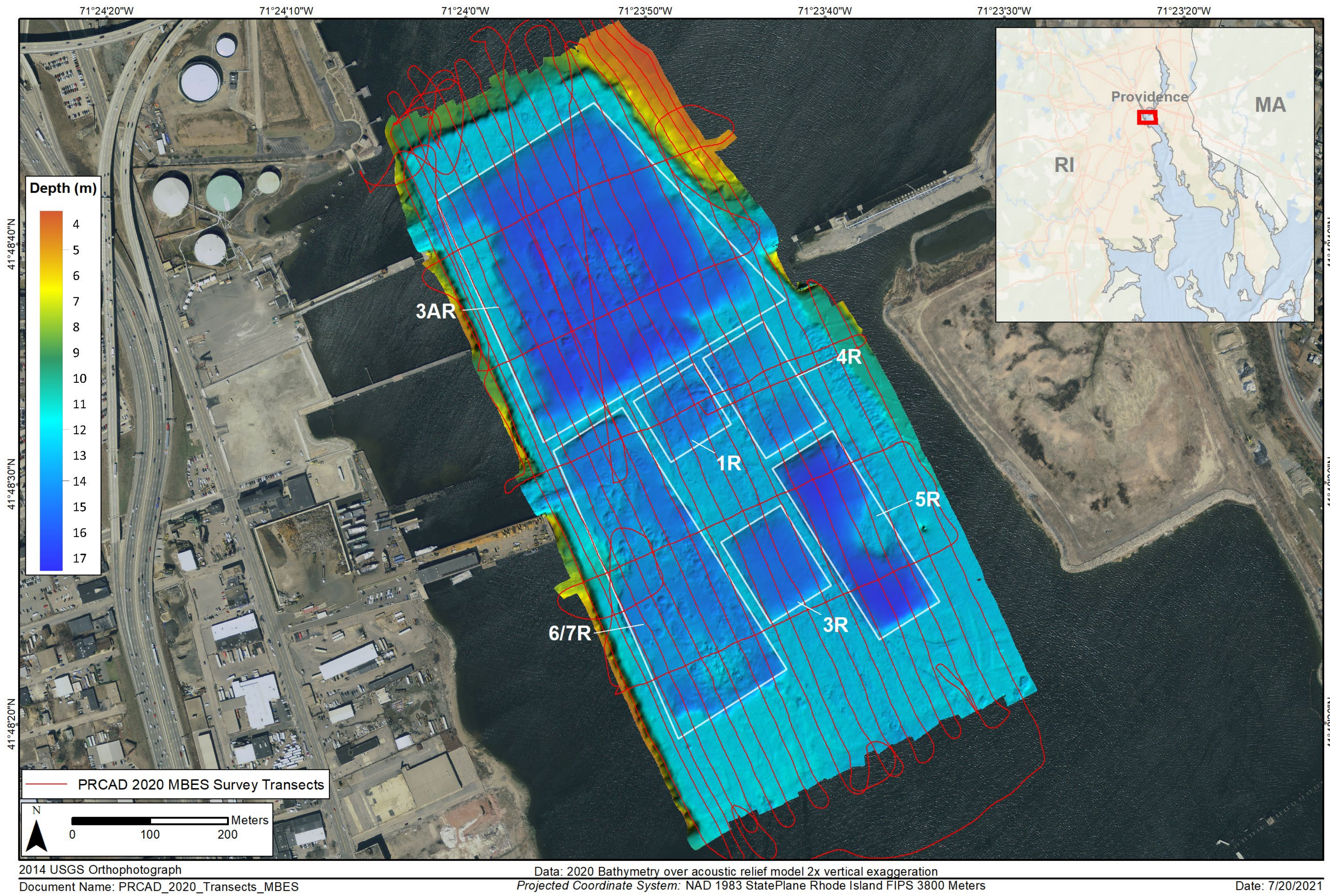

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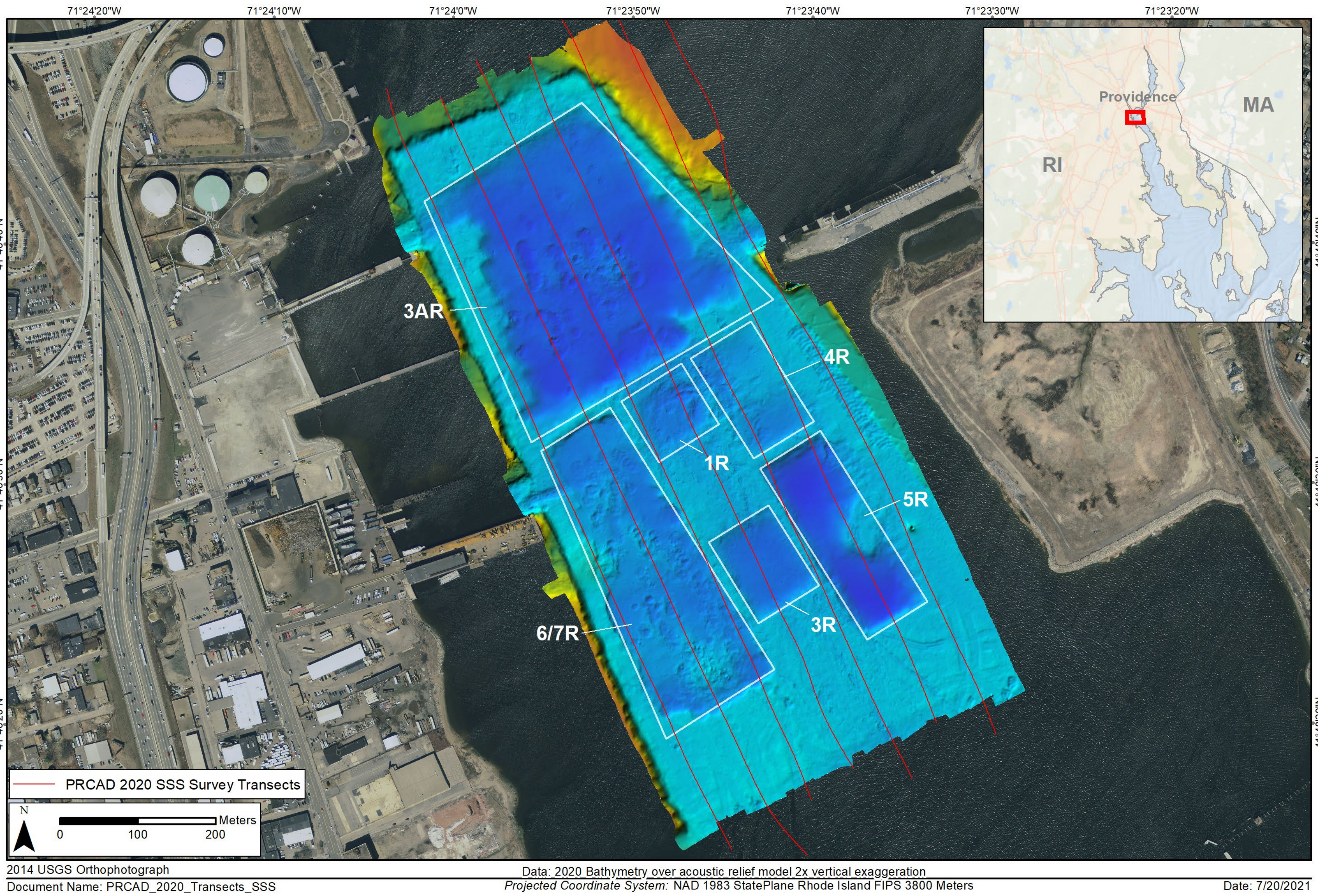

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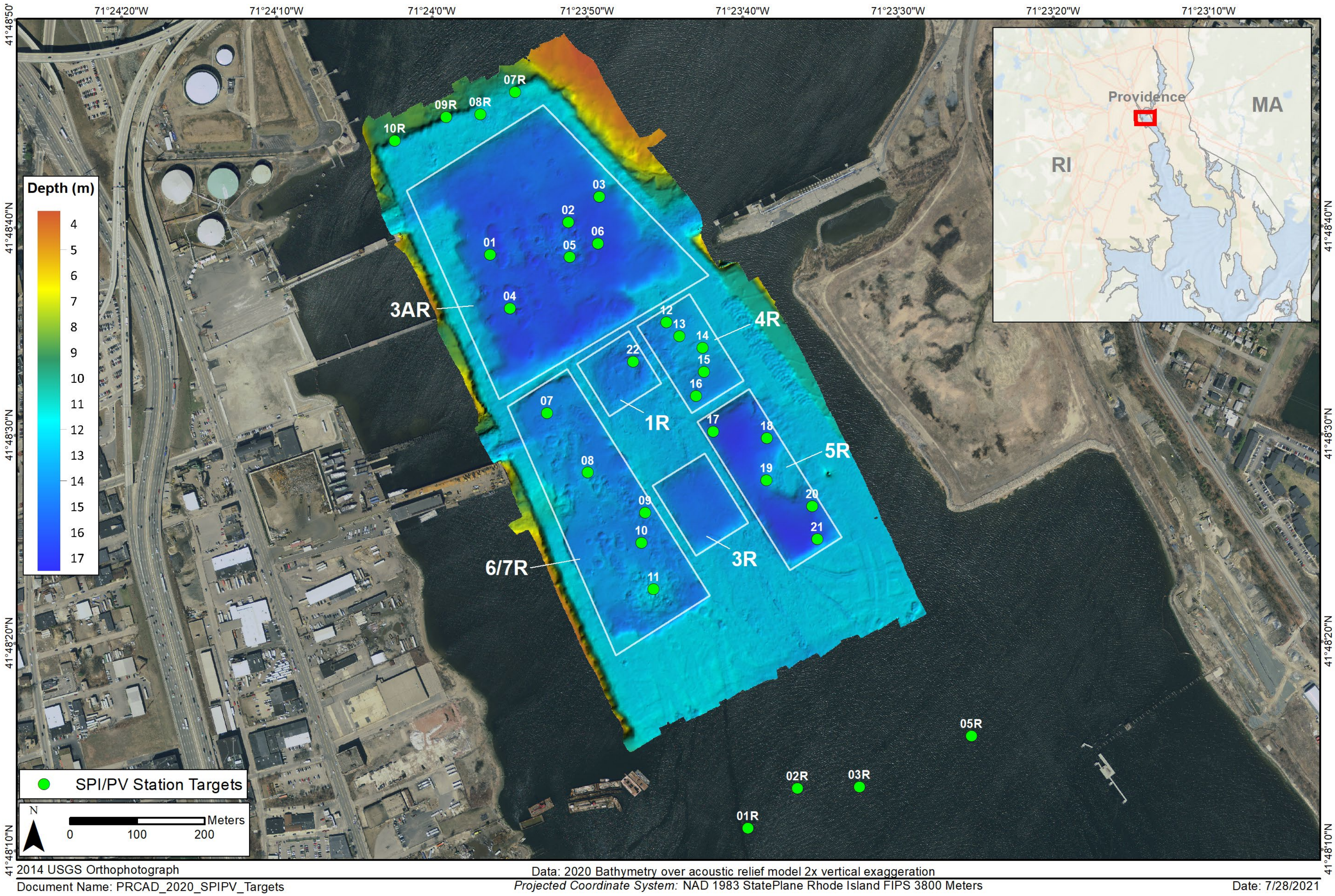

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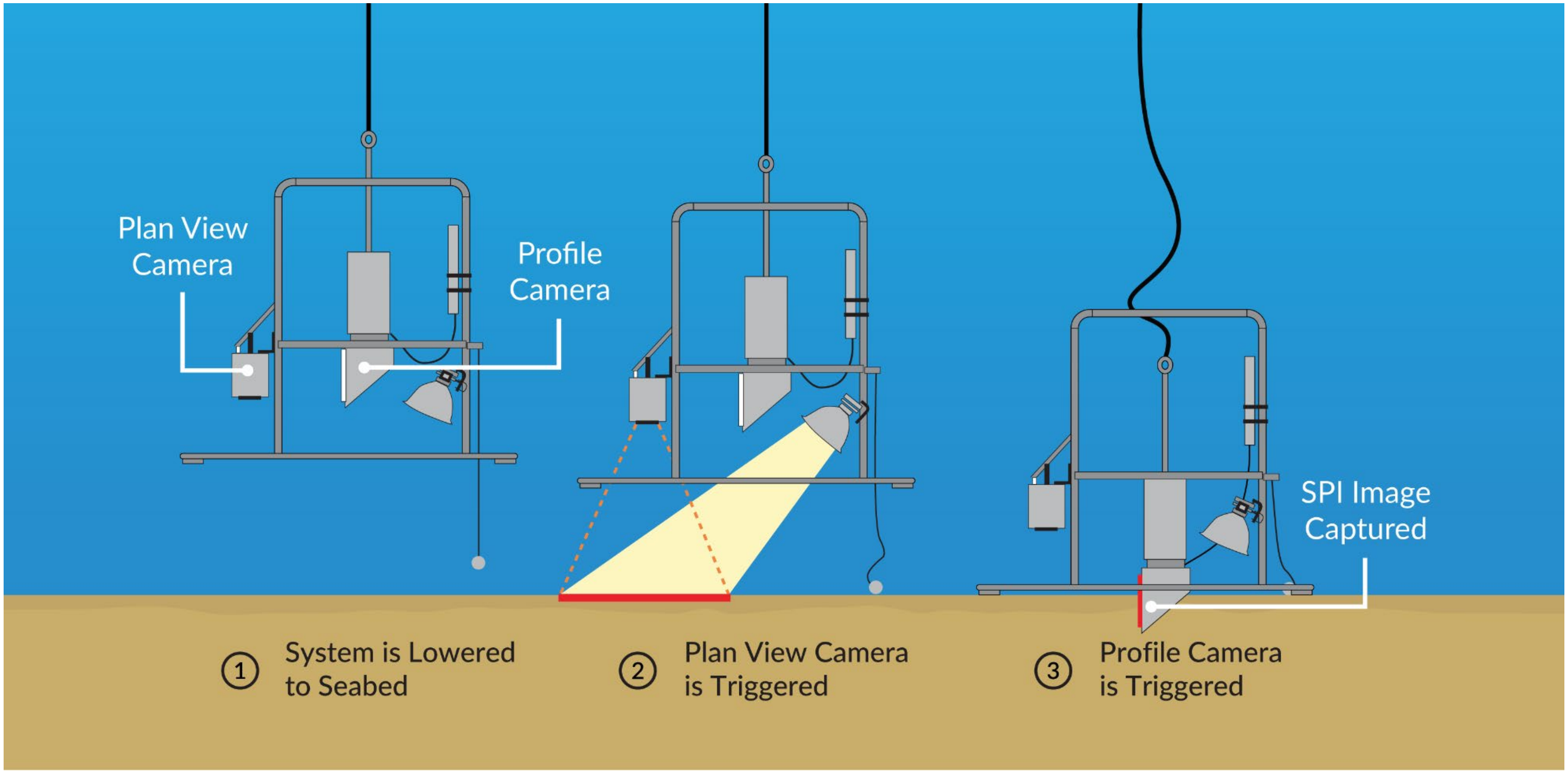

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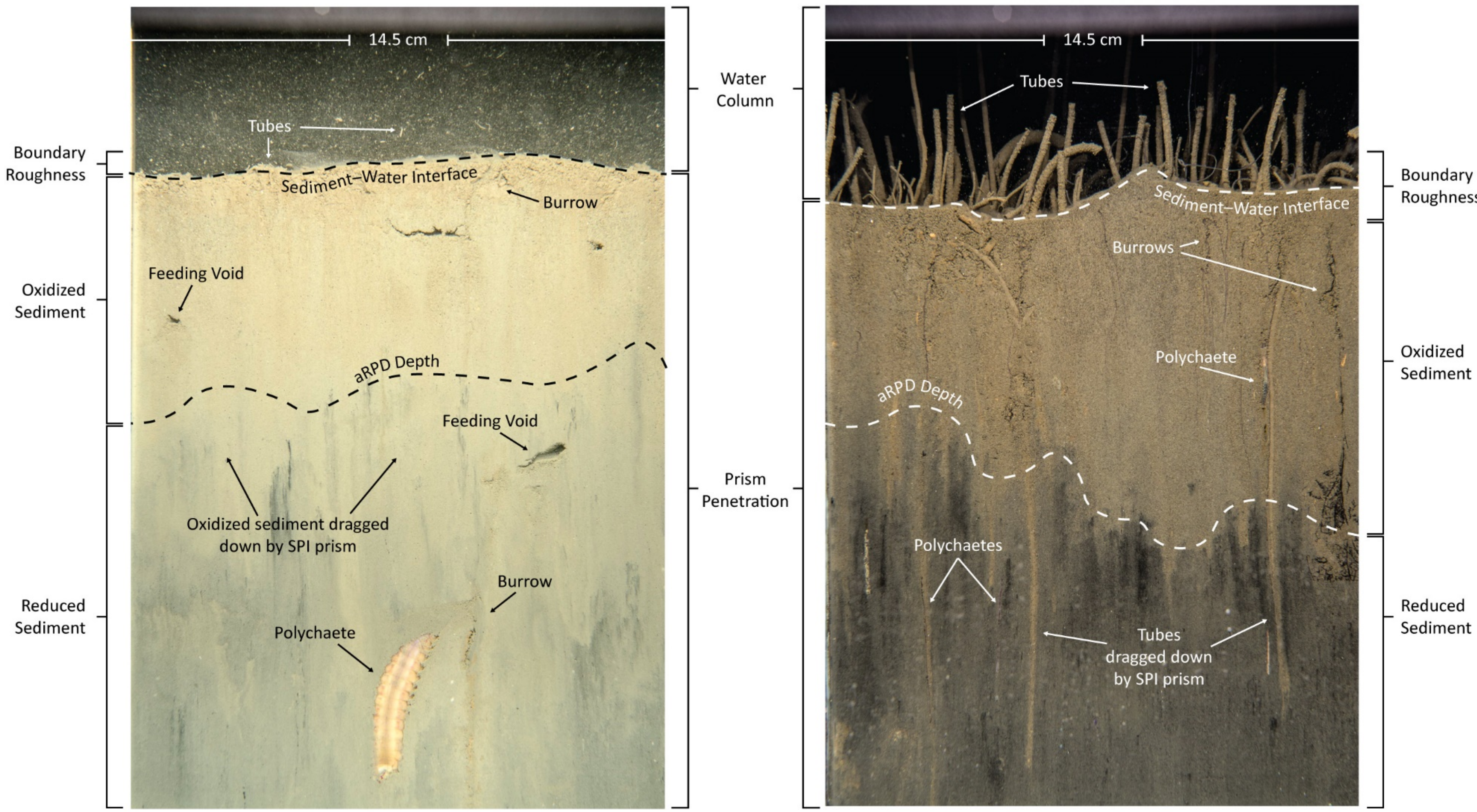

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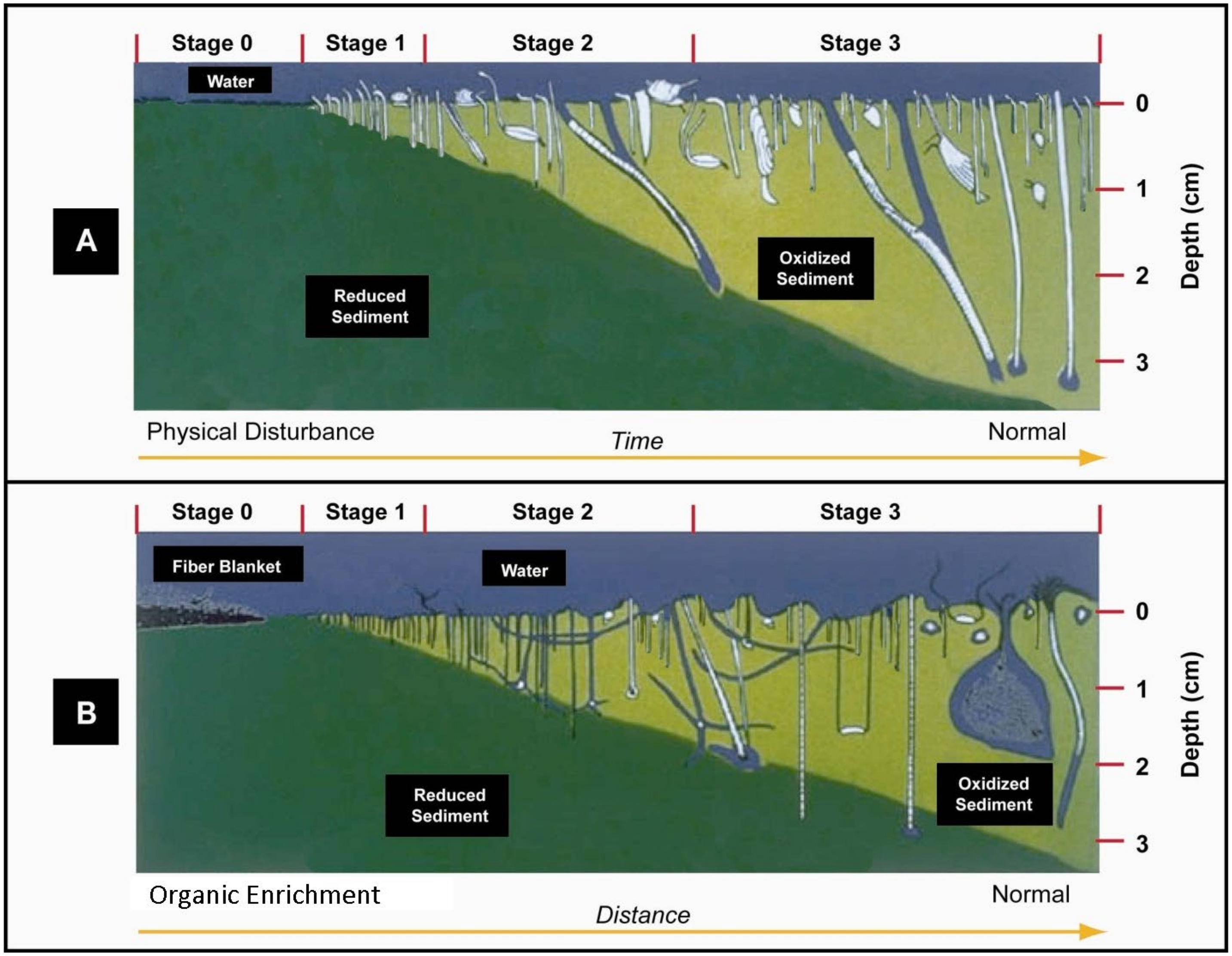

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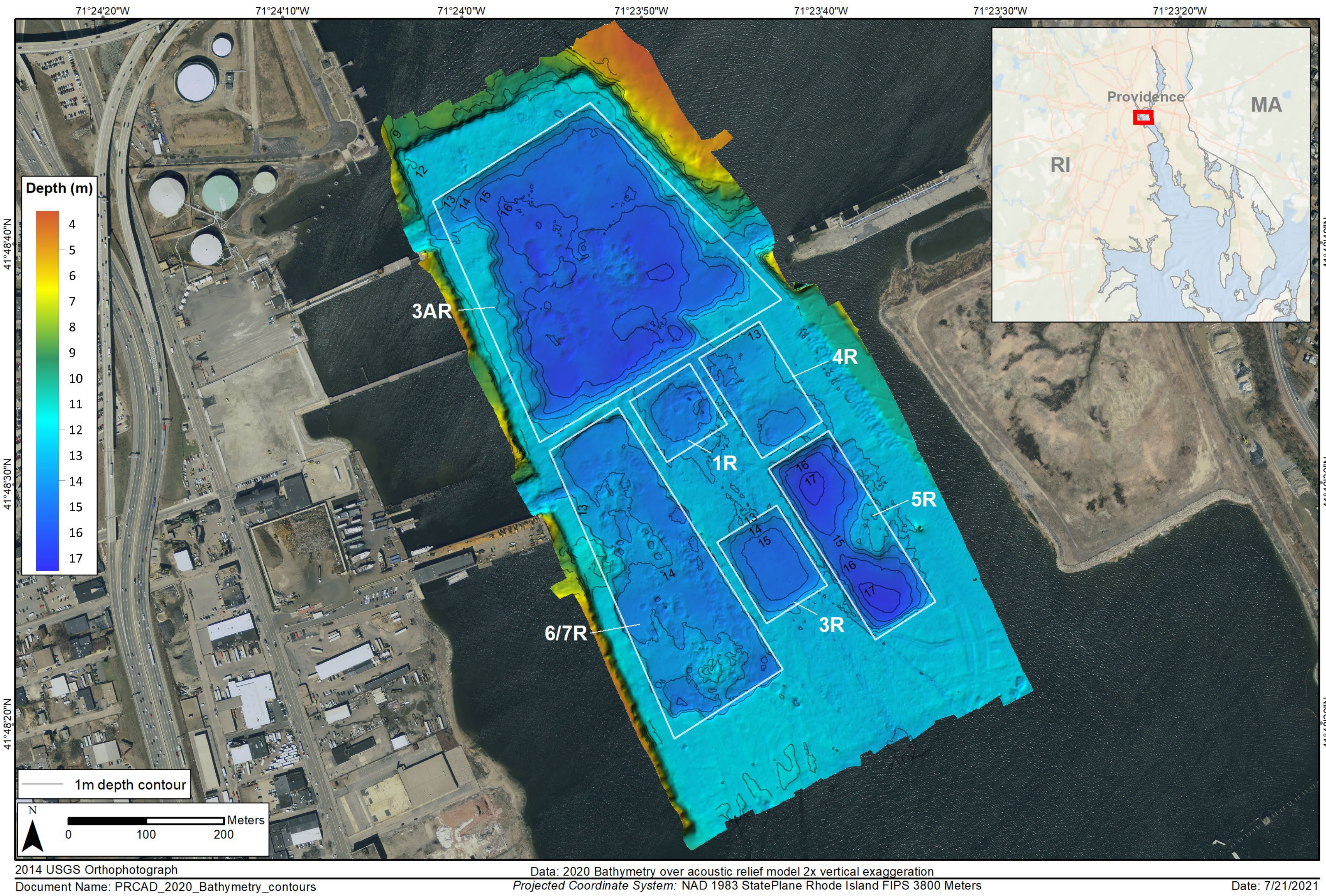

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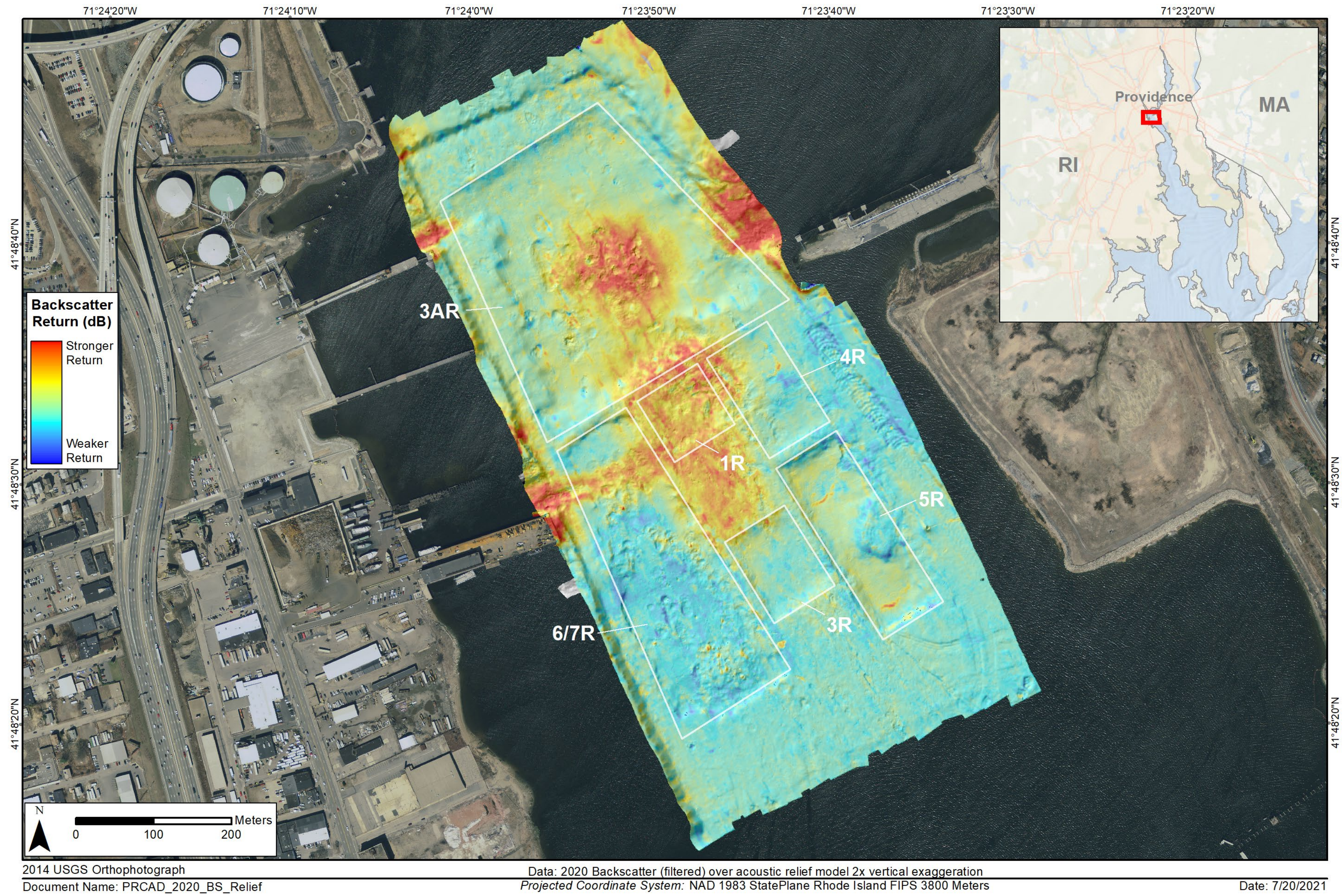

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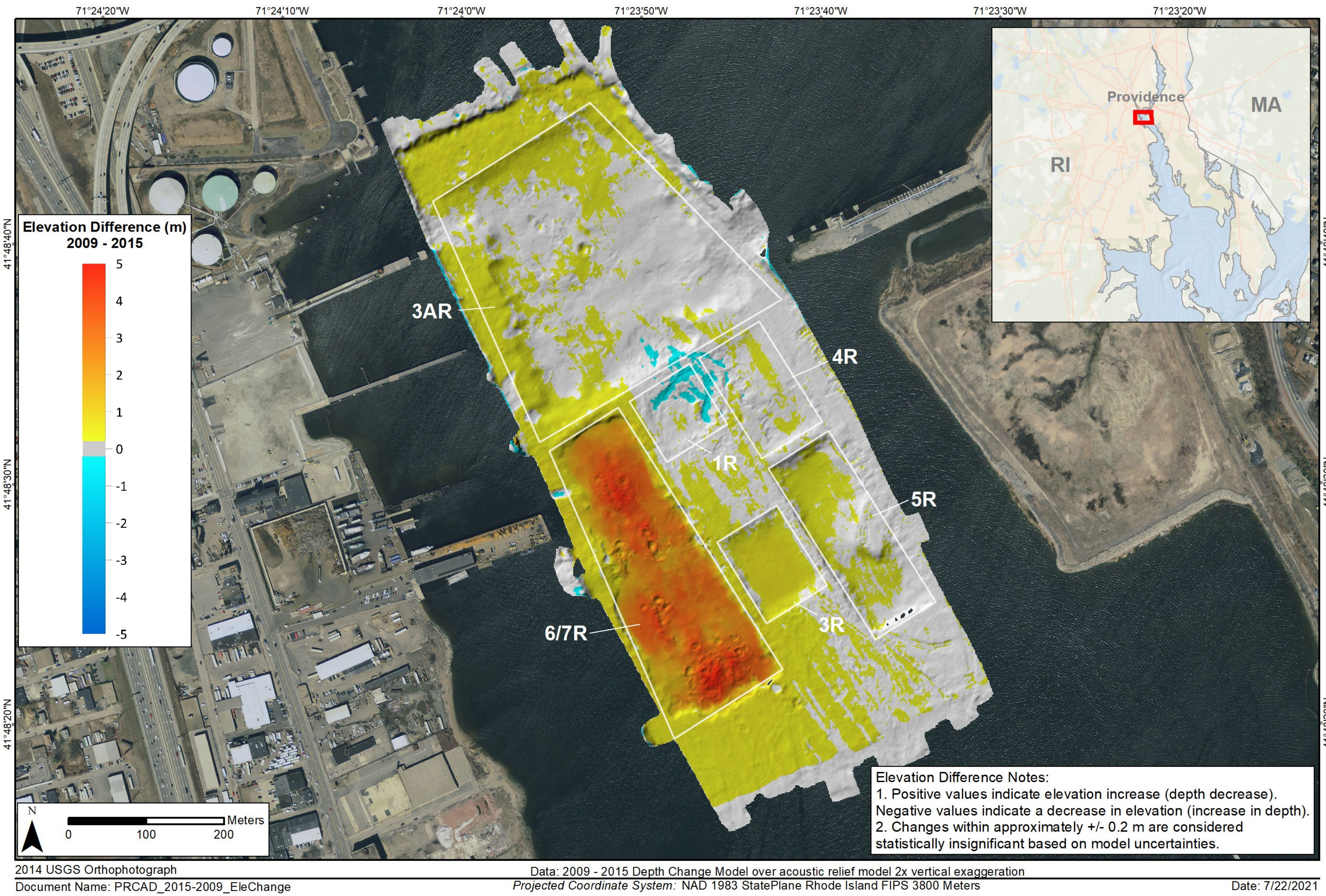

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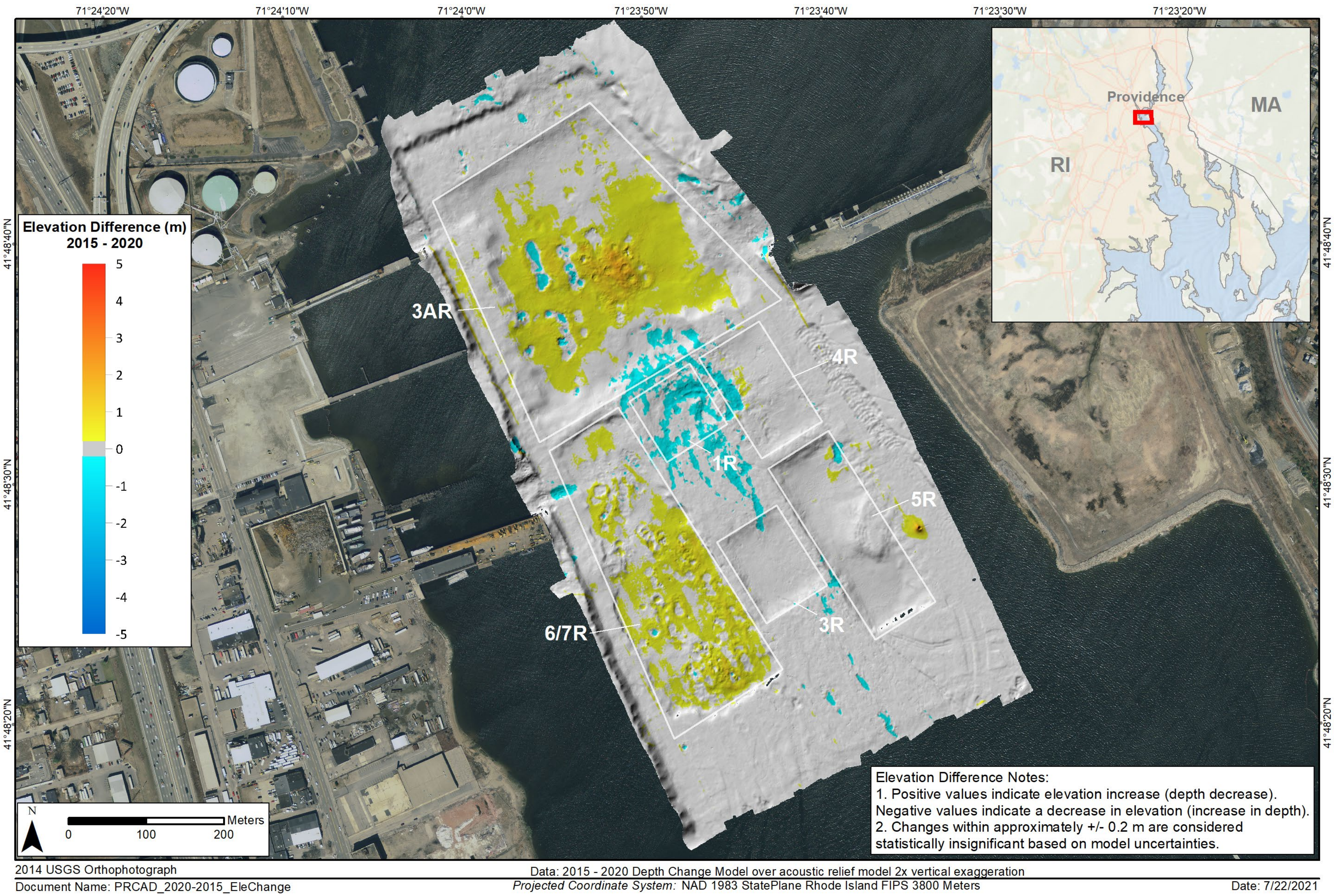

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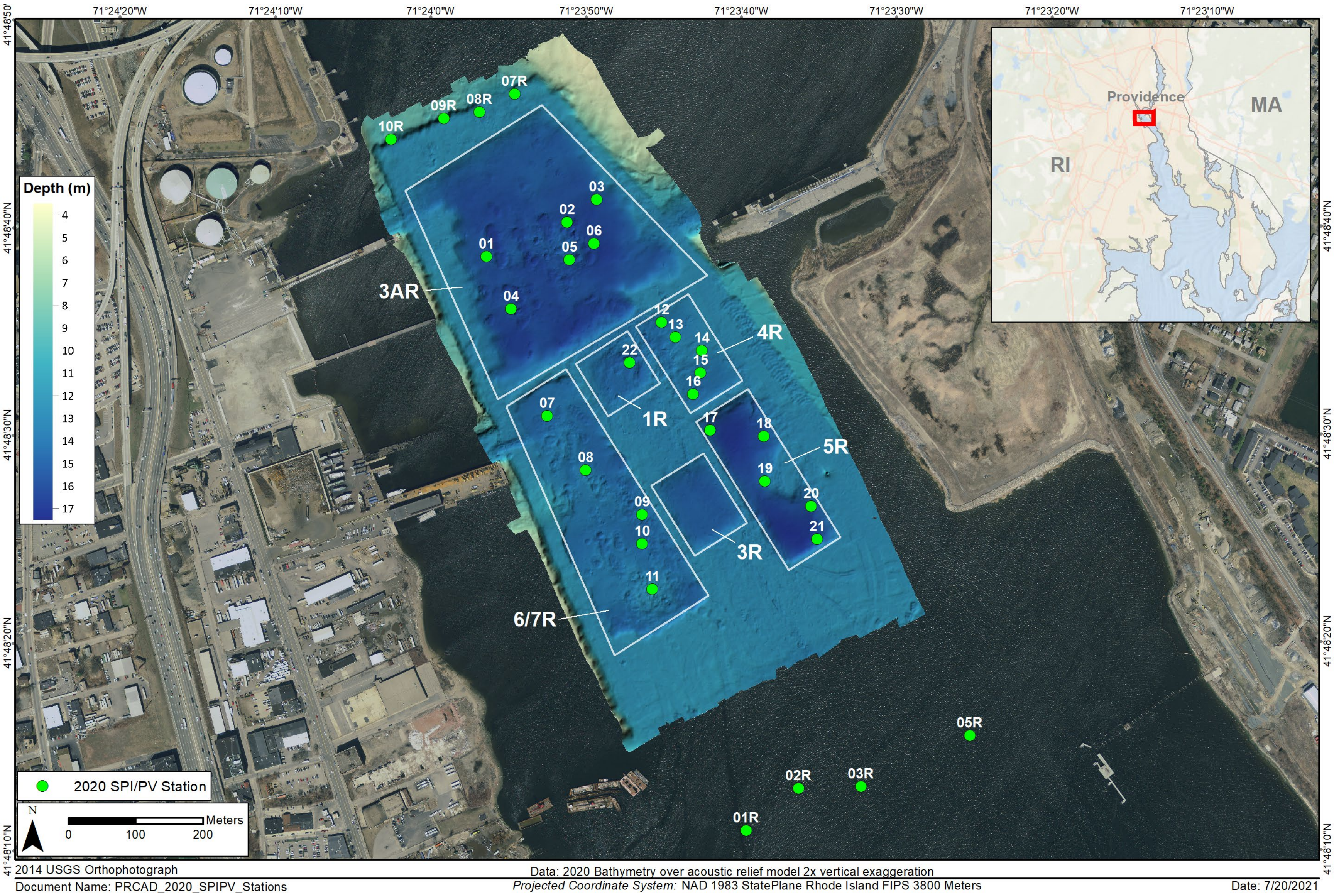

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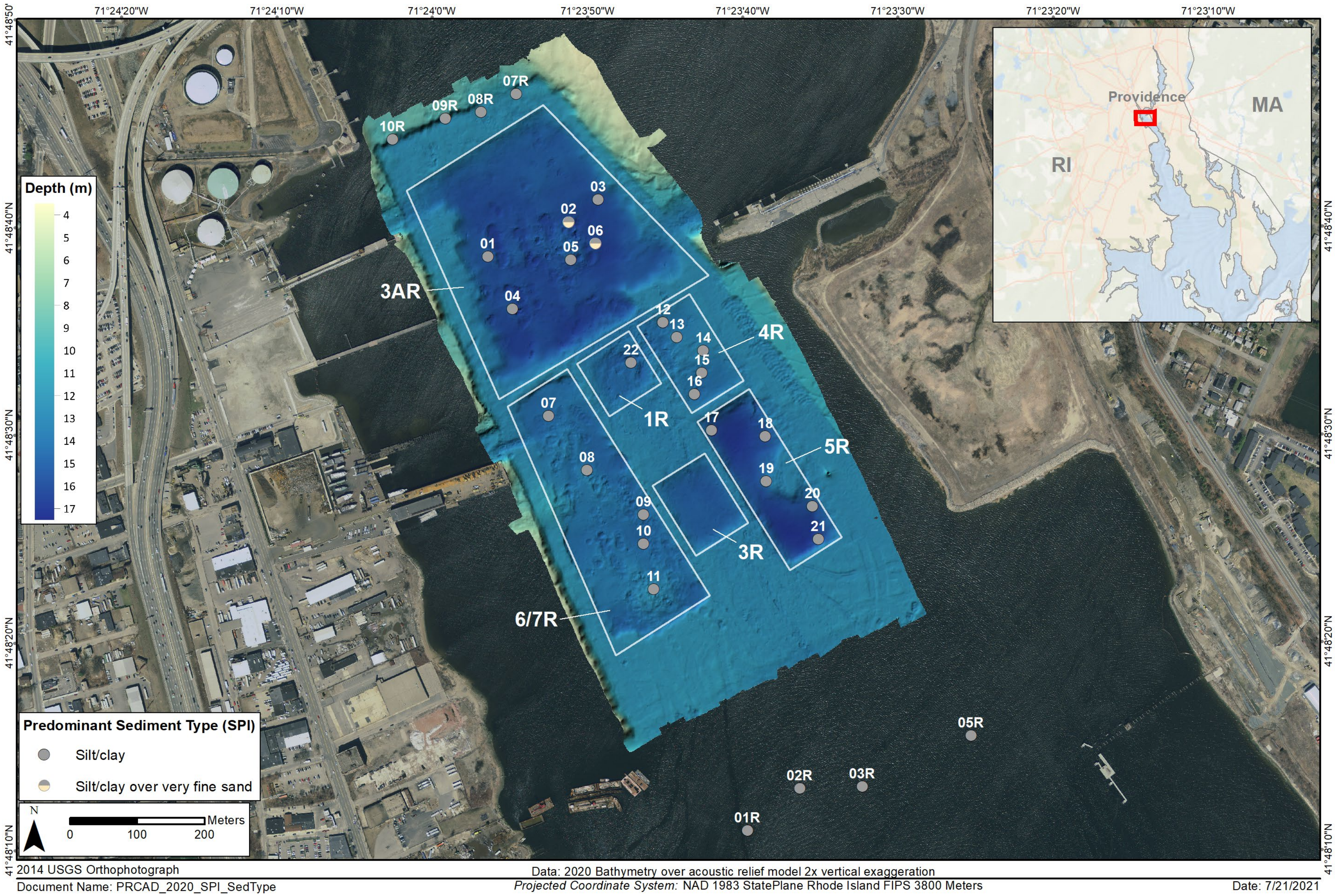

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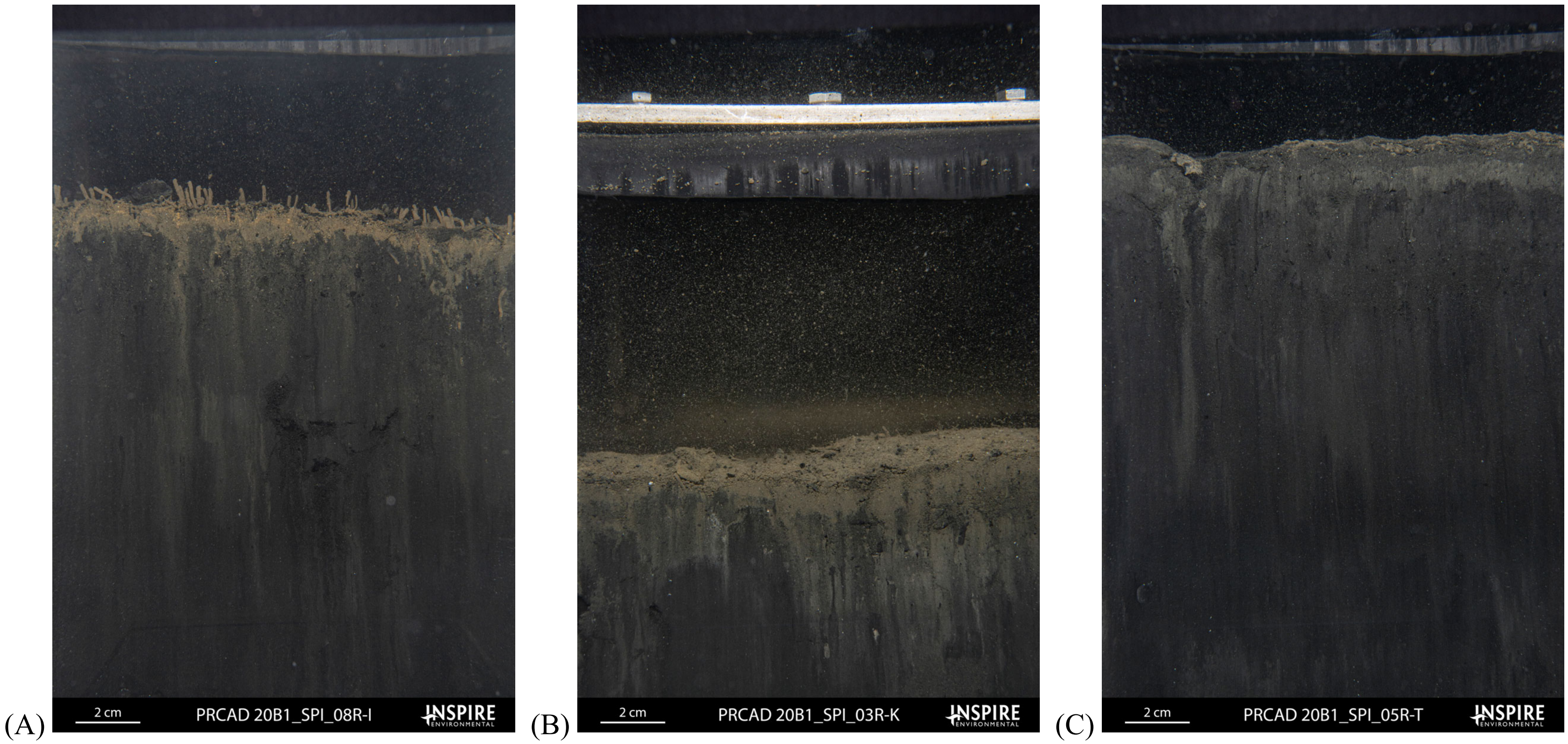

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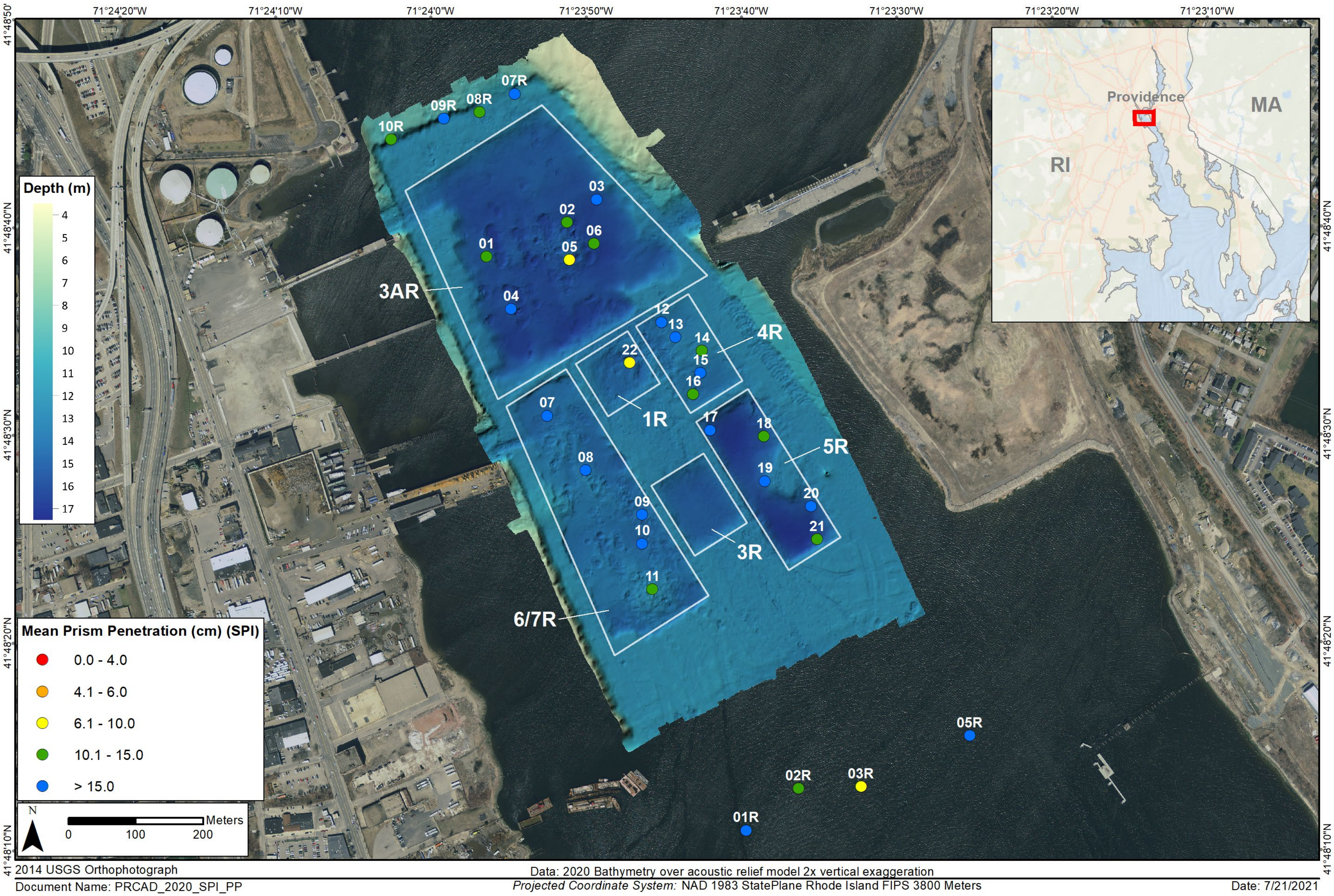

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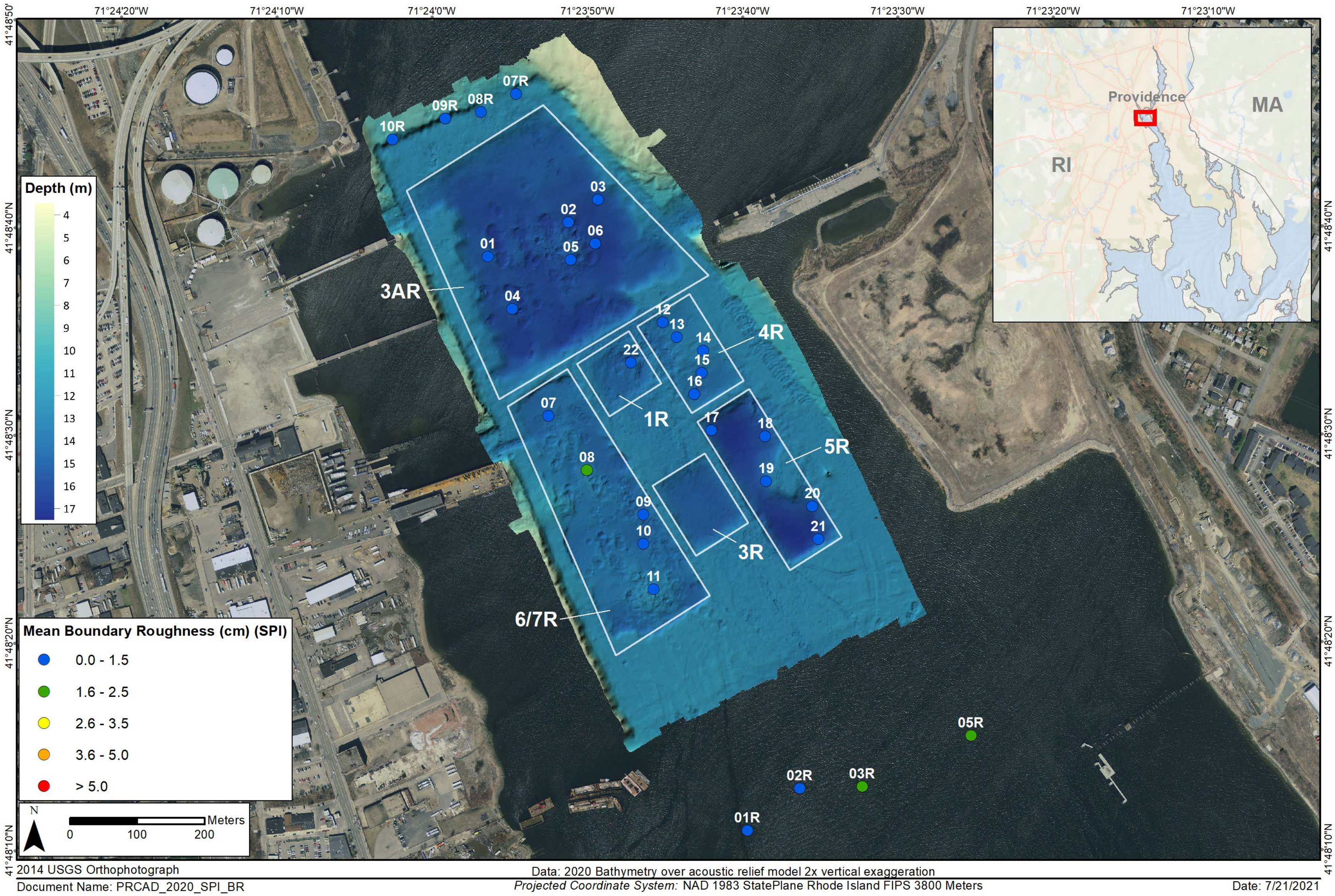

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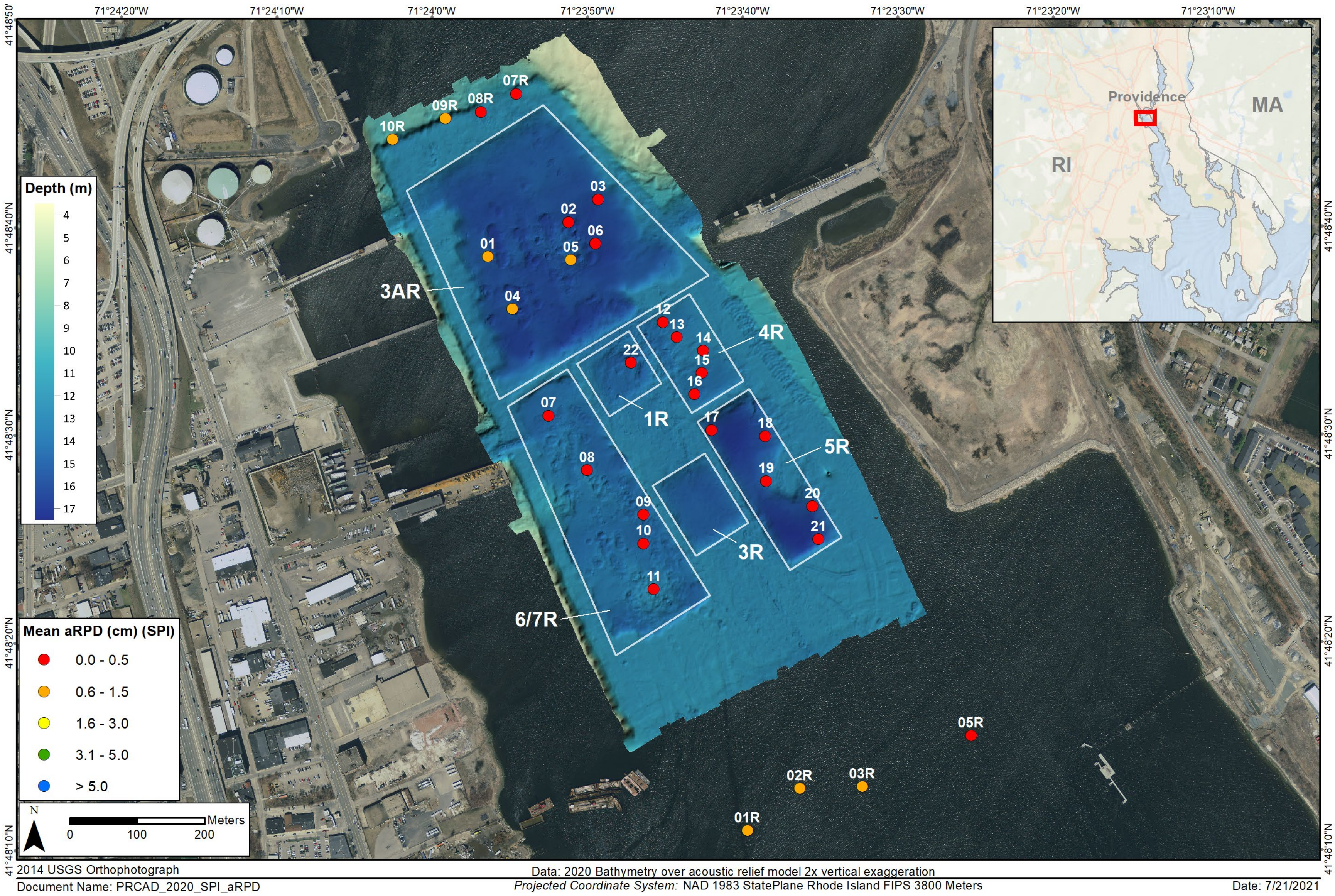

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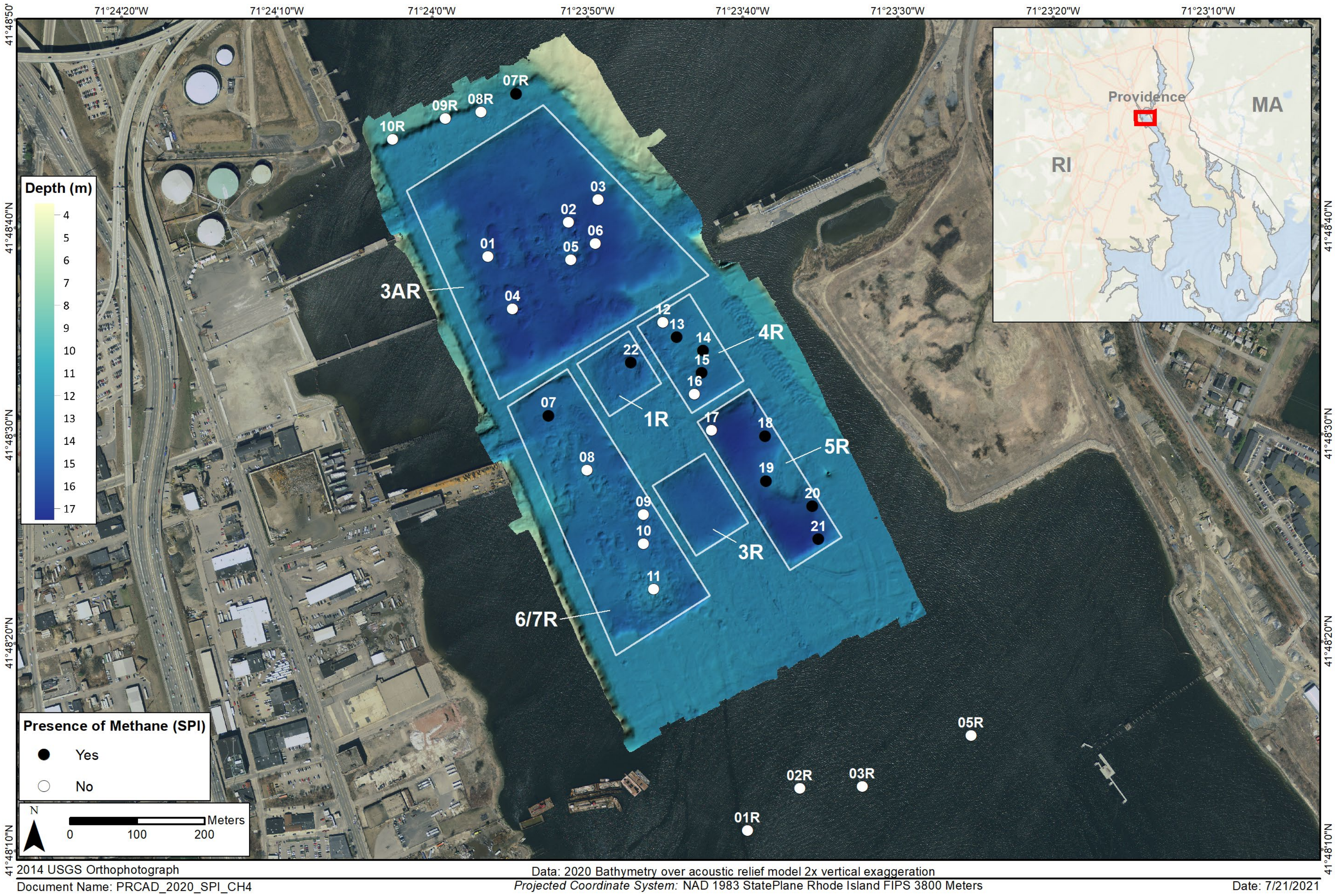

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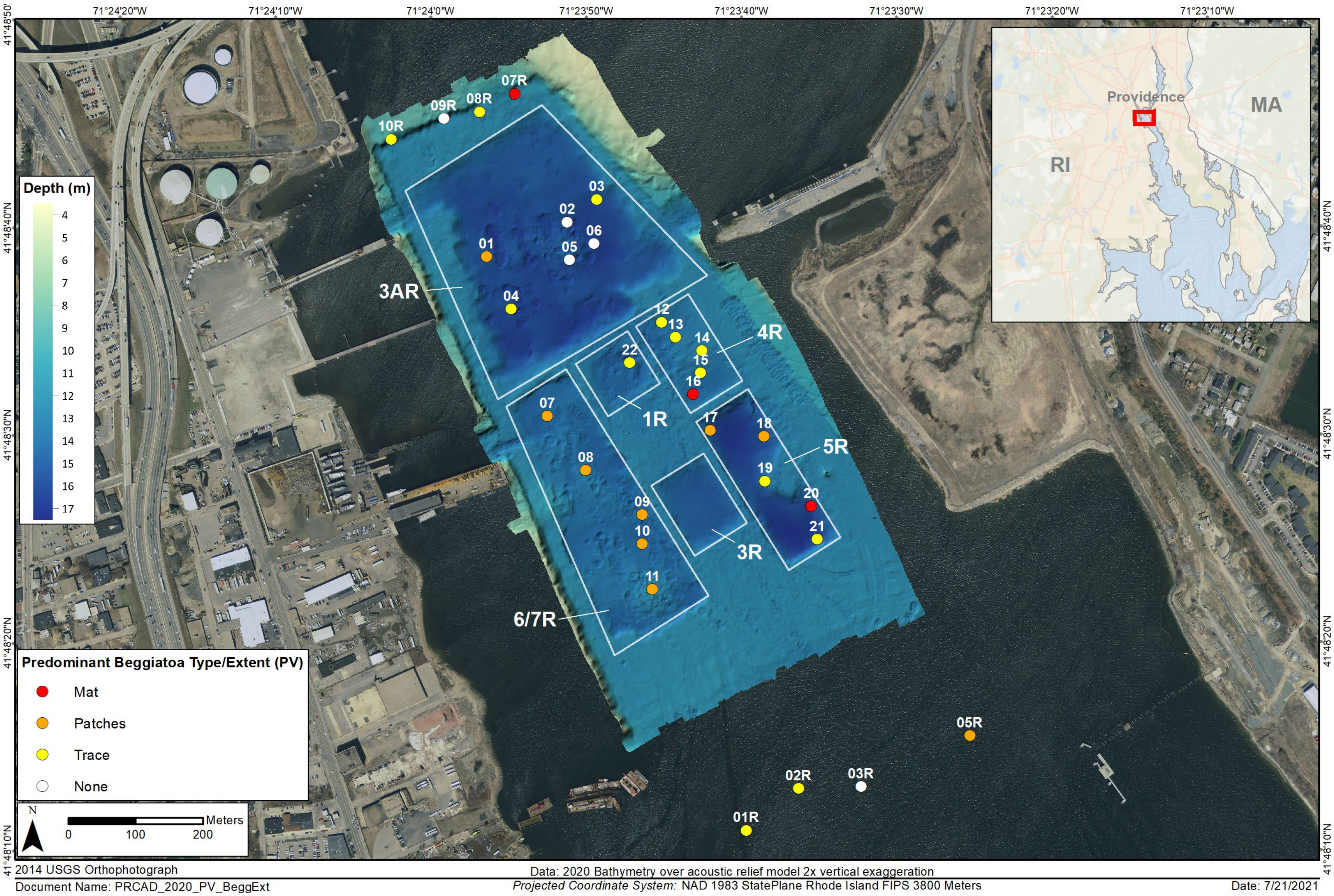

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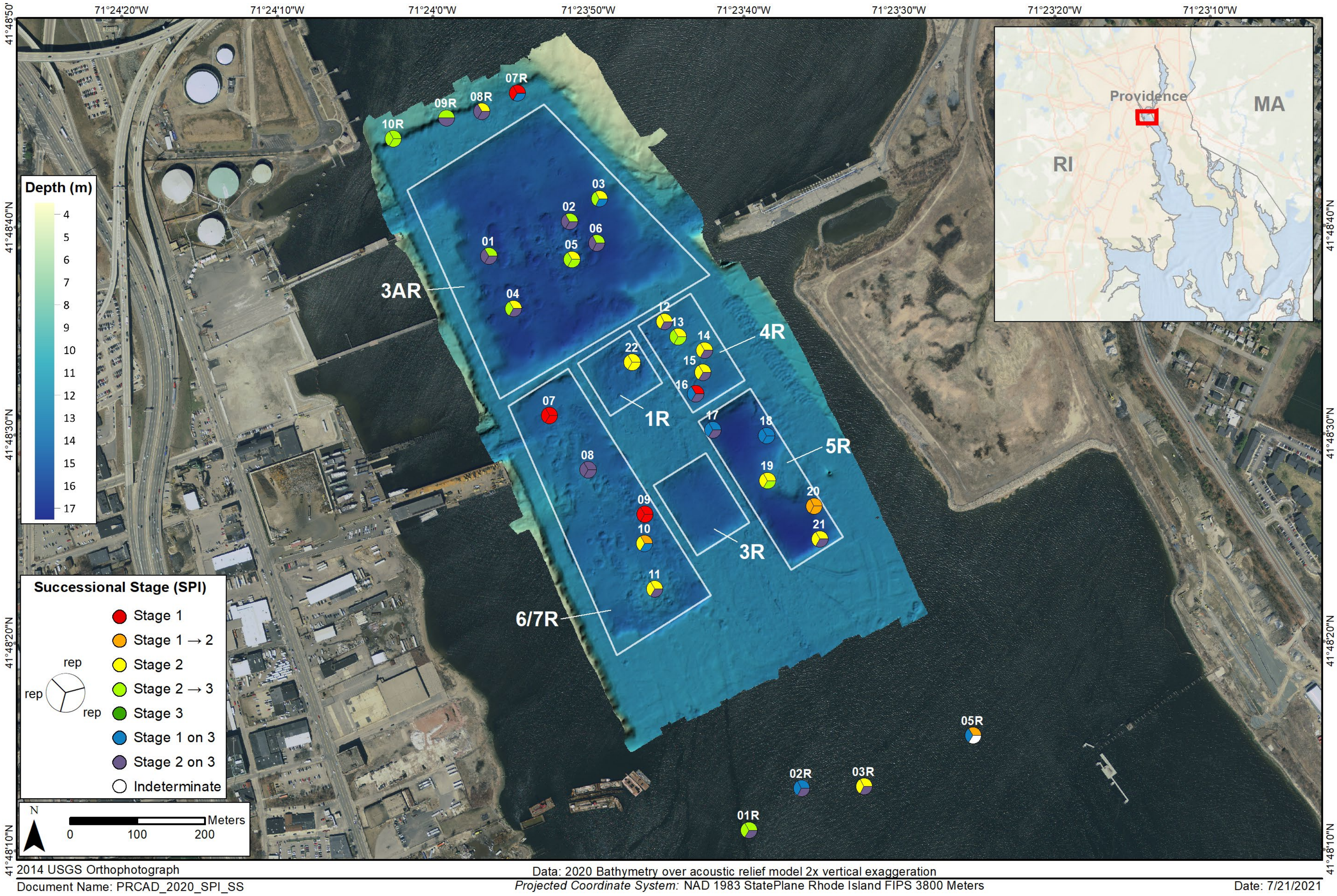

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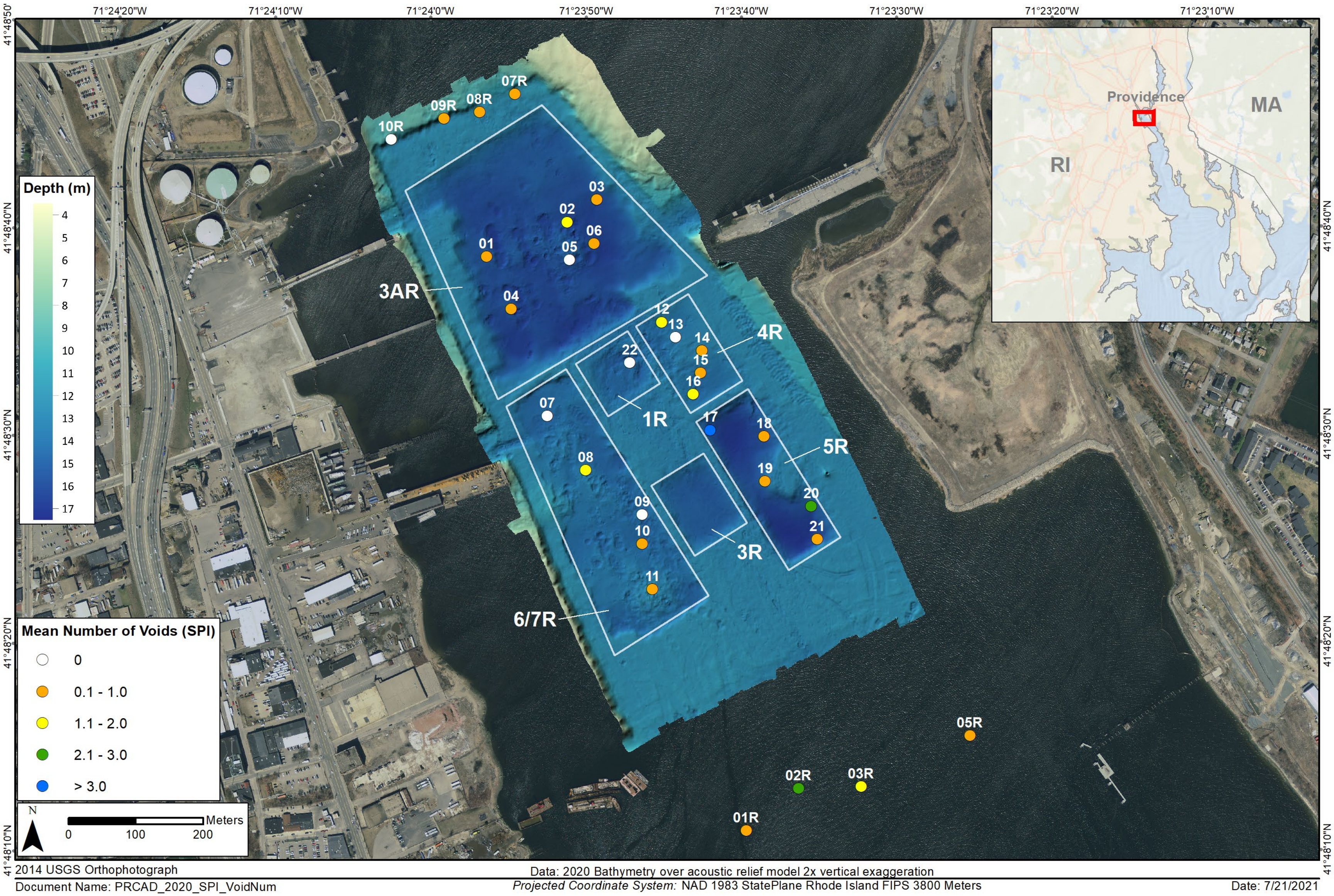

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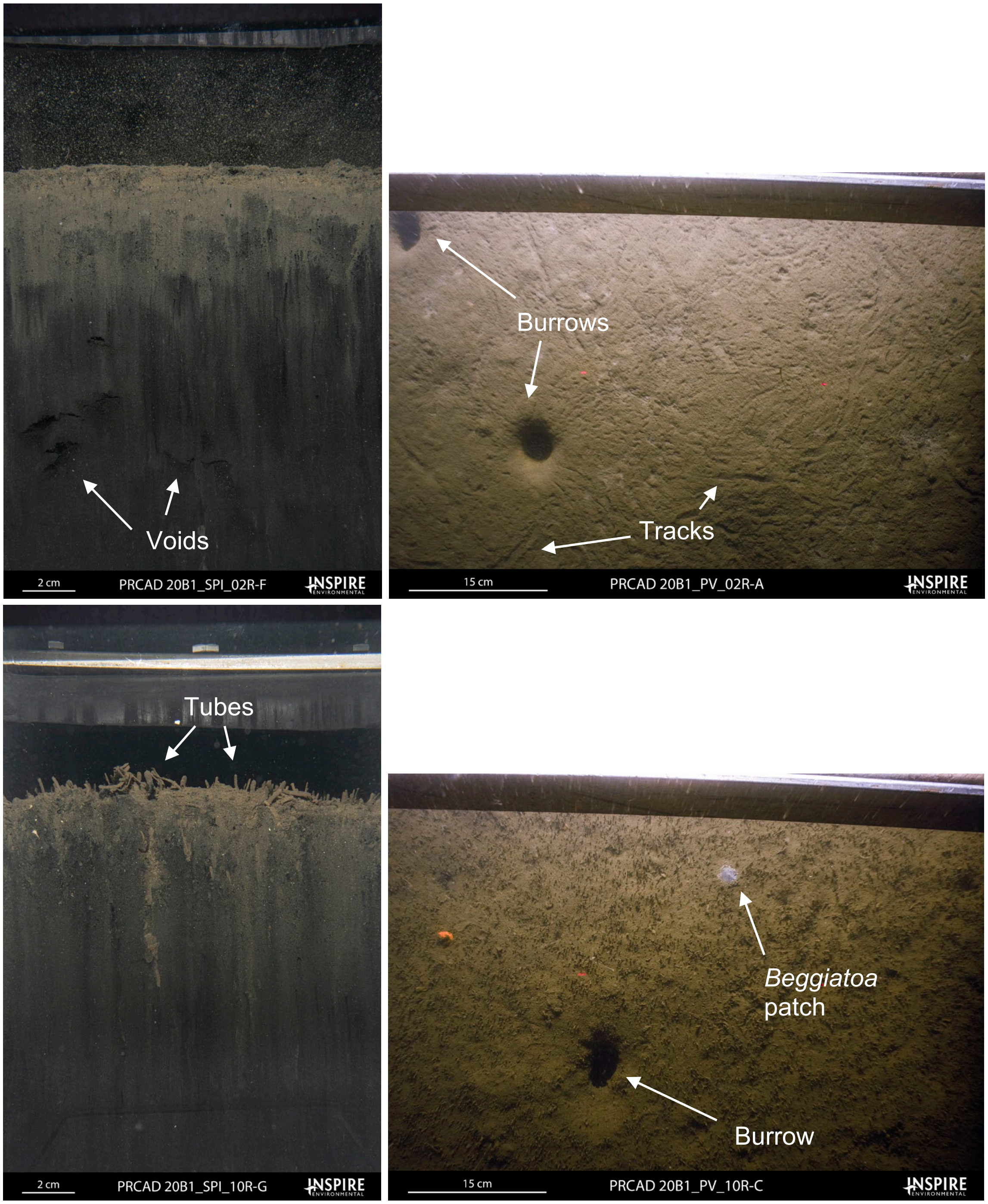

(A)

(B)

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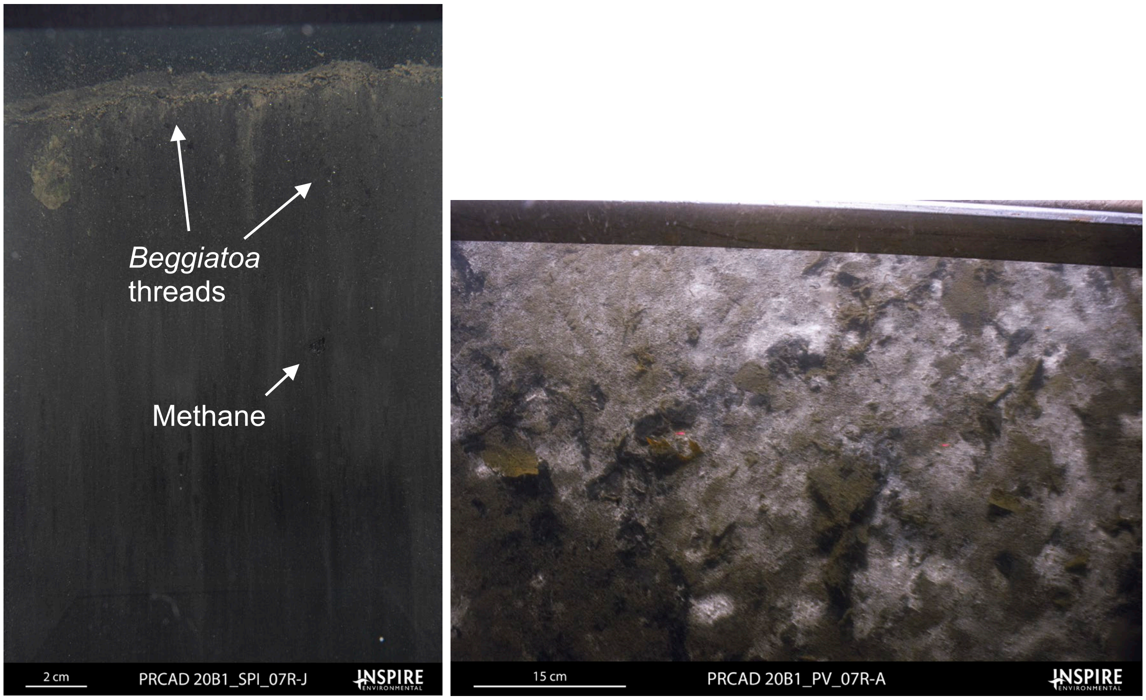
(C)



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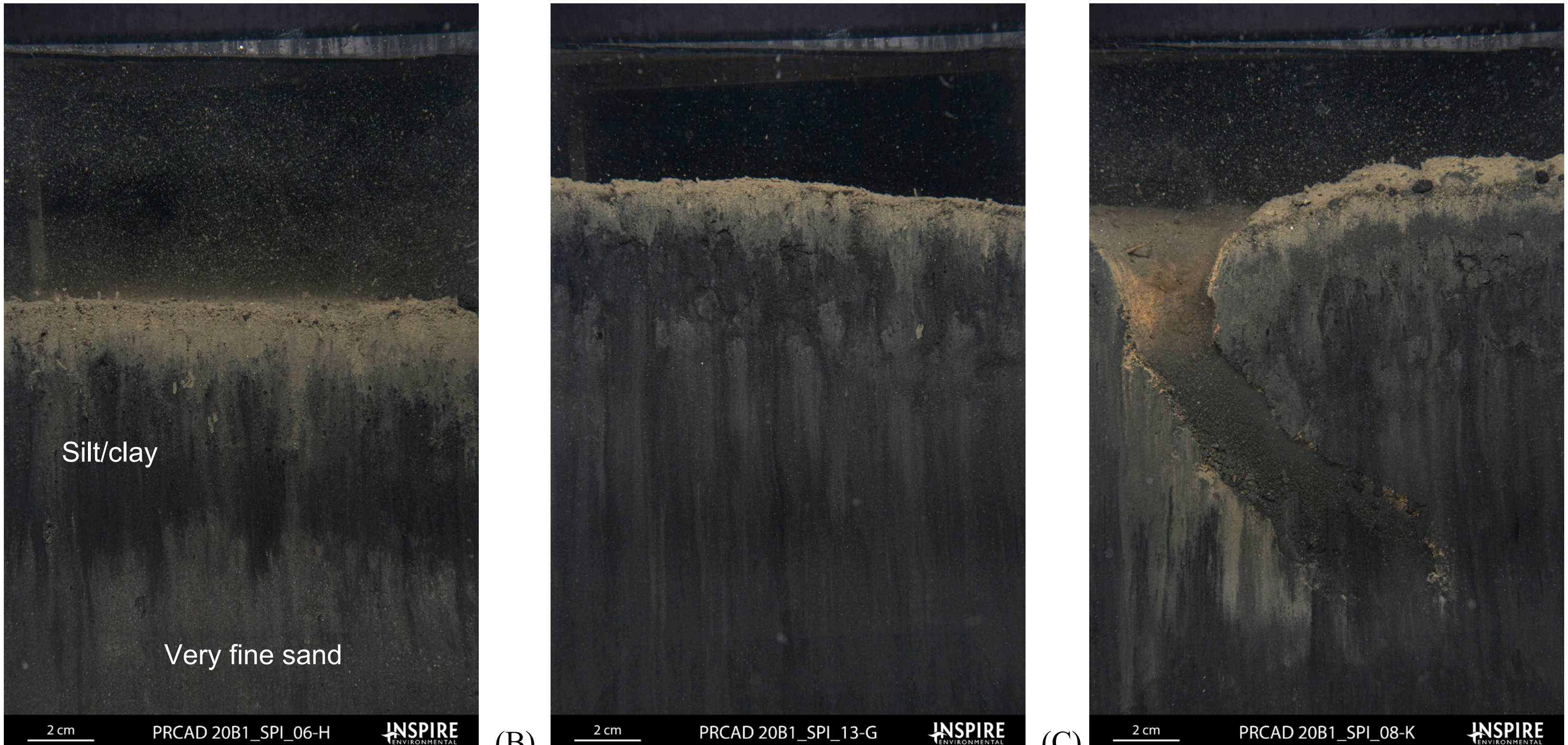
(A) (B) (C)



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(A)

(B)

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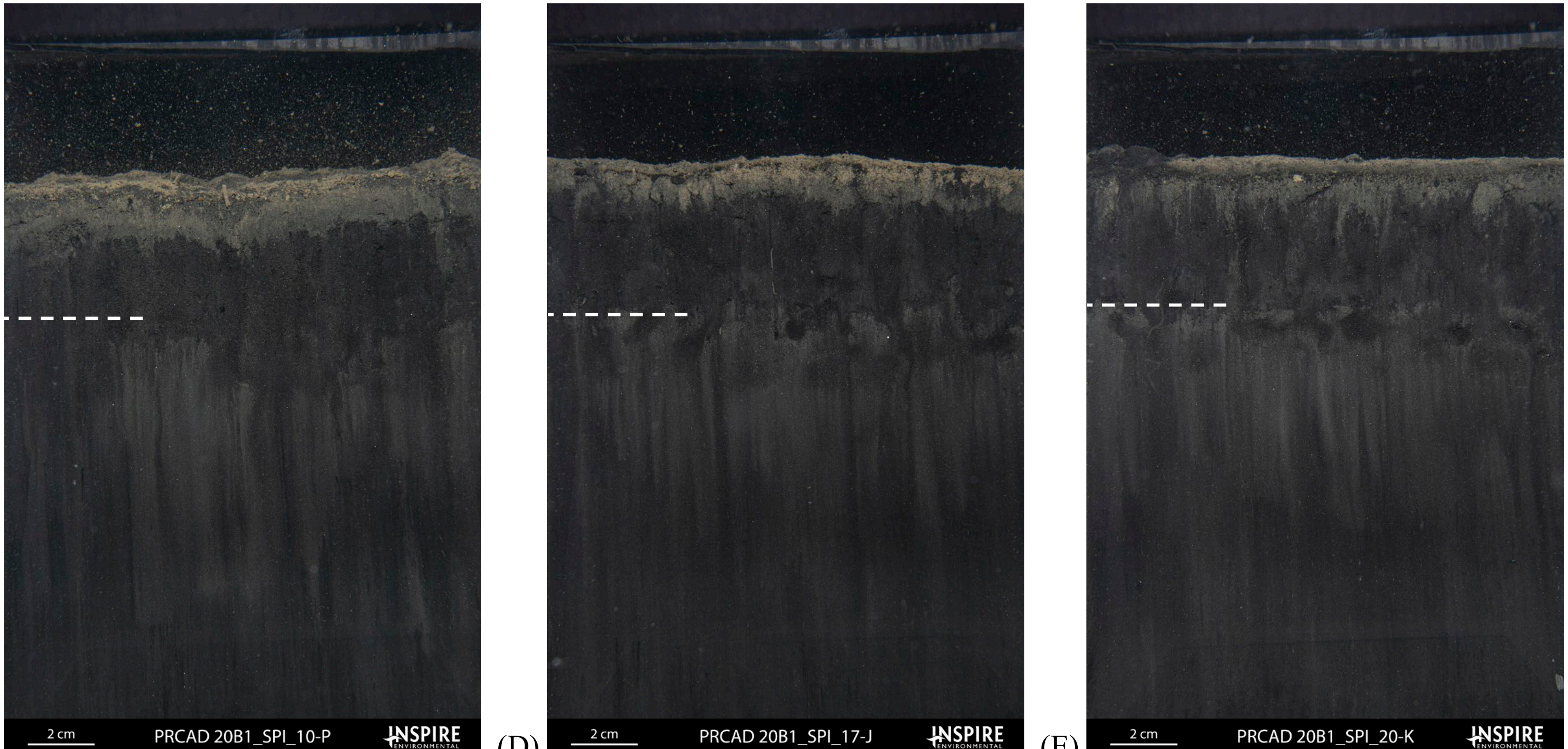
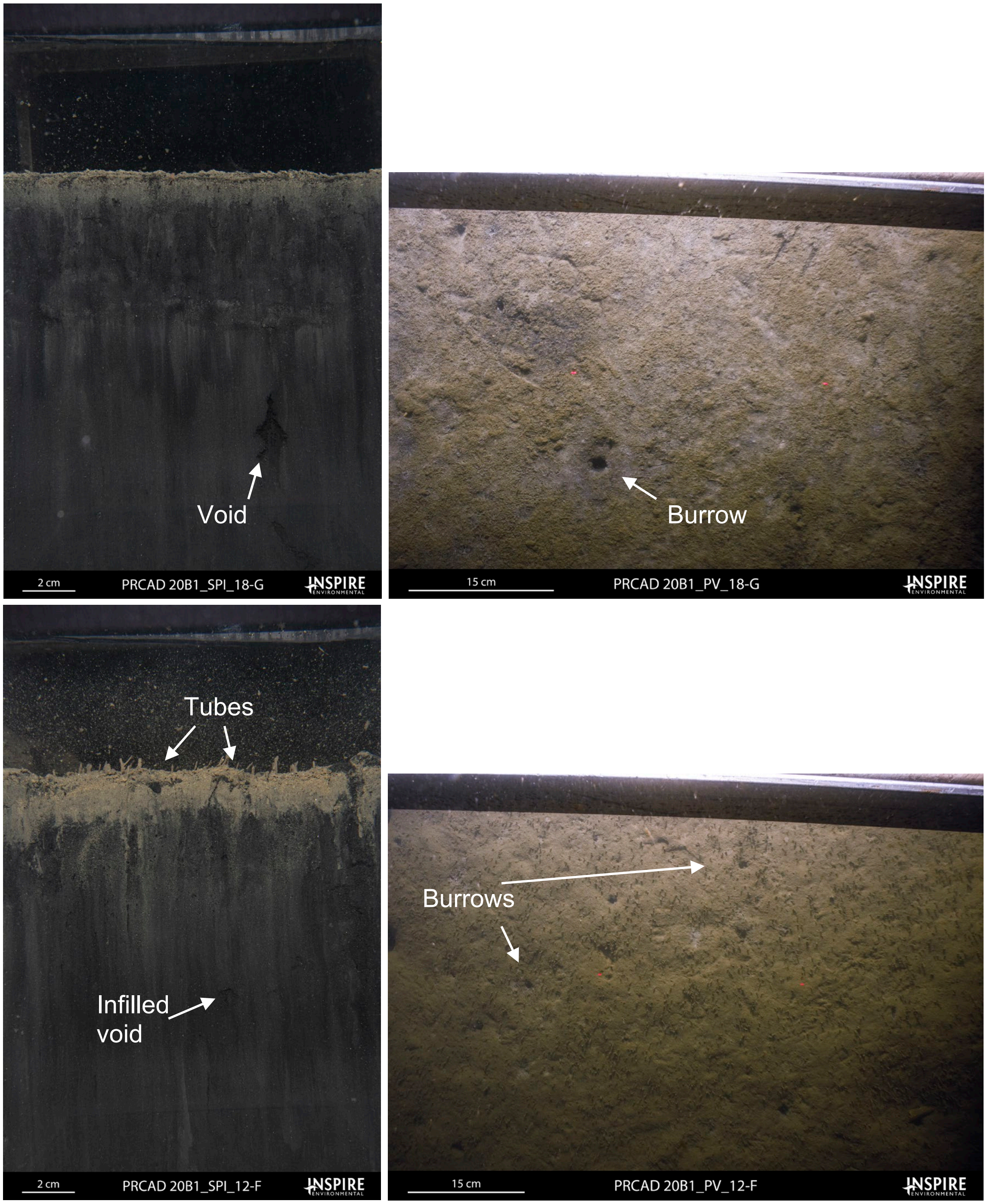


(C) (D) (E)

Figure 3-19. continued Representative sediment profile images depicting features indicative of dredged material presence, including layers and patches of white and light gray clay at (A) Station 01 (Cell 3AR) and (B) Station 08 (Cell 6/7R); and distinct, abrupt subsurface sediment horizons indicating discrete depositional event at (C) Station 10, (D) Station 17, and (E) Station 20



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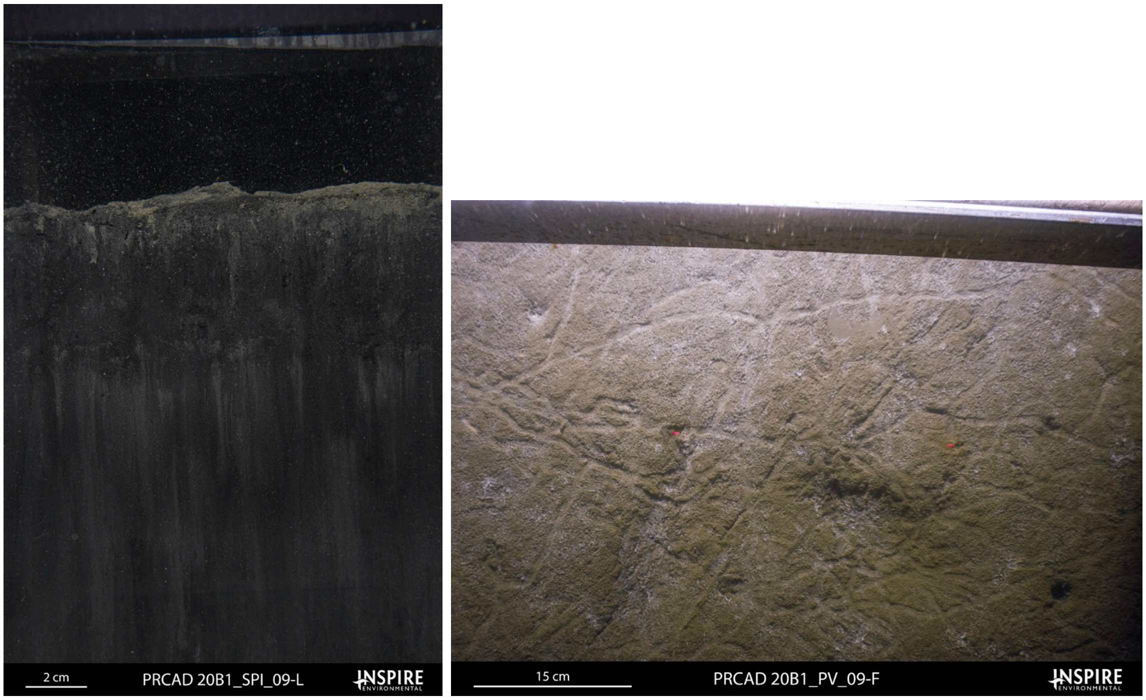
(C) 

Figure 3-20. continued Representative sediment profile and plan view images depicting infaunal successional stages at PRCAD stations including: (A) Stage 1 on 3 at Station 18 (Cell 5R) with a large burrow in plan view image with patches of *Beggiatoa* across the sediment surface, shallow burrowing and a large void at depth in SPI; (B) Stage 2 on 3 at Station 12 (Cell 4R) with numerous Stage 2 tubes at the surface and small burrows in PV, shallow burrowing, and small infilled voids at depth in SPI; (C) Stage 1 at Station 09 (Cell 6/7R) with numerous epifaunal tracks across then surface in PV, very shallow aRPD depth and limited biological activity in SPI

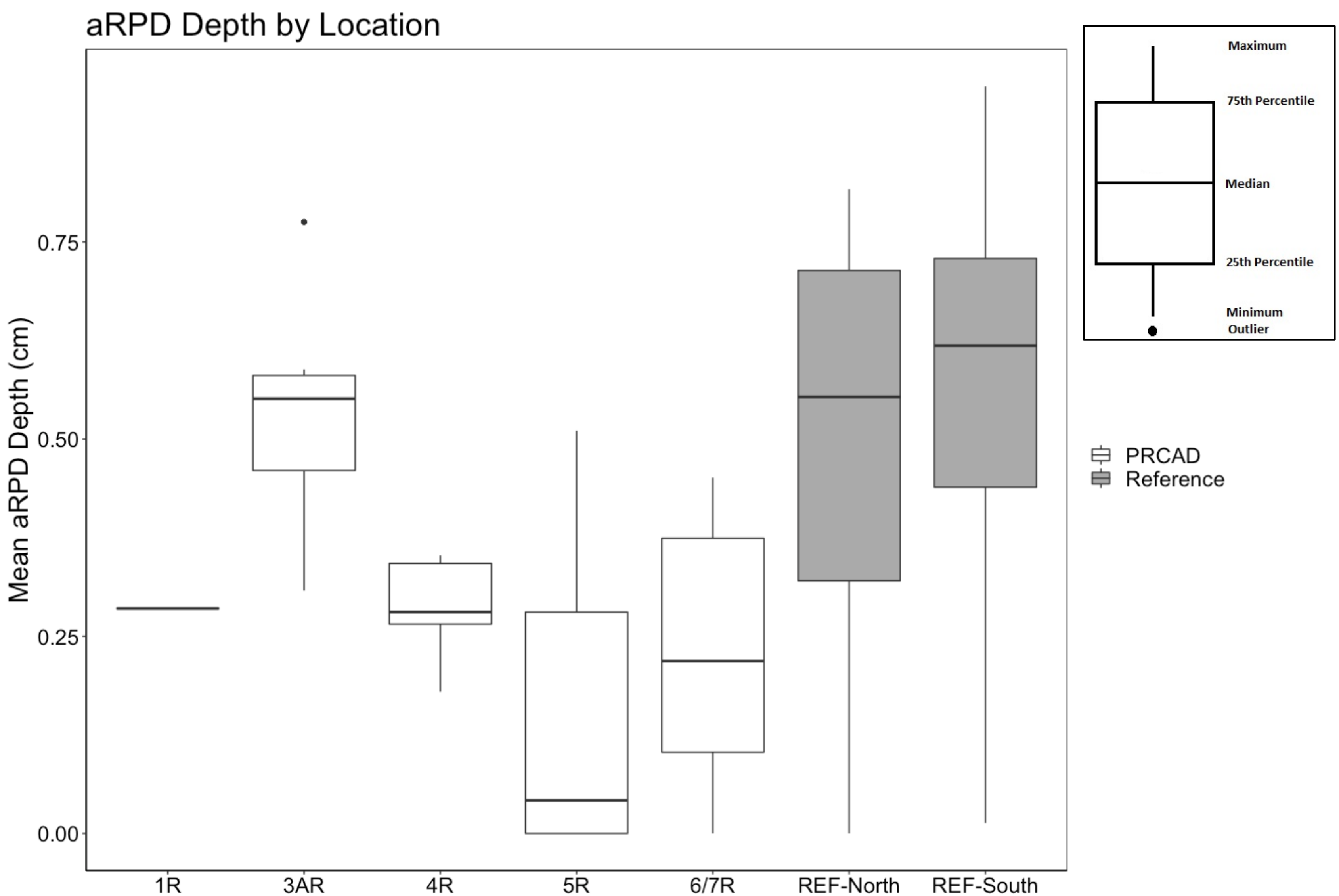


Figure 3-21. Distribution of aRPD depth measurements by sampling area at the PRCAD and reference areas

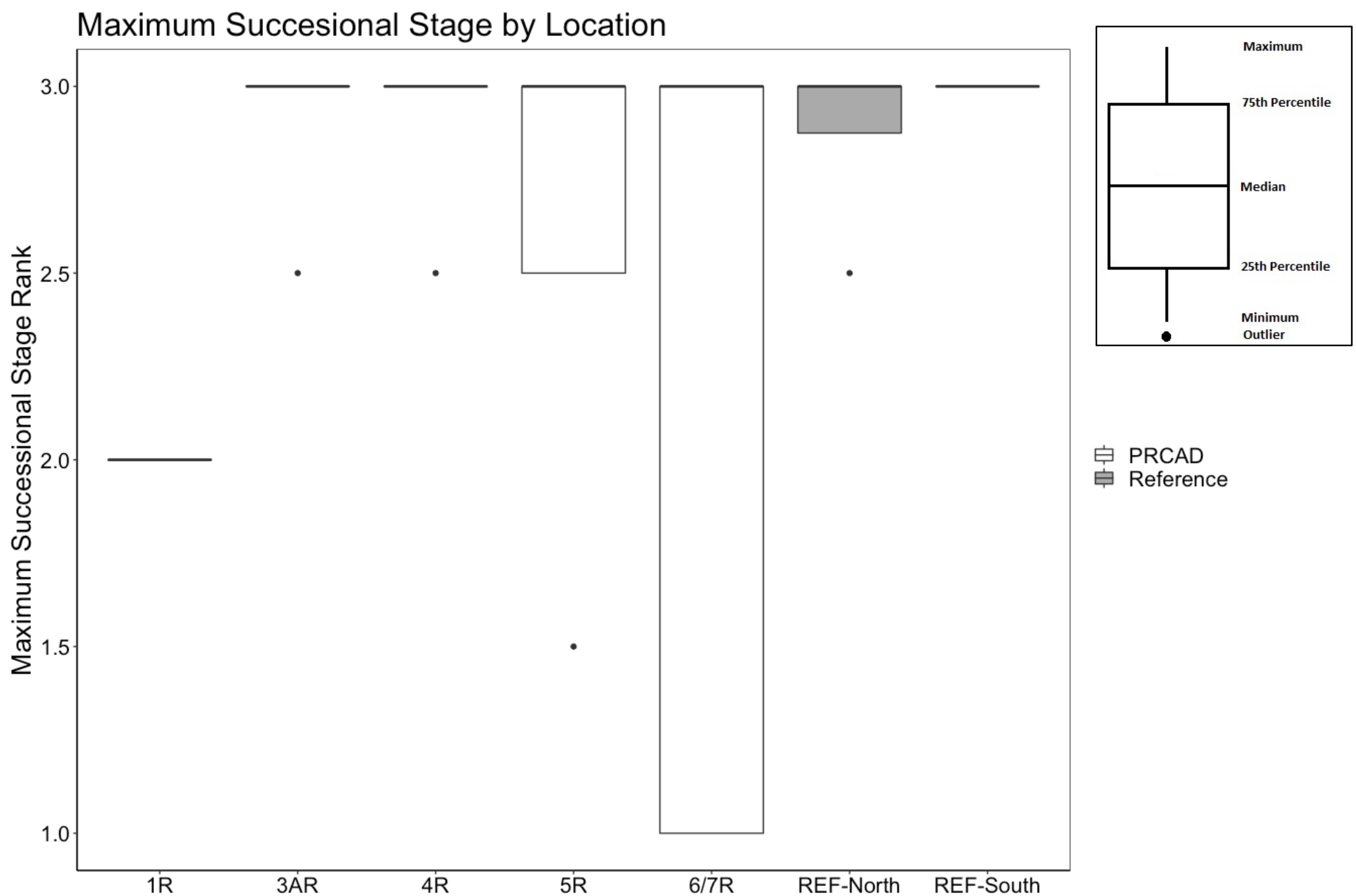
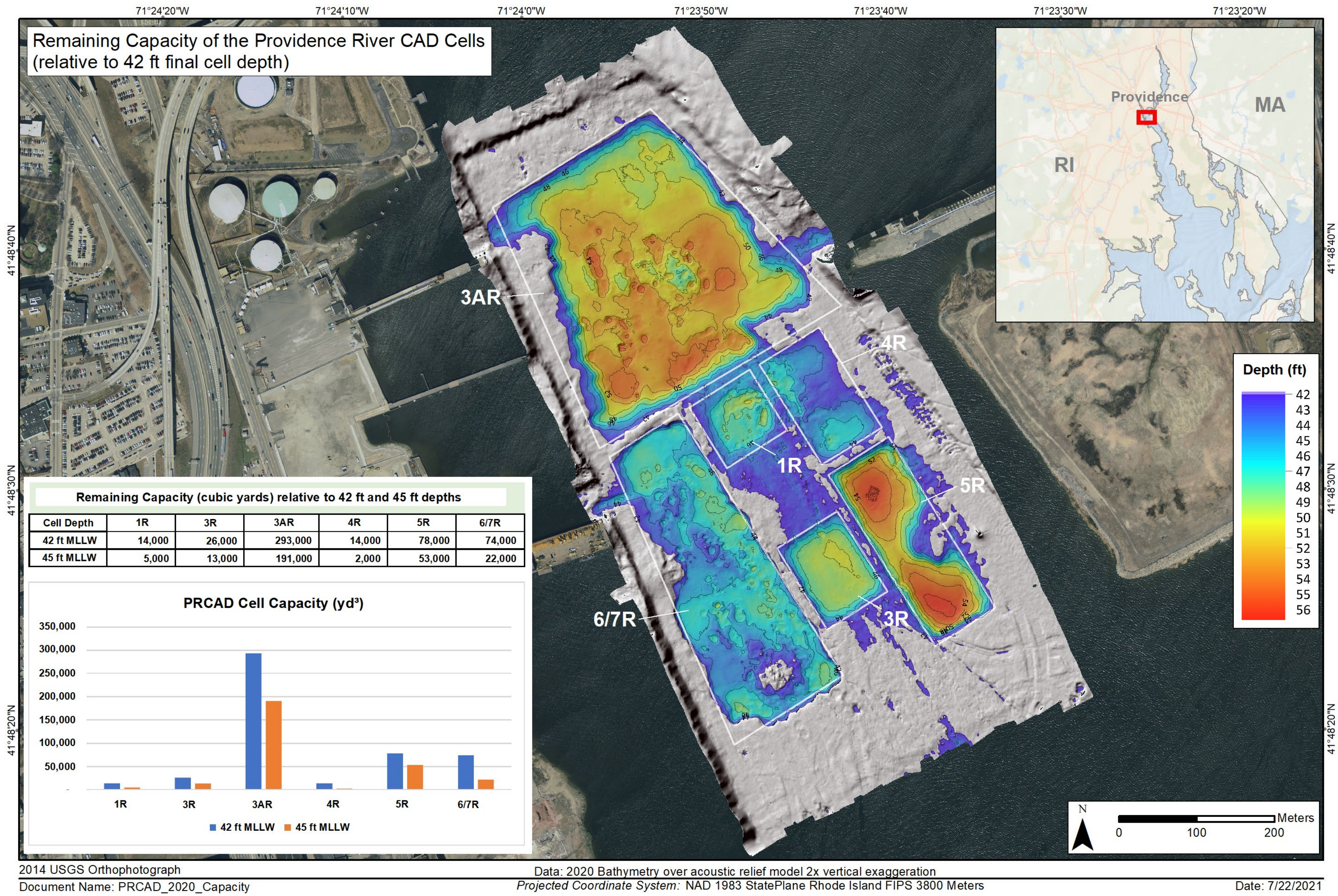


Figure 3-22. Distribution of station maximum Successional Stage rank by sampling area at PRCAD and reference areas



Cell Depth	1R	3R	3AR	4R	5R	6/7R
42 ft MLLW	14,000	26,000	293,000	14,000	78,000	74,000
45 ft MLLW	5,000	13,000	191,000	2,000	53,000	22,000

Figure 4-1. Estimated remaining capacity by cell at PRCAD targeting 42 ft depth, visualized using bathymetry over acoustic relief. Inset shows volume remaining in each cell targeting two depth scenarios (42 ft and 45 ft).

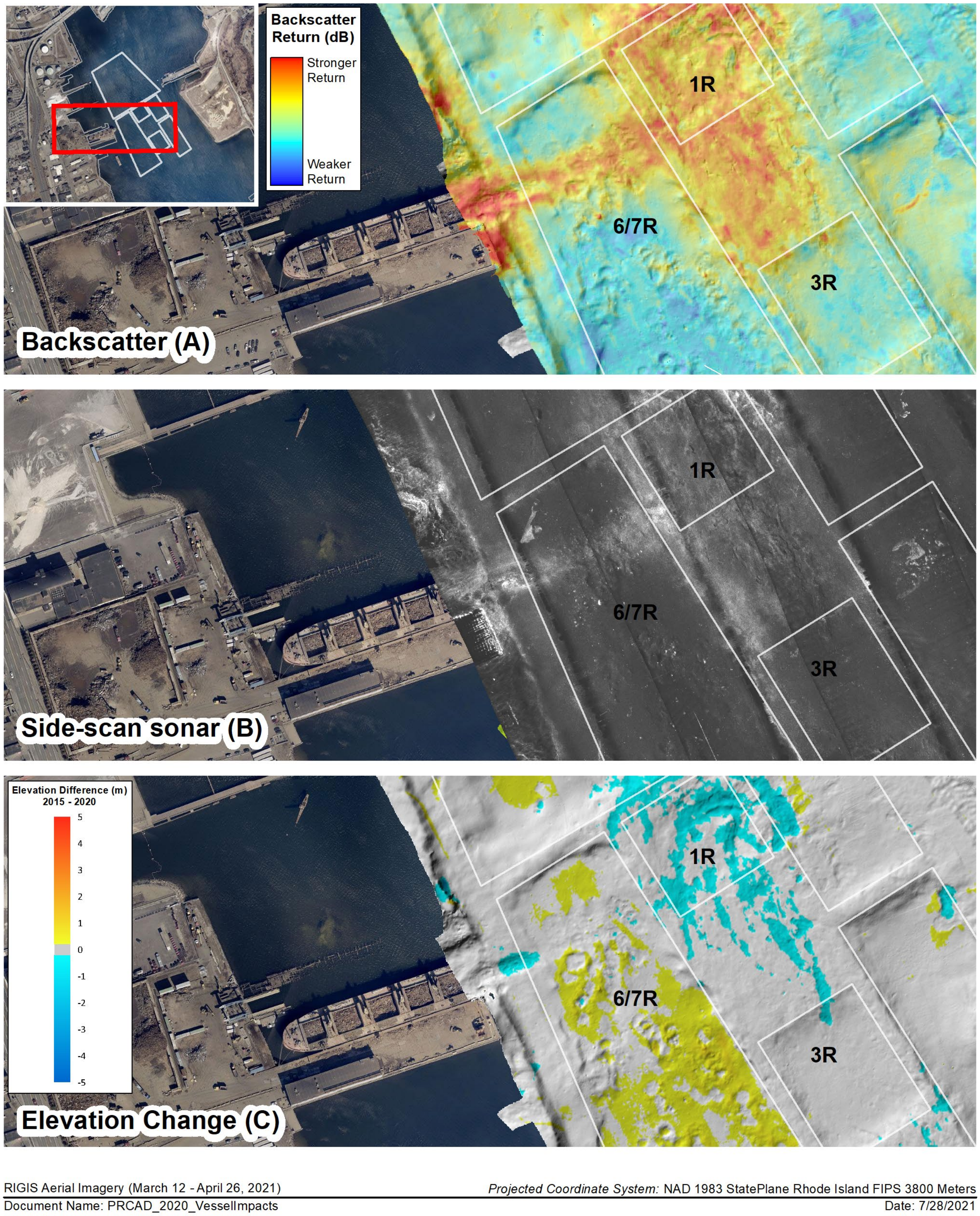


Figure 4-2. Area of potential propellor outwash as seen in (A) backscatter; (B) side-scan sonar; and (C) elevation change model

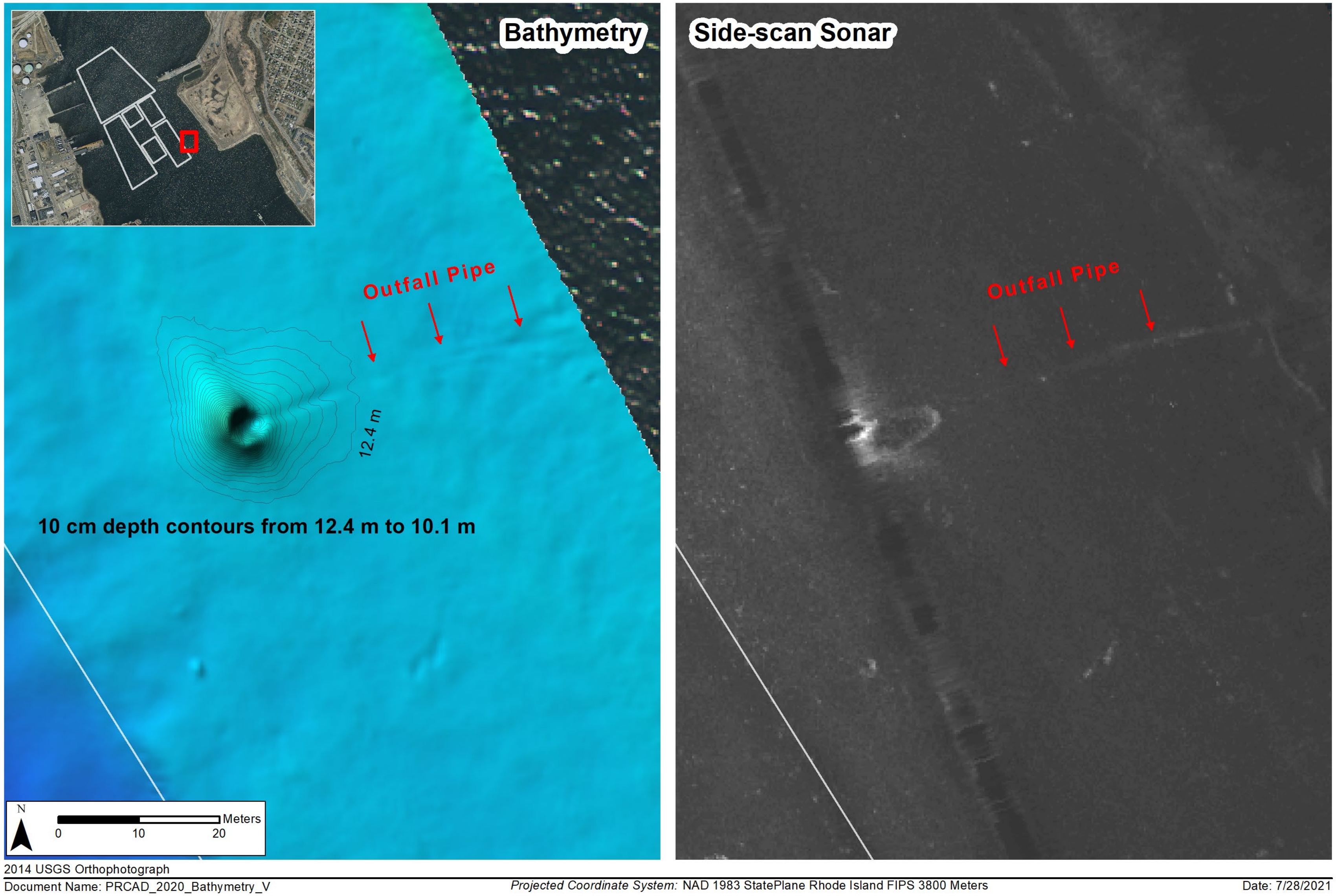


Figure 4-3. Dewatering pipe and deposit as seen in bathymetry and side-scan sonar

MONITORING SURVEY AT THE PROVIDENCE RIVER CONFINED AQUATIC DISPOSAL CELLS (PRCAD) SEPTEMBER/OCTOBER 2020

CONTRIBUTION #211

October 2021

APPENDICES

Contract No. W912WJ-19-D-0010
Delivery Order W912WJ19F0126

Funded and Managed by:
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Prepared by:
INSPIRE Environmental
513 Broadway
Newport, RI 02840

LIST OF APPENDICES

APPENDIX A
TABLE OF COMMON CONVERSIONS

APPENDIX A

TABLE OF COMMON CONVERSIONS

Metric Unit Conversion to English Unit		English Unit Conversion to Metric Unit	
1 meter	3.2808 ft	1 foot	0.3048 m
1 m		1 ft	
1 square meter	10.7639 ft^2	1 square foot	0.0929 m^2
1 m^2		1 ft^2	
1 kilometer	0.6214 mi	1 mile	1.6093 km
1 km		1 mi	
1 cubic meter	1.3080 yd^3	1 cubic yard	0.7646 m^3
1 m^3		1 yd^3	
1 centimeter	0.3937 in	1 inch	2.54 cm
1 cm		1 in	

APPENDIX B
ACTUAL SPI/PV REPLICATE LOCATIONS

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
3AR	01	A	10/26/20	14:24:04	108399.04	80792.65	41.81075	71.39892	51.4
3AR	01	B	10/26/20	14:25:20	108395.6	80796.26	41.81078	71.39896	50.7
3AR	01	C	10/26/20	14:26:11	108392.45	80792.74	41.81075	71.39900	51.7
3AR	01	D	10/26/20	14:26:57	108392.63	80790.6	41.81073	71.39900	52.4
3AR	01	E	10/26/20	14:27:43	108397.7	80788.92	41.81071	71.39894	51.9
3AR	01	F	10/28/20	11:51:44	108392	80789.48	41.81072	71.39901	50.7
3AR	01	G	10/28/20	11:52:46	108394.45	80791.98	41.81074	71.39898	50.2
3AR	01	H	10/28/20	11:53:46	108397.11	80795.57	41.81077	71.39895	49.8
3AR	01	I	10/28/20	11:54:32	108398.17	80790.97	41.81073	71.39893	50.4
3AR	01	J	10/28/20	11:55:36	108390.65	80790.97	41.81073	71.39902	50.1
3AR	02	A	10/26/20	14:36:26	108509.58	80836.99	41.81114	71.39759	53.6
3AR	02	B	10/26/20	14:37:20	108508.05	80842.73	41.81119	71.39761	53.5
3AR	02	C	10/26/20	14:38:20	108514.67	80837.71	41.81115	71.39753	53.2
3AR	02	D	10/26/20	14:39:33	108515.75	80842.59	41.81119	71.39752	53.7
3AR	02	E	10/26/20	14:40:58	108510.31	80839.45	41.81117	71.39758	54.4
3AR	02	F	10/28/20	11:38:08	108511.59	80840.67	41.81118	71.39757	51.1
3AR	02	G	10/28/20	11:39:06	108514.84	80837.76	41.81115	71.39753	51.4
3AR	02	H	10/28/20	11:39:53	108514.13	80843.33	41.81120	71.39754	52.0
3AR	02	I	10/28/20	11:40:55	108507.5	80840.72	41.81118	71.39762	51.3
3AR	02	J	10/28/20	11:41:58	108510.68	80844.23	41.81121	71.39758	51.5
3AR	03	A	10/26/20	14:55:28	108553.77	80876.92	41.81150	71.39706	53.2
3AR	03	B	10/26/20	14:56:16	108557.07	80878.38	41.81152	71.39702	53.9
3AR	03	C	10/26/20	14:57:10	108558.9	80882.05	41.81155	71.39700	53.7
3AR	03	D	10/26/20	14:58:25	108560.43	80876.08	41.81149	71.39698	53.3
3AR	03	E	10/26/20	15:00:00	108554.02	80879.92	41.81153	71.39706	53.2
3AR	03	F	10/28/20	11:44:38	108556.1	80874.44	41.81148	71.39703	52.8
3AR	03	G	10/28/20	11:45:26	108557.61	80877.7	41.81151	71.39701	51.8
3AR	03	H	10/28/20	11:46:16	108558.58	80881.78	41.81155	71.39700	52.0
3AR	03	I	10/28/20	11:47:08	108554.23	80879.12	41.81152	71.39705	51.9
3AR	03	J	10/28/20	11:48:09	108561.1	80878.77	41.81152	71.39697	52.1
3AR	04	A	10/26/20	16:12:38	108420.73	80712.16	41.81002	71.39866	54.8
3AR	04	B	10/26/20	16:13:22	108424.6	80712.8	41.81003	71.39862	54.2
3AR	04	C	10/26/20	16:14:18	108428.66	80712.68	41.81002	71.39857	54.1
3AR	04	D	10/26/20	16:15:21	108426.7	80709.83	41.81000	71.39859	53.7
3AR	04	E	10/26/20	16:16:14	108424.9	80716.79	41.81006	71.39861	54.1
3AR	04	F	10/27/20	16:24:05	108428.33	80711.59	41.81002	71.39857	53.4
3AR	04	G	10/27/20	16:25:10	108424.36	80716.29	41.81006	71.39862	56.3
3AR	04	H	10/27/20	16:25:58	108423.58	80712.61	41.81002	71.39863	52.7
3AR	04	I	10/27/20	16:26:42	108422.12	80709.32	41.80999	71.39865	53.6
3AR	04	J	10/27/20	16:27:36	108420.49	80711.82	41.81002	71.39867	53.3
3AR	05	A	10/26/20	14:30:28	108509.71	80789.08	41.81071	71.39759	52.5
3AR	05	B	10/26/20	14:31:18	108513.31	80792.57	41.81074	71.39755	50.7
3AR	05	C	10/26/20	14:32:37	108518.64	80788.24	41.81070	71.39748	50.0
3AR	05	D	10/26/20	14:33:36	108513.77	80788.75	41.81071	71.39754	50.3
3AR	05	E	10/26/20	14:34:31	108514.4	80784.84	41.81067	71.39753	50.1
3AR	05	F	10/28/20	11:31:18	108515.03	80784.46	41.81067	71.39753	51.3
3AR	05	G	10/28/20	11:32:26	108513.42	80788.27	41.81070	71.39755	49.7
3AR	05	H	10/28/20	11:33:33	108516.2	80790.97	41.81073	71.39751	49.4
3AR	05	I	10/28/20	11:34:31	108511.81	80790.65	41.81073	71.39757	49.5
3AR	05	J	10/28/20	11:35:54	108510.64	80785.18	41.81068	71.39758	51.8
3AR	06	A	10/26/20	14:43:41	108551.32	80809.31	41.81089	71.39709	54.2
3AR	06	B	10/26/20	14:44:30	108554.66	80813.01	41.81093	71.39705	53.9
3AR	06	C	10/26/20	14:45:43	108559.82	80809.8	41.81090	71.39699	54.6
3AR	06	D	10/26/20	14:46:51	108555.51	80809.04	41.81089	71.39704	54.0
3AR	06	E	10/26/20	14:48:12	108555.43	80804.91	41.81085	71.39704	54.2

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
3AR	06	F	10/28/20	11:25:12	108551.93	80808.68	41.81089	71.39708	52.8
3AR	06	G	10/28/20	11:26:07	108555.39	80808.7	41.81089	71.39704	52.8
3AR	06	H	10/28/20	11:27:02	108557.85	80811.34	41.81091	71.39701	53.2
3AR	06	I	10/28/20	11:27:59	108557.61	80805.24	41.81086	71.39701	54.2
3AR	06	J	10/28/20	11:29:05	108554.47	80812.84	41.81093	71.39705	53.7
6/7R	07	A	10/26/20	16:20:55	108476.81	80559.69	41.80865	71.39799	
6/7R	07	B	10/26/20	16:21:54	108482.93	80559.79	41.80865	71.39792	50.3
6/7R	07	C	10/26/20	16:22:57	108479.11	80556.01	41.80861	71.39796	50.5
6/7R	07	D	10/26/20	16:23:51	108477.06	80555.21	41.80861	71.39799	50.9
6/7R	07	E	10/26/20	16:24:57	108481.62	80553.71	41.80859	71.39793	50.6
6/7R	07	F	10/28/20	7:56:11	108481.81	80552.98	41.80859	71.39793	50.2
6/7R	07	G	10/28/20	7:57:01	108482.92	80559.47	41.80864	71.39792	51.5
6/7R	07	H	10/28/20	7:57:51	108482.27	80555.47	41.80861	71.39792	49.7
6/7R	07	I	10/28/20	7:58:35	108476.35	80556.42	41.80862	71.39800	50.5
6/7R	07	J	10/28/20	8:00:17	108478.67	80558.89	41.80864	71.39797	50.0
6/7R	08	A	10/26/20	16:35:00	108540.27	80468.32	41.80782	71.39723	46.6
6/7R	08	B	10/26/20	16:35:51	108543.62	80471.37	41.80785	71.39719	47.1
6/7R	08	C	10/26/20	16:36:50	108536.67	80468.52	41.80783	71.39727	47.1
6/7R	08	D	10/26/20	16:37:45	108539.24	80471.51	41.80785	71.39724	46.8
6/7R	08	E	10/26/20	16:38:54	108542.81	80465.19	41.80780	71.39720	48.2
6/7R	08	F	10/28/20	8:03:19	108542.79	80464.49	41.80779	71.39720	46.9
6/7R	08	G	10/28/20	8:04:05	108538.25	80464.97	41.80779	71.39725	48.8
6/7R	08	H	10/28/20	8:04:58	108540.2	80468.22	41.80782	71.39723	45.8
6/7R	08	I	10/28/20	8:05:48	108543	80469.53	41.80783	71.39720	45.6
6/7R	08	J	10/28/20	8:06:45	108540.9	80472.35	41.80786	71.39722	47.0
6/7R	08	K	10/28/20	9:29:52	108539.4	80472.34	41.80786	71.39724	47.7
6/7R	08	L	10/28/20	9:30:50	108537.37	80465.78	41.80780	71.39726	46.5
6/7R	08	M	10/28/20	9:31:49	108536.21	80465.94	41.80780	71.39728	46.8
6/7R	08	N	10/28/20	9:32:40	108536.34	80468.8	41.80783	71.39728	47.0
6/7R	08	P	10/28/20	9:33:39	108541.95	80466.22	41.80780	71.39721	43.9
6/7R	09	A	10/26/20	11:55:34	108630.09	80407.91	41.80728	71.39615	46.1
6/7R	09	B	10/26/20	11:56:39	108623.46	80408.06	41.80728	71.39623	46.8
6/7R	09	C	10/26/20	11:58:09	108622.29	80411.52	41.80731	71.39624	47.5
6/7R	09	D	10/26/20	11:58:49	108624.69	80413.16	41.80733	71.39621	47.7
6/7R	09	E	10/26/20	11:59:38	108628.67	80411.87	41.80731	71.39616	47.1
6/7R	09	F	10/28/20	8:11:16	108627.25	80405.51	41.80726	71.39618	49.9
6/7R	09	G	10/28/20	8:12:10	108621.86	80408.17	41.80728	71.39625	49.8
6/7R	09	H	10/28/20	8:12:52	108625.59	80409.72	41.80729	71.39620	49.4
6/7R	09	I	10/28/20	8:13:39	108623.8	80412.49	41.80732	71.39622	50.0
6/7R	09	J	10/28/20	8:14:46	108628.98	80411.32	41.80731	71.39616	50.4
6/7R	09	K	10/28/20	9:36:26	108629.39	80407.16	41.80727	71.39616	48.7
6/7R	09	L	10/28/20	9:37:12	108623.39	80406.24	41.80726	71.39623	47.1
6/7R	09	M	10/28/20	9:38:00	108625.23	80407.74	41.80728	71.39621	48.6
6/7R	09	N	10/28/20	9:38:48	108628.37	80412.79	41.80732	71.39617	49.2
6/7R	09	P	10/28/20	9:39:58	108623.16	80411.07	41.80731	71.39623	47.6
6/7R	10	A	10/26/20	12:03:17	108621.69	80359.93	41.80685	71.39625	47.1
6/7R	10	B	10/26/20	12:04:13	108624.39	80362.99	41.80687	71.39622	47.4
6/7R	10	C	10/26/20	12:05:13	108617.03	80360.85	41.80686	71.39631	46.6
6/7R	10	D	10/26/20	12:06:06	108620.78	80367.78	41.80692	71.39626	47.2
6/7R	10	E	10/26/20	12:07:01	108623.84	80367.28	41.80691	71.39622	48.2
6/7R	10	F	10/28/20	8:16:28	108621.95	80367.79	41.80692	71.39625	49.3
6/7R	10	G	10/28/20	8:17:16	108621.63	80360.04	41.80685	71.39625	48.8
6/7R	10	H	10/28/20	8:18:12	108620.52	80364.19	41.80689	71.39626	49.2
6/7R	10	I	10/28/20	8:19:20	108626.21	80366.67	41.80691	71.39620	49.5
6/7R	10	J	10/28/20	8:20:08	108618.63	80370.2	41.80694	71.39629	50.7

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
6/7R	10	K	10/28/20	9:52:06	108622.97	80359.84	41.80685	71.39623	47.2
6/7R	10	L	10/28/20	9:52:50	108622.94	80363.12	41.80688	71.39623	46.7
6/7R	10	M	10/28/20	9:53:35	108624.73	80365.58	41.80690	71.39621	47.7
6/7R	10	N	10/28/20	9:54:48	108619.2	80368.37	41.80692	71.39628	48.9
6/7R	10	P	10/28/20	9:55:36	108620.67	80365.6	41.80690	71.39626	47.9
6/7R	11	A	10/26/20	12:10:00	108641.76	80292.09	41.80624	71.39601	41.3
6/7R	11	B	10/26/20	12:11:36	108634.65	80294.03	41.80625	71.39609	40.3
6/7R	11	C	10/26/20	12:12:29	108635.27	80299.03	41.80630	71.39609	42.5
6/7R	11	D	10/26/20	12:13:23	108639.93	80299.77	41.80630	71.39603	41.1
6/7R	11	E	10/26/20	12:14:16	108642.9	80296.52	41.80628	71.39600	42.0
6/7R	11	F	10/26/20	12:15:24	108639.49	80294.21	41.80625	71.39604	39.7
6/7R	11	G	10/28/20	8:22:12	108638.41	80291.74	41.80623	71.39605	42.4
6/7R	11	H	10/28/20	8:23:13	108642.46	80293.82	41.80625	71.39600	41.3
6/7R	11	I	10/28/20	8:24:11	108637.38	80299.23	41.80630	71.39606	43.6
6/7R	11	J	10/28/20	8:25:11	108635.5	80296.66	41.80628	71.39608	41.3
6/7R	11	K	10/28/20	8:26:01	108638.22	80295.42	41.80627	71.39605	43.1
6/7R	11	L	10/28/20	9:57:36	108640.36	80292.04	41.80624	71.39603	41.5
6/7R	11	M	10/28/20	9:58:34	108638.06	80295.59	41.80627	71.39605	41.4
6/7R	11	N	10/28/20	9:59:24	108642.39	80295.73	41.80627	71.39600	39.6
6/7R	11	P	10/28/20	10:00:15	108639.01	80299.09	41.80630	71.39604	42.2
6/7R	11	Q	10/28/20	10:01:41	108640.34	80293.75	41.80625	71.39603	42.2
4R	12	A	10/26/20	14:01:53	108655.32	80689.26	41.80981	71.39584	46.1
4R	12	B	10/26/20	14:02:40	108657.38	80692.47	41.80984	71.39582	45.8
4R	12	C	10/26/20	14:03:34	108658.14	80696.19	41.80987	71.39581	45.3
4R	12	D	10/26/20	14:04:23	108658.19	80688.75	41.80981	71.39581	46.0
4R	12	E	10/26/20	14:05:51	108661.22	80694.92	41.80986	71.39577	46.6
4R	12	F	10/28/20	11:11:03	108652.39	80692.08	41.80984	71.39588	45.2
4R	12	G	10/28/20	11:11:58	108655.2	80689.3	41.80981	71.39584	46.0
4R	12	H	10/28/20	11:12:48	108658.59	80696.16	41.80987	71.39580	45.2
4R	12	I	10/28/20	11:14:22	108659.52	80696.29	41.80987	71.39579	44.0
4R	12	J	10/28/20	11:15:16	108662.95	80691.54	41.80983	71.39575	44.4
4R	12	K	10/28/20	11:16:20	108656.87	80691.19	41.80983	71.39582	45.1
4R	13	A	10/26/20	13:55:48	108672.52	80673.19	41.80967	71.39563	45.2
4R	13	B	10/26/20	13:56:37	108678.29	80675.27	41.80969	71.39556	46.1
4R	13	C	10/26/20	13:57:57	108680.53	80670.86	41.80965	71.39554	45.8
4R	13	D	10/26/20	13:59:04	108677.63	80670.89	41.80965	71.39557	47.0
4R	13	E	10/26/20	13:59:47	108674.86	80668.66	41.80963	71.39561	46.4
4R	13	F	10/28/20	11:18:19	108672.91	80669.75	41.80964	71.39563	44.3
4R	13	G	10/28/20	11:19:18	108676.55	80672.08	41.80966	71.39558	44.0
4R	13	H	10/28/20	11:20:02	108678.7	80675.05	41.80968	71.39556	43.8
4R	13	I	10/28/20	11:21:06	108677.61	80668.84	41.80963	71.39557	44.0
4R	13	J	10/28/20	11:22:01	108675.79	80675.04	41.80968	71.39559	44.5
4R	14	A	10/26/20	13:48:08	108713.88	80657.39	41.80952	71.39514	43.8
4R	14	B	10/26/20	13:50:23	108715.46	80653.04	41.80948	71.39512	43.6
4R	14	C	10/26/20	13:51:12	108711.72	80649.38	41.80945	71.39516	43.6
4R	14	D	10/26/20	13:52:12	108709.78	80652.92	41.80948	71.39519	43.7
4R	14	E	10/26/20	13:53:06	108707.93	80656.5	41.80952	71.39521	43.7
4R	14	F	10/28/20	10:46:15	108712.12	80649.65	41.80945	71.39516	19.9
4R	14	G	10/28/20	10:47:08	108713.48	80656.93	41.80952	71.39514	42.5
4R	14	H	10/28/20	10:47:52	108711.28	80653.85	41.80949	71.39517	42.8
4R	14	I	10/28/20	10:48:46	108715.13	80653.67	41.80949	71.39512	42.5
4R	14	J	10/28/20	10:49:37	108707.47	80653.34	41.80949	71.39521	42.8
4R	15	A	10/26/20	13:41:45	108710.34	80615.01	41.80914	71.39518	46.7
4R	15	B	10/26/20	13:43:18	108716.25	80619.04	41.80918	71.39511	45.6
4R	15	C	10/26/20	13:44:05	108712.67	80618.12	41.80917	71.39515	46.1

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
4R	15	D	10/26/20	13:44:55	108708.8	80619.6	41.80918	71.39520	46.1
4R	15	E	10/26/20	13:45:47	108714.14	80620.86	41.80920	71.39513	47.4
4R	15	F	10/28/20	10:41:29	108709.61	80616.86	41.80916	71.39519	45.6
4R	15	G	10/28/20	10:42:15	108712.87	80618.37	41.80917	71.39515	45.5
4R	15	H	10/28/20	10:43:08	108716.92	80618.59	41.80917	71.39510	45.5
4R	15	I	10/28/20	10:43:54	108713.31	80614.38	41.80914	71.39514	45.4
4R	15	J	10/28/20	10:44:39	108714.56	80622.18	41.80921	71.39513	44.6
4R	16	A	10/26/20	13:34:47	108704.2	80579.19	41.80882	71.39525	45.5
4R	16	B	10/26/20	13:35:28	108704.72	80582.29	41.80885	71.39525	46.2
4R	16	C	10/26/20	13:37:07	108698.29	80581.65	41.80884	71.39532	45.9
4R	16	D	10/26/20	13:37:53	108701.88	80586.42	41.80889	71.39528	46.8
4R	16	E	10/26/20	13:39:03	108701.5	80581.26	41.80884	71.39529	46.3
4R	16	F	10/28/20	10:35:58	108698.77	80585.18	41.80887	71.39532	46.3
4R	16	G	10/28/20	10:37:04	108700.72	80577.68	41.80881	71.39530	44.9
4R	16	H	10/28/20	10:37:37	108700.75	80582.84	41.80885	71.39529	45.8
4R	16	I	10/28/20	10:38:25	108702.17	80585.31	41.80888	71.39528	45.9
4R	16	J	10/28/20	10:39:18	108705.42	80581.48	41.80884	71.39524	46.8
5R	17	A	10/26/20	12:20:02	108727.45	80527.42	41.80835	71.39497	48.1
5R	17	B	10/26/20	12:20:44	108730.99	80527.44	41.80835	71.39493	49.8
5R	17	C	10/26/20	12:21:57	108723.81	80529.41	41.80837	71.39502	47.9
5R	17	D	10/26/20	12:22:48	108727.77	80531.49	41.80839	71.39497	48.8
5R	17	E	10/26/20	12:23:30	108728.8	80532.15	41.80840	71.39496	48.4
5R	17	F	10/28/20	10:30:23	108724.17	80531.68	41.80839	71.39501	46.4
5R	17	G	10/28/20	10:31:06	108726.4	80530.14	41.80838	71.39499	48.3
5R	17	H	10/28/20	10:31:54	108731.05	80528.72	41.80837	71.39493	49.7
5R	17	I	10/28/20	10:32:36	108726.67	80526.09	41.80834	71.39498	46.7
5R	17	J	10/28/20	10:33:25	108728.73	80532.72	41.80840	71.39496	52.5
5R	18	A	10/26/20	12:26:03	108804.52	80522.15	41.80831	71.39405	52.4
5R	18	B	10/26/20	12:26:54	108807.68	80523.9	41.80832	71.39401	51.9
5R	18	C	10/26/20	12:28:11	108811.64	80521.09	41.80830	71.39396	48.2
5R	18	D	10/26/20	12:28:50	108811.35	80518.3	41.80827	71.39396	48.5
5R	18	E	10/26/20	12:29:44	108806.07	80516.53	41.80825	71.39403	49.5
5R	18	F	10/28/20	10:24:09	108804.18	80522.86	41.80831	71.39405	51.4
5R	18	G	10/28/20	10:25:03	108803.8	80517.56	41.80826	71.39406	51.5
5R	18	H	10/28/20	10:25:47	108806.78	80521.1	41.80830	71.39402	52.2
5R	18	I	10/28/20	10:26:35	108808.81	80522.95	41.80831	71.39400	51.9
5R	18	J	10/28/20	10:27:25	108809.82	80522.63	41.80831	71.39398	52.7
5R	19	A	10/26/20	12:32:00	108803.9	80453.71	41.80769	71.39406	50.2
5R	19	B	10/26/20	12:32:41	108809.64	80456.06	41.80771	71.39399	49.2
5R	19	C	10/26/20	12:33:26	108806.27	80456.34	41.80771	71.39403	49.5
5R	19	D	10/26/20	12:34:13	108807.62	80459.76	41.80774	71.39401	47.5
5R	19	E	10/26/20	12:35:17	108805	80459.86	41.80774	71.39404	46.1
5R	19	F	10/28/20	10:17:49	108806.13	80461.26	41.80776	71.39403	46.4
5R	19	G	10/28/20	10:18:39	108805.35	80456.07	41.80771	71.39404	47.8
5R	19	H	10/28/20	10:19:43	108806.58	80453.17	41.80768	71.39402	49.0
5R	19	I	10/28/20	10:20:37	108809.08	80454.6	41.80770	71.39399	49.5
5R	19	J	10/28/20	10:21:33	108802.67	80454.99	41.80770	71.39407	48.7
5R	20	A	10/26/20	11:33:26	108877.84	80420.32	41.80739	71.39317	49.4
5R	20	B	10/26/20	11:34:19	108872.04	80421.44	41.80740	71.39324	51.1
5R	20	C	10/26/20	11:35:21	108870.41	80418.33	41.80737	71.39326	50.5
5R	20	D	10/26/20	11:36:18	108874	80414.85	41.80734	71.39321	51.6
5R	20	E	10/26/20	11:37:07	108875.32	80416.1	41.80735	71.39320	51.5
5R	20	F	10/27/20	12:07:54	108873.82	80422.86	41.80741	71.39321	50.1
5R	20	G	10/27/20	12:08:44	108874.99	80419.12	41.80738	71.39320	50.3
5R	20	H	10/27/20	12:09:29	108877.02	80415.61	41.80735	71.39318	

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
5R	20	I	10/27/20	12:10:25	108871.64	80417.53	41.80736	71.39324	50.1
5R	20	J	10/27/20	12:11:22	108876.86	80421.25	41.80740	71.39318	50.0
5R	20	K	10/28/20	10:11:53	108874.57	80418.5	41.80737	71.39321	51.1
5R	20	L	10/28/20	10:12:37	108872.36	80421.84	41.80740	71.39323	50.8
5R	20	M	10/28/20	10:13:51	108874.99	80416.38	41.80735	71.39320	51.3
5R	20	N	10/28/20	10:14:27	108871.58	80416.42	41.80735	71.39324	50.4
5R	20	O	10/28/20	10:15:14	108877.23	80416.22	41.80735	71.39317	48.1
5R	21	A	10/26/20	11:25:53	108877.65	80370.23	41.80694	71.39317	55.6
5R	21	B	10/26/20	11:26:53	108879.04	80372.52	41.80696	71.39315	53.8
5R	21	C	10/26/20	11:27:47	108883.42	80373.52	41.80697	71.39310	54.2
5R	21	D	10/26/20	11:28:52	108885.22	80369.05	41.80693	71.39308	52.8
5R	21	E	10/26/20	11:29:55	108883.02	80367.89	41.80692	71.39310	54.6
5R	21	F	10/28/20	10:05:11	108883.36	80369.59	41.80693	71.39310	45.9
5R	21	G	10/28/20	10:05:58	108881.67	80373.91	41.80697	71.39312	48.5
5R	21	H	10/28/20	10:06:52	108880.65	80366.6	41.80690	71.39313	44.8
5R	21	I	10/28/20	10:08:13	108884.21	80373.06	41.80696	71.39309	51.2
5R	21	J	10/28/20	10:09:19	108884.7	80368.83	41.80692	71.39308	54.6
1R	22	A	10/26/20	16:28:17	108606.01	80630.62	41.80928	71.39643	52.9
1R	22	B	10/26/20	16:29:11	108606.63	80637	41.80934	71.39643	51.6
1R	22	C	10/26/20	16:29:53	108607.75	80633.16	41.80931	71.39641	53.3
1R	22	D	10/26/20	16:30:45	108611.88	80633.49	41.80931	71.39636	52.1
1R	22	E	10/26/20	16:31:48	108604.87	80634.28	41.80932	71.39645	52.9
1R	22	F	10/27/20	16:31:26	108604.5	80631.97	41.80930	71.39645	49.4
1R	22	G	10/27/20	16:32:07	108607	80633.83	41.80931	71.39642	49.5
1R	22	H	10/27/20	16:32:46	108606.88	80637.04	41.80934	71.39642	49.4
1R	22	I	10/27/20	16:33:36	108605.31	80635.35	41.80933	71.39644	50.1
1R	22	J	10/27/20	16:34:44	108609.55	80630.66	41.80928	71.39639	50.0
REF-South	01R	A	10/26/20	9:55:01	108778.79	79940.88	41.80307	71.39437	42.4
REF-South	01R	B	10/26/20	9:55:47	108778.5	79940.46	41.80307	71.39437	42.4
REF-South	01R	C	10/26/20	9:56:34	108778.72	79940.51	41.80307	71.39437	42.4
REF-South	01R	D	10/26/20	9:57:15	108776.82	79940.85	41.80307	71.39439	42.4
REF-South	01R	E	10/26/20	9:57:47	108776.95	79940.92	41.80307	71.39439	42.4
REF-South	01R	F	10/26/20	10:27:02	108779.34	79938.22	41.80305	71.39436	42.4
REF-South	01R	G	10/26/20	10:27:52	108781.14	79938.89	41.80305	71.39434	42.4
REF-South	01R	H	10/26/20	10:28:14	108778.74	79937.25	41.80304	71.39437	42.4
REF-South	01R	I	10/26/20	10:28:35	108779.2	79939.63	41.80306	71.39436	42.4
REF-South	01R	J	10/26/20	10:28:56	108777.99	79938.03	41.80305	71.39438	42.4
REF-South	01R	K	10/28/20	7:43:35	108778.07	79937.42	41.80304	71.39437	45.4
REF-South	01R	L	10/28/20	7:45:13	108776.51	79942.57	41.80309	71.39439	44.9
REF-South	01R	M	10/28/20	7:45:53	108774.95	79940.19	41.80307	71.39441	45.6
REF-South	01R	N	10/28/20	7:46:43	108781.9	79941.25	41.80308	71.39433	45.1
REF-South	01R	P	10/28/20	7:47:33	108780.83	79943.42	41.80309	71.39434	45.7
REF-South	02R	A	10/26/20	10:49:26	108848.88	79997.45	41.80358	71.39352	43.0
REF-South	02R	B	10/26/20	10:50:21	108851.14	79998.93	41.80359	71.39349	43.0
REF-South	02R	C	10/26/20	10:51:07	108852.78	79999.88	41.80360	71.39347	43.0
REF-South	02R	D	10/26/20	10:52:03	108854	80001.24	41.80361	71.39346	42.9
REF-South	02R	E	10/26/20	10:52:55	108855.96	80001.76	41.80362	71.39344	42.9
REF-South	02R	F	10/28/20	9:06:04	108856.04	79999.66	41.80360	71.39343	44.3
REF-South	02R	G	10/28/20	9:06:54	108853.21	80003.46	41.80363	71.39347	44.6
REF-South	02R	H	10/28/20	9:08:34	108847.62	80001.01	41.80361	71.39354	44.6
REF-South	02R	I	10/28/20	9:09:25	108852.71	79998.33	41.80359	71.39347	44.0
REF-South	02R	J	10/28/20	9:10:13	108851.63	79995.8	41.80357	71.39349	44.6
REF-South	03R	A	10/26/20	11:06:23	108942.37	79998.32	41.80359	71.39240	44.1
REF-South	03R	B	10/26/20	11:07:19	108942.82	80000.32	41.80361	71.39239	44.1
REF-South	03R	C	10/26/20	11:08:06	108944.17	80001.61	41.80362	71.39237	44.1

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
REF-South	03R	D	10/26/20	11:08:48	108945.19	80003.4	41.80363	71.39236	45.2
REF-South	03R	E	10/26/20	11:10:08	108946.41	80000.49	41.80361	71.39235	44.3
REF-South	03R	F	10/27/20	11:31:53	108944.35	79998.66	41.80359	71.39237	44.6
REF-South	03R	G	10/27/20	11:32:55	108944.26	80003.72	41.80364	71.39237	46.1
REF-South	03R	H	10/27/20	11:33:48	108947.34	79999.55	41.80360	71.39234	45.5
REF-South	03R	I	10/27/20	11:34:59	108942.58	80002.5	41.80363	71.39239	46.3
REF-South	03R	J	10/27/20	11:35:37	108942.66	80000.87	41.80361	71.39239	
REF-South	03R	K	10/28/20	9:12:48	108948.91	80002.46	41.80362	71.39232	46.5
REF-South	03R	L	10/28/20	9:13:34	108944.28	79997.97	41.80358	71.39237	44.9
REF-South	03R	M	10/28/20	9:14:24	108945.41	80001.92	41.80362	71.39236	46.6
REF-South	03R	N	10/28/20	9:15:15	108945.25	80005.27	41.80365	71.39236	46.9
REF-South	03R	O	10/28/20	9:16:11	108942.25	80001.52	41.80362	71.39240	47.0
REF-South	05R	A	10/26/20	11:16:57	109110.68	80073.91	41.80427	71.39037	39.5
REF-South	05R	B	10/26/20	11:17:54	109107.18	80076.77	41.80429	71.39041	39.7
REF-South	05R	C	10/26/20	11:18:49	109109.25	80082.05	41.80434	71.39039	40.7
REF-South	05R	D	10/26/20	11:19:58	109110.87	80082.26	41.80434	71.39037	39.5
REF-South	05R	E	10/26/20	11:20:40	109114.14	80079.31	41.80431	71.39033	40.2
REF-South	05R	F	10/27/20	10:33:56	109108.61	80075.06	41.80428	71.39039	39.0
REF-South	05R	G	10/27/20	10:34:46	109112.51	80074.08	41.80427	71.39035	39.2
REF-South	05R	H	10/27/20	10:35:36	109112.05	80076.76	41.80429	71.39035	39.5
REF-South	05R	I	10/27/20	10:36:37	109114.03	80079.88	41.80432	71.39033	39.2
REF-South	05R	J	10/27/20	10:37:41	109108.72	80079.72	41.80432	71.39039	38.8
REF-South	05R	K	10/27/20	11:04:56	109114.37	80077.49	41.80430	71.39033	39.2
REF-South	05R	L	10/27/20	11:05:54	109114.9	80076.98	41.80429	71.39032	39.8
REF-South	05R	M	10/27/20	11:06:55	109111.02	80078.18	41.80430	71.39037	39.2
REF-South	05R	N	10/27/20	11:07:52	109110.07	80079.66	41.80432	71.39038	39.2
REF-South	05R	P	10/27/20	11:08:45	109107.36	80076.97	41.80429	71.39041	38.7
REF-South	05R	Q	10/28/20	9:19:29	109110.53	80078.16	41.80430	71.39037	41.3
REF-South	05R	R	10/28/20	9:20:11	109115.05	80077.71	41.80430	71.39032	41.9
REF-South	05R	S	10/28/20	9:20:58	109107.16	80076.66	41.80429	71.39041	41.8
REF-South	05R	T	10/28/20	9:21:54	109112.34	80081.56	41.80434	71.39035	41.6
REF-South	05R	U	10/28/20	9:22:52	109108.44	80080.38	41.80432	71.39040	42.1
REF-North	07R	A	10/26/20	15:44:44	108432.76	81038.42	41.81296	71.39851	36.4
REF-North	07R	B	10/26/20	15:45:42	108431.52	81033.86	41.81292	71.39853	37.7
REF-North	07R	C	10/26/20	15:46:34	108433.98	81031.44	41.81289	71.39850	41.2
REF-North	07R	D	10/26/20	15:47:30	108428.13	81035.47	41.81293	71.39857	39.4
REF-North	07R	E	10/26/20	15:48:46	108430.25	81031.06	41.81289	71.39854	41.4
REF-North	07R	F	10/27/20	15:44:30	108434.2	81031.27	41.81289	71.39850	40.7
REF-North	07R	G	10/27/20	15:45:15	108433.05	81035.13	41.81293	71.39851	40.7
REF-North	07R	H	10/27/20	15:46:01	108431.45	81037.02	41.81294	71.39853	41.0
REF-North	07R	I	10/27/20	15:46:59	108429.17	81036.46	41.81294	71.39856	40.9
REF-North	07R	J	10/27/20	15:48:01	108428.97	81032.81	41.81291	71.39856	40.7
REF-North	08R	A	10/26/20	15:50:56	108377.42	80999.71	41.81261	71.39918	43.6
REF-North	08R	B	10/26/20	15:52:03	108377.86	81002.91	41.81264	71.39917	41.2
REF-North	08R	C	10/26/20	15:52:54	108381.45	81001.31	41.81262	71.39913	43.5
REF-North	08R	D	10/26/20	15:53:40	108385.25	81002.22	41.81263	71.39909	44.0
REF-North	08R	E	10/26/20	15:55:50	108382.96	80996.95	41.81258	71.39911	43.8
REF-North	08R	F	10/27/20	15:59:23	108381.43	81004.25	41.81265	71.39913	42.5
REF-North	08R	G	10/27/20	16:00:11	108381.63	80996.52	41.81258	71.39913	42.2
REF-North	08R	H	10/27/20	16:01:02	108378.08	81001.5	41.81263	71.39917	42.8
REF-North	08R	I	10/27/20	16:01:56	108381.04	81000.3	41.81261	71.39914	42.4
REF-North	08R	J	10/27/20	16:02:55	108385.65	80999.41	41.81261	71.39908	43.2
REF-North	09R	A	10/26/20	15:57:22	108329.46	80996.44	41.81258	71.39976	36.6
REF-North	09R	B	10/26/20	15:58:09	108325.57	80996.58	41.81258	71.39980	33.9
REF-North	09R	C	10/26/20	15:58:57	108331.45	81000.6	41.81262	71.39973	43.4

Area	Station ID	Replicate	Date	Time	X (RI State Plane meters)	Y (RI State Plane meters)	Latitude NAD83 N	Longitude NAD83 W	Depth (ft)
REF-North	09R	D	10/26/20	16:00:22	108332.9	80994.39	41.81256	71.39972	33.6
REF-North	09R	E	10/26/20	16:01:10	108327.71	80999.73	41.81261	71.39978	32.8
REF-North	09R	F	10/27/20	16:11:24	108333.67	80998.02	41.81259	71.39971	42.5
REF-North	09R	G	10/27/20	16:12:27	108331.19	80997.18	41.81259	71.39974	42.2
REF-North	09R	H	10/27/20	16:13:18	108328.7	81000.2	41.81261	71.39977	42.5
REF-North	09R	I	10/27/20	16:14:13	108329.04	80994.31	41.81256	71.39976	42.6
REF-North	09R	J	10/27/20	16:15:09	108327.31	80996.61	41.81258	71.39978	42.2
REF-North	10R	A	10/26/20	16:03:15	108249.68	80960.8	41.81226	71.40072	43.7
REF-North	10R	B	10/26/20	16:04:04	108252.44	80965.52	41.81230	71.40068	43.7
REF-North	10R	C	10/26/20	16:05:12	108257.45	80962.56	41.81228	71.40062	33.9
REF-North	10R	D	10/26/20	16:06:49	108253.05	80961.56	41.81227	71.40068	33.2
REF-North	10R	E	10/26/20	16:07:33	108255.25	80958.7	41.81224	71.40065	35.2
REF-North	10R	F	10/27/20	16:17:11	108251.03	80960.16	41.81225	71.40070	43.4
REF-North	10R	G	10/27/20	16:17:55	108250.09	80963.71	41.81229	71.40071	43.2
REF-North	10R	H	10/27/20	16:18:44	108256.78	80964.35	41.81229	71.40063	40.5
REF-North	10R	I	10/27/20	16:19:50	108257.44	80960.25	41.81226	71.40062	36.6
REF-North	10R	J	10/27/20	16:20:39	108255.22	80957.72	41.81223	71.40065	43.9

APPENDIX C
SEDIMENT PROFILE IMAGE ANALYSIS RESULTS

Notes:

IND=Indeterminate

N/A=Not Applicable

SWI=Sediment-Water Interface

Successional Stage: "on" indicates one Stage is found on top of another Stage (i.e., 1 on 3);
"->" indicates one Stage is progressing to another Stage (i.e., 2 -> 3).

Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Image Width (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Grain Size Range (phi)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Over-penetration?	Boundary Roughness (cm)
3AR	01	F	50.7	10/28/2020	11:51:54	12	0	14.41	>4	>4	2	>4 to 2	16.38	16.08	16.70	No	0.62
3AR	01	G	50.2	10/28/2020	11:52:55	12	0	14.41	>4	>4	2	>4 to 2	13.96	13.70	14.23	No	0.52
3AR	01	I	50.4	10/28/2020	11:54:42	12	0	14.41	>4	>4	2	>4 to 2	12.15	11.75	12.81	No	1.06
3AR	02	F	51.1	10/28/2020	11:38:16	12	0	14.41	>4	>4	0	>4 to 0	9.43	8.72	10.09	No	1.36
3AR	02	G	51.4	10/28/2020	11:39:09	12	0	14.41	>4/4 to 3	>4	1	>4 to 1	9.82	9.20	10.16	No	0.96
3AR	02	H	52.0	10/28/2020	11:40:01	12	0	14.41	>4/4 to 3	>4	1	>4 to 1	11.18	10.96	11.48	No	0.52
3AR	03	F	52.8	10/28/2020	11:44:46	12	0	14.41	>4	>4	1	>4 to 1	14.72	14.15	15.29	No	1.13
3AR	03	H	52.0	10/28/2020	11:46:25	12	0	14.41	>4	>4	0	>4 to 0	15.53	15.16	15.81	No	0.65
3AR	03	J	52.1	10/28/2020	11:48:17	12	0	14.41	>4	>4	1	>4 to 1	15.52	15.26	15.76	No	0.50
3AR	04	F	53.4	10/27/2020	16:24:15	12	0	14.41	>4	>4	1	>4 to 1	14.96	13.85	16.07	No	2.22
3AR	04	G	56.3	10/27/2020	16:25:20	12	0	14.41	>4	>4	2	>4 to 2	15.11	14.55	15.52	No	0.96
3AR	04	I	53.6	10/27/2020	16:26:52	12	0	14.41	>4	>4	2	>4 to 2	15.27	14.94	15.70	No	0.76
3AR	05	F	51.3	10/28/2020	11:31:28	12	0	14.41	>4/4 to 3	>4	1	>4 to 1	7.28	6.66	7.94	No	1.28
3AR	05	I	49.5	10/28/2020	11:34:39	12	0	14.41	>4	>4	2	>4 to 2	6.69	6.21	7.34	No	1.14
3AR	05	J	51.8	10/28/2020	11:36:03	12	0	14.41	>4	>4	2	>4 to 2	9.34	8.54	9.99	No	1.46

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Image Width (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Grain Size Range (phi)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Over-penetration?	Boundary Roughness (cm)
3AR	06	F	52.8	10/28/2020	11:25:22	12	0	14.41	>4/4 to 3	>4	2	>4 to 2	11.20	10.52	11.72	No	1.20
3AR	06	G	52.8	10/28/2020	11:26:14	12	0	14.41	>4/4 to 3	>4	2	>4 to 2	10.48	10.00	10.78	No	0.78
3AR	06	H	53.2	10/28/2020	11:27:11	12	0	14.41	>4/4 to 3	>4	1	>4 to 1	12.48	12.20	12.66	No	0.45
6/7R	07	F	50.2	10/28/2020	7:56:21	12	0	14.41	>4	>4	2	>4 to 2	15.01	14.15	15.48	No	1.33
6/7R	07	G	51.5	10/28/2020	7:57:11	12	0	14.41	>4	>4	2	>4 to 2	15.10	14.63	16.06	No	1.43
6/7R	07	H	49.7	10/28/2020	7:57:59	12	0	14.41	>4	>4	2	>4 to 2	16.43	15.92	16.94	No	1.03
6/7R	08	K	47.7	10/28/2020	9:30:01	12	0	14.41	>4	>4	1	>4 to 1	15.48	12.64	17.01	No	4.37
6/7R	08	L	46.5	10/28/2020	9:30:59	12	0	14.41	>4	>4	2	>4 to 2	14.94	13.88	15.71	No	1.83
6/7R	08	M	46.8	10/28/2020	9:31:57	12	0	14.41	>4	>4	1	>4 to 1	15.33	15.02	15.48	No	0.45
6/7R	09	L	47.1	10/28/2020	9:37:20	12	0	14.41	>4	>4	2	>4 to 2	15.40	14.81	15.79	No	0.98
6/7R	09	M	48.6	10/28/2020	9:38:09	12	0	14.41	>4	>4	2	>4 to 2	16.56	16.18	16.90	No	0.72
6/7R	09	P	47.6	10/28/2020	9:40:07	12	0	14.41	>4	>4	1	>4 to 1	14.75	13.59	15.78	No	2.19
6/7R	10	L	46.7	10/28/2020	9:52:58	12	0	14.41	>4	>4	2	>4 to 2	17.29	16.86	17.83	No	0.97
6/7R	10	M	47.7	10/28/2020	9:53:44	12	0	14.41	>4	>4	1	>4 to 1	16.20	15.94	16.62	No	0.69
6/7R	10	P	47.9	10/28/2020	9:55:45	12	0	14.41	>4	>4	2	>4 to 2	16.51	16.12	17.14	No	1.02
6/7R	11	M	41.4	10/28/2020	9:58:42	12	0	14.41	>4	>4	1	>4 to 1	13.41	13.10	13.90	No	0.80
6/7R	11	N	39.6	10/28/2020	9:59:33	12	0	14.41	>4	>4	2	>4 to 2	14.92	14.52	15.17	No	0.66
6/7R	11	Q	42.2	10/28/2020	10:01:50	12	0	14.41	>4	>4	1	>4 to 1	15.39	15.12	15.61	No	0.49
4R	12	F	45.2	10/28/2020	11:11:11	12	0	14.41	>4	>4	2	>4 to 2	15.35	15.01	16.03	No	1.02
4R	12	H	45.2	10/28/2020	11:12:57	12	0	14.41	>4	>4	2	>4 to 2	15.75	15.22	16.61	No	1.39

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Image Width (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Grain Size Range (phi)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Over-penetration?	Boundary Roughness (cm)
4R	12	I	44.0	10/28/2020	11:14:31	12	0	14.41	>4	>4	0	>4 to 0	15.15	14.63	15.48	No	0.86
4R	13	F	44.3	10/28/2020	11:18:30	12	0	14.41	>4	>4	2	>4 to 2	15.38	15.12	15.52	No	0.40
4R	13	G	44.0	10/28/2020	11:19:26	12	0	14.41	>4	>4	1	>4 to 1	16.02	15.41	16.32	No	0.92
4R	13	I	44.0	10/28/2020	11:21:14	12	0	14.41	>4	>4	1	>4 to 1	15.79	15.50	16.02	No	0.52
4R	14	F	19.9	10/28/2020	10:46:24	12	0	14.41	>4	>4	2	>4 to 2	15.70	15.05	16.04	No	0.99
4R	14	H	42.8	10/28/2020	10:48:02	12	0	14.41	>4	>4	3	>4 to 3	14.96	14.61	15.49	No	0.88
4R	14	I	42.5	10/28/2020	10:48:55	12	0	14.41	>4	>4	2	>4 to 2	14.35	13.92	14.76	No	0.84
4R	15	F	45.6	10/28/2020	10:41:38	12	0	14.41	>4	>4	2	>4 to 2	15.14	14.85	15.37	No	0.52
4R	15	H	45.5	10/28/2020	10:43:16	12	0	14.41	>4	>4	2	>4 to 2	16.76	16.05	17.34	No	1.29
4R	15	I	45.4	10/28/2020	10:44:02	12	0	14.41	>4	>4	3	>4 to 3	15.77	15.49	16.00	No	0.51
4R	16	F	46.3	10/28/2020	10:36:07	12	0	14.41	>4	>4	2	>4 to 2	15.52	15.15	15.97	No	0.83
4R	16	G	44.9	10/28/2020	10:37:01	12	0	14.41	>4	>4	2	>4 to 2	13.58	13.09	13.89	No	0.80
4R	16	J	46.8	10/28/2020	10:39:26	12	0	14.41	>4	>4	3	>4 to 3	14.72	14.32	14.95	No	0.63
5R	17	F	46.4	10/28/2020	10:30:32	12	0	14.41	>4	>4	2	>4 to 2	14.20	13.77	14.77	No	1.01
5R	17	H	49.7	10/28/2020	10:32:02	12	0	14.41	>4	>4	2	>4 to 2	15.07	14.58	15.45	No	0.86
5R	17	J	52.5	10/28/2020	10:33:34	12	0	14.41	>4	>4	2	>4 to 2	16.85	16.56	17.07	No	0.51
5R	18	F	51.4	10/28/2020	10:24:15	12	0	14.41	>4	>4	2	>4 to 2	14.15	13.92	14.40	No	0.47
5R	18	G	51.5	10/28/2020	10:25:10	12	0	14.41	>4	>4	2	>4 to 2	15.19	15.03	15.31	No	0.28
5R	18	H	52.2	10/28/2020	10:25:56	12	0	14.41	>4	>4	2	>4 to 2	15.67	15.34	15.92	No	0.58
5R	19	G	47.8	10/28/2020	10:18:48	12	0	14.41	>4	>4	1	>4 to 1	17.11	16.46	17.77	No	1.31

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Image Width (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Grain Size Range (phi)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Over-penetration?	Boundary Roughness (cm)
5R	19	H	49.0	10/28/2020	10:19:51	12	0	14.41	>4	>4	3	>4 to 3	14.98	14.14	15.55	No	1.41
5R	19	J	48.7	10/28/2020	10:21:43	12	0	14.41	>4	>4	3	>4 to 3	17.09	16.88	17.38	No	0.50
5R	20	K	51.1	10/28/2020	10:12:04	12	0	14.41	>4	>4	2	>4 to 2	16.98	16.84	17.41	No	0.56
5R	20	L	50.8	10/28/2020	10:12:48	12	0	14.41	>4	>4	2	>4 to 2	16.79	16.33	17.21	No	0.88
5R	20	O	48.1	10/28/2020	10:15:23	12	0	14.41	>4	>4	2	>4 to 2	16.74	16.41	17.12	No	0.71
5R	21	F	45.9	10/28/2020	10:05:20	12	0	14.41	>4	>4	1	>4 to 1	13.98	13.46	14.28	No	0.82
5R	21	H	44.8	10/28/2020	10:07:02	12	0	14.41	>4	>4	0	>4 to 0	15.18	14.50	15.68	No	1.17
5R	21	I	51.2	10/28/2020	10:08:21	12	0	14.41	>4	>4	2	>4 to 2	15.04	14.67	15.59	No	0.92
1R	22	F	49.4	10/27/2020	16:31:36	12	0	14.41	>4	>4	3	>4 to 3	12.05	11.77	12.25	No	0.48
1R	22	H	49.4	10/27/2020	16:32:57	12	0	14.41	>4	>4	1	>4 to 1	8.32	7.67	8.81	No	1.14
1R	22	I	50.1	10/27/2020	16:33:46	12	0	14.41	>4	>4	1	>4 to 1	8.95	8.76	9.19	No	0.43
REF-South	01R	K	45.4	10/28/2020	7:43:44	12	0	14.41	>4	>4	1	>4 to 1	16.09	15.59	16.49	No	0.90
REF-South	01R	L	44.9	10/28/2020	7:45:18	12	0	14.41	>4	>4	2	>4 to 2	15.19	14.92	15.39	No	0.46
REF-South	01R	M	45.6	10/28/2020	7:46:04	12	0	14.41	>4	>4	2	>4 to 2	15.12	14.69	15.68	No	0.98
REF-South	02R	F	44.3	10/28/2020	9:06:15	12	0	14.41	>4	>4	1	>4 to 1	15.39	15.17	15.61	No	0.44
REF-South	02R	H	44.6	10/28/2020	9:08:44	12	0	14.41	>4	>4	1	>4 to 1	11.71	11.45	12.11	No	0.66
REF-South	02R	I	44.0	10/28/2020	9:09:34	12	0	14.41	>4	>4	0	>4 to 0	14.13	14.00	14.23	No	0.24
REF-South	03R	K	46.5	10/28/2020	9:12:57	12	0	14.41	>4	>4	0	>4 to 0	7.15	6.66	7.86	No	1.20
REF-South	03R	M	46.6	10/28/2020	9:14:32	12	0	14.41	>4	>4	1	>4 to 1	5.58	4.93	6.58	No	1.65
REF-South	03R	O	47.0	10/28/2020	9:16:20	12	0	14.41	>4	>4	1	>4 to 1	7.04	5.98	8.05	No	2.08

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Image Width (cm)	Grain Size Major Mode (phi)	Grain Size Minimum (phi)	Grain Size Maximum (phi)	Grain Size Range (phi)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Over-penetration?	Boundary Roughness (cm)
REF-South	05R	Q	41.3	10/28/2020	9:19:38	12	0	14.41	>4	>4	2	>4 to 2	16.32	15.28	17.20	No	1.92
REF-South	05R	S	41.8	10/28/2020	9:21:07	12	0	14.41	>4	>4	2	>4 to 2	13.88	13.15	15.26	No	2.12
REF-South	05R	T	41.6	10/28/2020	9:22:03	12	0	14.41	>4	>4	2	>4 to 2	17.37	16.78	17.71	No	0.93
REF-North	07R	F	40.7	10/27/2020	15:44:40	14	0	14.41	>4	>4	2	>4 to 2	19.98	19.26	20.52	No	1.25
REF-North	07R	I	40.9	10/27/2020	15:47:09	14	0	14.41	>4	>4	2	>4 to 2	18.74	17.92	19.43	No	1.52
REF-North	07R	J	40.7	10/27/2020	15:48:12	14	0	14.41	>4	>4	2	>4 to 2	18.91	17.95	19.72	No	1.77
REF-North	08R	F	42.5	10/27/2020	15:59:33	12	0	14.41	>4	>4	2	>4 to 2	12.97	12.35	14.04	No	1.69
REF-North	08R	H	42.8	10/27/2020	16:01:12	12	0	14.41	>4	>4	2	>4 to 2	14.83	14.26	15.25	No	0.99
REF-North	08R	I	42.4	10/27/2020	16:02:07	12	0	14.41	>4	>4	2	>4 to 2	15.21	14.62	15.53	No	0.91
REF-North	09R	I	42.6	10/27/2020	16:14:23	12	0	14.41	>4	>4	2	>4 to 2	13.61	13.24	13.99	No	0.75
REF-North	09R	J	42.2	10/27/2020	16:15:19	12	0	14.41	>4	>4	2	>4 to 2	17.77	17.35	18.44	No	1.09
REF-North	10R	G	43.2	10/27/2020	16:18:05	12	0	14.41	>4	>4	0	>4 to 0	14.41	14.00	14.85	No	0.85
REF-North	10R	H	40.5	10/27/2020	16:18:54	12	0	14.41	>4	>4	0	>4 to 0	13.47	12.75	13.99	No	1.24
REF-North	10R	J	43.9	10/27/2020	16:20:49	12	0	14.41	>4	>4	0	>4 to 0	13.94	13.37	14.36	No	0.99

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Area	Station ID	Replicate	Boundary Roughness Type	aRPD Mean (cm)	aRPD > Pen	Mud Clast Number	Mud Clast State	Dredged Material Notes	Methane Present?	Low DO Present?	Sediment Oxygen Demand	Beggiatoa Present?	Beggiatoa Type/Extent
3AR	01	F	Biological	0.52	No	0	None	Buried layer of gray, very fine sand beneath highly reduced silt/clay. Buried layer extends beyond prism penetration.	No	Yes	High	Yes	Threads
3AR	01	G	Biological	0.47	No	0	None	Buried layer of gray, very fine sand beneath highly reduced silt/clay. Buried layer extends beyond prism penetration.	No	Yes	High	Yes	Threads
3AR	01	I	Biological	0.78	No	0	None	Buried layer of white clay that extends beyond prism penetration.	No	No	High	No	None
3AR	02	F	Biological	0.40	No	0	None	Buried clay of various optical reflectance. Left side of image appears to be patchy red clay that extends beyond prism penetration and right side of image is patches of white clay also extending beyond prism penetration.	No	No	High	No	None
3AR	02	G	Biological	0.43	No	0	None	Buried layer of fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	Medium	No	None
3AR	02	H	Biological	0.46	No	0	None	Buried layer of fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	Medium	No	None
3AR	03	F	Biological	0.23	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
3AR	03	H	Biological	0.26	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
3AR	03	J	Biological	0.43	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
3AR	04	F	Biological	0.64	No	0	None		No	No	High	No	None
3AR	04	G	Biological	1.04	No	0	None		No	No	High	No	None
3AR	04	I	Biological	0.65	No	0	None		No	No	High	No	None
3AR	05	F	Biological	0.46	No	0	None	Buried layer of sand and intermixed white clay that extends beyond prism penetration.	No	No	High	No	None
3AR	05	I	Biological	0.61	No	0	None	Trace white clay intermixed amongst reduced silt/clay layer.	No	No	High	No	None
3AR	05	J	Biological	0.61	No	0	None	Patches of white clay intermixed amongst reduced silt/clay.	No	No	High	No	None

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Area	Station ID	Replicate	Boundary Roughness Type	aRPD Mean (cm)	aRPD > Pen	Mud Clast Number	Mud Clast State	Dredged Material Notes	Methane Present?	Low DO Present?	Sediment Oxygen Demand	Beggiatoa Present?	Beggiatoa Type/Extent
3AR	06	F	Biological	0.31	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
3AR	06	G	Biological	0.68	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
3AR	06	H	Biological	0.64	No	0	None	Buried layer of very fine sand beneath reduced silt/clay that extends beyond prism penetration.	No	No	High	No	None
6/7R	07	F	Biological	0.00	No	0	None		Yes	Yes	High	Yes	Threads
6/7R	07	G	Biological	0.00	No	2	Reduced/Oxidized		No	Yes	High	Yes	Threads
6/7R	07	H	Biological	0.31	No	0	None		No	Yes	High	Yes	Threads
6/7R	08	K	Biological	0.31	No	0	None		No	No	High	No	None
6/7R	08	L	Biological	0.69	No	0	None	Buried band of somewhat reworked white clay.	No	No	High	No	None
6/7R	08	M	Biological	0.35	No	0	None	Buried layer of reworked white clay at depth.	No	No	High	No	None
6/7R	09	L	Biological	0.00	No	0	None	Band of light gray silt/clay.	No	Yes	High	Yes	Threads
6/7R	09	M	Biological	0.00	No	5	Reduced	Trace lighter silt/clay intermixed with reduced sediment.	No	Yes	High	Yes	Threads
6/7R	09	P	Biological	0.00	No	0	None	Band of light gray silt/clay.	No	Yes	High	Yes	Threads
6/7R	10	L	Biological	0.31	No	0	None	Band of light gray silt/clay.	No	No	High	No	None
6/7R	10	M	Biological	0.45	No	0	None	Band of light gray silt/clay that has been reworked.	No	Yes	High	Yes	Threads
6/7R	10	P	Biological	0.36	No	0	None	Band of light gray silt/clay.	No	Yes	High	Yes	Threads
6/7R	11	M	Biological	0.26	No	0	None		No	No	High	No	None
6/7R	11	N	Biological	0.39	No	0	None		No	No	High	No	None
6/7R	11	Q	Biological	0.00	No	0	None		No	No	High	No	None
4R	12	F	Biological	0.55	No	0	None		No	No	High	No	None
4R	12	H	Biological	0.21	No	0	None		No	No	High	No	None

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Area	Station ID	Replicate	Boundary Roughness Type	aRPD Mean (cm)	aRPD > Pen	Mud Clast Number	Mud Clast State	Dredged Material Notes	Methane Present?	Low DO Present?	Sediment Oxygen Demand	Beggiatoa Present?	Beggiatoa Type/Extent
4R	12	I	Biological	0.27	No	0	None		No	No	High	No	None
4R	13	F	Biological	0.15	No	0	None	Trace white clay just beneath SWI.	No	No	High	No	None
4R	13	G	Biological	0.27	No	0	None	Trace white clay just beneath SWI.	Yes	No	High	No	None
4R	13	I	Biological	0.38	No	0	None		No	No	High	No	None
4R	14	F	Biological	0.23	No	0	None		Yes	Yes	High	Yes	Threads
4R	14	H	Biological	0.33	No	0	None		No	Yes	High	Yes	Patches
4R	14	I	Biological	0.51	No	0	None		No	Yes	High	Yes	Threads
4R	15	F	Biological	0.32	No	0	None		No	No	High	No	None
4R	15	H	Biological	0.10	No	0	None	A partially reworked layer of white clay just beneath SWI.	No	No	High	No	None
4R	15	I	Biological	0.41	No	0	None		Yes	Yes	High	No	None
4R	16	F	Biological	0.00	No	0	None		No	No	High	Yes	Threads
4R	16	G	Biological	0.48	No	0	None		No	No	High	No	None
4R	16	J	Biological	0.06	No	0	None		No	No	High	No	None
5R	17	F	Biological	IND	No	1	Reduced	Trace white clay beneath SWI.	No	Yes	High	Yes	Threads
5R	17	H	Biological	0.08	No	0	None	A thin band of buried white clay.	No	Yes	High	Yes	Threads
5R	17	J	Biological	0.00	No	0	None	A thin band of buried white clay.	No	Yes	High	Yes	Threads
5R	18	F	Biological	0.00	No	1	Reduced/Oxidized	Trace, layer of buried grayish silt/clay with white clay patch intermixed. Mostly reworked	No	No	High	No	None
5R	18	G	Biological	0.00	No	0	None	Trace band of white clay a few centimeters beneath SWI. Mostly reworked	No	Yes	High	Yes	Threads
5R	18	H	Biological	0.00	No	0	None	Trace, reworked band of white clay a few centimeters beneath SWI.	Yes	Yes	High	Yes	Threads
5R	19	G	Biological	0.25	No	2	Reduced/Oxidized		Yes	Yes	High	No	None

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Area	Station ID	Replicate	Boundary Roughness Type	aRPD Mean (cm)	aRPD > Pen	Mud Clast Number	Mud Clast State	Dredged Material Notes	Methane Present?	Low DO Present?	Sediment Oxygen Demand	Beggiatoa Present?	Beggiatoa Type/Extent
5R	19	H	Biological	0.35	No	0	None		No	No	High	No	None
5R	19	J	Biological	0.24	No	0	None		No	No	High	No	None
5R	20	K	Biological	0.00	No	0	None	Trace, reworked band of white clay a few centimeters beneath SWI.	Yes	Yes	High	Yes	Threads
5R	20	L	Biological	0.00	No	0	None	Trace, reworked band of white clay a few centimeters beneath SWI.	Yes	Yes	High	Yes	Threads
5R	20	O	Biological	0.00	No	2	Reduced	Trace white clay that appears to have been reworked a few centimeters beneath SWI	No	Yes	High	Yes	Threads
5R	21	F	Biological	0.54	No	0	None		Yes	Yes	High	No	None
5R	21	H	Biological	0.61	No	0	None		No	No	High	No	None
5R	21	I	Biological	0.38	No	2	Reduced/Oxidized		No	No	High	No	None
1R	22	F	Biological	0.27	No	0	None		No	No	High	No	None
1R	22	H	Biological	0.31	No	2	Reduced		Yes	Yes	High	No	None
1R	22	I	Biological	0.27	No	4	Reduced/Oxidized		No	No	High	No	None
REF-South	01R	K	Biological	1.36	No	0	None		No	No	High	No	None
REF-South	01R	L	Biological	0.66	No	0	None		No	No	High	No	None
REF-South	01R	M	Biological	0.82	No	0	None		No	No	High	No	None
REF-South	02R	F	Biological	0.61	No	0	None		No	No	High	No	None
REF-South	02R	H	Biological	0.53	No	0	None		No	No	High	No	None
REF-South	02R	I	Biological	0.82	No	0	None		No	No	High	No	None
REF-South	03R	K	Biological	0.53	No	0	None	Trace white clay intermixed amongst reduced silt/clay layer.	No	No	High	No	None
REF-South	03R	M	Biological	0.64	No	0	None		No	No	High	No	None
REF-South	03R	O	Biological	0.57	No	0	None		No	No	High	No	None

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Area	Station ID	Replicate	Boundary Roughness Type	aRPD Mean (cm)	aRPD > Pen	Mud Clast Number	Mud Clast State	Dredged Material Notes	Methane Present?	Low DO Present?	Sediment Oxygen Demand	Beggiatoa Present?	Beggiatoa Type/Extent
REF-South	05R	Q	Physical	0.00	No	0	None		No	No	High	No	None
REF-South	05R	S	Physical	0.00	No	0	None		No	No	High	No	None
REF-South	05R	T	Biological	0.04	No	0	None		No	No	High	No	None
REF-North	07R	F	Biological	0.00	No	0	None		Yes	Yes	High	Yes	Threads
REF-North	07R	I	Biological	0.00	No	0	None		No	Yes	High	Yes	Threads
REF-North	07R	J	Biological	0.00	No	0	None		Yes	Yes	High	Yes	Threads
REF-North	08R	F	Biological	0.32	No	0	None		No	No	High	No	None
REF-North	08R	H	Biological	0.45	No	0	None		No	No	High	No	None
REF-North	08R	I	Biological	0.51	No	1	Reduced		No	No	High	No	None
REF-North	09R	I	Biological	0.68	No	0	None		No	No	High	No	None
REF-North	09R	J	Biological	IND	No	0	None		No	No	High	No	None
REF-North	10R	G	Biological	0.65	No	0	None		No	No	Medium	No	None
REF-North	10R	H	Biological	1.10	No	1	Reduced		No	No	Medium	No	None
REF-North	10R	J	Biological	0.71	No	1	Reduced		No	No	Medium	No	None

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Area	Station ID	Replicate	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Successional Stage	Comment
3AR	01	F	1	7.35	8.62	2 on 3	Highly reduced sediment with Beggiatoa threads within sediment column. Stage 2 tubes at SWI and an open void within sediment column. Buried layer of gray very fine sand beneath reduced silt/clay layer.
3AR	01	G	0	N/A	N/A	2 -> 3	Highly reduced sediment with Beggiatoa threads within sediment column. Stage 2 tubes at SWI. Buried layer of gray very fine sand beneath reduced silt/clay layer.
3AR	01	I	2	7.07	11.42	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. Buried layer of white clay dredged material beneath reduced sediment and moves beyond prism penetration.
3AR	02	F	0	N/A	N/A	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay with a buried layer of mixed clays. Stage 2 tubes and a large burrow beginning at SWI and moving to depth.
3AR	02	G	0	N/A	N/A	2 -> 3	Thin layer of oxidized silt/clay over reduced silt/clay with a buried layer of fine sand. Stage 2 tubes dense at SWI and burrowing evident beyond aRPD boundary.
3AR	02	H	4	5.58	10.74	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay with a buried layer of fine sand. Stage 2 tubes dense at SWI. Some burrowing present but seems restricted to upper centimeters of sediment. Oxidized infilled voids at depth.
3AR	03	F	1	7.39	7.73	1 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. A buried layer of reduced very fine sand beneath silt/clay extends beyond prism penetration. An infilled void at boundary of reduced silt/clay and buried very fine sand.
3AR	03	H	0	N/A	N/A	2	Thin layer of oxidized silt/clay over reduced silt/clay. A buried layer of reduced very fine sand beneath silt/clay extends beyond prism penetration. Stage 2 tubes at SWI.
3AR	03	J	0	N/A	N/A	2 -> 3	Thin layer of oxidized silt/clay over reduced silt/clay. A buried layer of reduced very fine sand beneath silt/clay extends beyond prism penetration. Stage 2 tubes at SWI. Burrowing evident beyond aRPD boundary.
3AR	04	F	1	7.24	7.78	2 on 3	Silt/clay with a slightly disturbed SWI. Stage 2 tubes at SWI and an infilled void in reduced sediment layer.
3AR	04	G	0	N/A	N/A	2	Silt/clay with Stage 2 tubes at SWI. Burrowing visible above aRPD boundary but not evident moving to depth.
3AR	04	I	0	N/A	N/A	2 -> 3	Silt/clay. Stage 2 tubes at SWI and burrowing evident throughout sediment column.
3AR	05	F	0	N/A	N/A	2 -> 3	Silt/clay with a buried layer of very fine sand and white clay that extends beyond prism penetration. Stage 2 tubes at SWI and burrowing evident in sediment column.
3AR	05	I	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes at SWI. Burrowing visible and intermixed white clay near maximum prism penetration.
3AR	05	J	0	N/A	N/A	2	Silt/clay with buried patches of white clay at depth. Stage 2 tubes at SWI.

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Area	Station ID	Replicate	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Successional Stage	Comment
3AR	06	F	2	3.06	42.00	2 on 3	Silt/clay with a thin aRPD. A few partially infilled voids in reduced sediment. A buried layer of sand beneath the reduced silt/clay.
3AR	06	G	0	N/A	N/A	2 -> 3	Silt/clay over very fine sand that extends beyond prism penetration. Stage 2 tubes at SWI and a few burrows moving beyond aRPD boundary.
3AR	06	H	1	6.69	7.42	2 on 3	Silt/clay over very fine sand that extends beyond prism penetration. Stage 2 tubes at SWI and a few burrows moving beyond aRPD boundary. Small void at depth in sediment column at left.
6/7R	07	F	0	N/A	N/A	1	Silt/clay with many small methane bubbles in sediment column and threads of Beggiatoa near SWI.
6/7R	07	G	0	N/A	N/A	1	Reduced silt/clay with threads of Beggiatoa in sediment near SWI. Some deposition of fines at SWI with a reduced and an oxidized mud clast.
6/7R	07	H	0	N/A	N/A	1	Reduced silt/clay with some deposition of fines at SWI. Stage 1 and a few Stage 2 tubes at SWI. Infilled voids a few centimeters beneath SWI. Threads of Beggiatoa present in sediment near SWI.
6/7R	08	K	0	N/A	N/A	2 on 3	Reduced silt/clay with thin oxygenated layer at SWI. Stage 2 tubes and large burrow opening at SWI. Burrow opening goes deep in to visible sediment column.
6/7R	08	L	2	4.96	14.23	2 on 3	Reduced silt/clay with thin oxygenated layer at SWI. Stage 2 tubes at SWI. Large burrow and a few partially infilled voids in sediment column. A band of reworked white clay buried in sediment.
6/7R	08	M	3	13.03	11.96	2 on 3	Reduced silt/clay with a thin aRPD and many Stage 2 tubes at SWI. Open voids at depth within reworked layer of white clay.
6/7R	09	L	0	N/A	N/A	1	Highly reduced silt/clay with threads of Beggiatoa near SWI and a buried band of light gray silt/clay.
6/7R	09	M	0	N/A	N/A	1	Highly reduced silt/clay with threads of Beggiatoa near SWI and a buried band of reworked light gray silt/clay.
6/7R	09	P	0	N/A	N/A	1	Highly reduced silt/clay with threads of Beggiatoa near SWI and a buried band of light gray silt/clay.
6/7R	10	L	1	5.44	5.98	1 on 3	Silt/clay with very thin aRPD, Stage 1 tubes at SWI, and an open void within buried band of dredged material.
6/7R	10	M	0	N/A	N/A	1 -> 2	Silt/clay with Beggiatoa threads in upper centimeters of sediment. A buried layer of reworked gray silt/clay with burrowing evident above and within.
6/7R	10	P	0	N/A	N/A	2	Silt/clay with Beggiatoa threads in upper centimeters of sediment and Stage 2 tubes at SWI. A buried layer of reworked gray silt/clay with burrowing evident above and within.
6/7R	11	M	1	3.37	3.99	2 on 3	Silt/clay with Stage 1 and 2 tubes at SWI and an open void a few centimeters in to sediment column.
6/7R	11	N	0	N/A	N/A	2	Silt/clay with a few Stage 2 tubes at SWI and some shallow burrowing.
6/7R	11	Q	0	N/A	N/A	2	Silt/clay with a few Stage 2 tubes at SWI and some shallow burrowing.
4R	12	F	4	4.11	8.64	2 on 3	Silt/clay with Stage 2 tubes at SWI. A thin aRPD with multiple partially infilled voids beneath the aRPD boundary.
4R	12	H	0	N/A	N/A	2	Silt/clay with a couple of Stage 2 tubes at SWI and some shallow burrowing visible.

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Area	Station ID	Replicate	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Successional Stage	Comment
4R	12	I	0	N/A	N/A	2	Silt/clay with a couple of Stage 2 tubes at SWI and some shallow burrowing visible.
4R	13	F	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes at SWI and a large burrow at SWI moving in to sediment column. A trace layer of white clay just beneath SWI.
4R	13	G	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes at SWI and shallow burrowing visible. Some possible methane beneath shallow aRPD boundary.
4R	13	I	0	N/A	N/A	2	Silt/clay with Stage 2 tubes at SWI and burrowing just beneath SWI.
4R	14	F	0	N/A	N/A	2	Silt/clay with a Stage 2 tube at SWI. Threads of Beggiatoa dense in upper centimeters of sediment, small methane bubbles at depth.
4R	14	H	0	N/A	N/A	2	Silt/clay with patches of Beggiatoa at SWI and threads within the sediment column. A few Stage 1 tubes at SWI and some shallow to medium burrowing visible.
4R	14	I	3	4.22	8.32	2 on 3	Silt/clay with Beggiatoa threads in sediment. Stage 2 tubes at SWI and a few open voids beneath aRPD boundary.
4R	15	F	1	7.41	8.02	2 on 3	Silt/clay with Stage 2 tubes at SWI and an open void beneath thin aRPD boundary.
4R	15	H	1	4.21	4.99	2	Silt/clay with Stage 2 tubes at SWI and an infilled void beneath thin aRPD boundary.
4R	15	I	1	12.25	12.74	2	Silt/clay with Stage 2 tubes at SWI and multiple methane bubbles throughout the sediment column.
4R	16	F	0	N/A	N/A	1	Silt/clay with Stage 1 tubes at SWI, threads of Beggiatoa in upper centimeters of sediment, and reworked white clay is barely visible.
4R	16	G	2	4.02	12.09	2 on 3	Silt/clay with Stage 2 tubes at SWI, a few burrow openings at SWI, and a pair of partially infilled voids.
4R	16	J	4	7.46	14.62	1 on 3	Reduced silt/clay with a very thin aRPD but multiple open and partially infilled voids going to depth.
5R	17	F	3	4.80	11.30	1 on 3	Reduced silt/clay with threads of Beggiatoa in upper centimeters of sediment but multiple open and partially infilled voids going to depth.
5R	17	H	3	11.47	14.52	2 on 3	Reduced silt/clay with threads of Beggiatoa in upper centimeters of sediment. A Stage 2 tube at SWI and a large, open burrow moving from SWI to depth with multiple associated feeding voids.
5R	17	J	5	1.61	4.93	1 on 3	Reduced silt/clay with threads of Beggiatoa in upper centimeters of sediment and a thin band of white clay buried in sediment. Visible worms in burrows and many small, shallow feeding voids visible.
5R	18	F	1	8.99	9.66	1 on 3	Reduced silt/clay with a thick layer of buried dredged material going beyond prism penetration. An open void just within dredged material upper boundary.
5R	18	G	1	9.05	10.85	1 on 3	Reduced silt/clay with a band of white clay dredged material a few centimeters in to sediment column. Threads of Beggiatoa in upper centimeters, burrowing evident, and a large burrow moving to depth with an open void.
5R	18	H	1	5.10	5.61	1 on 3	Reduced silt/clay with many threads of Beggiatoa near SWI. A band of reworked white clay in upper centimeters of sediment, multiple methane bubbles throughout, and an infilled void right at dredged material boundary.
5R	19	G	0	N/A	N/A	2	Silt/clay with a thin aRPD and many Stage 2 tubes at SWI. A large methane bubble in sediment near SWI.

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Area	Station ID	Replicate	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Successional Stage	Comment
5R	19	H	0	N/A	N/A	2	Silt/clay with a thin aRPD and many Stage 2 tubes at SWI. Shallow burrowing visible.
5R	19	J	2	3.98	11.56	2 -> 3	Silt/clay with trace dredged material in upper centimeters of sediment. Stage 1 tubes at SWI with evidence of shallow burrowing.
5R	20	K	4	4.12	5.59	1 -> 2	Reduced silt/clay with threads of Beggiatoa throughout. A band of white clay with many infilled voids present a few centimeters beneath SWI. Stage 1 tubes at SWI and a methane bubble near dredged material.
5R	20	L	3	1.49	5.61	1 -> 2	Reduced silt/clay with threads of Beggiatoa throughout. A band of white clay present a few centimeters beneath SWI. Stage 1 tubes at SWI and a methane bubble at depth. Infilled voids at depth.
5R	20	O	2	4.61	13.84	1 -> 2	Reduced silt/clay with threads of Beggiatoa throughout. Trace reworked white clay within sediment column. Infilled voids at depth.
5R	21	F	0	N/A	N/A	2	Silt/clay with a thin aRPD and many Stage 2 tubes at SWI. A small methane bubble just beneath aRPD boundary.
5R	21	H	0	N/A	N/A	2	Silt/clay with a thin aRPD and many Stage 2 tubes at SWI. Shallow burrowing visible.
5R	21	I	1	7.29	8.41	2 on 3	Silt/clay with a few Stage 2 tubes at SWI. A large, open void beneath aRPD boundary.
1R	22	F	0	N/A	N/A	2	Silt/clay with Stage 2 tubes at SWI.
1R	22	H	0	N/A	N/A	2	Silt/clay with Stage 2 tubes at SWI and a large methane bubble at left of image just beneath SWI.
1R	22	I	0	N/A	N/A	2	Silt/clay with Stage 2 tubes at SWI.
REF-South	01R	K	0	N/A	N/A	2 -> 3	Thin layer of oxidized silt/clay over reduced silt/clay. A few Stage 2 tubes at SWI and evidence of burrowing moving beyond aRPD and to depth.
REF-South	01R	L	0	N/A	N/A	2 -> 3	Thin layer of oxidized silt/clay over reduced silt/clay. A few Stage 2 tubes at SWI and evidence of burrowing moving beyond aRPD and to depth.
REF-South	01R	M	1	4.66	5.15	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. A few Stage 2 tubes at SWI and a partially infilled void beyond aRPD boundary.
REF-South	02R	F	5	6.48	11.58	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. A Stage 2 tube at SWI and many open and partially infilled burrows at depth.
REF-South	02R	H	1	6.95	7.26	1 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. An open void at left of image in reduced silt/clay.
REF-South	02R	I	2	8.27	12.32	1 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. Infilled voids near buried layer of white clay.
REF-South	03R	K	4	1.42	4.52	2 on 3	Thin layer of oxidized silt/clay over reduced silt/clay. Trace white clay intermixed in reduced silt/clay. Stage 2 tubes at SWI. Open and partially infilled voids present.
REF-South	03R	M	0	N/A	N/A	2	Thin layer of oxidized silt/clay over reduced silt/clay. Buried layer of whitish silt/clay. SWI appears to have been recently disturbed. Stage 2 tubes at SWI in background of image.
REF-South	03R	O	0	N/A	N/A	2	Silt/clay with a disturbed SWI. A gastropod shell visible at SWI with Stage 2 tubes also present. A piece of some sort of debris at the SWI as well.

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Area	Station ID	Replicate	# of Feeding Voids	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Successional Stage	Comment
REF-South	05R	Q	0	N/A	N/A	IND	Reduced silt/clay with a disturbed SWI. Unable to determine aRPD and successional stage because of a lack of SWI data.
REF-South	05R	S	2	2.93	5.12	1 on 3	Reduced silt/clay with a few partially infilled voids.
REF-South	05R	T	0	N/A	N/A	1 -> 2	Reduced silt/clay with very thin aRPD. Small fauna visible in upper centimeter of sediment.
REF-North	07R	F	0	N/A	N/A	1	Reduced silt/clay with multiple methane bubbles in sediment, Beggiatoa threads in upper centimeters of sediment. Small Stage 1 tubes visible.
REF-North	07R	I	1	4.60	5.17	1 on 3	Reduced silt/clay with threads of Beggiatoa in sediment near SWI. Stage 1 and Stage 2 tubes at SWI. A burrow running from SWI to deep in to sediment column. Oxidized infilled voids.
REF-North	07R	J	0	N/A	N/A	1	Reduced silt/clay with threads of Beggiatoa in upper centimeters of sediment and a methane bubble at depth.
REF-North	08R	F	0	N/A	N/A	2	Reduced silt/clay with a thin aRPD and many Stage 2 tubes at SWI.
REF-North	08R	H	1	7.59	8.66	2 on 3	Reduced silt/clay with thin aRPD, many Stage 2 tubes at SWI and a large open void in center of image.
REF-North	08R	I	1	6.58	8.80	2 on 3	Reduced silt/clay with thin aRPD, many Stage 2 tubes at SWI and a large open void in center of image.
REF-North	09R	I	0	N/A	N/A	2 -> 3	Reduced silt/clay with many Stage 2 tubes at SWI and burrowing evident throughout sediment column.
REF-North	09R	J	2	7.82	13.52	2 on 3	Silt/clay with dense Stage 2 tubes at SWI, burrowing visible, and a few open voids at depth.
REF-North	10R	G	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes dense at SWI and burrowing evident in sediment column below aRPD.
REF-North	10R	H	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes dense at SWI and burrowing evident in sediment column below aRPD.
REF-North	10R	J	0	N/A	N/A	2 -> 3	Silt/clay with Stage 2 tubes dense at SWI and burrowing evident in sediment column below aRPD.

APPENDIX D

PLAN VIEW IMAGE ANALYSIS RESULTS

Notes:

IND=Indeterminate

Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Image Width (cm)	Image Height (cm)	Field of View	Sediment Type	Surface Oxidation	Bedforms	Beggiatoa Present?	Beggiatoa Type/Extent	Dredged Material Notes	Debris	Tubes
3AR	01	B	50.7	10/26/2020	14:25:19	65.96	43.97	0.29	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
3AR	01	C	51.7	10/26/2020	14:26:12	60.56	40.37	0.24	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	01	E	51.9	10/26/2020	14:27:44	62.6	41.73	0.26	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	02	A	53.6	10/26/2020	14:36:26	72.42	48.28	0.35	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	02	B	53.5	10/26/2020	14:37:19	66.3	44.2	0.29	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	02	C	53.2	10/26/2020	14:38:21	77.69	51.79	0.40	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	03	B	53.9	10/26/2020	14:56:16	66.02	44.01	0.29	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	03	C	53.7	10/26/2020	14:57:09	60.3	40.2	0.24	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	03	F	52.8	10/28/2020	11:44:36	68.54	45.69	0.31	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
3AR	04	A	54.8	10/26/2020	16:12:39	69.06	46.04	0.32	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
3AR	04	B	54.2	10/26/2020	16:13:23	62.08	41.38	0.26	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
3AR	04	I	53.6	10/27/2020	16:26:41	74.57	49.71	0.37	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
3AR	05	A	52.5	10/26/2020	14:30:28	82.45	54.97	0.45	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	05	C	50.0	10/26/2020	14:32:37	76.62	51.08	0.39	Sand or finer	Oxidized	None	No	None		Whelk shell	Yes
3AR	05	E	50.1	10/26/2020	14:34:30	69.15	46.1	0.32	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	06	B	53.9	10/26/2020	14:44:31	67.24	44.83	0.30	Sand or finer	Oxidized	None	No	None		None	Yes
3AR	06	C	54.6	10/26/2020	14:45:44	67.71	45.14	0.31	Sand or finer	Oxidized	None	No	None		Unidentified debris	Yes
3AR	06	F	52.8	10/28/2020	11:25:10	82.54	55.03	0.45	Sand or finer	Oxidized	None	No	None		None	Yes
6/7R	07	A		10/26/2020	16:20:56	61.25	40.83	0.25	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
6/7R	07	B	50.3	10/26/2020	16:21:55	60.84	40.56	0.25	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
6/7R	07	G	51.5	10/28/2020	7:57:01	62.65	41.77	0.26	Sand or finer	>50% Oxidized	None	Yes	Patches	Clasts of mud/clay at sediment surface.	None	Yes
6/7R	08	A	46.6	10/26/2020	16:35:01	64.7	43.14	0.28	Sand or finer	Oxidized	None	No	None		None	Yes
6/7R	08	B	47.1	10/26/2020	16:35:50	69.71	46.47	0.32	Sand or finer	Oxidized	None	Yes	Patches		Leaf	Yes

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Image Width (cm)	Image Height (cm)	Field of View	Sediment Type	Surface Oxidation	Bedforms	Beggiatoa Present?	Beggiatoa Type/Extent	Dredged Material Notes	Debris	Tubes
6/7R	08	G	48.8	10/28/2020	8:04:05	61.93	41.29	0.26	Sand or finer	Oxidized	None	No	None		None	Yes
6/7R	09	A	46.1	10/26/2020	11:55:30	67.68	45.12	0.31	Sand or finer	Oxidized	None	Yes	Patches		None	No
6/7R	09	B	46.8	10/26/2020	11:56:40	59.02	39.35	0.23	Sand or finer	>50% Oxidized	None	Yes	Patches		None	No
6/7R	09	F	49.9	10/28/2020	8:11:15	65.63	43.75	0.29	Sand or finer	Oxidized	None	Yes	Patches		None	No
6/7R	10	A	47.1	10/26/2020	12:03:17	67.04	44.69	0.30	Sand or finer	>50% Oxidized	None	Yes	Patches		None	Yes
6/7R	10	B	47.4	10/26/2020	12:04:13	61.95	41.3	0.26	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
6/7R	10	F	49.3	10/28/2020	8:16:29	66.13	44.09	0.29	Sand or finer	>50% Oxidized	None	Yes	Patches		None	No
6/7R	11	A	41.3	10/26/2020	12:09:59	76.55	51.03	0.39	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
6/7R	11	G	42.4	10/28/2020	8:22:10	81.76	54.51	0.45	Sand or finer	Oxidized	None	No	None		None	Yes
6/7R	11	H	41.3	10/28/2020	8:23:07	68.27	45.51	0.31	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
4R	12	A	46.1	10/26/2020	14:01:54	62.95	41.97	0.26	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	12	F	45.2	10/28/2020	11:11:01	76.47	50.98	0.39	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	12	H	45.2	10/28/2020	11:12:47	57.18	38.12	0.22	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	13	A	45.2	10/26/2020	13:55:49	65.57	43.72	0.29	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
4R	13	C	45.8	10/26/2020	13:57:57	69.43	46.28	0.32	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	13	F	44.3	10/28/2020	11:18:19	66.61	44.41	0.30	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	14	A	43.8	10/26/2020	13:48:09	59.25	39.5	0.23	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	14	B	43.6	10/26/2020	13:50:21	65.05	43.37	0.28	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
4R	14	G	42.5	10/28/2020	10:47:04	65.05	43.37	0.28	Sand or finer	>50% Oxidized	None	Yes	Patches	Clasts of mud/clay at sediment surface.	None	Yes
4R	15	A	46.7	10/26/2020	13:41:46	61.68	41.12	0.25	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
4R	15	F	45.6	10/28/2020	10:41:27	64.68	43.12	0.28	Sand or finer	Oxidized	None	Yes	Trace	Clasts of mud/clay at sediment surface.	None	Yes
4R	15	G	45.5	10/28/2020	10:42:15	62.8	41.87	0.26	Sand or finer	>50% Oxidized	None	No	None	Reduced mud/clay across sediment surface.	None	Yes
4R	16	A	45.5	10/26/2020	13:34:48	53.87	35.91	0.19	Sand or finer	Oxidized	None	Yes	Mat		None	No

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Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Image Width (cm)	Image Height (cm)	Field of View	Sediment Type	Surface Oxidation	Bedforms	Beggiatoa Present?	Beggiatoa Type/Extent	Dredged Material Notes	Debris	Tubes
4R	16	G	44.9	10/28/2020	10:36:50	72.26	48.17	0.35	Sand or finer	Oxidized	None	Yes	Trace	A few clasts at sediment surface.	None	Yes
4R	16	J	46.8	10/28/2020	10:39:17	65.05	43.37	0.28	Sand or finer	>50% Oxidized	None	Yes	Mat		None	No
5R	17	A	48.1	10/26/2020	12:20:03	66.81	44.54	0.30	Sand or finer	>50% Oxidized	None	Yes	Patches		None	Yes
5R	17	B	49.8	10/26/2020	12:20:44	69.15	46.1	0.32	Sand or finer	Oxidized	None	Yes	Trace	A few clasts at sediment surface.	None	Yes
5R	17	F	46.4	10/28/2020	10:30:21	70.56	47.04	0.33	Sand or finer	>50% Oxidized	None	Yes	Patches	Small clasts at sediment surface.	None	Yes
5R	18	A	52.4	10/26/2020	12:26:04	63.7	42.47	0.27	Sand or finer	>50% Oxidized	None	Yes	Patches		None	No
5R	18	F	51.4	10/28/2020	10:24:05	64.49	42.99	0.28	Sand or finer	>50% Oxidized	None	Yes	Patches	Small clasts at sediment surface.	None	No
5R	18	G	51.5	10/28/2020	10:25:00	61.51	41.01	0.25	Sand or finer	>50% Oxidized	None	Yes	Patches		None	Yes
5R	19	A	50.2	10/26/2020	12:32:01	59.36	39.57	0.23	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
5R	19	F	46.4	10/28/2020	10:17:48	80.95	53.97	0.44	Sand or finer	>50% Oxidized	None	Yes	Patches		None	Yes
5R	19	H	49.0	10/28/2020	10:19:40	54.72	36.48	0.20	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
5R	20	B	51.1	10/26/2020	11:34:20	61.3	40.86	0.25	Sand or finer	>50% Oxidized	None	Yes	Mat		None	Yes
5R	20	C	50.5	10/26/2020	11:35:22	61.39	40.93	0.25	Sand or finer	>50% Oxidized	None	Yes	Mat		None	Yes
5R	20	F	50.1	10/27/2020	12:07:53	58.78	39.19	0.23	Sand or finer	>50% Oxidized	None	Yes	Mat	A few clasts at sediment surface.	None	Yes
5R	21	A	55.6	10/26/2020	11:25:54	66.38	44.26	0.29	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
5R	21	F	45.9	10/28/2020	10:05:09	78.27	52.18	0.41	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
5R	21	G	48.5	10/28/2020	10:05:57	67.62	45.08	0.30	Sand or finer	Oxidized	None	Yes	Patches	Small clasts at sediment surface.	Gastropod shell	Yes
1R	22	A	52.9	10/26/2020	16:28:19	62.08	41.38	0.26	Sand or finer	Oxidized	None	No	None		None	Yes
1R	22	D	52.1	10/26/2020	16:30:45	71.66	47.77	0.34	Sand or finer	Oxidized	None	No	None		None	Yes
1R	22	F	49.4	10/27/2020	16:31:26	81.12	54.08	0.44	Sand or finer	>50% Oxidized	None	Yes	Trace		None	Yes
REF-South	01R	K	45.4	10/28/2020	7:43:34	62.45	41.63	0.26	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-South	01R	L	44.9	10/28/2020	7:45:08	59.56	39.71	0.24	Sand or finer	Oxidized	None	Yes	Trace		None	Yes

Area	Station ID	Replicate	Water Depth (ft)	Date	Time	Image Width (cm)	Image Height (cm)	Field of View	Sediment Type	Surface Oxidation	Bedforms	Beggiatoa Present?	Beggiatoa Type/Extent	Dredged Material Notes	Debris	Tubes
REF-South	01R	M	45.6	10/28/2020	7:45:53	68.97	45.98	0.32	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-South	02R	A	43.0	10/26/2020	10:49:27	64.44	42.96	0.28	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-South	02R	F	44.3	10/28/2020	9:06:04	72.39	48.26	0.35	Sand or finer	Oxidized	None	No	None		None	Yes
REF-South	02R	H	44.6	10/28/2020	9:08:33	77.34	51.56	0.40	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
REF-South	03R	A	44.1	10/26/2020	11:06:24	61.59	41.06	0.25	Sand or finer	Oxidized	None	No	None		None	Yes
REF-South	03R	K	46.5	10/28/2020	9:12:46	79.59	53.06	0.42	Sand or finer	Oxidized	None	No	None		None	Yes
REF-South	03R	L	44.9	10/28/2020	9:13:32	70.84	47.23	0.33	Sand or finer	Oxidized	None	No	None		None	Yes
REF-South	05R	A	39.5	10/26/2020	11:16:57	63.31	42.21	0.27	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
REF-South	05R	E	40.2	10/26/2020	11:20:42	72.22	48.15	0.35	Sand or finer	Oxidized	None	Yes	Patches		None	Yes
REF-South	05R	Q	41.3	10/28/2020	9:19:27	64.54	43.03	0.28	Sand or finer	Oxidized	None	Yes	Patches	Clasts of mud/clay at sediment surface.	None	No
REF-North	07R	A	36.4	10/26/2020	15:44:42	68.15	45.43	0.31	Sand or finer	Reduced	None	Yes	Mat		None	Yes
REF-North	07R	C	41.2	10/26/2020	15:46:33	68.69	45.79	0.31	Sand or finer	>50% Oxidized	None	Yes	Mat		None	Yes
REF-North	07R	J	40.7	10/27/2020	15:48:01	67.47	44.98	0.30	Sand or finer	IND	None	Yes	Patches	Clasts of mud/clay at sediment surface.	None	Yes
REF-North	08R	A	43.6	10/26/2020	15:50:56	67.68	45.12	0.31	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-North	08R	C	43.5	10/26/2020	15:52:54	66.75	44.5	0.30	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-North	08R	D	44.0	10/26/2020	15:53:41	64.01	42.68	0.27	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-North	09R	C	43.4	10/26/2020	15:58:57	IND	IND	IND	Sand or finer	IND	None	No	None		None	Yes
REF-North	09R	D	33.6	10/26/2020	16:00:22	75.51	50.34	0.38	Sand or finer	Oxidized	None	No	None		None	Yes
REF-North	09R	F	42.5	10/27/2020	16:11:24	37.54	25.02	0.09	Sand or finer	Oxidized	None	No	None		None	Yes
REF-North	10R	A	43.7	10/26/2020	16:03:16	88.14	58.76	0.52	Sand or finer	Oxidized	None	No	None		None	Yes
REF-North	10R	C	33.9	10/26/2020	16:05:13	64.54	43.03	0.28	Sand or finer	Oxidized	None	Yes	Trace		None	Yes
REF-North	10R	H	40.5	10/27/2020	16:18:44	58.76	39.17	0.23	Sand or finer	Oxidized	None	No	None		Leaf	Yes

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Area	Station ID	Replicate	Burrows	Tracks	Epifauna	Flora	Number of Fish	Comments
3AR	01	B	Yes	Yes	None	None	0	Sandy sediment surface with many Stage 2 tubes at surface. A few burrows present. Tracks of various types scattered about sediment surface. Two small patches of Beggiatoa at sediment surface.
3AR	01	C	Yes	Yes	None	None	0	Sandy sediment surface with many Stage 2 tubes at surface. A large burrow at right of image. Tracks of various types scattered about sediment surface.
3AR	01	E	Yes	No	None	None	0	Sandy sediment surface with many Stage 2 tubes at surface. A few large burrows in image.
3AR	02	A	Yes	Yes	None	None	0	Sandy sediment surface with dense Stage 2 tubes. A few small burrows and tracks visible.
3AR	02	B	Yes	Yes	None	None	0	Sandy sediment surface with many Stage 2 tubes. A few large burrows and many tracks visible.
3AR	02	C	Yes	Yes	None	None	0	Sandy sediment surface with dense Stage 2 tubes. A few small burrows and tracks visible.
3AR	03	B	Yes	No	None	None	0	Sandy sediment surface with many Stage 2 tubes present. Many small burrows and a large burrow also visible.
3AR	03	C	Yes	No	None	None	0	Sandy sediment surface with many Stage 2 tubes present. Many small burrows and a large burrow also visible.
3AR	03	F	Yes	Yes	None	Green Algae	0	Sandy sediment with tracks, Stage 2 tubes, and burrows throughout. Some trace Beggiatoa in upper right of image and possible green algae also in upper right.
3AR	04	A	Yes	No	None	None	0	Sandy sediment with patches of Beggiatoa at sediment surface. Stage 2 tubes and a few burrows also visible.
3AR	04	B	Yes	No	None	None	0	Sandy sediment with trace Beggiatoa at sediment surface. Tubes throughout image and two large burrows visible.
3AR	04	I	Yes	Yes	None	None	0	Sandy sediment with trace Beggiatoa at sediment surface. Tubes and burrows scattered about image. A few tracks present in lower right corner.
3AR	05	A	Yes	Yes	None	None	0	Sandy sediment with dense tubes and fecal material. A few burrows and tracks visible as well.
3AR	05	C	No	Yes	None	None	0	Sandy sediment with a few small tubes visible and some tracks throughout. Possible whelk shell that has been broken down in top center of image.
3AR	05	E	Yes	Yes	None	None	0	Sandy sediment with dense tubes and fecal material. A few burrows and tracks visible as well.
3AR	06	B	Yes	Yes	None	None	0	Sandy sediment with many small tubes, a couple of small burrows, and a track. Possible imprint of SPI system from a previous drop
3AR	06	C	Yes	Yes	Bryozoans/Hydroids	None	0	Sandy sediment with scattered small tubes, a large burrow, some tracks. Possible hydroids/bryozoans near unknown item on seafloor in center left of image.
3AR	06	F	Yes	Yes	Bryozoans/Hydroids	None	0	Sandy sediment with scattered small tubes, a large burrow, some tracks. Possible large grouping of hydroids/bryozoans in center left of image
6/7R	07	A	Yes	Yes	None	None	0	Sandy sediment with patches of Beggiatoa. A few burrows, scattered small tubes, and some tracks.
6/7R	07	B	Yes	Yes	None	None	0	Sandy sediment with patches of Beggiatoa. A few burrows, scattered small tubes, and some tracks.
6/7R	07	G	No	No	None	None	0	Mud/clay clasts throughout image at sediment surface with a layer of sand at surface. Patches of Beggiatoa and a few small tubes present.
6/7R	08	A	Yes	No	None	None	0	Sandy sediment with dense tubes and a few burrows visible.
6/7R	08	B	Yes	Yes	None	None	0	Sandy sediment with patches of Beggiatoa at surface. A leaf visible in upper left of image. A few small tubes, burrows, and tracks.

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Area	Station ID	Replicate	Burrows	Tracks	Epifauna	Flora	Number of Fish	Comments
6/7R	08	G	Yes	Yes	None	None	0	Sandy sediment with many tubes, a few large burrows, and some tracks at sediment surface.
6/7R	09	A	Yes	Yes	None	None	0	Sandy sediment with many patches of Beggiatoa at sediment surface. A few burrows and some tracks visible.
6/7R	09	B	Yes	Yes	None	None	0	Sandy sediment with many patches of Beggiatoa at sediment surface. A few burrows and some tracks visible.
6/7R	09	F	Yes	Yes	None	None	0	Sandy sediment with many patches of Beggiatoa at sediment surface. A few burrows and some tracks visible.
6/7R	10	A	Yes	No	None	None	0	Sandy sediment with patches of Beggiatoa, a few burrows, and scattered small tubes visible.
6/7R	10	B	Yes	No	None	None	0	Sandy sediment with trace Beggiatoa in upper portion of image, a few burrows, and scattered small tubes visible.
6/7R	10	F	Yes	No	None	None	0	Sandy sediment surface with patches of Beggiatoa, a few mud clasts at surface, and a burrow or two.
6/7R	11	A	Yes	No	None	None	0	Sandy sediment surface with a patch of Beggiatoa in upper left corner. Some small burrows and tubes scattered about sediment surface.
6/7R	11	G	Yes	Yes	None	None	0	Sandy sediment surface with tracks in bottom left corner and scattered small tubes and burrows
6/7R	11	H	Yes	Yes	None	None	0	Sandy sediment surface with patches of Beggiatoa, small tubes throughout, and a few small burrows and tracks.
4R	12	A	Yes	Yes	None	None	0	Sandy sediment covered in tracks and tubes, with a few small burrows and trace Beggiatoa also present.
4R	12	F	Yes	Yes	None	None	0	Sandy sediment covered in tubes, with a few small burrows, tracks, and trace Beggiatoa also present.
4R	12	H	Yes	Yes	None	None	0	Sandy sediment covered in tracks and tubes, with a few small burrows and trace Beggiatoa also present.
4R	13	A	No	No	None	None	0	Sandy sediment with patches of Beggiatoa across sediment surface. Scattered small tubes also visible.
4R	13	C	Yes	Yes	None	None	0	Sandy sediment surface with visible Beggiatoa scattered throughout image. Dense tracks on sediment surface.
4R	13	F	Yes	Yes	None	None	0	Sandy sediment surface with visible Beggiatoa scattered throughout image. Dense tracks on sediment surface.
4R	14	A	Yes	Yes	None	None	0	Sandy sediment with trace Beggiatoa, small tubes, many tracks, and a couple of small burrows.
4R	14	B	Yes	Yes	None	None	0	Sandy sediment with trace Beggiatoa, many small tubes, and scattered tracks and burrows.
4R	14	G	Yes	No	None	None	0	Entire image is clasts of mud/clay with patches of Beggiatoa throughout image. Some small tubes and burrows visible.
4R	15	A	No	Yes	None	None	0	Sand with small patches of Beggiatoa and many tracks and small tubes at sediment surface.
4R	15	F	Yes	No	None	None	0	Sediment surface covered in clasts of mud/clay. A couple large burrows, small tubes throughout. Trace Beggiatoa in upper portion of image.
4R	15	G	No	No	None	None	0	Sediment surface partially covered in dark, reduced mud/clay. Small tubes scattered throughout.
4R	16	A	No	Yes	None	None	0	Sandy surface mostly covered in Beggiatoa. A few tracks visible, especially near bottom of image.

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Area	Station ID	Replicate	Burrows	Tracks	Epifauna	Flora	Number of Fish	Comments
4R	16	G	Yes	Yes	None	None	0	Sandy sediment with some trace Beggiatoa in upper left of image. Tracks, small tubes, and a few small burrows scattered about image.
4R	16	J	No	No	None	None	0	Sandy sediment with a dense coverage of Beggiatoa, reduced sediment at sediment surface also visible.
5R	17	A	Yes	Yes	None	None	0	Sandy sediment with large patches of Beggiatoa on sediment surface. Scattered small tubes, burrows, and tracks.
5R	17	B	No	Yes	None	None	0	Soft sediment with a few clasts of mud/clay at surface. Trace Beggiatoa, dense tubes, and a few tracks visible.
5R	17	F	Yes	Yes	None	None	0	Sandy sediment with scattered small mud/clay clasts. A few small tubes, burrows, and tracks visible.
5R	18	A	No	Yes	None	Algae	0	Sandy sediment with reduced sediment and patches of Beggiatoa at SWI. A large grouping of algae in bottom right corner.
5R	18	F	No	No	None	None	0	Sandy sediment with many small clasts of mud/clay at sediment surface. Patches of Beggiatoa throughout.
5R	18	G	Yes	No	None	None	0	Sandy sediment with many patches of Beggiatoa at sediment surface. A few burrows and some small tubes visible.
5R	19	A	Yes	Yes	None	None	0	Sandy sediment with many Stage 2 tubes visible. A few small instances of Beggiatoa and burrows.
5R	19	F	Yes	No	None	None	0	Sandy sediment with patches of Beggiatoa and reduced surficial sediment. Small tubes and a few large burrows visible.
5R	19	H	Yes	Yes	None	None	0	Sandy sediment with large burrows, scattered tubes and tracks.
5R	20	B	No	No	None	None	0	Sandy sediment covered in a mat of Beggiatoa with a few tubes present.
5R	20	C	No	No	None	None	0	Sandy sediment covered in a mat of Beggiatoa with a few tubes present.
5R	20	F	No	No	None	None	0	Sandy sediment covered in a mat of Beggiatoa with a few tubes present.
5R	21	A	No	Yes	None	None	0	Sandy sediment with trace Beggiatoa, and a few scattered tubes and tracks.
5R	21	F	Yes	Yes	None	None	0	Sandy sediment with scattered tubes, a burrow, and many tracks. Trace Beggiatoa at surface
5R	21	G	Yes	Yes	None	None	0	Sandy sediment with large patches of Beggiatoa on sediment surface. Scattered small tubes, burrows, and tracks.
1R	22	A	Yes	Yes	None	None	0	Sandy surface with many small tubes and tracks. A few burrows.
1R	22	D	Yes	Yes	None	None	0	Sandy surface with many small tubes and tracks. A few burrows.
1R	22	F	Yes	No	None	None	0	Sandy sediment surface with reduced sediment at sediment surface. Scattered small tubes and burrows
REF-South	01R	K	Yes	No	None	None	0	Sandy sediment surface with many clasts. A few Stage 2 tubes visible, a very large burrow with excavated sediment at seafloor surface in upper left of image. Trace Beggiatoa on sediment surface.
REF-South	01R	L	Yes	Yes	None	None	0	Sandy sediment surface with many clasts and tracks. A few Stage 2 tubes and burrows visible. Trace Beggiatoa on sediment surface.

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Area	Station ID	Replicate	Burrows	Tracks	Epifauna	Flora	Number of Fish	Comments
REF-South	01R	M	Yes	Yes	None	None	0	Sandy sediment surface with many clasts. A few Stage 2 tubes visible, a very large burrow to right of image, and some tracks across image. Trace Beggiatoa on sediment surface.
REF-South	02R	A	Yes	Yes	None	None	0	Sandy sediment surface with a few Stage 2 tubes present, a pair of large burrows, and dense tracks present. Trace Beggiatoa at surface.
REF-South	02R	F	Yes	Yes	None	Green Algae	0	Sandy sediment surface with a few Stage 2 tubes present, a large burrow, and a few tracks present. A patch of green algae with sediment partially covering it in the center of image.
REF-South	02R	H	No	Yes	None	None	0	Sandy sediment with many tracks, a few Stage 2 tubes, and a few small patches of Beggiatoa present.
REF-South	03R	A	No	Yes	None	None	0	Sandy sediment with scattered small tubes and a few tracks.
REF-South	03R	K	No	Yes	None	None	0	Sandy sediment with many tracks, some clearly arthropod tracks, and scattered small tubes.
REF-South	03R	L	No	No	None	None	0	Sandy sediment with many clasts at sediment surface. Scattered tubes.
REF-South	05R	A	Yes	Yes	None	None	0	Sandy sediment with patches of Beggiatoa at sediment surface. One or two small tubes and burrows. Some scattered tracks.
REF-South	05R	E	No	Yes	None	None	0	Sandy sediment with patches of Beggiatoa at sediment surface. One or two small tubes and scattered tracks.
REF-South	05R	Q	No	No	None	None	0	Sediment surface is covered in clasts of cohesive material. No visible tubes, burrows, or tracks. Patches of Beggiatoa throughout. Moon jelly near camera
REF-North	07R	A	No	No	None	Green Algae	0	Reduced sediment surface mostly covered in Beggiatoa. Multiple patches of green algae at sediment surface.
REF-North	07R	C	Yes	No	None	Green Algae	0	Sandy with mat of Beggiatoa across most of image. Some green algae, tubes, and a large burrow also visible.
REF-North	07R	J	No	No	None	Green Algae	0	Difficult to see image with poor lighting. Visible sediment has mud/clay clasts at sediment surface, as well as patches of Beggiatoa, green algae, and a few small tubes.
REF-North	08R	A	Yes	Yes	None	None	0	Sandy sediment with dense tubes, a few burrows, trace Beggiatoa, and small tracks in upper center of image.
REF-North	08R	C	Yes	Yes	None	None	0	Sandy sediment with large arthropod track moving diagonally across image. Tubes, trace Beggiatoa, and small burrows also visible.
REF-North	08R	D	Yes	Yes	None	Green Algae	0	Sandy sediment with some small tubes, tracks, and a couple of large burrows. Scattered green algae and a large patch of green algae in upper left of image.
REF-North	09R	C	No	No	None	None	0	Sandy sediment with dense Stage 2 tubes making any other determinations difficult.
REF-North	09R	D	Yes	No	None	None	0	Sandy sediment with dense Stage 2 tubes and a large burrow visible.
REF-North	09R	F	Yes	No	None	None	0	Sandy sediment with dense Stage 2 tubes and a large burrow visible.
REF-North	10R	A	Yes	No	None	None	0	Sandy sediment with dense Stage 2 tubes and a few large burrows visible.
REF-North	10R	C	Yes	No	None	None	0	Sandy sediment with dense tubes, a large burrow, and a small grouping of Beggiatoa at the top center of image.
REF-North	10R	H	Yes	No	None	None	0	Sandy sediment with dense tubes, a few small burrows, and a leaf at sediment surface.

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APPENDIX E
GRAIN SIZE SCALE FOR SEDIMENTS

APPENDIX E

GRAIN SIZE SCALE FOR SEDIMENTS

Phi (Φ) Size	Size Range (mm)	Size Class (Wentworth Class)
<-1	>2	Gravel
0 to –1	1 to 2	Very coarse sand
1 to 0	0.5 to 1	Coarse sand
2 to 1	0.25 to 0.5	Medium sand
3 to 2	0.125 to 0.25	Fine sand
4 to 3	0.0625 to 0.125	Very fine sand
>4	<0.0625	Silt/clay

APPENDIX F

NON-PARAMETRIC BOOTSTRAPPED CONFIDENCE LIMITS

Non-parametric Bootstrapped Confidence Limits

Bootstrapping is a statistical resampling procedure that uses the sample data to represent the entire population in order to construct confidence limits around population parameters. Bootstrapping assumes only that the sample data are representative of the underlying population, so random sampling is a prerequisite for appropriate application of this method.

Bootstrapping procedures entail resampling, with replacement, from the observed sample of size n. Each time the sample is resampled, a summary statistic (e.g., mean or standard deviation) of the bootstrapped sample is computed and stored. After repeating this procedure many times, a summary of the bootstrapped statistics is used to construct the confidence limit. For the bootstrap-*t* method (e.g., Manly 1997, pp. 56-59; or Lunneborg 2000, pp. 129-131), the bootstrapped statistic (T) is a pivotal statistic, which means that the distribution of T is the same for all values of the true mean (θ). The bootstrap-*t* is essentially the "Studentized" version (i.e., subtract the mean and divide by the standard error, as is done to obtain the Student *t*-distribution for the sample mean) of the statistic of interest. This approach is quite versatile and can be applied to construct a confidence interval around any linear combination of means (Lunneborg 2000, p. 364).

For the purpose of constructing a confidence interval around the true value for the linear combination of means ($\Theta = \mu_{Ref} - \mu_{CADCell}$) the pivotal statistic T for the true difference is defined as

$$T = \frac{d - \theta}{SE(d)} \quad \text{(Eq. A-1)}$$

We assume that this is adequately approximated by the bootstrap sampling distribution of T, denoted T*:

$$T^* = \frac{d^* - \hat{\theta}}{SE(d^*)} \quad \text{(Eq. A-2)}$$

This distribution is comprised of the studentized statistic (T^*_B) computed from a large number (B) of randomly chosen bootstrapped samples y_1^*, y_2^*, ... y_B^* from each of the four groups or populations. Here, d^* is the linear combination of group means for the bootstrapped sample; $\hat{\theta}$ is the observed difference in sample means from the original samples; $SE(d^*)$ is the estimated standard error of the linear contrast.

The 5th and the 95th quantiles of the T^* distribution ($T^*_{0.05}$ and $T^*_{0.95}$, respectively) satisfy the equations:

$$\Pr\left[\frac{\theta - d}{SE(d)} > T^*_{0.05}\right] = 0.95 \quad \text{(Eq. A-3a)}$$

$$\Pr\left[\frac{\theta - d}{SE(d)} < T^*_{0.95}\right] = 0.95 \quad \text{(Eq. A-3b)}$$

Rearranging these equations yields 95% confidence in each of the following two inequalities:

$$\Pr[d + T^*_{0.05}\, SE(d) < \theta] = 0.95 \qquad \text{(Eq. A-4a)}$$

$$\Pr[d + T^*_{0.95}\, SE(d) > \theta] = 0.95 \qquad \text{(Eq. A-4b)}$$

Bootstrapping is used to estimate the values $T^*_{0.05}$, $T^*_{0.95}$ and $SE(d)$. The left side of equation A-4a represents the 95% lower confidence limit on the difference equation ($\mu_y - \mu_x$); the left side of equation A-4b is the 95% upper confidence limit on the difference equation. Based on the two one-sided testing (TOST) approach presented in McBride (1999), if the bounds computed by Equations A-4a and A-4b are fully contained within the interval [–δ , +δ], then we conclude equivalence within δ units.

The specific steps used to compute the 95% upper and 95% lower confidence limits on the difference between two means using the bootstrap-*t* method are described below.

1. Bootstrap (sample with replacement from the original sample of size n) B = 10,000 samples from each of the five populations (1 pooled reference group and 4 CAD cells) separately.

2. Compute the T^*_B statistic for each bootstrapped set of independent samples. T^*_i is the bootstrapped-*t* statistic computed from the i^{th} bootstrap sample, defined by the following equation

$$T *_i = \frac{\sum_{j=1}^{5} c_j \bar{y}*_{ji} - \sum_{j=1}^{5} c_j \bar{y}_j}{SE\left(\sum_{j=1}^{5} c_j \bar{y}*_{ji}\right)} = \frac{\sum_{j=1}^{5} c_j \bar{y}*_{ji} - \sum_{j=1}^{4} c_j \bar{y}_j}{\sqrt{\sum_{j=1}^{5} s^2_{y*ji} c_j^2 / n_j}} \qquad \text{(Eq. A-5)}$$

   where $\bar{y}*_{ji}$, and $s^2_{y*_{ji}}$ are the means and variances for the i^{th} bootstrapped sample from the j^{th} group (j=1 to 5); and $\bar{y}_j$ is the observed mean for the j^{th} group. Multiplying these group means by their respective coefficients c_j ($^1/2$, -1, -1, -1, -1) and summing the products yields the difference equation we wish to test (Equation 1). This step produces 10,000 values of the bootstrapped-*t* statistic which comprise the "bootstrap-*t* distribution".

3. Compute the standard deviation of the 10,000 bootstrapped linear combinations, $\sum_{j=1}^{4} c_j\, \bar{y}\, *_{ji}$ and save it as $SE(d)$. This is the bootstrap estimate of the true standard error.

4. Find $T^*_{0.05}$ and $T^*_{0.95,}$ the 5th and 95th quantiles of the bootstrap-*t* distribution generated in Step 2. These values satisfy Equations A- 3a and A-3b.

5. Applying Equations A-4a and A-4b using the values $T^*_{0.05}$ and $T^*_{0.95}$ found in Step 4 gives the bootstrap-*t* estimate of the 95% lower and upper confidence limits on the difference equation, i.e.,

95% LCL = $\sum_{j=1}^{5} c_j \, \bar{y}_j + T *_{0.05} SE(d)$ (Eq. A-6a)

95% UCL = $\sum_{j=1}^{5} c_j \bar{y}_j + T *_{0.95} SE(d)$ (Eq. A-6b)

where ($\sum_{j=1}^{5} c_j \bar{y}_j$) is the linear combination expressing the difference between the mean of the reference group and the mean of the four CAD cells based on the original sample observations, and *SE(d)* is the standard deviation of the bootstrapped differences computed in Step 3.

References

Lunneborg, Clifford E. 2000. Data Analysis by Resampling: Concepts and Applications. Duxbury. 556 pp. + Appendices.

Manly, Bryan F.J. 1997. Randomization, Bootstrap and Monte Carlo Methods in Biology. Second edition. Chapman & Hall, London. 340 pp. + Appendices