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May 2006 Post-Disposal SPI Mapping at the Port Everglades Harbor ODMDS

Prepared for:

U.S. Environmental Protection Agency Region 4

Water Management Division,
Coastal Section

61 Forsyth Street
Atlanta, GA 30303

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Germano & Associates, Inc.

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Region 4 of the U.S. Environmental Protection Agency (EPA) is responsible for management of the three Ocean Dredged Material Disposal Sites (ODMDSs) offshore Southeast Florida: Palm Beach Harbor ODMDS, Port Everglades Harbor ODMDS, and Miami ODMDS. These sites were designated by EPA Region 4 pursuant to Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The Site Management and Monitoring Plan (SMMP) for each site outlines a monitoring strategy and, in some cases, specific monitoring techniques and schedules for implementation.

The Port Everglades Harbor ODMDS was designated in February 2005. Prior to designation, this site had not received any dredged material from past disposal activities. Surveys performed prior to site designation showed that surface sediments in the Port Everglades Harbor ODMDS area consisted of fine-to-coarse grained sand containing 16% fines, with small, isolated patches of cobbles or coralline rubble scattered over the site (EPA 1999; EPA 2000).

It has been estimated that up to 90,000 cubic yards of maintenance dredged material from Port Everglades Harbor may be placed every three years at the Port Everglades Harbor ODMDS. Samples of the material to be dredged from the harbor collected in 1997 showed the material was predominantly sandy, with samples from the bay containing 38% fines and samples from the inlet containing 5% fines.

In addition to maintenance dredged material, the Port Everglades Harbor ODMDS may be used for disposal of an estimated 8 million cubic yards of dredged material from a proposed deepening project. Until further capacity studies are conducted, however, this site is currently restricted to project volumes of less than 500,000 cubic yards. To maintain the disposal mound within the boundaries of the site, the SMMP restricts disposal to a 600-foot radius disposal zone at the center of this ODMDS (EPA 2004a; 2004b; 2004c).

Issues raised during designation of the Port Everglades Harbor ODMDS include: 1) the size of the disposal mound (including apron) for routine maintenance projects and for larger projects; 2) burial of essential fish habitat, especially the boulder/rubble areas found during the site designation studies; and 3) effect on and recovery of benthic prey species for managed fisheries. Using the U.S. Army Corps of Engineers' short-term fate (STFATE) model, EPA has made estimates of disposal mound dimensions. To verify disposal mound dimensions, the SMMP requires post-disposal bathymetric surveys following initial use and after any project involving disposal of significant dredged material volumes (i.e., >100,000 cubic yards).

The SMMP also requires the use of Sediment Profile Imaging (SPI), both to determine the extent of the disposal mound "apron" or "flank" that is not detectable using bathymetric surveys and to evaluate recovery rates of benthic populations over the dredged material deposits (EPA 2004b; EPA 2004c).

1.2 STUDY PURPOSE

The first use of the Port Everglades Harbor ODMDS was completed in August 2005, with the disposal of approximately 60,000 cubic yards of maintenance material from the north extension turning basin within Port Everglades Harbor. Material from this basin was characterized as having approximately 40 percent silts/clays. Following this disposal, and as part of EPA Region 4's efforts to address the above concerns regarding disposal impacts, scientists from Germano & Associates, Inc. (G&A) conducted a Sediment Profile Imaging (SPI) survey in May 2006.

Given the issues raised during site designation about the size of the disposal mound, burial of essential fish habitat, and effect on benthic prey species, the objectives of the May 2006 SPI survey were to:

- map the spatial distribution of disposed dredged material on the seafloor,
- characterize physical changes in the seafloor resulting from disposal, and
- evaluate the extent of benthic infaunal recolonization through the mapping of infaunal successional stages.

2.0
MATERIALS AND METHODS

2.1 MAY 2006 SURVEY LOGISTICS

The SPI survey of the Port Everglades Harbor ODMDS was conducted on May 21-22, 2006 aboard EPA's Ocean Survey Vessel (OSV) *Bold*. Scientists from G&A operated the SPI camera with assistance from EPA Region 4 scientists and OSV *Bold* personnel.

The sampling involved the collection of sediment-profile images at a total of 54 stations, which can be broken down as follows (see Figure 2-1):

- Three (3) reference stations (Stations R1 through R3) were located about 2.3 miles (3.7 km) to the south of the disposal site center.
- Forty-four (44) stations were located within and to the north of the disposal site (labeled with prefixes H11 through M11 in Figure 2-1).
- Seven (7) stations were added in the field (station prefix of "X") based on a preliminary review of the results.

At each sampling station, the SPI camera was lowered onto the seafloor at least three times to obtain three replicate images of suitable quality for analysis. Upon contact of the camera with the bottom, a navigational fix was recorded for each replicate. Due to the strong northward current that exists in this area, the actual location of each replicate tended to be slightly north of the original or "target" station coordinates (Figure 2-2). However, the replicates themselves were located relatively close together (Figure 2-2). The location of each station plotted in Figure 2-1 was determined by averaging the coordinates of the replicate camera drops depicted in Figure 2-2.

The original survey plan called for collecting at least one "plan-view" (i.e., horizontal plane) photograph of the sediment surface along with the replicate SPI images at each station. This was accomplished using a downward-looking camera system attached to the SPI camera frame (described below). One plan-view photograph of suitable quality for analysis was obtained at each of the first thirteen stations that were sampled. Upon retrieval of the camera at the thirteenth station, the field crew discovered that the plan-view camera had been sheared off the SPI camera frame by the vessel's winch wire. Although the plan-view camera was recovered, it was damaged beyond immediate repair. Therefore, it was not possible to collect the planned number of seafloor surface images during the remainder of the Port Everglades Harbor ODMDS survey. The plan-view results for the thirteen stations that were sampled successfully are presented and discussed herein.

2.2 PLANVIEW IMAGE ACQUISITION AND ANALYSIS

The plan-view photographs were acquired using a Model DSC 6000 digital still camera and Model 3831 self-powered strobe (Ocean Imaging Systems, Inc., North Falmouth, MA). The camera and strobe were attached to the sediment-profile camera frame in a downward-looking position, and a bottom contact switch activated by a hang weight was used to trigger a photograph of the sediment surface when the base of the camera frame was about 1 or 2 meters above the bottom (Figure 2-3). This provided a photograph of an approximately 200 x 300 cm area of the undisturbed sediment surface immediately prior to each landing of the frame on the bottom.

The analysis of each plan-view image consisted of the following: 1) enumeration of biological features such as biogenic mounds, burrow openings, feeding pits/furrows, tracks, sea stars, crabs, etc., 2) enumeration of physical sedimentary features (e.g., rocks, sand ripples, etc.), and 3) apparent presence/absence of dredged material.

2.3 SPI OVERVIEW

SPI was developed as a rapid reconnaissance tool for characterizing physical, chemical, and biological seafloor processes and has been used in numerous seafloor surveys throughout the United States, Pacific Rim, and Europe (Rhoads and Germano 1982, 1986, 1990; Revelas et al. 1987; Valente et al. 1992). The sediment profile camera works like an inverted periscope. A Nikon D100 6-megapixel SLR camera, equipped with a 1-gigabyte compact flash card for image storage, is mounted horizontally inside a watertight housing on top of a wedge-shaped prism. The prism is the part that penetrates into the seafloor; it has a Plexiglas® faceplate at the front and a mirror placed at a 45° angle at the back. The camera lens looks down at the mirror, which reflects the image visible through the faceplate.

The prism has a strobe mounted inside, near the back of the wedge, to provide illumination for the image. Because the prism is filled with distilled water, the camera always has an optically clear path. The complete assembly, consisting of the watertight camera housing attached to the top of the water-filled prism, is mounted on a moveable carriage within a stainless steel frame. Onboard a survey vessel, this frame is attached to the winch wire and lowered slowly to the seafloor. Tension on the wire keeps the prism in its “up” position. When the frame comes to rest on the seafloor, the winch wire slackens (Figure 2-3) and the camera prism descends into the sediment at a slow, controlled rate that reduces disturbance at the sediment-water interface. As the prism descends and begins to penetrate into the sediment, it trips a trigger that activates a 15-second time-delay circuit. This time delay allows the prism to penetrate fully into the sediment before the image is taken. After the 15-second delay, the internal strobe discharges and the camera’s shutter releases. In this manner, the camera takes a picture of the sediment-water interface and the upper portion of the sediment column that is in direct contact with the prism's Plexiglas® faceplate (i.e., a sediment cross-section or "profile" image). The resulting images give the viewer the same perspective as if looking through the side of an aquarium that is half-filled with sediment.

During the Port Everglades Harbor ODMDS SPI survey of May 2006, the camera was lowered onto the seafloor three times at each sampling station, while the vessel maintained position at the sea surface. After the first drop, the camera frame was raised by the vessel's winch to a height of about 2 to 3 meters above the sediment surface, giving the strobe sufficient time (5 seconds) to recharge. The camera was then lowered immediately for the second drop, and, after the 15-second time delay and camera firing, the entire process of raising and lowering the camera was repeated again for the third drop. As depicted in Figure 2-2, the station replicates were typically very close to each station's target coordinates and within several meters of each other. In general, SPI surveys can be accomplished rapidly by "pogo-sticking" the camera across an area of seafloor while recording positional fixes on the surface vessel.

Most the sediments at the Port Everglades Harbor ODMDS stations consisted of fine sand with varying amounts of silt. Because the sand was relatively firm, a full set of lead weights (250 lbs total) was added to the camera frame at the beginning of the survey to ensure that the prism penetrated to the maximum extent possible. Electronic software adjustments also were made to control the settings of the Nikon D100 digital camera. Camera settings (F-stop, shutter speed, ISO equivalents, digital file format, color balance, etc.) were selected through a water-tight USB port on the camera housing and Nikon Capture® software. For the May 2006 survey at the Port Everglades Harbor ODMDS, the camera settings were as follows: ISO-equivalent was 200, shutter speed was 1/160, F/8, white balance set to flash, color mode to Adobe RGB, sharpening to none, noise reduction off, and storage in raw (NEF) format (2000 x 3008). Details of the camera settings for each raw digital image were recorded in the associated parameters file embedded in the electronic image file.

At the beginning of the survey, the time on the sediment profile camera's internal data logger was synchronized with the time on the vessel's navigation system. Each image was assigned a unique time stamp by the camera's data logger, while the time and position of each camera drop was recorded by taking navigational fix. The field crew also maintained a redundant electronic log where the time, coordinates (latitude and longitude), and water depth of each camera drop (replicate) were recorded. Images were downloaded periodically (sometimes after each station) to verify successful sample acquisition or to assess what type of sediment was present at a particular location. To assign each image to the appropriate station after downloading, the time stamp in the attributes file was matched against the time recorded by the field crew in the electronic logbook. Each digital image file was re-named to indicate the station and replicate number immediately after downloading.

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of each survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. Each time the camera was brought back to the surface and placed on the vessel's aft deck, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth for at least one of the three replicate images. If images were missed (frame counter indicator or verification from digital download) or the penetration depth was insufficient (penetration indicator), the station was re-occupied and additional replicate images were taken.

Following completion of field operations, the digital images were analyzed from this survey using Bersoft Image Measurement© software version 3.06 (Bersoft, Inc.). The images were first adjusted in Adobe Photoshop® by using the levels command to expand the available pixels to their maximum light and dark threshold range; no other image adjustments were performed. Pixel width, used to measure linear distance and area, was calibrated within the image analysis software by measuring 1-cm gradations from the Kodak® Color Separation Guide. This calibration information was applied to all the SPI images analyzed. Linear and area measurements were recorded as number of pixels and converted to scientific units by using the calibration information.

Measured parameters were recorded on a Microsoft® Excel© spreadsheet. G&A's Senior Scientist, Dr. Joseph Germano, subsequently checked all these data as an independent quality assurance/quality control review of the measurements before final interpretation and report preparation.

2.4 MEASURING, INTERPRETING, AND MAPPING SPI PARAMETERS

2.4.1 Sediment Grain Size

The sediment grain-size major mode and range were visually estimated from the color images by overlaying a grain-size comparator that was at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes; Table 2-1) with the SPI camera. Seven grain-size classes, expressed in phi (ϕ) units, were on this comparator: >4 ϕ (silt-clay), 4 to 3 ϕ (very fine sand), 3 to 2 ϕ (fine sand), 2 to 1 ϕ (medium sand), 1 to 0 ϕ (coarse sand), 0 to (-1) ϕ (very coarse sand), and < -1 ϕ (granule and larger). The lower limit of optical resolution of the SPI photographic system was about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt ($\geq 4\ \phi$). The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (Rhoads and Germano 1984).

Table 2-1. Grain Size Scales for Sediment

ASTM (Unified) Classification [1]	U.S. Std. Mesh [2]	Size in mm	PHI Size	Wentworth Classification [3]
Boulder		4096.	-12.0	
		1024.	-10.0	Boulder
	12 in (300 mm)	256.	-8.0	
		128.	-7.0	Large Cobble
Cobble		107.64	-6.75	
		90.51	-6.5	Small Cobble
	3 in. (75 mm)	76.11	-6.25	
		64.00	-6.0	
		53.82	-5.75	
		45.26	-5.5	Very Large Pebble
Coarse Gravel		38.05	-5.25	
		32.00	-5.0	
		26.91	-4.75	
		22.63	-4.5	Large Pebble
	3/4 in (19 mm)	19.03	-4.25	
		16.00	-4.0	
		13.45	-3.75	
		11.31	-3.5	Medium Pebble
Fine Gravel		9.51	-3.25	
	2.5	8.00	-3.0	
	3	6.73	-2.75	
	3.5	5.66	-2.5	Small Pebble
	4	4.76	-2.25	
	5	4.00	-2.0	
Coarse Sand	6	3.36	-1.75	
	7	2.83	-1.5	Granule
	8	2.38	-1.25	
	10	2.00	-1.0	
	12	1.68	-0.75	
	14	1.41	-0.5	Very Coarse Sand
	16	1.19	-0.25	
Medium Sand	18	1.00	0.0	
	20	0.84	0.25	
	25	0.71	0.5	Coarse Sand
	30	0.59	0.75	
	35	0.50	1.0	
	40	0.420	1.25	
	45	0.354	1.5	Medium Sand
	50	0.297	1.75	
	60	0.250	2.0	
	70	0.210	2.25	
Fine Sand	80	0.177	2.5	Fine Sand
	100	0.149	2.75	
	120	0.125	3.0	
	140	0.105	3.25	
	170	0.088	3.5	Very Fine Sand
	200	0.074	3.75	
	230	0.0625	4.0	
Fine-grained Soil:	270	0.0526	4.25	
	325	0.0442	4.5	Coarse Silt
Clay if PI $\geq$ 4	400	0.0372	4.75	
Silt if PI < 4		0.0312	5.0	
		0.0156	6.0	Medium Silt
		0.0078	7.0	Fine Silt
		0.0039	8.0	Very Fine Silt
		0.00195	9.0	Coarse Clay
		0.00098	10.0	Medium Clay
		0.00049	11.0	Fine Clay
		0.00024	12.0	
		0.00012	13.0	
		0.000061	14.0	

1. ASTM Standard D 2487-92. This is the ASTM version of the Unified Soil Classification System. Both systems are similar (from ASTM (1993)).
2. Note that British Standard, French, and German DIN mesh sizes and classifications are different.
3. Wentworth sizes (in inches) cited in Krumbein and Sloss (1963).

Source: U.S. Army Corps of Engineers. (1995). Engineering and Design Coastal Geology, "Engineer Manual 1110-2-1810, Washington, D.C.

The comparison of the SPI images with Udden-Wentworth sediment standards photographed through the SPI optical system also was used to map near-surface stratigraphy, such as sand-over-mud and mud-over-sand. In general, inferences can be made about sediment deposition and/or transport patterns from observing such stratigraphy. For example, if sandy sediment is placed on top of native muddy sediment at a dredged material disposal site, SPI images collected in and around the disposal location will show increasingly thinner layers of sand (over mud) with increasing distance from the disposal point. The SPI results can be used to prepare maps showing the thickness of the deposited layer and the overall footprint of the dredged material deposit on the seafloor.

2.4.2 Prism Penetration Depth

In general, overconsolidated or relic sediments and shell-bearing sands resist camera penetration, while deeper penetration occurs in unconsolidated muds. The greatest penetration typically occurs in muds having high water content and/or that are highly bioturbated, sulfidic, or methanogenic.

The SPI prism penetration depth was measured from the bottom of the image to the sediment-water interface. The area of the entire cross-sectional sedimentary portion of the image was digitized, and this number was divided by the calibrated linear width of the image to determine the average penetration depth. Linear maximum and minimum depths of penetration also were measured. All three measurements (maximum, minimum, and average penetration depths) were recorded in the data file. Because the weighting of the camera frame was held constant throughout the survey, the measured penetration depths presented herein provide an indication of variation in sediment compactness across the surveyed area.

2.4.3 Small-Scale Surface Boundary Roughness

Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment profile images typically ranges from 0.02 to about 4.0 cm and may be related to physical structures (ripples, rip-up structures, mud clasts) or biogenic features (burrow openings, fecal mounds, foraging depressions). Biogenic roughness can change seasonally as a result of the interaction of bottom turbulence and bioturbational activities.

2.4.4 Dredged Material Layer Thickness

During image analysis, the thickness of any newly deposited sedimentary layers attributed to dredged material disposal was determined by measuring the distance between the pre- and post-depositional sediment-water interface. Recently deposited layers of dredged material were evident because of their unique texture and color relative to the underlying material representing the pre-depositional surface. If the point of contact between the two layers was clearly visible, the thickness of the dredged material layer could be measured easily. In some images, dredged material occupied the entire area of imaged sediment. In such cases, it was assumed that the dredged material layer extended below the maximum imaging (i.e., penetration) depth of the camera prism. The thickness of the dredged material layer was measured from the sediment-water interface to the bottom of the prism window, and this thickness was expressed with a "greater than" sign to indicate that it is a minimal or conservative estimate of the actual thickness of the dredged material layer at that location.

2.4.5 Mud Clasts

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

2.4.6 Apparent Redox Potential Discontinuity Depth

In general, the apparent RPD (aRPD) provides an estimate of the depth to which sediment geochemical processes are primarily aerobic or oxidative; below this layer such processes are anaerobic or reducing. The term apparent is used because no actual measurements are made of porewater chemistry or redox potential (Eh). Given the complexities of iron and sulfate reduction-oxidation chemistry, it is assumed that the lighter, reddish-brown color tones of surface and near-surface sediments in SPI images indicate an oxidative, or at least not intensely reducing, geochemical state, in contrast with underlying anoxic sediments exhibiting darker (typically gray or black) coloration (Diaz and Schaffner 1988; Rosenberg et al. 2001). This is in accordance with the classical concept which associates the RPD layer depth with sediment color (Fenchel 1969; Lyle 1983; Vismann 1991).

To determine the depth of the aRPD layer in each sediment-profile image, the area of lighter-colored sediment observed at and just below the sediment-water interface was digitized and measured. This area (in cm^2) was divided by the width of the image to estimate the average aRPD layer depth for the image. In general, it has been demonstrated that the aRPD depth can be a reliable indicator of benthic habitat disturbance from physical factors (e.g., dredged material disposal, erosion, trawling), low dissolved oxygen, and/or excessive organic enrichment (Rhoads and Germano 1986; Diaz and Shaffner 1988; Valente et al. 1992; Nilsson and Rosenberg 2000).

Because the determination of the aRPD requires discrimination of the optical contrast between oxidized (high optical reflectance) and reduced (low optical reflectance) particles, it can be difficult to make this measurement in well-sorted sands of any size that have little to no silt or organic matter in them. Many of the stations sampled during the Port Everglades Harbor ODMDS SPI survey were characterized by fine carbonate sands that were fairly homogenous in color. In the absence of an optical contrast and the apparent paucity of organic matter in these sediments, it was assumed that oxygen penetration was fairly deep and that these sediments, if not well-oxidized, were at least not strongly reducing. In many images, the layer of oxidized sediment was assumed to extend from the sediment-water interface to the bottom of the prism window (i.e., the penetration depth). The measured aRPD depth was expressed with a "greater than" sign to indicate that it was a minimal or conservative estimate of the actual aRPD depth (i.e., it is assumed that the actual layer of oxidized sediment extended below the camera's imaging depth).

2.4.7 Infaunal Successional Stage

The widely accepted model for marine infaunal succession predicts that macrobenthic invertebrates belonging to specific functional groups will appear sequentially with time following a physical seafloor disturbance or with increasing distance along an organic enrichment gradient (McCall 1977; Pearson and Rosenberg 1978; Rhoads and Boyer 1982; Rhoads and Germano 1982; 1986). The continuum of change in animal communities after a disturbance or along an organic enrichment gradient has been divided subjectively into four stages, numbered 0 to 3 (Figure 2-4).

Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source. Stage 1 is the initial community of tiny, densely populated polychaete assemblages that can appear within days following a disturbance. In the absence of any repeated disturbances over the following weeks to months, the initial tube-dwelling suspension or surface-deposit feeding taxa are followed by burrowing, head-down deposit-feeders that rework the sediment deeper and deeper over time and mix oxygen from the overlying water into the sediment. Stage 2 is the start of the transition to head-down deposit feeders, while Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders that typically develops, in the absence of disturbance, over time periods of months to years in soft muddy sediments (Figure 2-4).

The animals in the later-appearing communities (Stage 2 or 3) are larger, have lower overall population densities (10 to 100 individuals per m^2), and can rework the sediments to depths of 3 to 20 cm or more. These animals "loosen" the sedimentary fabric, increase the water content in the sediment, thereby lowering the sediment shear strength, and actively recycle nutrients because of the high exchange rate with the overlying waters resulting from their burrowing and feeding activities.

An important caveat exists with respect to the assignment of an infaunal successional stage to each of the Port Everglades Harbor ODMDS images. Namely, while the successional dynamics of invertebrate communities in soft, organic-rich, muddy marine sediments have been well-documented (e.g., Figure 2-4), these dynamics are not well known in sand and coarser sediments. The successional model depicted in Figure 2-4, therefore, is not applicable to all substrata. This is particularly true of organic-poor sands, like those at the Port Everglades Harbor ODMDS, which occur in a relatively deep, sub-tropical, open shelf environment characterized by relatively high current velocities. In such an environment, it is likely that benthic communities comprised of small-bodied, surface-dwelling suspension feeders (e.g., tube-dwelling polychaetes) remain dominant over the long-term, and the successional "end-point" (Stage 3) may not always consist of larger-bodied, subsurface deposit-feeders.

Although the successional models depicted in Figure 2-4 are not an ideal fit for an environment like the one at the Port Everglades Harbor ODMDS, they nevertheless provided an established conceptual framework within which to evaluate the degree of infaunal activity observed in each image. A successional stage therefore was assigned to each image based on the observation of one or more of the features depicted in the models of Figure 2-4. None of the Port Everglades images showed either Stage 0 (i.e., azoic conditions) or Stage 1 (i.e., low numbers of small, thin tubes on the sediment surface). Stage 2 was assigned if there were moderate to high numbers of different types of tubes on the sediment surface and/or low numbers of small-bodied polychaetes visible within the upper sediment column (i.e., just below the sediment surface). Low numbers of small polychaetes at depth within the sediment column suggest the benthic community was beginning to become established below the sediment-water interface (so-called "infaunalization").

Stage 3 was assigned based on the presence of larger-bodied, head-down-deposit-feeding, "equilibrium" taxa. In general, Stage 3 organisms rarely are seen in images, but the distinct feeding chambers or "voids" that develop at depth near their head ends serve as visible evidence of their presence. Bioturbation by these deposit-feeders can significantly aerate the sediment and increase aRPD depths to several centimeters. An image from the Port Everglades Harbor ODMDS SPI survey was designated as Stage 3 if any of the following five features were observed, alone or in combination: 1) a larger-bodied organism (typically a polychaete) at depth within the sediment column, 2) a biogenic mound at the sediment surface, 3) one or more relatively thick tubes at the sediment surface, 4) a sub-surface feeding void, and/or 5) a sub-surface burrow.

In dynamic estuarine and coastal environments, it is simplistic to assume that benthic communities always progress completely and sequentially through all four stages in accordance with the idealized conceptual model depicted in Figure 2-4. Various combinations of the four basic successional stages are possible. For example, surface- and near-surface-dwelling Stage 1 or 2 organisms can occur at the same time and place with Stage 3, resulting in the assignment of "Stage 1 on 3" or "Stage 2 on 3".

In the Port Everglades Harbor ODMDS survey, Stage 2 on 3 was assigned to any image showing moderate to high numbers of small polychaetes at or near the sediment surface, along with any of the five diagnostic features of Stage 3. If an image showed both high numbers of thicker, larger surface tubes and limited evidence of subsurface activity by Stage 3 organisms (e.g., just one or two small burrows at depth), then it was assigned to the transitional "Stage 2 going to 3" category. Images showing examples of the various successional stages are provided in Section 3 (Results).

2.4.8 Organism-Sediment Index

The Organism-Sediment Index (OSI) is a summary mapping statistic that was calculated from four independently measured SPI parameters: apparent mean RPD depth, presence of methane gas, low/no dissolved oxygen at the sediment-water interface, and infaunal successional stage. Table 2-2 shows how these parameters are summed to derive the OSI.

The highest possible OSI is +11, which reflects a mature benthic community in relatively undisturbed conditions (generally a good yardstick for high benthic habitat quality). These conditions are characterized by deeply oxidized sediment with a low inventory of anaerobic metabolites and low sediment oxygen demand (SOD), and by the presence of a climax (Stage 3) benthic community. The lowest possible OSI is −10, which indicates that the sediment has a high inventory of anaerobic metabolites, has a high oxygen demand, and is azoic. In our mapping experience over the past 15 years, we have found that OSI values of +6 or less indicate that the benthic habitat has experienced physical disturbance, organic enrichment, or excessive bioavailable contamination in the recent past.

2.4.9 Benthic Habitat Type

Similar to the approach used in Diaz (1995), a benthic habitat classification scheme was developed to provide a simple descriptive integration of several of the key physical and biological SPI parameters discussed above. First, a distinction was made between ambient (i.e., native) sediments and disposed dredged material. The ambient sediment was further characterized as being comprised of silty fine sand, typically with small tubes present at the sediment surface. The dredged material (DM) was categorized as being sandy; it was either layered (i.e., a relatively thin surface layer of DM was visible over ambient sediment) or else extended from the sediment surface to the bottom of the prism window.

Table 2-2. Calculation of the SPI Organism-Sediment Index

PARAMETER	INDEX VALUE
A. Mean RPD Depth (choose one)	
0.00 cm	0
> 0-0.75 cm	1
0.76-1.50 cm	2
1.51-2.25 cm	3
2.26-3.00 cm	4
3.01-3.75 cm	5
> 3.75 cm	6
B. Successional Stage (choose one)	
Stage 0	-4
Stage 1	1
Stage 1 → 2	2
Stage 2	3
Stage 2 → 3	4
Stage 3	5
Stage 1 on 3	5
Stage 2 on 3	5
C. Chemical Parameters (choose one or both if appropriate)	
Methane Present	-2
No/Low Dissolved Oxygen[a]	-4
Organism-sediment Index = Total of above subset indices (A+B+C)	
Range: -10 to +11	

[a] This is not based on a Winkler or polarigraphic electrode measurement. Instead, low DO conditions in the benthic boundary layer are inferred based on the imaged evidence of reduced, low reflectance (i.e., high-oxygen-demand) sediment at the sediment-water interface.

2.5 USING SPI DATA TO ASSESS BENTHIC QUALITY & HABITAT CONDITIONS

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

In contrast, surface sediments (upper 10 to 20 cm) have many biological and geochemical features that can persist over much longer time scales. Sea- and river-beds thereby provide an integrated record of long-term environmental conditions in overlying waters. Values for many measured sediment variables are the result of physical, chemical, and biological interactions on time scales much longer than those present in a rapidly moving fluid. The seafloor is thus an excellent indicator of environmental quality, both in terms of historical impacts and of future trends for any particular variable.

The following paragraphs discuss, in general terms, how various SPI parameters like the aRPD depth, infaunal successional stage, and the Organism-Sediment Index are used for assessing benthic habitat quality and response to disturbance. In response to physical disturbance or organic enrichment of the seafloor, these parameters have been shown to vary in predictable ways, both to each other and to more traditional measures like benthic species richness and abundance (Figures 2-4 and 2-5).

Physical measurements made with the SPI system from profile images provide background information about gradients in physical disturbance (caused by dredging, disposal, oil platform cuttings/drilling muds discharge, trawling, or storm resuspension and transport) in the form of maps of sediment grain size, boundary roughness, sediment textural fabrics, and structures. The concentration of organic matter and the SOD can be inferred from the optical reflectance of the sediment column and the apparent RPD depth. Organic matter is an important indicator of the relative value of the sediment as a carbon source for both bacteria and infaunal deposit feeders. SOD is an important measure of ecological health; oxygen can be depleted quickly in sediment by the accumulation of organic matter and by bacterial respiration, both of which place an oxygen demand on the porewater and compete with animals for a potentially limited oxygen resource (Figure 2-5; see also Kennish 1986).

The aRPD depth is useful in assessing the quality of a habitat for epifauna and infauna from both physical and biological points of view. The aRPD depth in profile images has been shown to be directly correlated to the quality of the benthic habitat in polyhaline and mesohaline estuarine zones (Rhoads and Germano 1986; Revelas et al. 1987; Valente et al. 1992; Nilsson and Rosenberg 1997; 2000). Controlling for differences in sediment type and physical disturbance factors, apparent RPD depths < 1 cm can indicate chronic benthic environmental stress or recent catastrophic disturbance.

The distribution of successional stages in the context of the mapped disturbance gradients is one of the most sensitive indicators of the ecological condition of the seafloor (Rhoads and Germano 1986; Figure 2-5). The presence of Stage 3 equilibrium taxa (mapped from subsurface feeding voids as observed in profile images) can be a good indication of high benthic habitat stability and relative lack of disturbance from natural or anthropogenic factors. A Stage 3 assemblage indicates that the sediment surrounding these organisms has not been disturbed severely in the recent past and that the inventory of bioavailable contaminants is relatively small. These inferences are based on past work, primarily in temperate latitudes, showing that Stage 3 species are relatively intolerant to sediment disturbance, organic enrichment, and sediment contamination. Stage 3 species expend metabolic energy on sediment bioturbation (both particle advection and porewater irrigation) to control sediment properties, including porewater profiles of sulfate, nitrate, and RPD depth in the sedimentary matrix near their burrows or tubes (Aller and Stupakoff 1996; Rice and Rhoads 1989). Bioturbation results in an enhanced rate of decomposition of polymerized organic matter by stimulating microbial decomposition (“microbial gardening”). Stage 3 benthic assemblages are very stable and are also called climax or equilibrium seres.

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

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

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

3.0 RESULTS

3.1 QA/QC DISCUSSION OF SPI DATASET

All of G&A's standard QA/QC procedures were followed in the field, as described previously in the Quality Assurance Project Plan (Germano and Associates, Inc. 2006). The frame counter on the camera was checked immediately following each camera retrieval to ensure that the expected number of images had been taken. In addition, the images were downloaded using the SPI camera's external USB port and reviewed at regular intervals during the field operations to verify that they were of acceptable quality. Initial review of the images showed the sediments to be relatively firm, and the camera was operated using a full set of weights and the "stop collars" raised to a relatively high position.

At the majority of stations, three replicate images of acceptable quality for analysis were obtained. At stations L10 and L11, only two images of acceptable quality were obtained. At these stations, the camera failed to penetrate sufficiently on the third replicate drop, and it was not possible to add any more weight to the camera to improve penetration. Average station values (i.e., averages of the n = 3 or, in the case of stations L10 and L11, 2 replicate images that were analyzed at each station) for key SPI parameters are presented in the tables and figures that follow.

As indicated, the plan-view camera system was damaged, and images were obtained at only thirteen of the Port Everglades Harbor ODMDS stations. In lieu of collecting plan-view images at the remaining stations, seven SPI stations were added in the field (identified with an "X" prefix) to improve the precision of mapping the dredged material footprint.

Following the completion of image analysis, Dr. Joseph Germano provided an independent QA/QC review of all the measurement data. The reviewed data were used to create the summary tables and interpretive maps in this report.

3.2 PLAN-VIEW IMAGING RESULTS

A complete set of measurement data for the plan-view images is provided in Appendix A; these results are summarized in Table 3-1.

Overall, the sediment surface in most of the plan-view images was relatively smooth and, with the exception of biological features, displayed fairly homogenous texture and composition across the field of view. The major biological features visible in the plan-view images included: 1) small mounds of sediment excavated by burrowing infauna

Table 3-1. Summary of plan-view image analysis results.

Station	Rep	Biogenic mounds	Foraging pits	Burrow openings	Sea stars	Crabs	Rocks	Dredged material?
J10	3	17	5	60	1	0	0	N
J11	1	5	4	14	0	0	0	N
J12	2	2	7	20	0	0	0	N
J13	3	5	3	10	3	0	0	Y
J14	3	7	4	3	2	0	0	Y
J15	3	0	0	8	2	1	15	Y
J16	2	5	2	7	1	0	0	N
J17	1	6	3	10	3	0	0	N
J18	3	2	5	14	1	0	0	N
L13	2	0	4	8	1	0	0	N
R1	2	4	2	7	1	0	0	N
R2	2	0	0	30	0	0	0	N
R3	1	0	0	34	1	0	0	N

(i.e., “biogenic mounds” that generally ranged from 6 to 10 cm in diameter), 2) small depressions or pits in the sediment surface (ranging from 4 to 12 cm in diameter) attributed to the foraging activity of demersal fish and/or other epibenthic predators, and 3) small holes or “pockmarks” in the sediment surface (each on the order of 1 cm or less in diameter) that were assumed to be burrow openings (Figure 3-1). Given the relatively small size of these burrow openings, they are most readily attributed to smaller worms or juvenile shrimp as opposed to larger organisms such as tilefish. Asteroids (sea stars) ranging from about 12 to 18 cm in diameter also were observed at the sediment surface in many of images. Each individual typically had 10 or 11 arms and was possibly the species *Coronaster briareus*, which is common on the southeastern continental shelf (Figure 3-2). A crab was visible in a single image from Station J15 (Figure 3-3).

At 7 of the 10 disposal stations and all 3 of the reference stations, the sediment in the plan-view images appeared to consist of very silty, ambient fine sand (e.g., Figure 3-1). At Stations J13, J14 and J15, the sediment surface appeared less silty and somewhat coarser due to a higher apparent sand content. In addition, there were numerous aluminum cans scattered over the sediment surface at Station J15 (Figures 3-2 and 3-3). Based on these distinguishing features, the sediment at Stations J13, J14 and J15 was characterized as dredged material (Table 3-1).

3.3 SPI Physical/Chemical Parameters

3.3.1 Sediment Grain Size

A complete set of measurement data for each replicate SPI image obtained in the May 2006 survey is provided in Appendix B; these data are summarized in Tables 3-2 and 3-3.

Table 3-2. Summary SPI results (averages or median values) for the disposal site stations sampled during the May 2006 survey of the Port Everglades Harbor ODMDS.

Station	Grain Size Major Mode (phi)	Average Penetration Depth (cm)	Avg. boundary roughness (cm)	Avg. RPD depth (cm)	Avg. no. of mud clasts	Avg. thickness of DM layer	Methane or Low DO?	Highest Successional Stage	OSI
H11	4 to 3	4.5	1.5	>4.5	0		No	Stage 2 on 3	+11
H12	4 to 3	4.8	0.9	>4.8	0		No	Stage 2	+9
H13	4 to 3	3.7	0.9	>3.7	0		No	Stage 2 on 3	+9
H14	4 to 3	3.9	0.8	>3.9	0		No	Stage 2 on 3	+10
H15	4 to 3	4.4	1.3	>4.4	0		No	Stage 2 on 3	+11
H16	4 to 3	3.6	0.9	>3.6	0		No	Stage 2 on 3	+11
H17	4 to 3	3.6	1.3	>3.6	0		No	Stage 2 on 3	+9
I10	4 to 3	4.3	1.0	>4.3	0		No	Stage 2 to 3	+10
I11	4 to 3	3.6	1.3	>3.6	0		No	Stage 2 on 3	+10
I12	4 to 3	5.1	2.0	>5.1	0		No	Stage 2 on 3	+11
I13	3 to 2	3.7	1.6	>3.7	0		No	Stage 2	+8
I14	4 to 3	4.0	0.8	>4.0	0		No	Stage 2 on 3	+10
I15	4 to 3	4.5	0.7	>4.5	0	Trace	No	Stage 2	+9
I16	4 to 3	3.9	0.9	>3.9	0		No	Stage 2 on 3	+11
I17	4 to 3	4.5	2.5	>4.5	0		No	Stage 2 on 3	+10
I18	4 to 3	3.9	1.3	>3.9	0		No	Stage 2 on 3	+10
J10	4 to 3	4.1	0.7	>4.1	0		No	Stage 2 on 3	+9
J11	4 to 3	4.2	1.4	>4.2	0		No	Stage 2 to 3	+9
J12	3 to 2/4 to 3	4.0	0.6	>4.0	0	2.5	No	Stage 2 to 3	+10
J13	3 to 2/4 to 3	4.2	0.7	>4.2	0	2.8	No	Stage 2	+9
J14	3 to 2	4.1	1.0	>4.1	0	>4.7	No	Stage 2 on 3	+9
J15	4 to 3	7.3	1.3	1.0	0	6.4	No	Stage 2 to 3	+6
J16	4 to 3	4.4	0.8	>4.4	0		No	Stage 2 on 3	+11
J17	4 to 3	4.9	1.0	>4.9	0		No	Stage 2 on 3	+11
J18	4 to 3	4.3	1.4	>4.3	0		No	Stage 2 on 3	+11
K10	4 to 3	4.3	0.9	>4.3	0	2.0	No	Stage 2 to 3	+10
K11	3 to 2	3.7	0.8	>3.7	0	2.4	No	Stage 2 to 3	+9
K12	3 to 2	3.7	1.3	>3.7	0	>4.3	No	Stage 2 on 3	+10
K13	3 to 2/>4 to 3	3.5	0.9	>3.5	0	2.3	No	Stage 2 to 3	+9
K14	4 to 3	3.8	0.7	>3.8	0	2.6	No	Stage 2 on 3	+10
K15	4 to 3	3.2	1.7	>3.2	0	>4.2	No	Stage 2	+8
K16	4 to 3	4.3	2.0	>4.3	0		No	Stage 2 to 3	+10
K17	4 to 3	4.2	1.2	>4.2	0		No	Stage 2 to 3	+10
K18	4 to 3	4.3	1.2	>4.3	0		No	Stage 2 to 3	+9
L10	4 to 3	3.7	0.7	>3.7	0	Trace	No	Stage 2 to 3	+10
L11	3 to 2	3.4	0.9	>3.4		2.2	No	Stage 2	+8
L12	3 to 2	3.6	0.8	>3.6		>4.1	No	Stage 2	+8.5
L13	4 to 3	3.9	1.3	>3.9	0		No	Stage 2 on 3	+9
L14	4 to 3	3.9	0.7	>3.9	0	Trace	No	Stage 2 to 3	+9
L15	4 to 3	3.5	1.1	>3.5	0		No	Stage 2 on 3	+10
L16	4 to 3	3.6	1.0	>3.6	0		No	Stage 2 on 3	+11
L17	4 to 3	4.2	0.8	>4.2	0		No	Stage 2	+9
M10	4 to 3	3.7	1.8	>3.7	0		No	Stage 2 to 3	+9
M11	4 to 3	4.1	1.1	>4.1	0		No	Stage 2 on 3	+10
X1	3 to 2	3.5	0.9	>3.5	0	2.6	No	Stage 2	+9
X2	3 to 2/4 to 3	4.0	1.1	>4.0	0	2.8	No	Stage 2 on 3	+10
X3	3 to 2/4 to 3	4.1	0.7	>4.1	0	3.1	No	Stage 2 to 3	+10
X4	3 to 2	3.6	0.9	>3.6	0	2.6	No	Stage 2	+9
X5	3 to 2/4 to 3	3.7	0.8	>3.7	0	3.8	No	Stage 2 on 3	+9
X6	>4 to 3	4.8	0.6	0.8	0	>5.1	No	Stage 2	+4.5
X7	3 to 2/4 to 3	5.4	1.3	>5.4	0	2.6	No	Stage 2 on 3	+11

Native surface sediment consisting of silty, very fine sand (grain size major mode of 4 to 3 phi) occurred at the majority of disposal site and reference stations, outside of the dredged material footprint (Tables 3-2 and 3-3; Figures 3-4 through 3-6). At stations within the dredged material footprint, the sediment appeared to have a slightly higher proportion of silty fine sand (as opposed to the silty, *very* fine sand comprising the native sediment type). Most of the stations having dredged material, therefore, were mapped with a grain size major mode of 3 to 2 phi (Table 3-2 and Figure 3-4). The profile images at many of these stations showed a surface depositional layer of 3 to 2 phi fine sand (i.e., dredged material) overlying ambient very fine sand at depth (described in greater detail in the following section).

Table 3-3. Summary SPI results (averages or median values) for the reference stations sampled during the May 2006 survey of the Port Everglades Harbor ODMDS.

Station	Grain Size Major Mode (phi)	Average Penetration Depth (cm)	Avg. boundary roughness (cm)	Avg. RPD depth (cm)	Avg. no. of mud clasts	Avg. thickness of DM layer	Methane or Low DO?	Highest Successional Stage	OSI
R1	4 to 3	4.0	1.1	>4.0	0		No	Stage 2 on 3	+11
R2	4 to 3	4.5	0.6	>4.5	0		No	Stage 2 on 3	+10
R3	4 to 3	4.9	1.0	>4.9	0		No	Stage 2 on 3	+11

3.3.2 Dredged Material Layer Thickness and Spatial Distribution

Dredged material was observed in the images at 22 of the 51 stations located within and to the north of the disposal site; there was no dredged material observed at any of the three reference stations (Tables 3-2 and 3-3). The overall footprint of the dredged material deposit formed an uneven ellipse that was elongated in the north-south direction (Figure 3-7). Within this ellipse, the average thickness of the surface dredged material layer ranged from 6.4 cm at station J15 to trace amounts at a few of the perimeter stations (Table 3-2 and Figure 3-7).

The dredged material was distinguishable from the ambient surface sediments by its overall darker color, presence of a higher apparent proportion of fine sand (3 to 2 phi), presence of dark patches of silt, and/or presence of small white shell fragments (Figures 3-8 and 3-9). At most of the stations, the surface depositional layer of dredged material was relatively thin, and its point of contact with the underlying ambient sediment (former sediment surface) was visible in the images. The thickness of the dredged material layer was measured as a discrete value at such stations (e.g., Figure 3-8). At five of the stations, the dredged material extended from the sediment surface to below the camera's imaging depth (e.g., Figure 3-9), resulting in the mapped thickness values being displayed with a "greater than" sign in Table 3-2 and Figure 3-7.

In general, the thickest layers of dredged material were found at a cluster of stations (stations J15, J15, K15 and X6) located just to the north of the circular disposal zone within the ODMDS (Figure 3-7). The thickness generally decreased moving northward away from the disposal zone, except for a cluster of four stations (stations K12, L12, X3 and X5) located near the northern boundary of the ODMDS.

3.3.3 Mud Clasts and Surface Boundary Roughness

Given the overall absence of consolidated/cohesive muddy sediments at the sampled stations, mud clasts were not observed at the sediment surface in any of the SPI images from this survey (Tables 3-2 and 3-3). Average small-scale boundary roughness values at the disposal site stations ranged from 0.6 to 2.5 cm, with 48 of the 51 stations (94%) having values of 2.0 cm or less (Table 3-2). The average boundary roughness values at the three reference stations likewise were all less than 2.0 cm (Table 3-3). In general, these are low values, indicating very little small-scale relief across the 14 cm field of view in most of the images. This reflects the largely unconsolidated nature of the surface sediments across the surveyed area and is consistent with the observation of a generally smooth sediment surface at the stations where plan-view images were collected.

In 69% of the analyzed images at the disposal site stations, the boundary roughness was considered to be of biogenic origin (Appendix B). The boundary roughness was of physical origin in 30% of the disposal site images, and of indeterminate origin in <1% of the images. The biogenic boundary roughness was due to the presence of both upright tubes and, in particular, small mounds of sediment excavated by organisms (Figure 3-10). These types of circular biogenic mounds also were observed in many of the plan-view images (Table 3-1 and Figure 3-1). At the reference stations, the boundary roughness likewise was considered to be of biogenic origin in 78% of the images, and of physical origin in 22% of the images (Appendix B).

3.3.4 Prism Penetration Depth

The SPI prism penetration depth measurement has a potential range from 0 cm (no penetration) to about 20 cm (close to the maximum vertical height of the prism window). The average prism penetration depth values at the disposal site stations were all very similar, ranging between 3.2 cm at Station K15 and 7.3 cm at Station J15 (Table 3-2). Most of the values (48 of 51 stations, or 94%) fell in the relatively narrow range of 3 to 5 cm (Table 3-2). Likewise, the average values at the reference stations fell between 4 and 5 cm (Table 3-3).

There were no consistent spatial patterns in the average prism penetration depth values at the disposal site or reference stations (Figure 3-11). All of the values were near the lower end of the potential range of 0 to 20 cm, indicating that both the ambient surface sediments and the sandy dredged material were of uniform firmness across the surveyed area.

3.3.5 Methane Gas and Low Dissolved Oxygen

There were no methane gas bubbles in the sediment or low dissolved oxygen conditions in the benthic boundary layer at any of the stations sampled in the May 2006 survey at the Port Everglades Harbor ODMDS (Tables 3-2 and 3-3).

3.3.6 Apparent Redox Potential Discontinuity Depth

Surface sediments at most of the stations across the surveyed area had uniformly high optical reflectance, with a notable absence of any strong vertical color contrasts that typically denote the transition from a positive to negative redox state with depth in the sediment column (e.g., Figure 3-6). Although the sediment tended to be darker in color at the stations with dredged material, there was a similar absence of any strong vertical color contrasts that typically are associated with a change in the redox state of marine sediments.

In general, aRPD depths greater than about 3 cm are considered indicative of good oxygen penetration into estuarine and coastal marine surface sediments. With the exception of Stations X6 and J15, the average aRPD depths measured in the Port Everglades Harbor ODMDS survey were consistently greater than 3 cm (Tables 3-2 and 3-3; Figures 3-12 and 3-13). At all of the stations where the average aRPD depth was greater than 3 cm, the sediment was considered to be oxidized from the sediment surface to below the camera's imaging depth, and the measured aRPD depth therefore was indicated with a "greater than" sign to show that it is a minimum or conservative estimate of the actual aRPD depth.

Stations X6 and J15 both had measureable, relatively thin average aRPD depths, based on the color contrast between oxidized, lighter-colored surface sediment and underlying darker sediment (Figure 3-14). The dredged material that was present at both of these stations appeared to contain somewhat elevated levels of fines, organic matter, and associated levels of reduced sulfides at depth, leading to the vertical color contrasts that were the basis for the aRPD measurements at these stations.

3.4 SPI BIOLOGICAL PARAMETERS

3.4.1 Infaunal Successional Stage

The infaunal successional status at the disposal site stations was relatively advanced, comprised of Stages 2 and 3 (Table 3-2 and Figure 3-15). The Stage 2 designation was based on observing moderate to high numbers of different-sized tubes at the sediment surface (Figure 3-16); this was the highest successional stage at 11 of the 51 disposal site stations (Figure 3-17).

At 14 of the 51 disposal site stations, Stage 2 going to 3 was the highest successional designation (Figure 3-17). At these stations, in addition to the moderate numbers of different types of surface tubes, there was also evidence of some limited subsurface activity, such as a single small polychaete worm or burrow (Figure 3-18).

Among the different types of Stage 2 surface tubes observed in the images, distinct, thin, tube-like stalks with frills near the top were observed at many stations (Figure 3-19). These are tentatively identified as a type of hydrozoan.

Just over half of the disposal site stations (26 of 51, or 51%) had an advanced successional status consisting of Stage 2 on 3 (Table 3-2; Figures 3-15 and 3-17). At some stations, the Stage 3 designation was assigned because biogenic mounds, indicative of subsurface activity by larger-bodied infauna, were observed at the sediment surface along with the Stage 2 tubes (e.g., Figures 3-1 and 3-10). At other stations, the presence of Stage 3 was based on the presence of larger-bodied polychaetes at depth within the sediment (Figure 3-20).

Stage 2 on 3 occurred at 6 of the stations within the dredged material footprint, as well as at many of the disposal site stations located outside the footprint (Figure 3-15). Stage 2 on 3 also was the highest successional stage at all three of the reference stations (Table 3-3 and Figure 3-15).

In summary, there were a total of 22 stations located within the dredged material footprint. Of these, 8 stations (36%) exhibited Stage 2, 8 (36%) had Stage 2 going to 3, and 6 (27%) were assigned a successional stage of 2 on 3.

3.4.2 Organism-Sediment Index

As described in Section 2.3.9 and illustrated in Figure 2-5, the OSI is a summary metric that provides a way to order, or rank, the stations in terms of the relative degree of benthic habitat disturbance or degradation. For the May 2006 SPI survey at the Port Everglades Harbor ODMDS, the median OSI values at almost all of the disposal site stations, as well as at all three of the reference stations, were in the range of +7 to +11 (Figures 3-21 and 3-22). Values in this range are considered indicative of little or no appreciable benthic habitat disturbance.

Stations X6 and J15 near the disposal zone had median OSI values of +4.5 and +6, respectively. These values fall in the range of +1 to +6, which is generally considered indicative of a moderate degree of benthic habitat disturbance. Although the successional stage at both of these stations was relatively advanced (Stage 2 and Stage 2 to 3), the median OSI values reflect the relatively shallow aRPD depths, which were attributed to the input of dredged material having a moderately reducing geochemical status.

It is notable that the relatively high OSI values were found at stations both within and outside the dredged material footprint. These values reflect a combination of relatively deep RPD depths across all of the surveyed stations in combination with a relatively advanced successional status.

3.4.3 Benthic Habitat Type

The benthic habitat classification scheme developed for the Port Everglades Harbor ODMDS largely reflects the information on sediment grain size, presence/absence of dredged material layers, and biological features discussed above. There was little variation in benthic habitat conditions across the surveyed area. The most common habitat type consisted of silty, native (i.e., ambient) fine sand, with tubes present at the surface (Figure 3-23). Within the dredged material footprint, there was typically a very slight and subtle coarsening of the sediment texture, due to higher apparent amounts of fine sand and small shell fragments. Stations within the dredged material footprint therefore had a benthic habitat type consisting of either sandy dredged material exceeding the prism penetration depth, or a thin surface layer of sandy dredged material overlying ambient very fine sand at depth (Figure 3-23).

4.0
DISCUSSION

The first objective of the May 2006 SPI survey at the Port Everglades Harbor ODMDS was to map the spatial distribution of disposed dredged material on the seafloor. The SPI images revealed dredged material layers that appeared to be of relatively recent origin (i.e., deposited within the past year or two) at a number of the sampling locations. Based on using a grid of evenly spaced stations, it was possible to create a contour map showing the overall footprint of recently deposited dredged material. The deposit formed an uneven ellipse that was elongated in the south-to-north/northeast direction, with the lower half of the ellipse centered within the disposal site, and the upper half occurring to the north of the disposal site (Figure 4-1). Compared to the predicted dredged material footprint (determined using the STFATE model), the actual footprint occurred slightly more to the east/northeast of the disposal zone and was more elongated (Figure 4-1).

At some stations, it was not possible to measure the full thickness of the deposited dredged material, because the interface between the surface dredged material layer and the underlying ambient (i.e., pre-disposal) sediment surface occurred below the depth of penetration of the profile camera. Despite this limitation, it appeared that the greatest accumulation of the disposed sediment had occurred just to the north of the 600-ft radius disposal zone located in the center of the ODMDS. Dredged material layers in excess of the camera's imaging depth were observed at a cluster of stations in this area (stations J14, K15 and X6). At station J15, a discrete depositional layer of dredged material having an average measured thickness of 6.4 cm was observed in the replicate profile images. The possibility exists that the actual dredged material layer thickness at nearby Stations J14, K15 and X6 also was around 6 cm, but the critical interface with the pre-disposal sediment surface occurred just below the camera's penetration (i.e., imaging) depth at these stations.

With increasing distance to the north/northeast of the disposal zone, the dredged material layers generally became increasingly thinner, ranging from about 2.8 cm to less than 0.5 cm (i.e., trace) amounts. This pattern is attributed to the influence of the Florida Current, which flows strongly from south to north at this site. As a result, dredged material released within the disposal zone is transported northward during its descent through the water column and deposited in increasingly thinner layers on the seafloor.

The exception to this pattern are the relatively thick dredged material layers of 3.1 to >4.3 cm observed at Stations K12, L12, X3 and X6 near the northern boundary of the disposal site (Figure 3-7). Because these layers were of comparable thickness to those at stations near the 600-ft radius disposal zone within the ODMDS, the possibility exists that some direct disposal may also have inadvertently occurred in this area. Northward transport of this mis-placed dredged material during its descent through the water column might explain the relatively thin depositional layers measured at the cluster of stations in the northern-most part of the survey grid (i.e., Stations K10, K11, L10, L11, X1 and X2).

If a future site management goal is to keep more of the dredged material deposit confined within the ODMDS boundaries, the disposal zone (surface release point) should be located to the south of its present location. Given the strong currents in the area, even locating the disposal zone more to the south may not guarantee that all of the dredged material remains completely within the boundaries as this site continues to be utilized in the future. However, the May 2006 SPI survey serves to demonstrate relatively rapid recovery of the local benthic community following disposal of the type of material observed (discussed in greater detail below).

The second objective of the survey was to characterize physical changes in the seafloor resulting from disposal. The SPI images showed that the main physical change was a subtle shift in sediment texture and color. Specifically, compared to the silty, light-colored, very fine sand that characterized the ambient seafloor, the new surface layers of dredged material possessed: 1) a grain size major mode that was slightly sandier, 2) a darker color, and 3) higher amounts of fine shell hash. At some stations, the dredged material also contained patches of dark silt (e.g., Figure 3-9).

Based on their uniform light color, the ambient surface sediments were well-oxidized and contained relatively low levels of labile organic carbon. Although the deposited dredged material was darker in color, there was a general lack of color gradients within the sediment column that normally indicate a change from a primarily oxidizing to a primarily reducing geochemical state with depth. The only exceptions to this occurred in the images of dredged material at Stations J15 and X6, where relatively shallow aRPD depths were measured. These results suggest that a relatively limited volume of the dredged material had somewhat elevated levels of labile organic carbon compared to ambient sediments. At these two stations, decomposition of this organic carbon apparently was sufficient to result in oxygen consumption and the development of reducing conditions at depth.

It is anticipated that over time, the organic carbon levels will decrease as a result of both continuing microbial decomposition and direct consumption of the organic matter by infaunal organisms, with associated deepening of the aRPD depths. Overall, at the majority of stations within the dredged material footprint and in surrounding areas, it did not appear that there had been any adverse changes in oxygen demand, redox state, or other geochemical properties as a result of disposal.

The third and final objective of the survey was to evaluate benthic recolonization through the mapping of infaunal successional stages. The stations having surface layers of dredged material were found to have intermediate (Stages 2 or 2 going to 3) to advanced (Stage 2 on 3) benthic recolonization. The recolonizing community consisted of both surface-dwelling infauna, as evidenced by the moderate to high numbers of surface tubes visible in most of the images, as well as subsurface-dwelling Stage 3 taxa capable of extensive bioturbation. The circular mounds of excavated sediment, which were visible in both the plan-view and profile images, provided the primary evidence that burrowing Stage 3 infauna were present across the surveyed area.

Overall, the successional status at most of the disposal site stations was comparable to that at the reference stations. Within the dredged material footprint, more of the stations were in an intermediate stage of recolonization (i.e., Stage 2 or 2 going to 3) compared to the stations outside the footprint, where Stage 2 on 3 was most common. These results suggest that while benthic conditions over the dredged material deposit were rapidly approaching those on the ambient seafloor relatively soon after disposal, this process was on-going and not yet complete at the time of May 2006 SPI survey. In the absence of further disposal, the density of slower-growing and larger-bodied Stage 3 organisms could be expected to increase over the dredged material deposit, such that a higher proportion of stations would eventually exhibit the Stage 2 on 3 conditions found on the ambient seafloor.

The observed recolonization of the dredged material deposit by Stage 2 and increasing numbers of Stage 3 communities at the time of the May 2006 SPI survey largely represents a return to ambient seafloor conditions relatively soon following disposal. This in part is attributed to the absence of any significant changes in sediment physical or geochemical characteristics resulting from disposal, since the dredged material appeared largely similar in texture and organic content to ambient surface sediments. If very dissimilar material were to be disposed in the future, then it is possible that the process of recolonization might require more time and/or result in significant changes in benthic community structure compared to the ambient seafloor. Due to the high current velocities in the general area where the Port Everglades Harbor ODMDS is located, native benthic communities presumably are adapted to frequent physical disturbance. Therefore, in the present study, the relatively rapid benthic recolonization of the areas that were physically disturbed by dredged material disposal is not surprising.

5.0
CONCLUSIONS AND RECOMMENDATIONS

1. The May 2006 SPI survey at the Port Everglades Harbor ODMDS showed that dredged material of relatively recent origin formed an elliptical deposit on the seafloor. The deposit was elongated in the south-to-north/northeasterly direction, with the lower half of the ellipse centered within the disposal site, just to the north of the 600-foot radius disposal zone. The upper half of the elliptical deposit occurred to the north of the disposal site.

2. The thickest layers of dredged material were found in two areas: immediately to the north of the circular disposal zone in the center of the disposal site and at a cluster of stations located north of the northern disposal site boundary. Northward to these two areas, the dredged material was deposited in increasingly thinner layers.

3. Given the strong northward drift of the dredged material following its release at the Port Everglades Harbor ODMDS, it is recommended that the disposal zone be located to the south of its present location. This should help to ensure that more of the resulting seafloor deposit is located within the ODMDS boundaries. However, even moving the disposal point to the southern end of the currently designated site perimeter will not necessarily guarantee that the resulting dredged material deposit remains completely within the site boundary, given the strong northward transport conditions at this particular location.

4. The main physical change resulting from disposal appeared to be a subtle shift in sediment texture, with the new surface layers of dredged material having a grain size major mode that was slightly more sandy and with higher amounts of fine shell hash than the silty, very fine sand comprising the ambient seafloor.

5. The ambient surface sediments were uniformly light-colored, suggesting oxidized conditions. The deposited dredged material was darker in color but, except for two stations, it generally lacked any strong vertical color contrasts indicative of a change in redox conditions. Overall, at the majority of stations within the dredged material footprint and in surrounding areas, it did not appear that there had been any adverse changes in oxygen demand, redox state, or other geochemical properties as a result of disposal.

6. Given the lack of any major physical changes to the surface sediments as a result of disposal, stations within the dredged material footprint appeared to be in an intermediate to advanced stage of benthic recolonization. The recolonizing community consisted of both surface-dwelling infauna, as evidenced by moderate

to high numbers of surface tubes visible in most of the images, as well as subsurface-dwelling Stage 3 taxa capable of extensive bioturbation.

7. Within the dredged material footprint, more of the stations were in an intermediate stage of recolonization (i.e., Stage 2 or 2 going to 3) compared to the stations outside the footprint, where Stage 2 on 3 was most common. These results suggest that while benthic conditions over the dredged material deposit were rapidly approaching those on the ambient seafloor relatively soon after disposal, this process was on-going and not yet complete at the time of May 2006 SPI survey.

8. Overall, the results indicate that local benthic communities are capable of rapidly recolonizing the type of sandy dredged material that had been deposited at the Port Everglades Harbor ODMDS prior to the May 2006 SPI survey.

6.0
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FIGURES

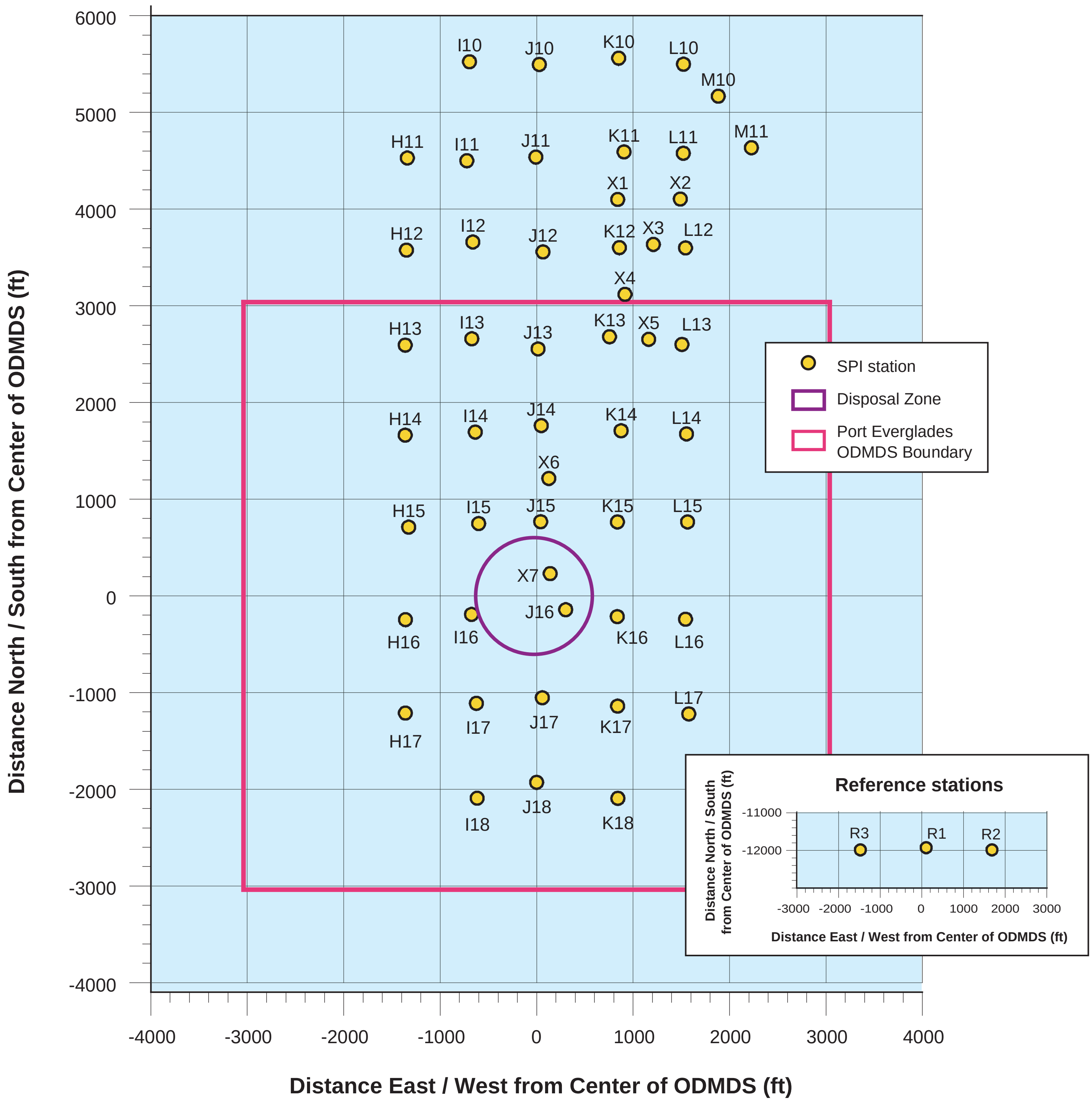


Figure 2-1: SPI sampling locations for the May 2006 survey at the Port Everglades Harbor ODMDS.

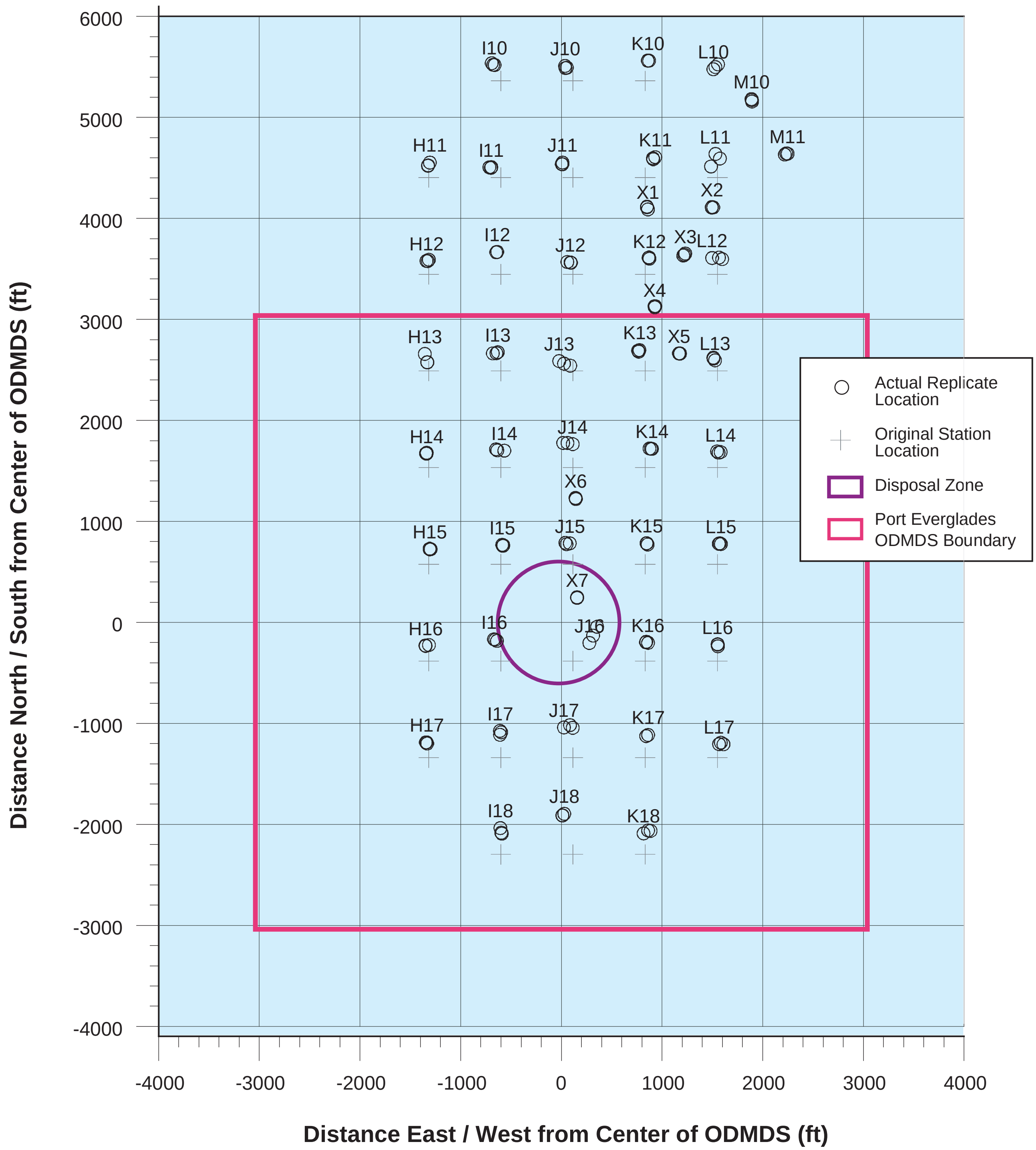


Figure 2-2: Map showing the target sampling location versus the actual location of each replicate camera drop for the May 2006 SPI survey at the Port Everglades Harbor ODMDS.

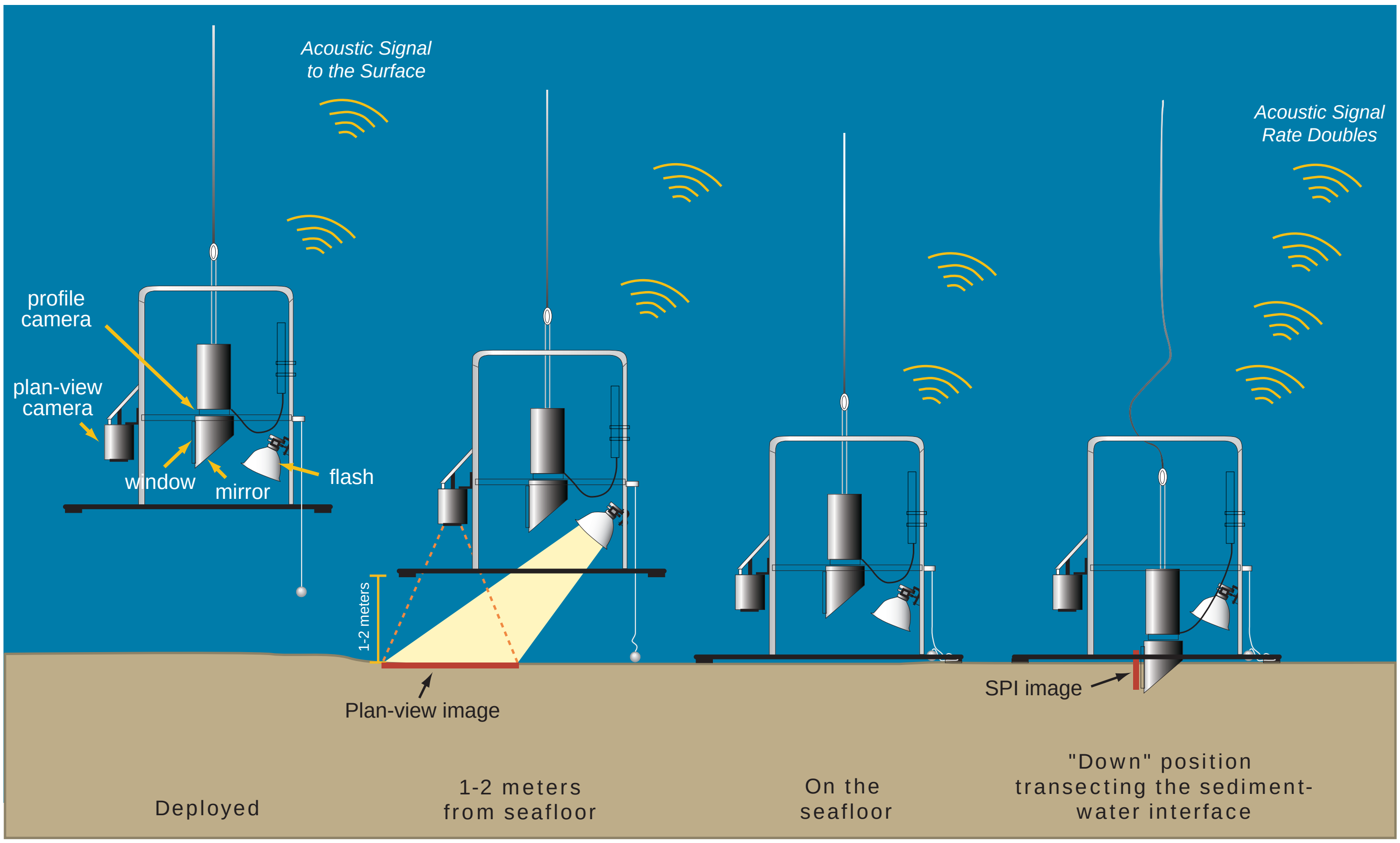


Figure 2-3: Operation of the sediment plan-view and sediment-profile cameras during deployment.

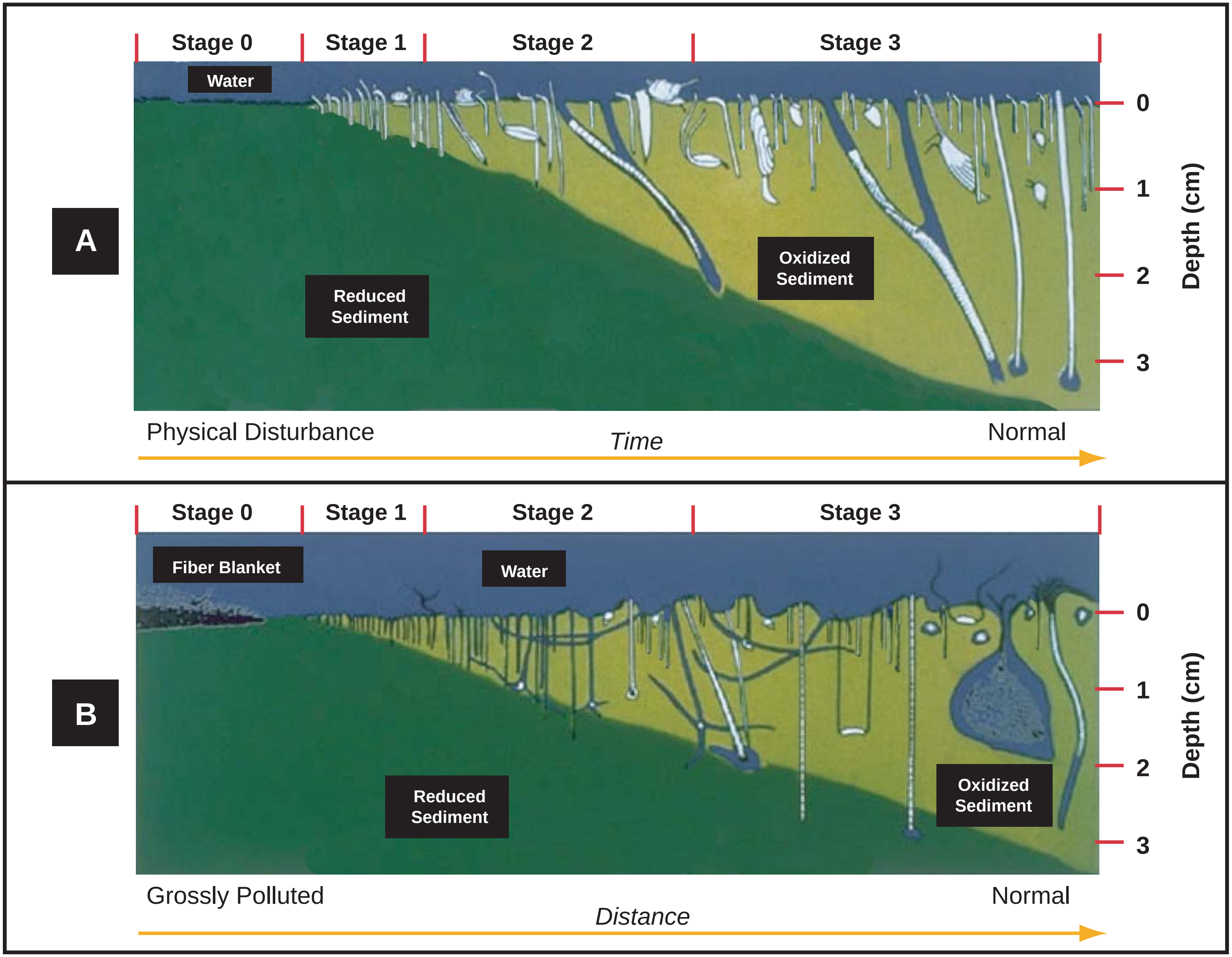


Figure 2-4: Models of soft-bottom benthic community response to physical disturbance (top panel) or organic enrichment (bottom panel). From Rhoads and Germano, 1982.

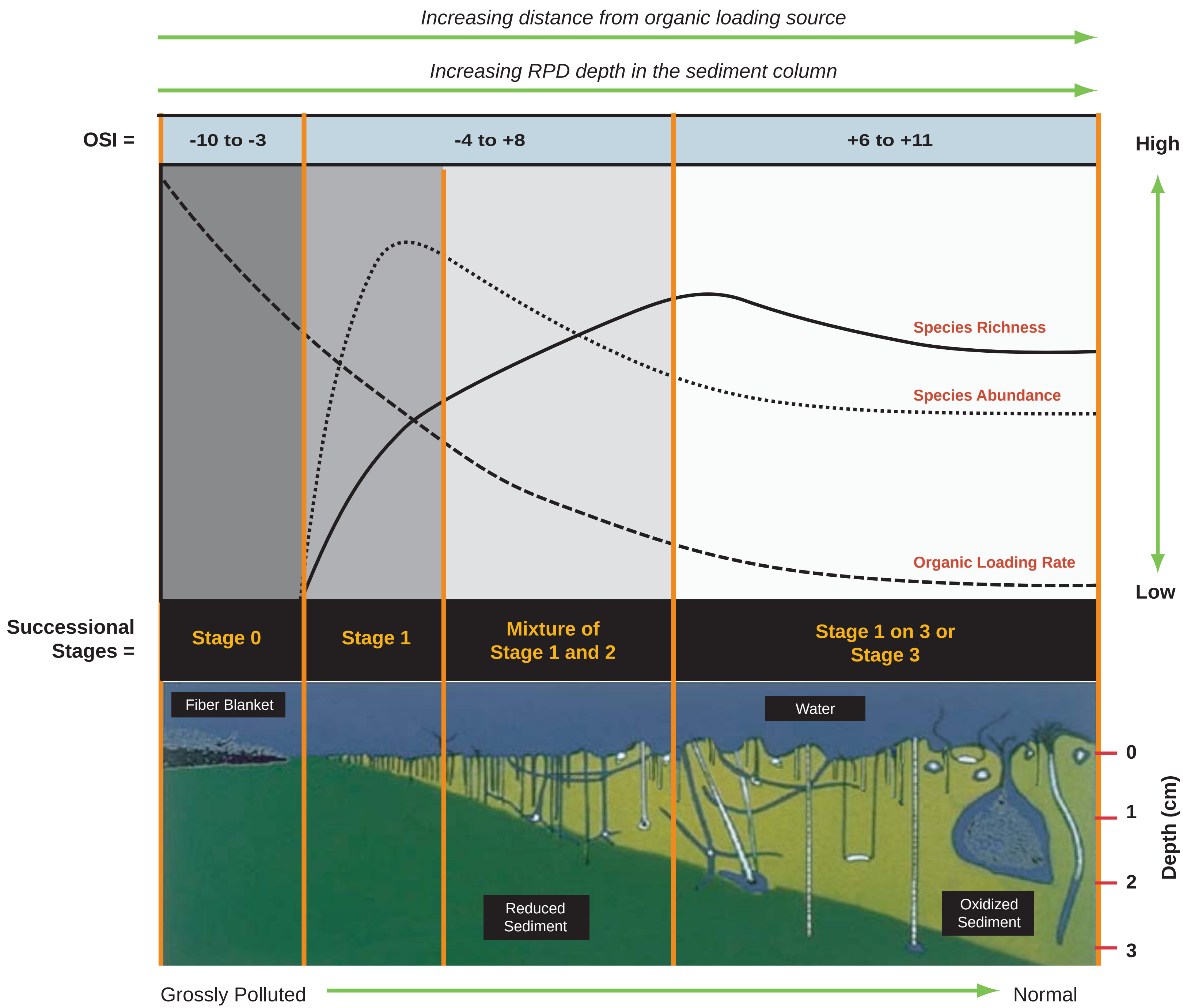


Figure 2-5: Model illustrating the relationships among key SPI parameters and traditional measures of species richness and abundance along an organic enrichment gradient.

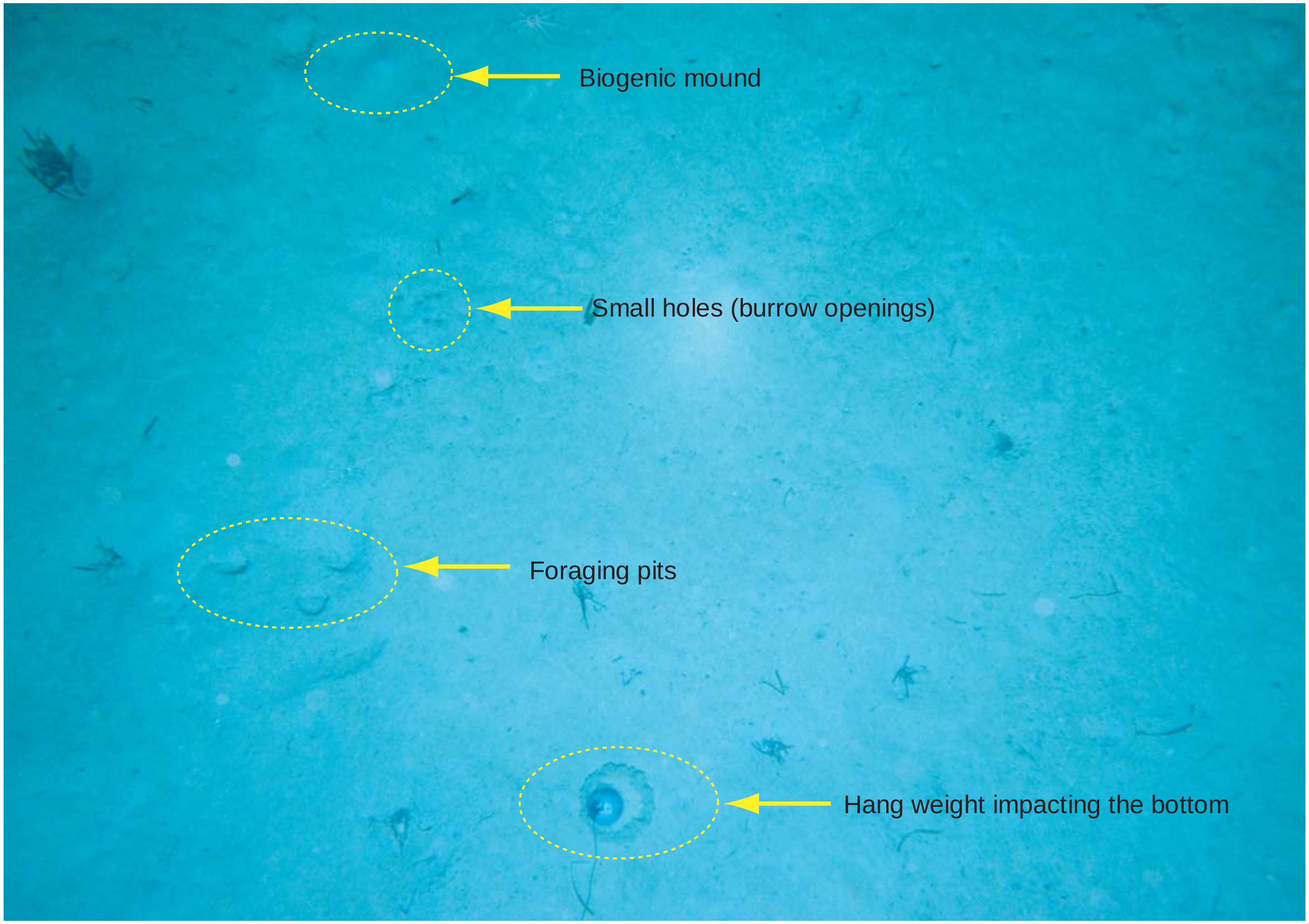


Figure 3-1: Plan-view image showing native, or ambient, sediment at Station J10, with several commonly observed biogenic features. Scale = dimensions of image are roughly 200 by 300 cm.

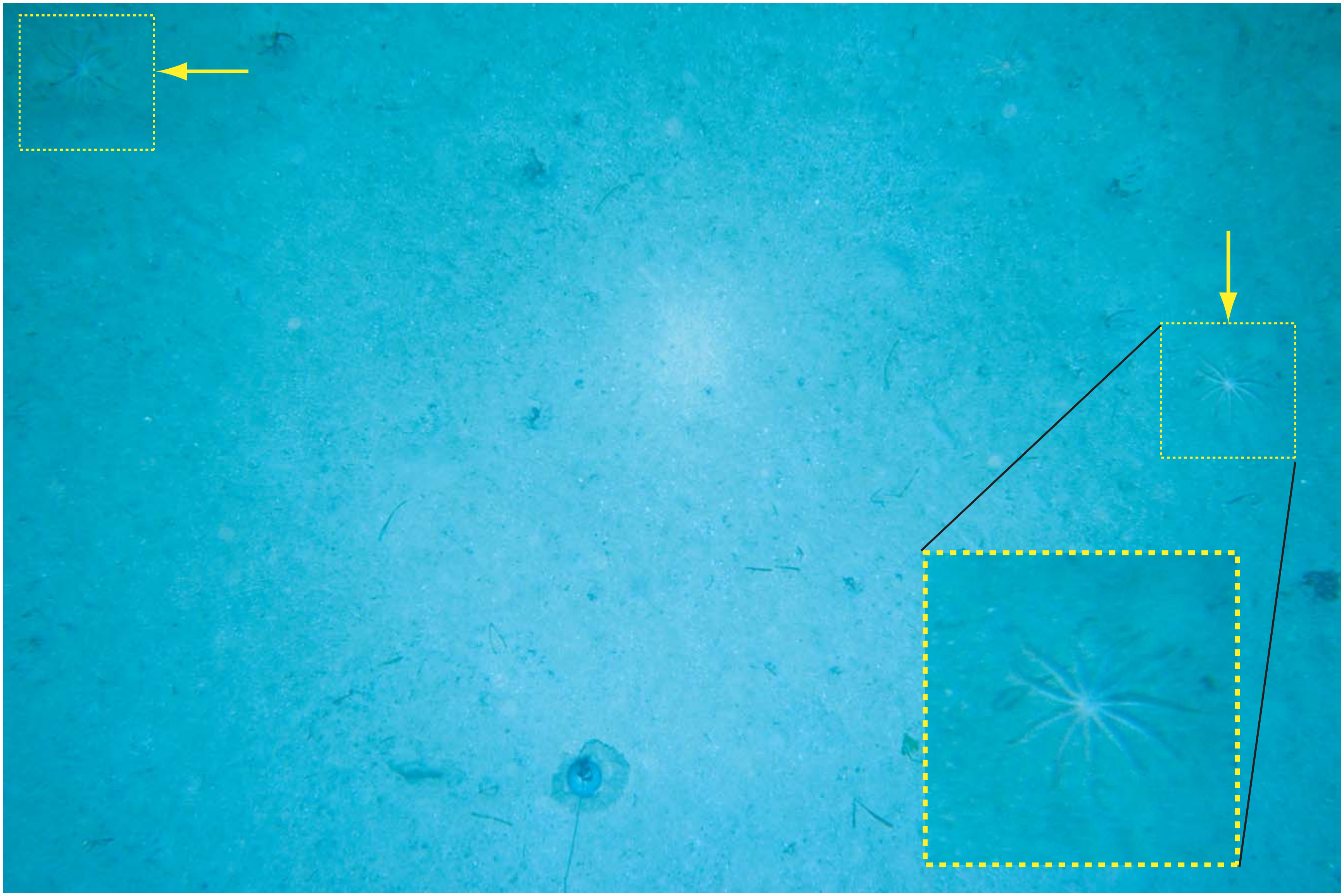


Figure 3-2: Plan-view image from Station J13 showing sea stars (possibly *Coronaster briareus*) at the sediment surface (arrows). The sediment appears to have a higher fraction of sand in this image, attributed to the presence of dredged material. Scale = dimensions of image are roughly 200 by 300 cm.

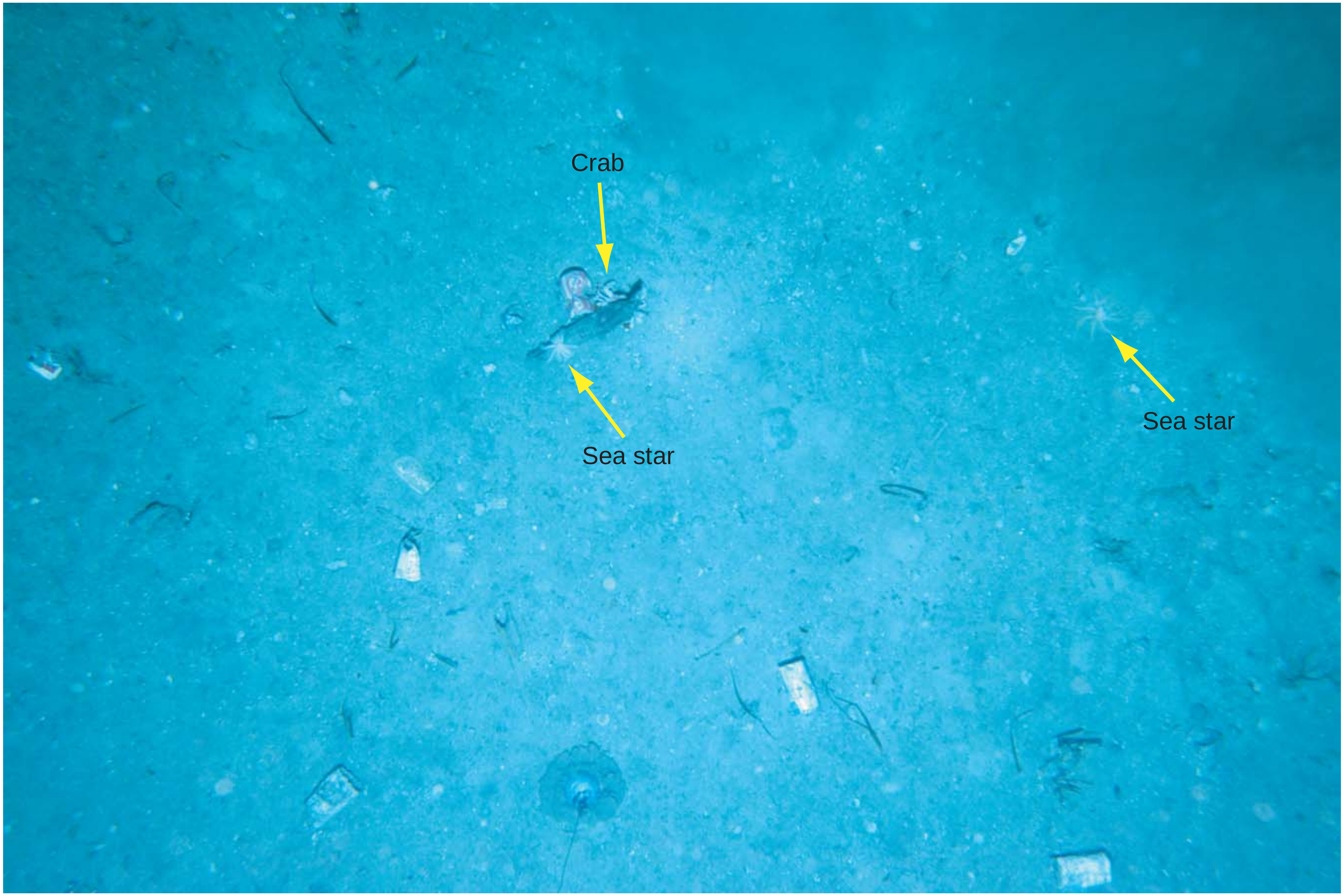


Figure 3-3: Plan-view image from Station J15 showing a crab and two sea stars at the sediment surface. This sediment clearly consists of dredged material, which contains shell fragments, small rocks, and a number of discarded aluminum cans. Scale = dimensions of image are roughly 200 by 300 cm.

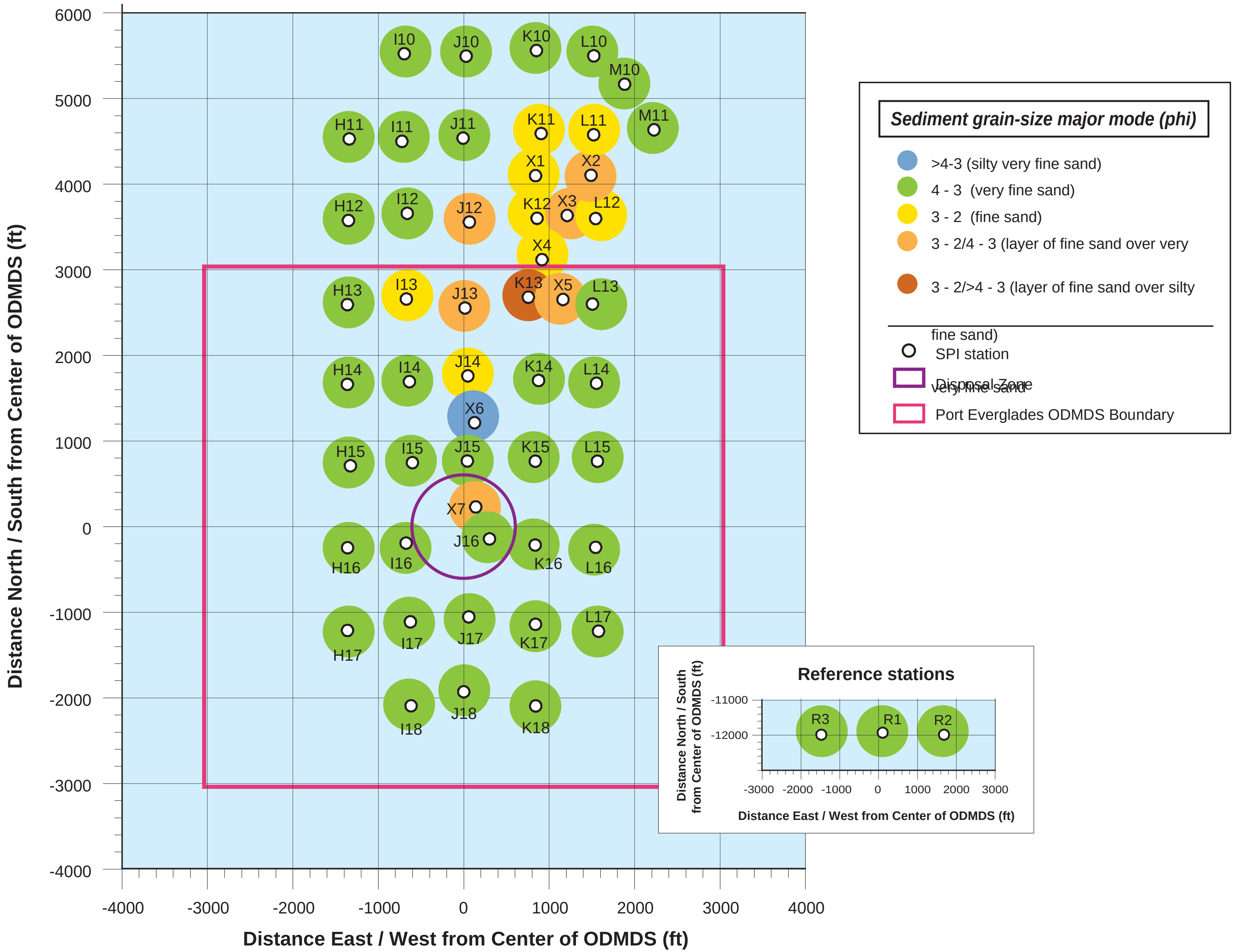


Figure 3-4: Grain size major mode (in phi units) at the Port Everglades Harbor ODMDS SPI stations.

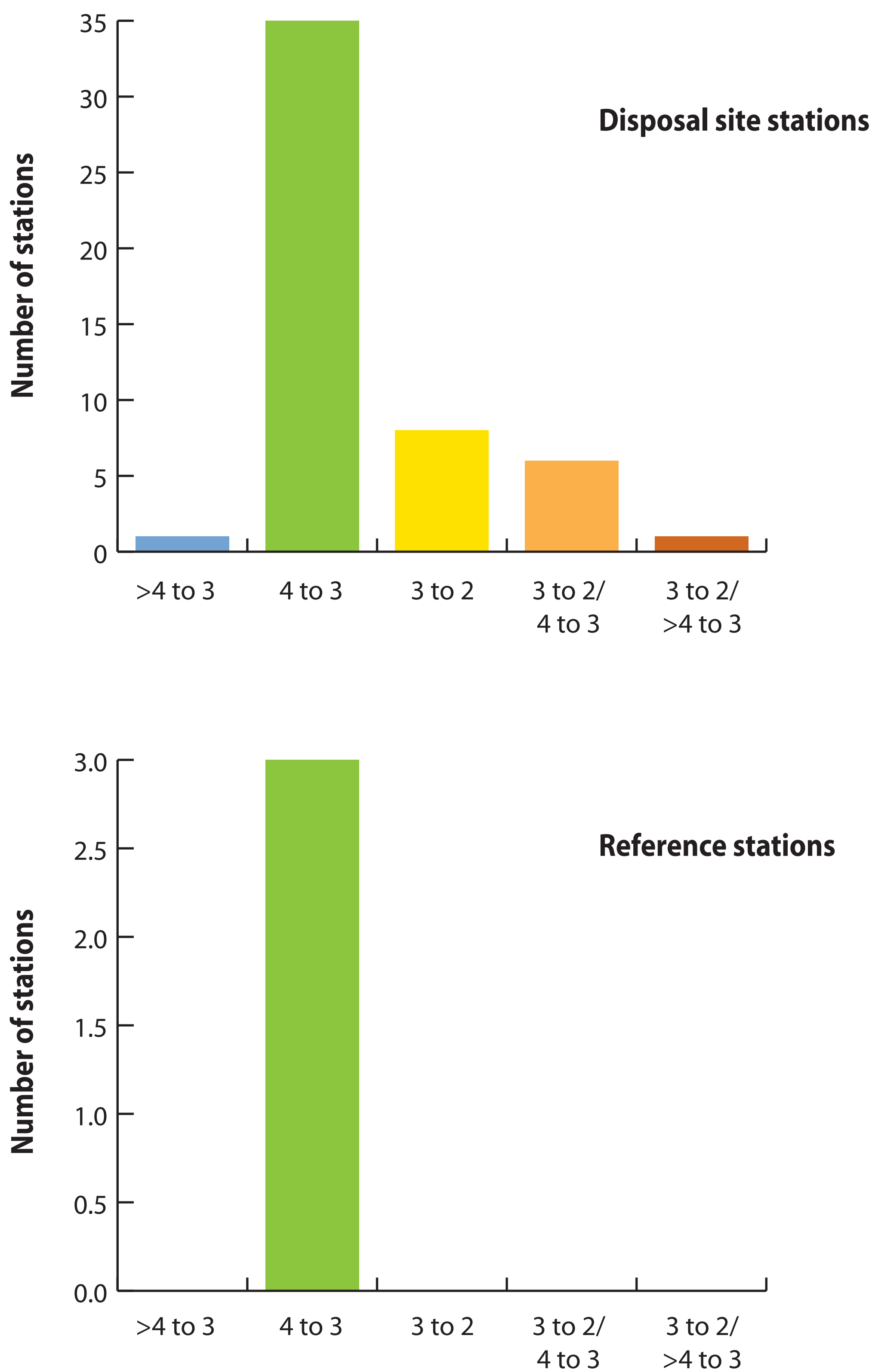
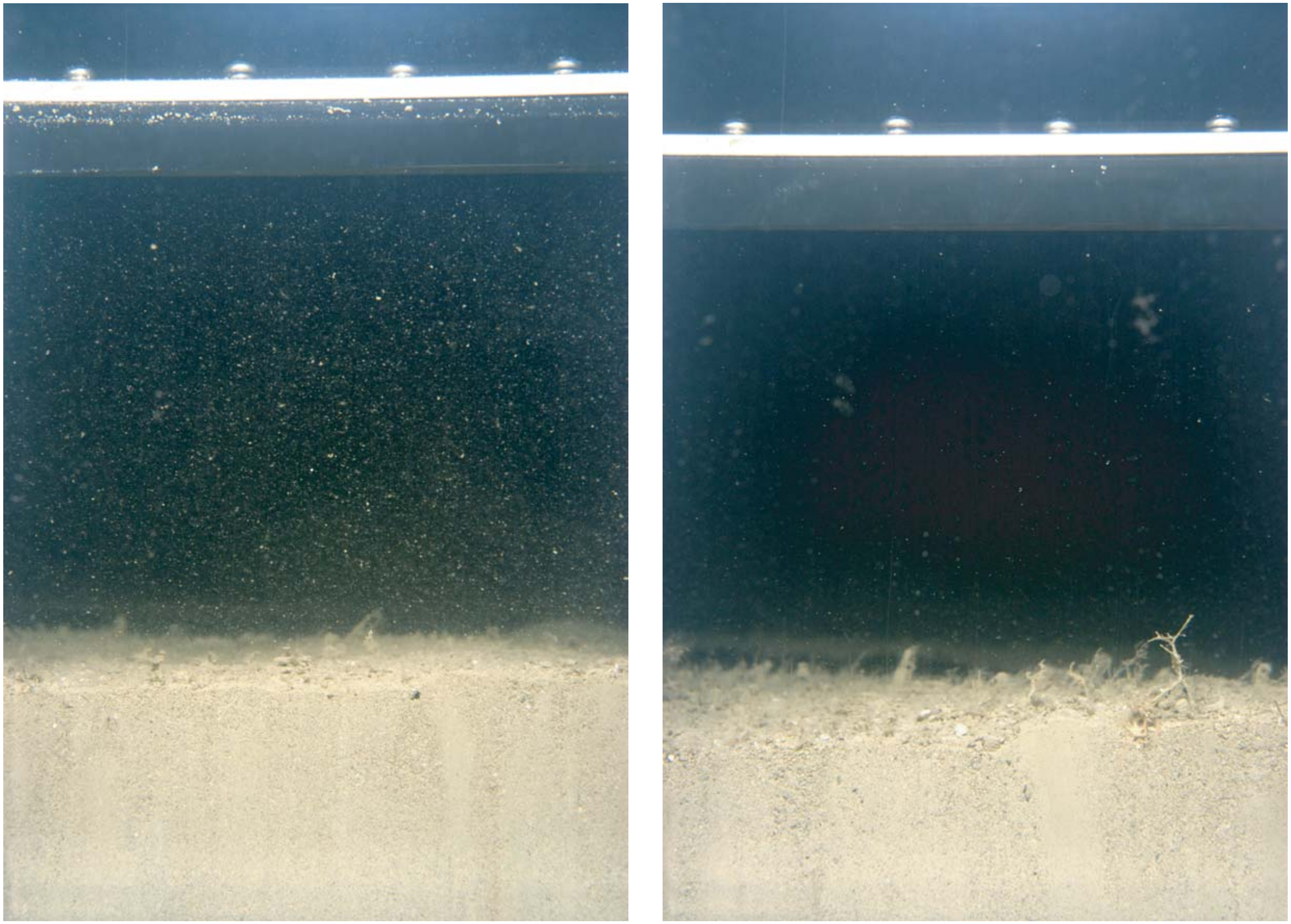


Figure 3-5: Frequency distributions of grain size major mode (in phi units) at the disposal site stations (top) and reference stations (bottom).



A. H12-1B **B. R2-2B**

Figure 3-6: SPI images from disposal site station H12 (left) and reference station R2 (right) showing typical ambient sediment consisting of very homogenous, silty, very fine sand (grain size major mode of 4 to 3 phi). Numerous tubes of different types and sizes occur at the sediment surface in both images (Stage 2), and the right image also shows a few small subsurface worms and burrows (Stage 2 going to 3). The sediment in both images is uniformly light-colored, without any strong vertical color contrasts that typically denote the aRPD. Scale = actual image width is 14.4 cm.

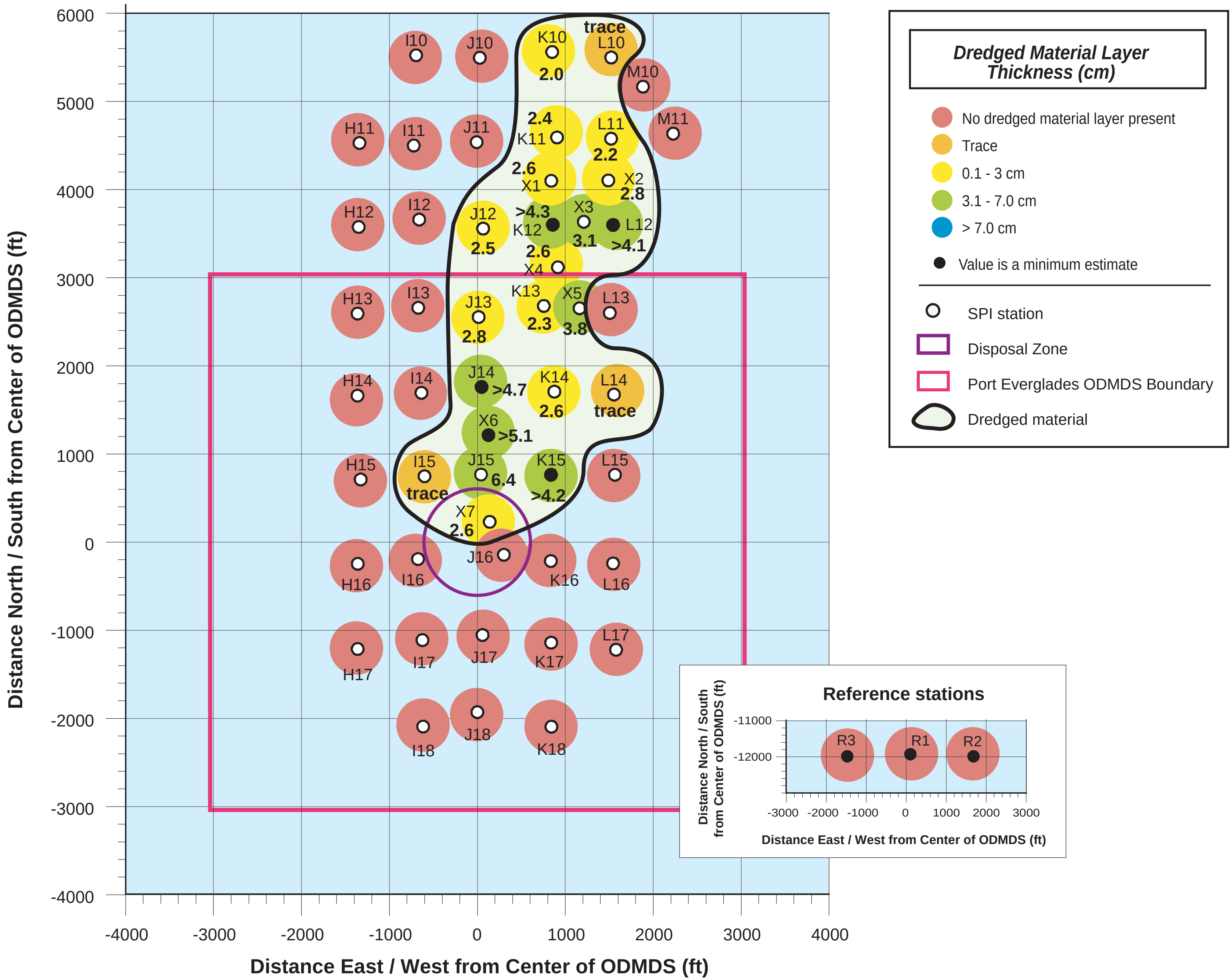
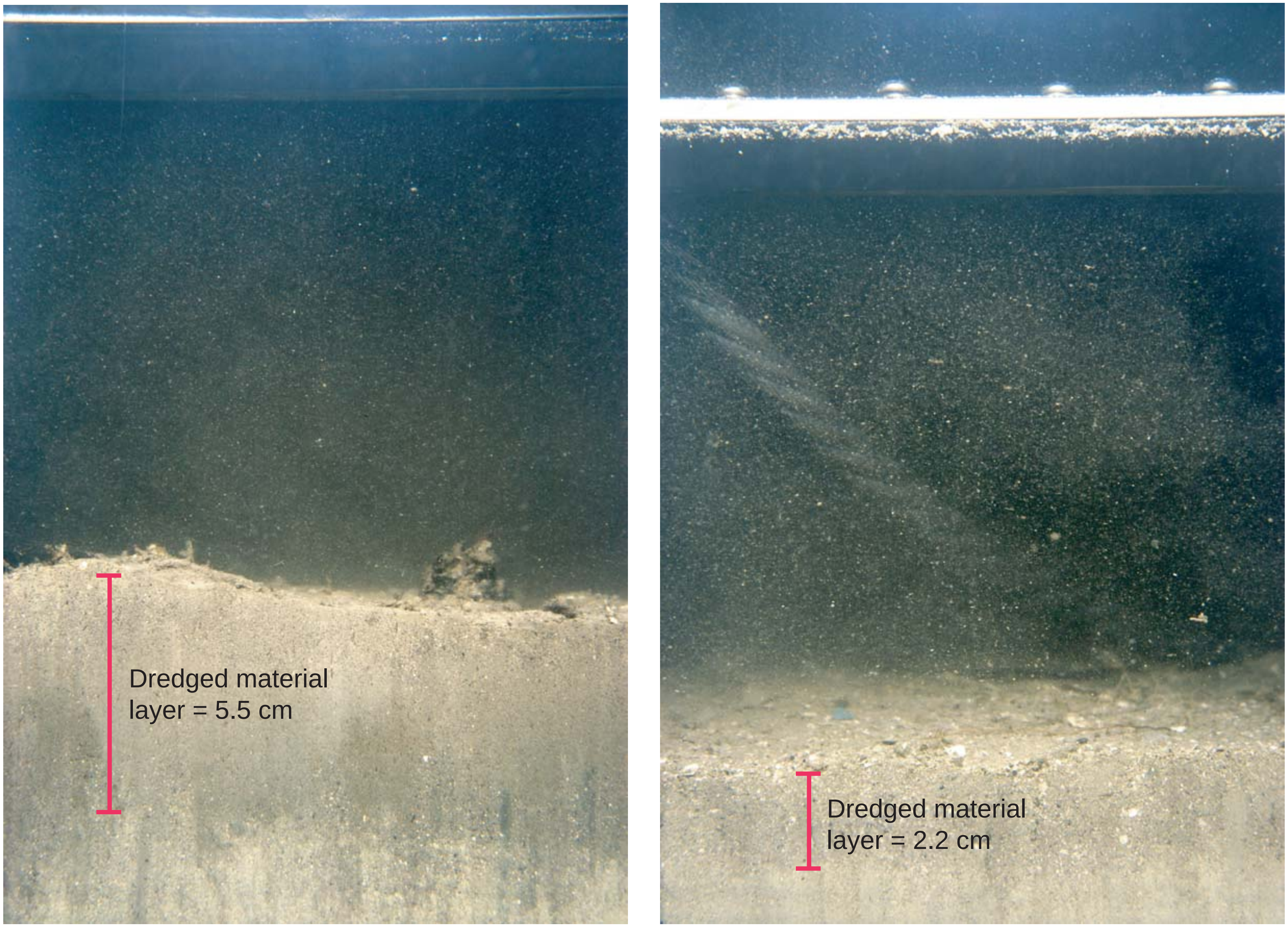
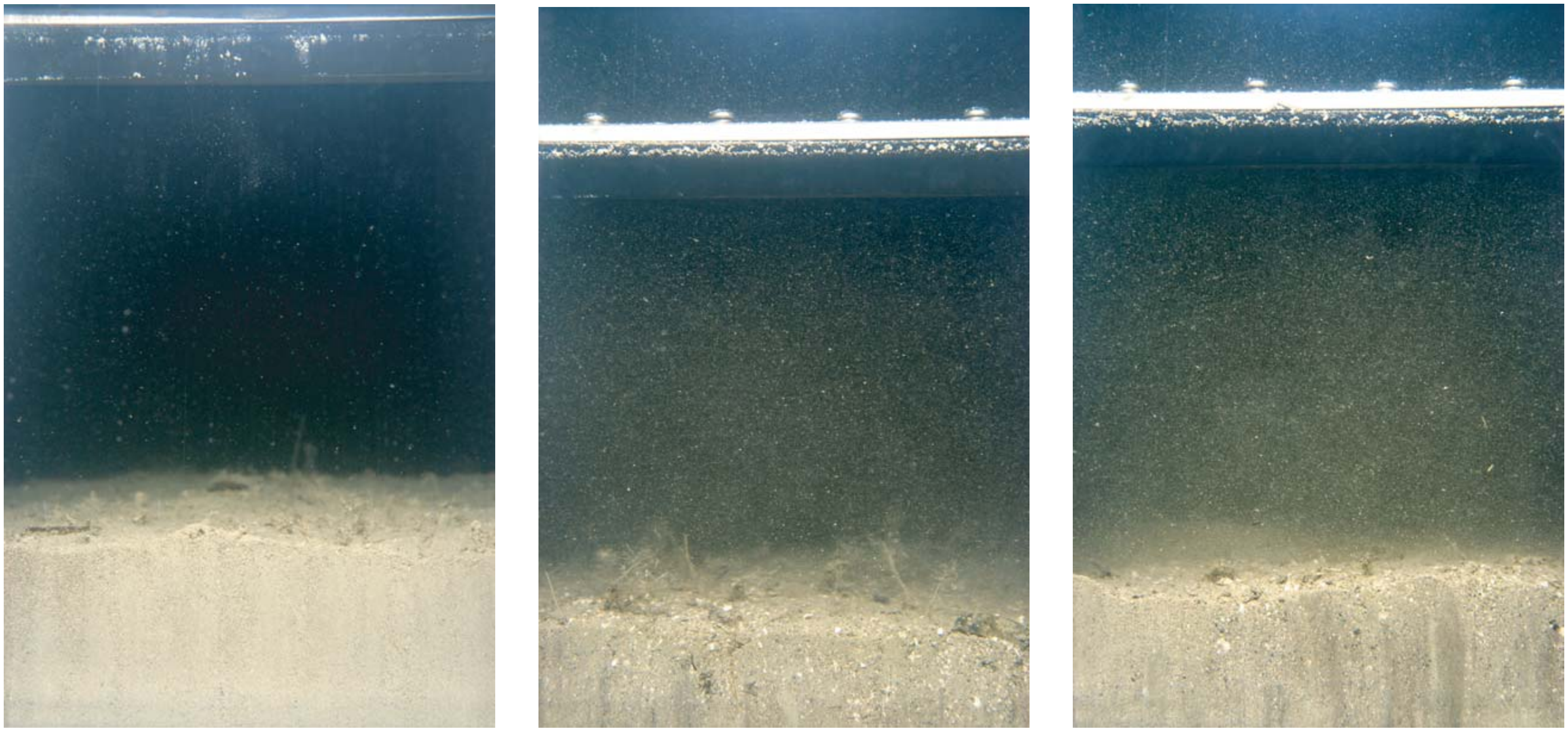


Figure 3-7: Average thickness of the dredged material layer at each of the Port Everglades Harbor ODMDS SPI stations.



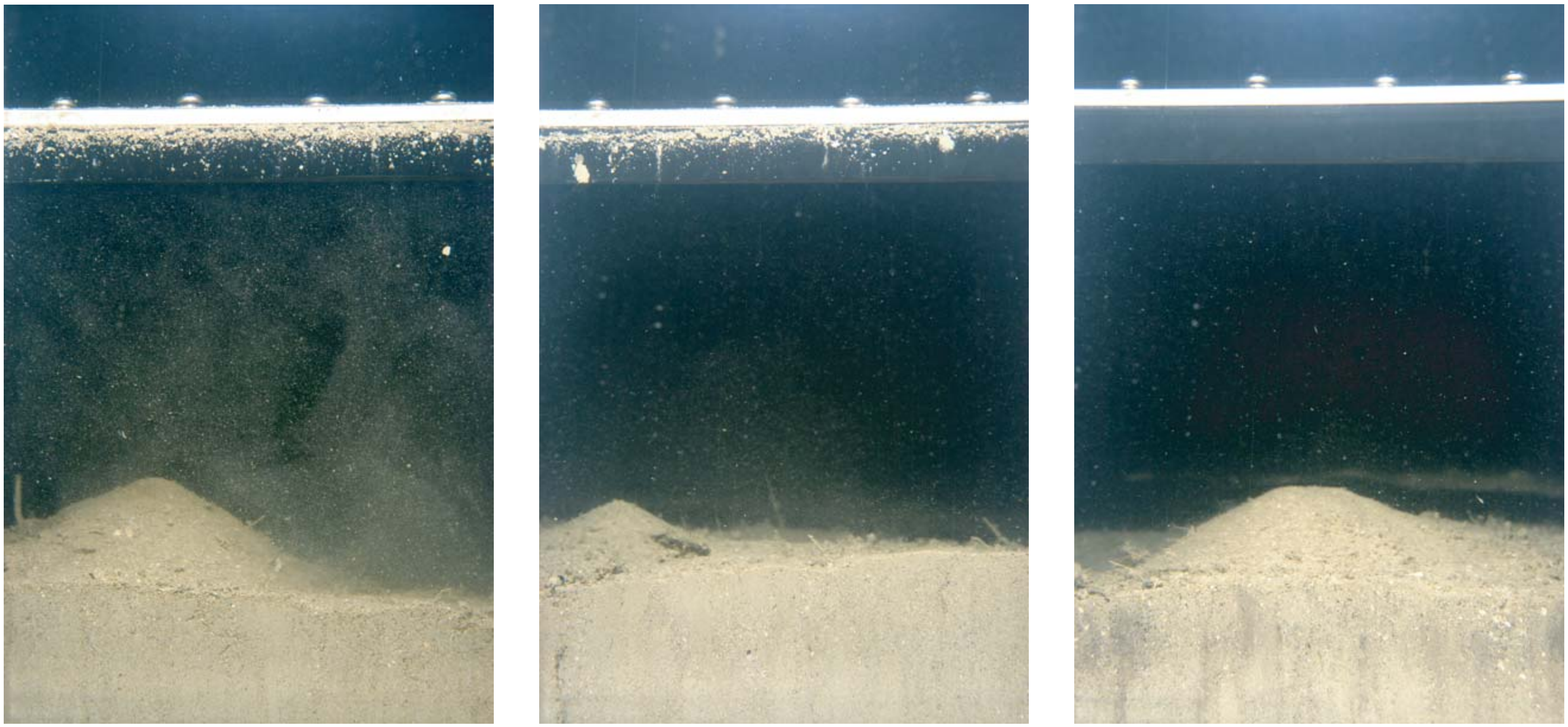
A. J15-1B **B. K13-1B**

Figure 3-8: SPI images from stations J15 (left) and K13 (right) showing discrete surface layers of recent dredged material consisting of dark, silty fine sand (3 to 2 phi) with shell fragments overlying ambient very fine sand (4 to 3 phi) at depth. Scale = actual image width is 14.4 cm.



A. K18-3B **B. X5-1B** **C. J14-3B**

Figure 3-9: Three replicate SPI images illustrating how the appearance of the dredged material contrasted with the ambient sediment. Image A (left) shows ambient sediment at Station K18, consisting of silty, light-colored, very fine sand with an homogenous texture. Image B (center) from Station X5 and Image C (right) from Station J14 both show dredged material that is characterized by overall darker color, patches of dark silt, and a coarser/more homogenous texture due to the presence of numerous small white shell fragments. In both of these images, the dredged material extends from the sediment surface to below the camera's imaging depth. Scale = actual image width is 14.4 cm.



A. H13-2B **B. I12-1B** **C. K14-1A**

Figure 3-10: In these SPI images from Stations H13 (left), I12 (center) and K14 (right), the small-scale vertical relief across the field-of-view (i.e., "boundary roughness") is due primarily to the presence of small circular mounds of sediment excavated by organisms. This is an example of biogenic boundary roughness. Scale = actual image width is 14.4 cm.

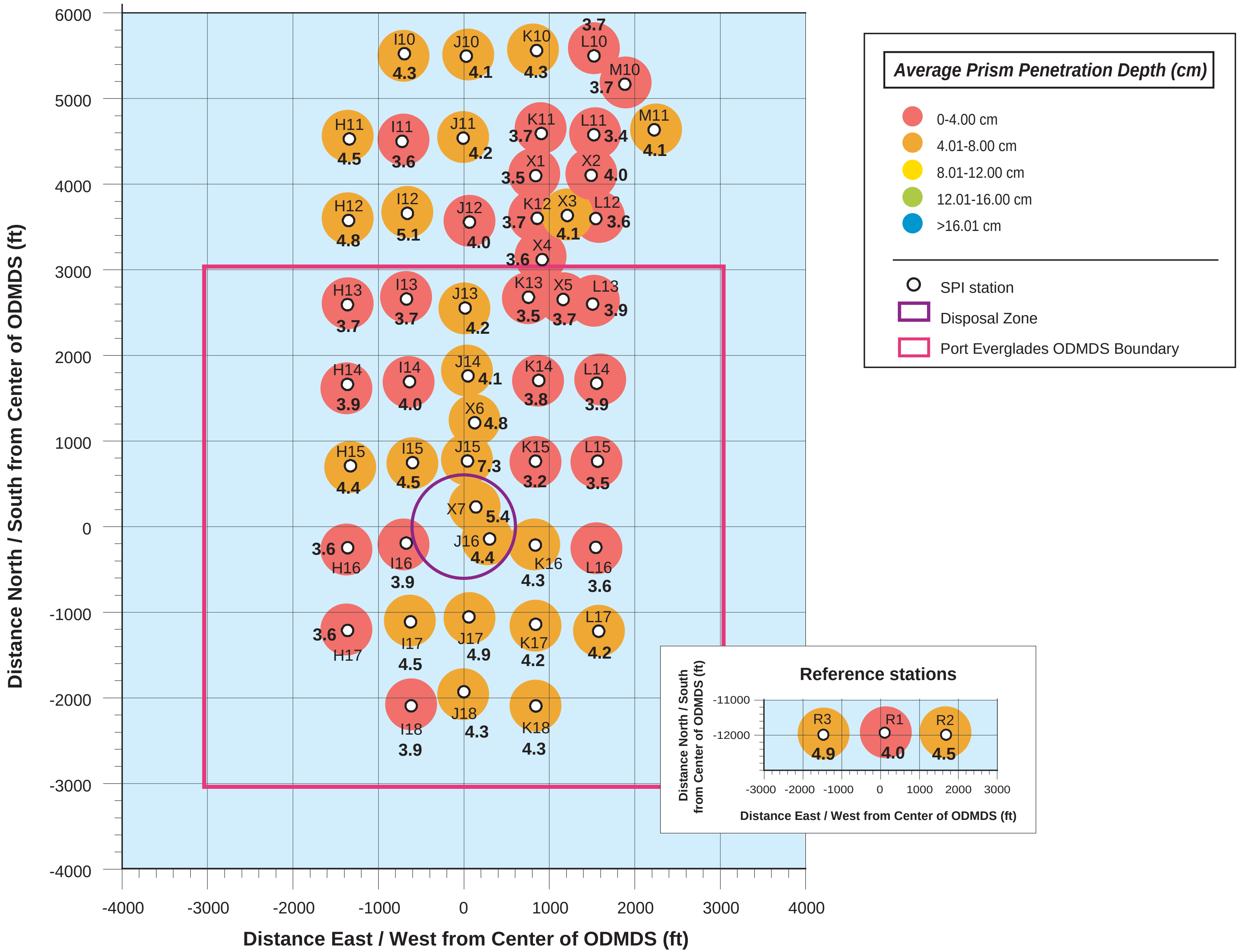


Figure 3-11: Average prism penetration depths (cm) at the Port Everglades Harbor ODMDS SPI stations.

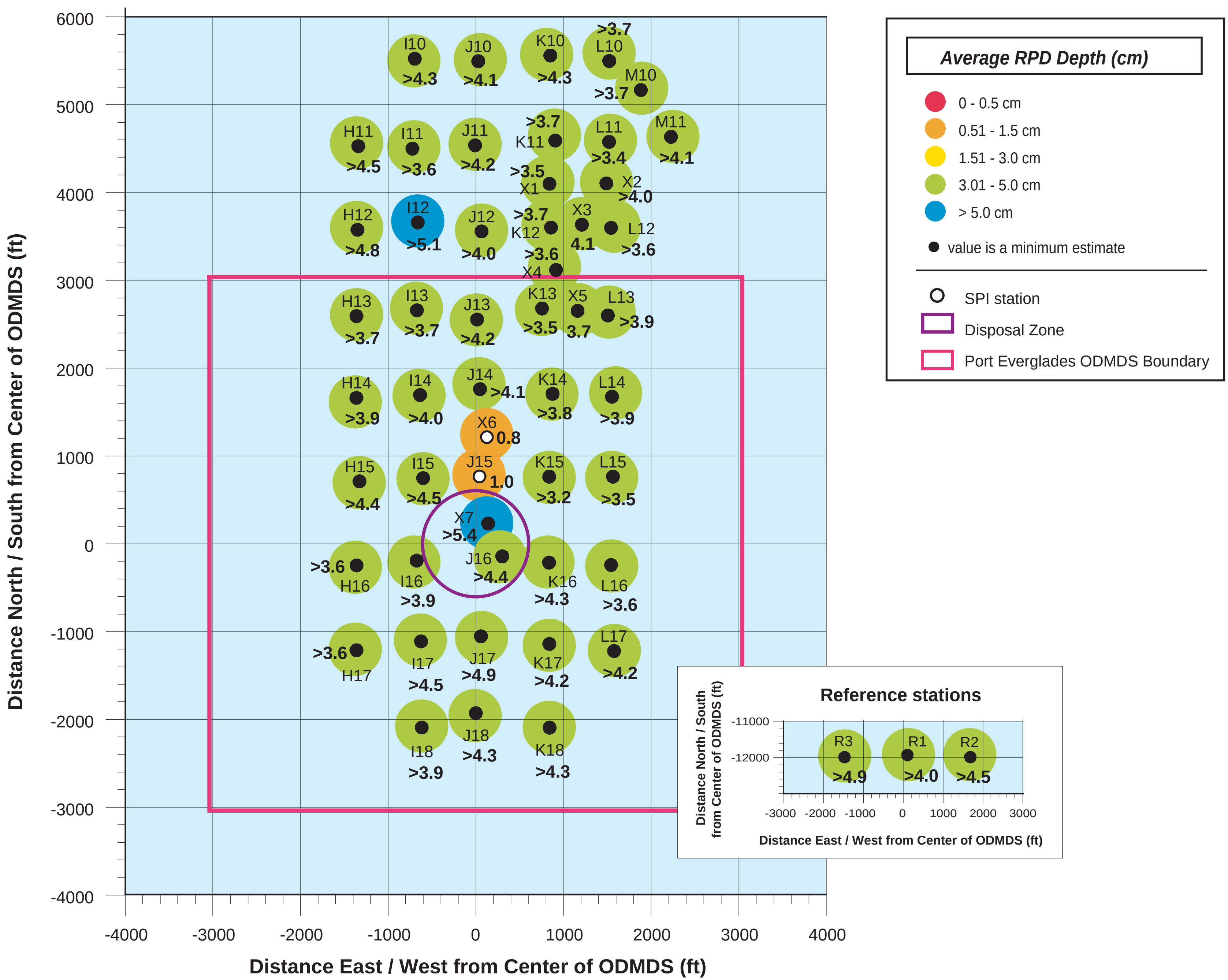
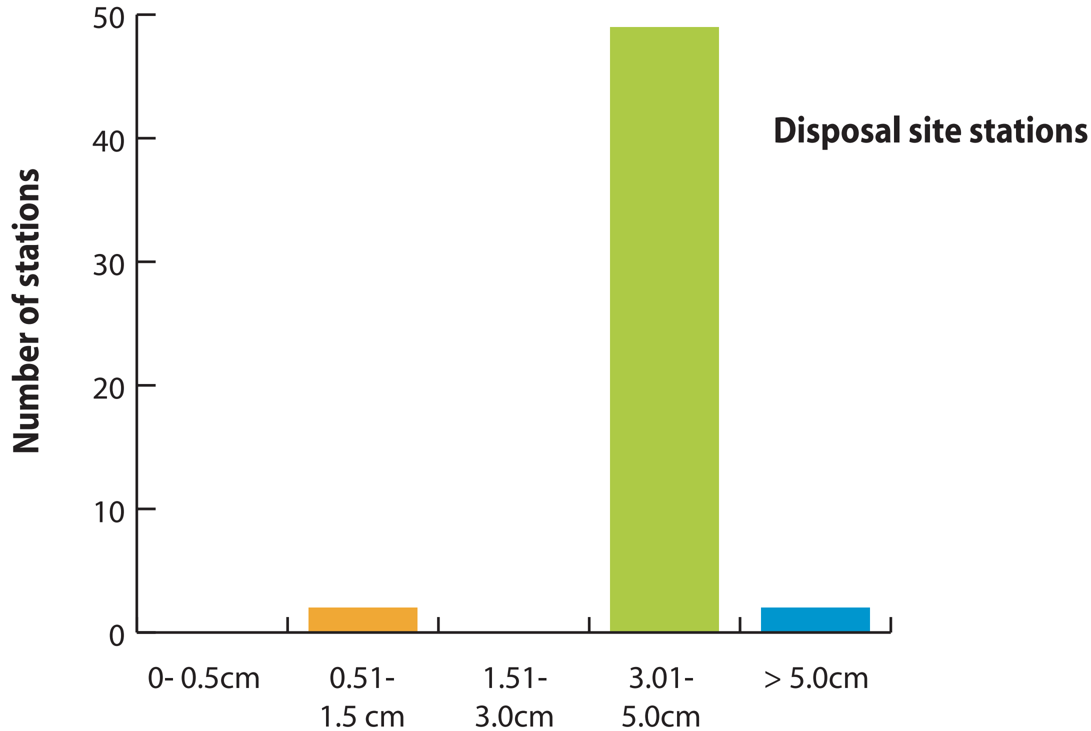


Figure 3-12: Average aRPD depths (cm) at the Port Everglades Harbor ODMDS SPI stations.



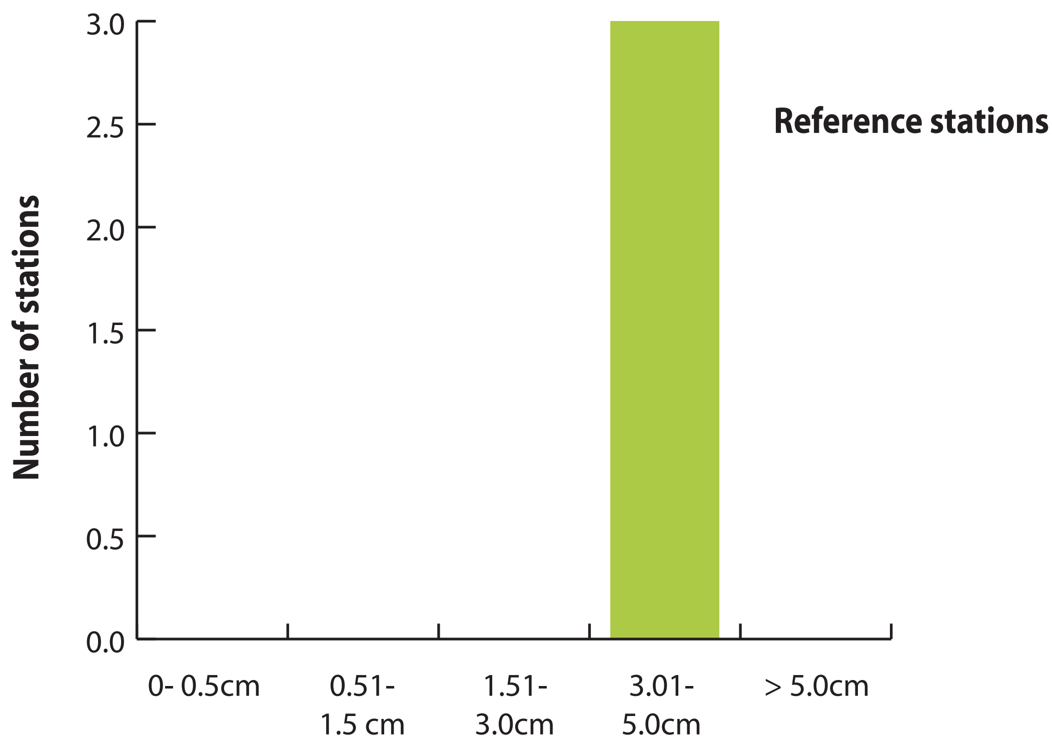


Figure 3-13: Frequency distribution of average RPD depths at the disposal site stations (top) and reference stations (bottom).

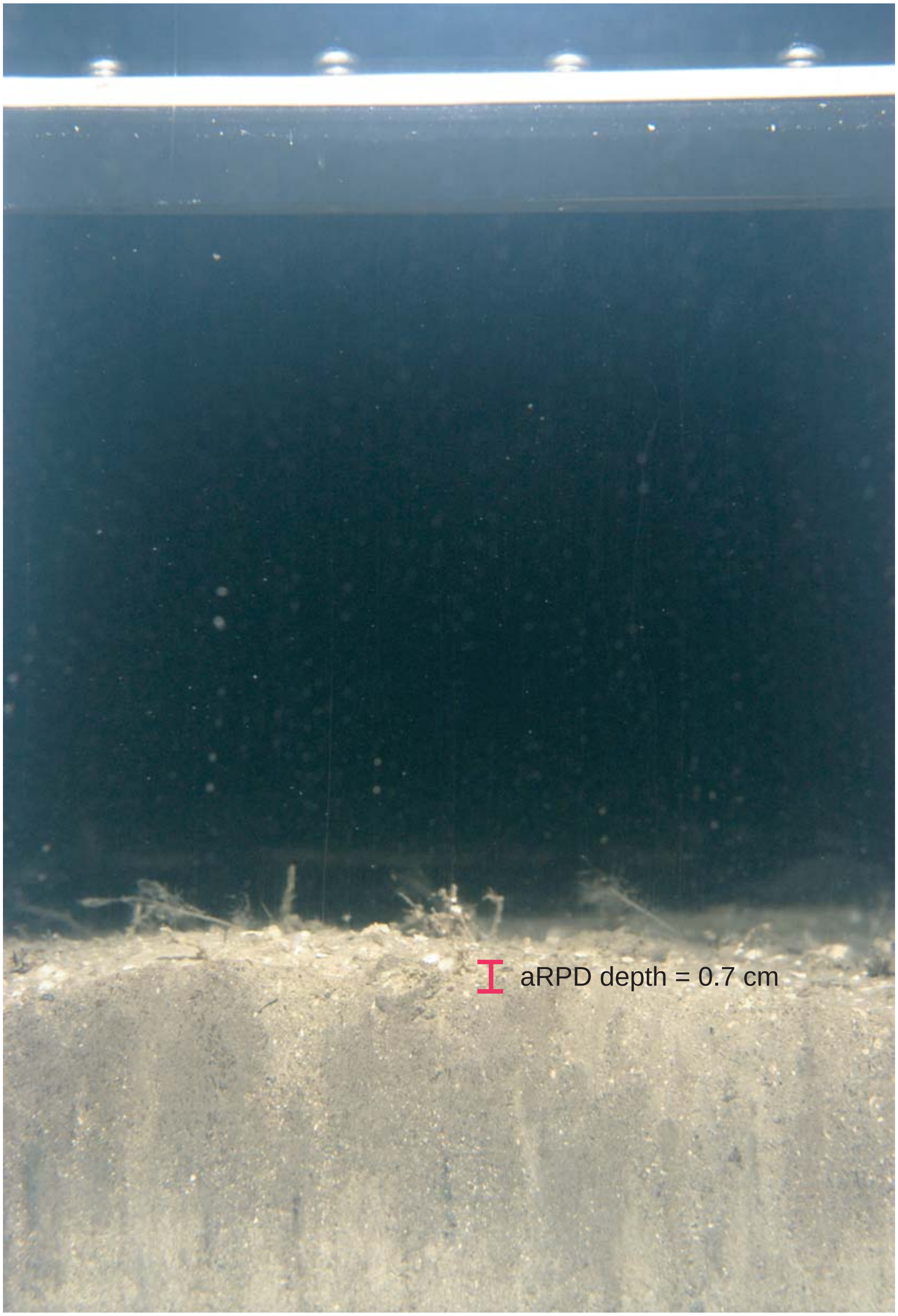


Figure 3-14: SPI image from Station X6 showing a thin and patchy area of lighter-colored surface sediment overlying darker sediment at depth. The area of lighter-colored sediment was measured and found to have an average depth of 0.7 cm across the field of view, representing the aRPD depth. Scale = actual image width is 14.4 cm.

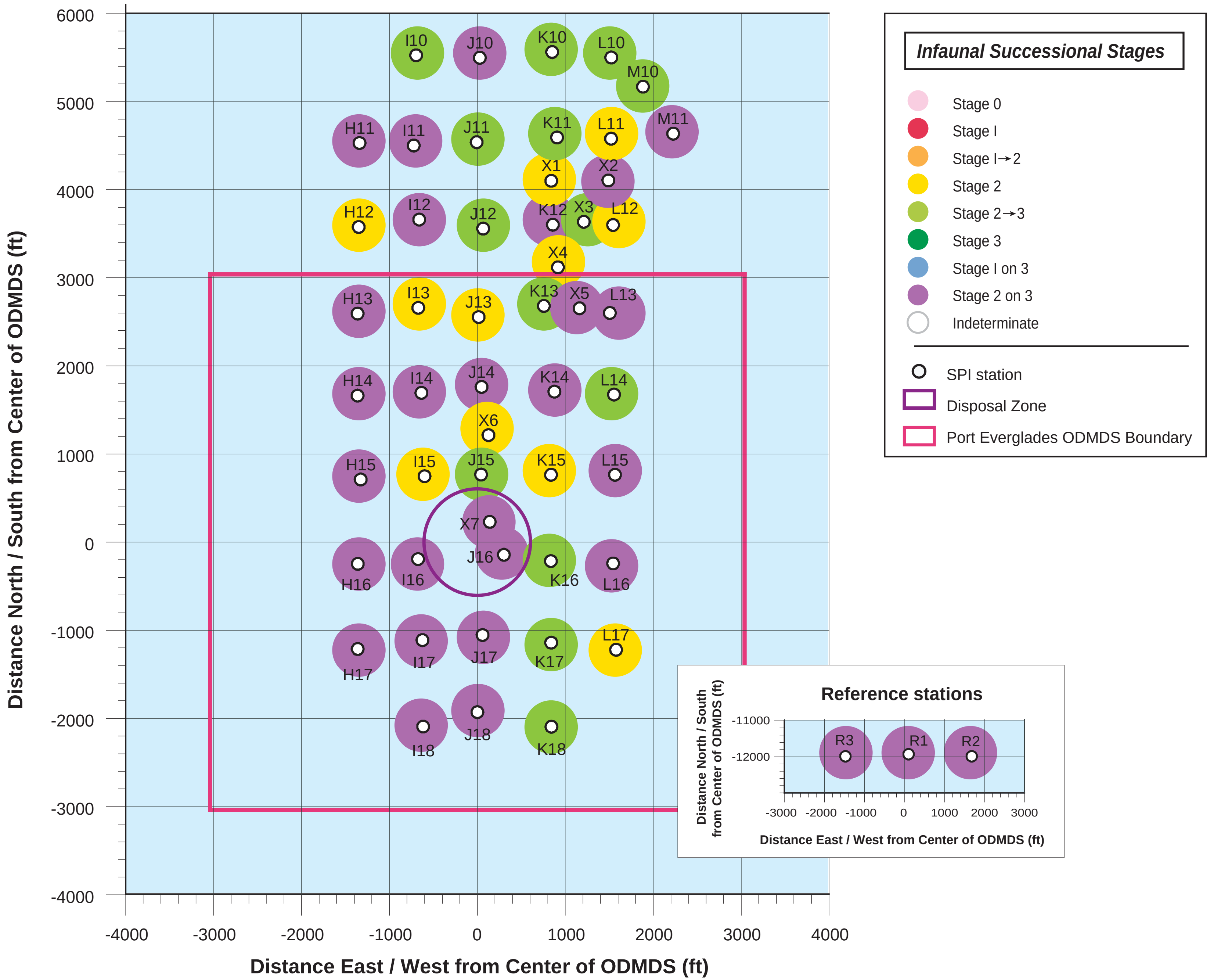
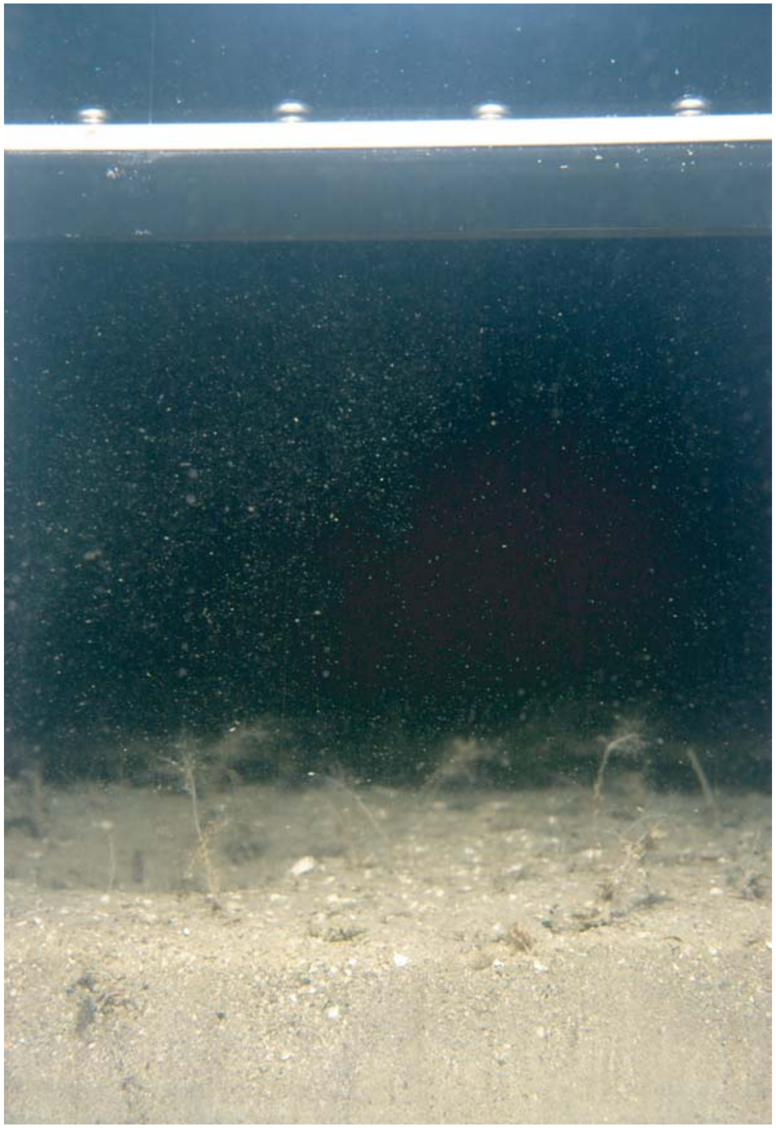


Figure 3-15: Map showing the highest infaunal successional stage observed among the replicate SPI images analyzed at each station in the May 2006 survey.

A. I13-2B



B. L12-2B

Figure 3-16: SPI images from Stations I13 (left) and L12 (right) illustrating Stage 2, where the visible evidence of biological activity consisted of several different types/sizes of tubes occurring at the sediment surface. Scale = actual image width is 14.4 cm.

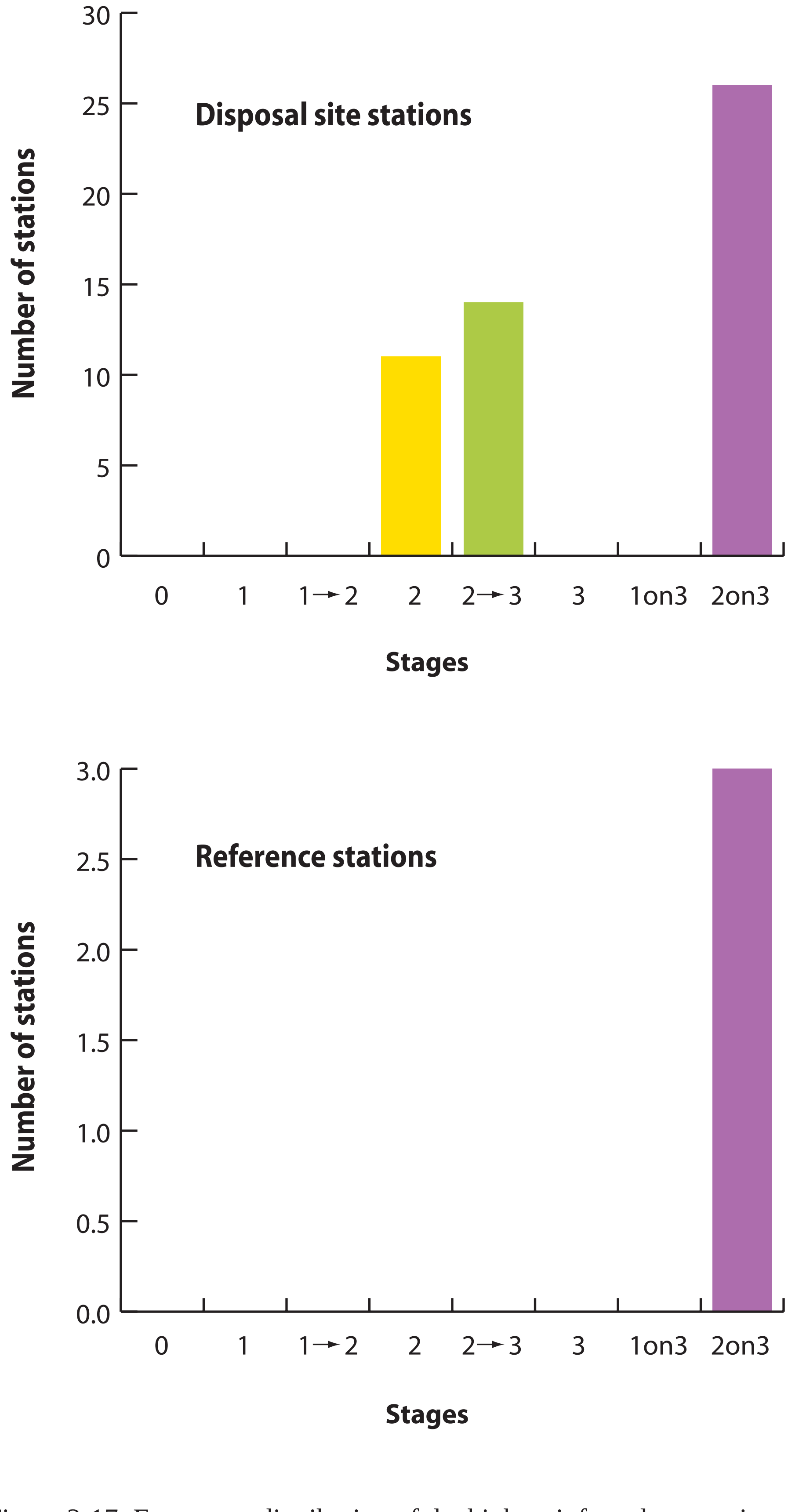


Figure 3-17: Frequency distribution of the highest infaunal successional stage observed at each of the disposal site stations (top) and reference stations (bottom).

Figure 3-18: SPI image from Station K16 illustrating Stage 2 advancing to Stage 3, based on the presence of moderate numbers of different types of tubes at the sediment surface and one small polychaete worm visible at depth (arrow). Scale = actual image width is 14.4 cm.

Figure 3-19: SPI image from Station L13 showing relatively long, tube-like stalks with frilly ends (hydroids?) that were common at the sediment surface at many of the surveyed stations. Scale = actual image width is 14.4 cm.

Figure 3-20: SPI image from station H15 illustrating Stage 2 on 3, based on the presence of high numbers of different types of surface tubes and a larger-bodied polychaete visible at depth within the sediment (arrow). Scale = actual image width is 14.4 cm.

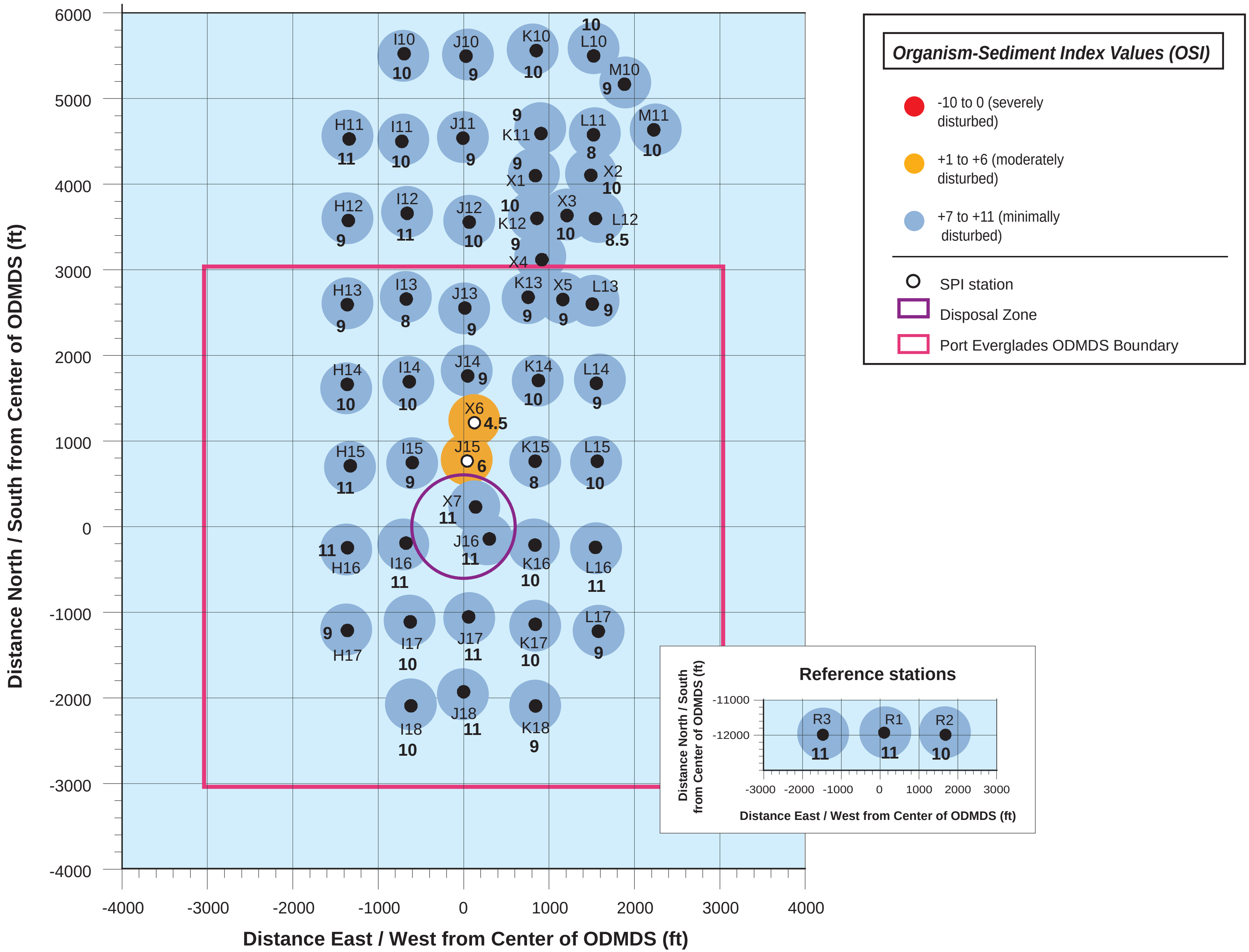


Figure 3-21: Median OSI values at the Port Everglades Harbor ODMDS SPI stations.

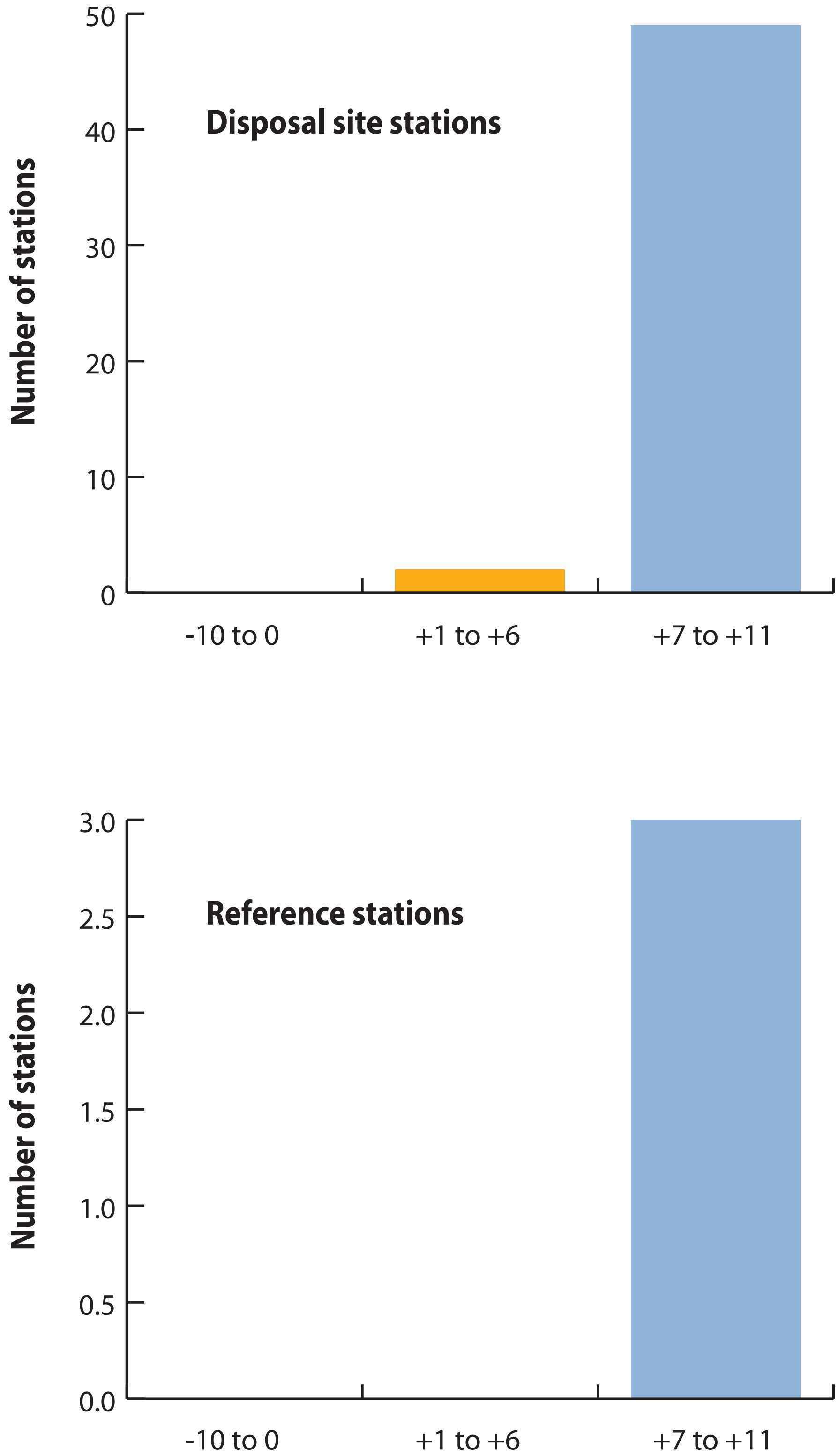


Figure 3-22: Frequency distribution of median OSI values at the disposal site stations (top) and reference stations (bottom).

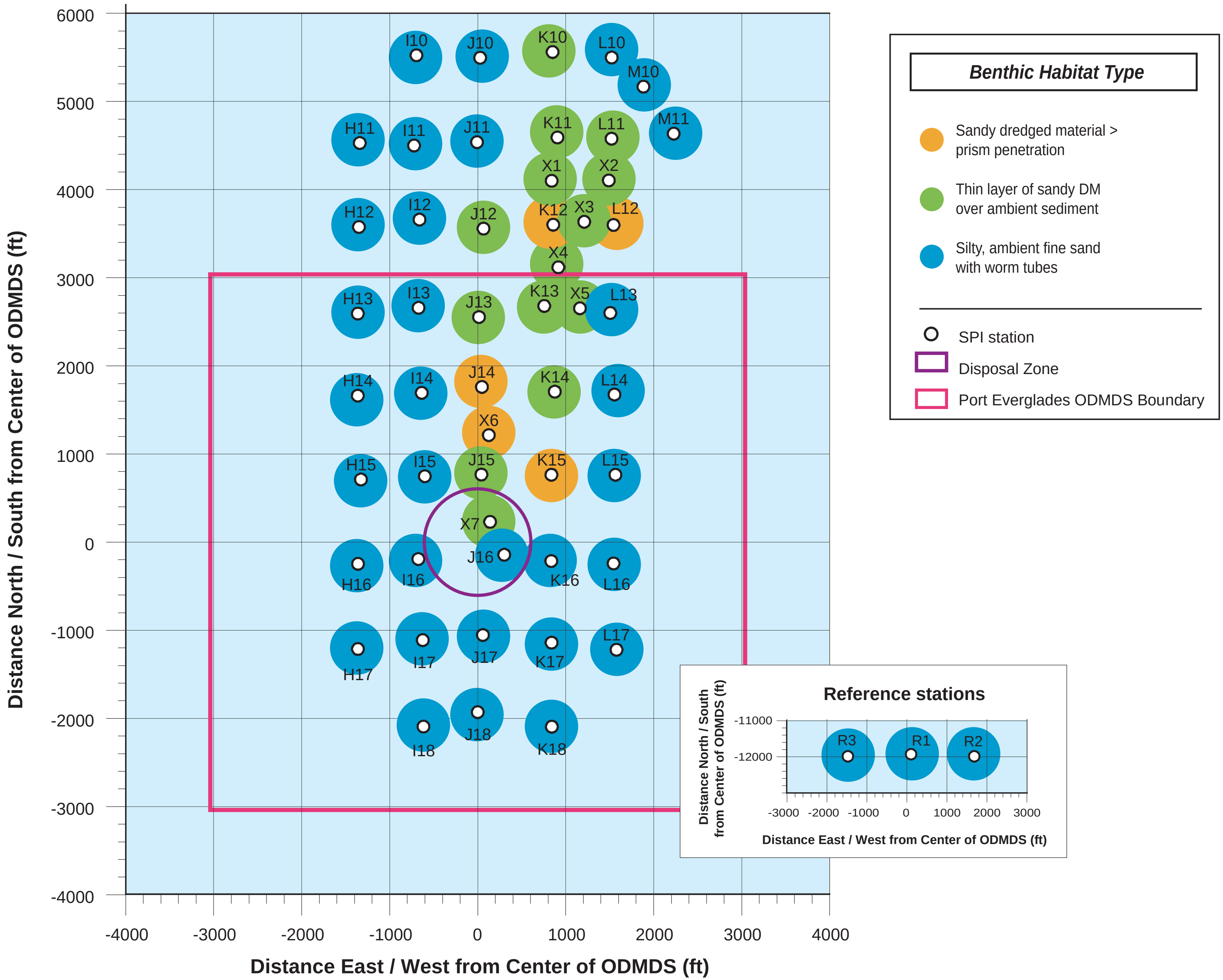


Figure 3-23: Map of benthic habitat types at the Port Everglades Harbor ODMDS SPI stations.

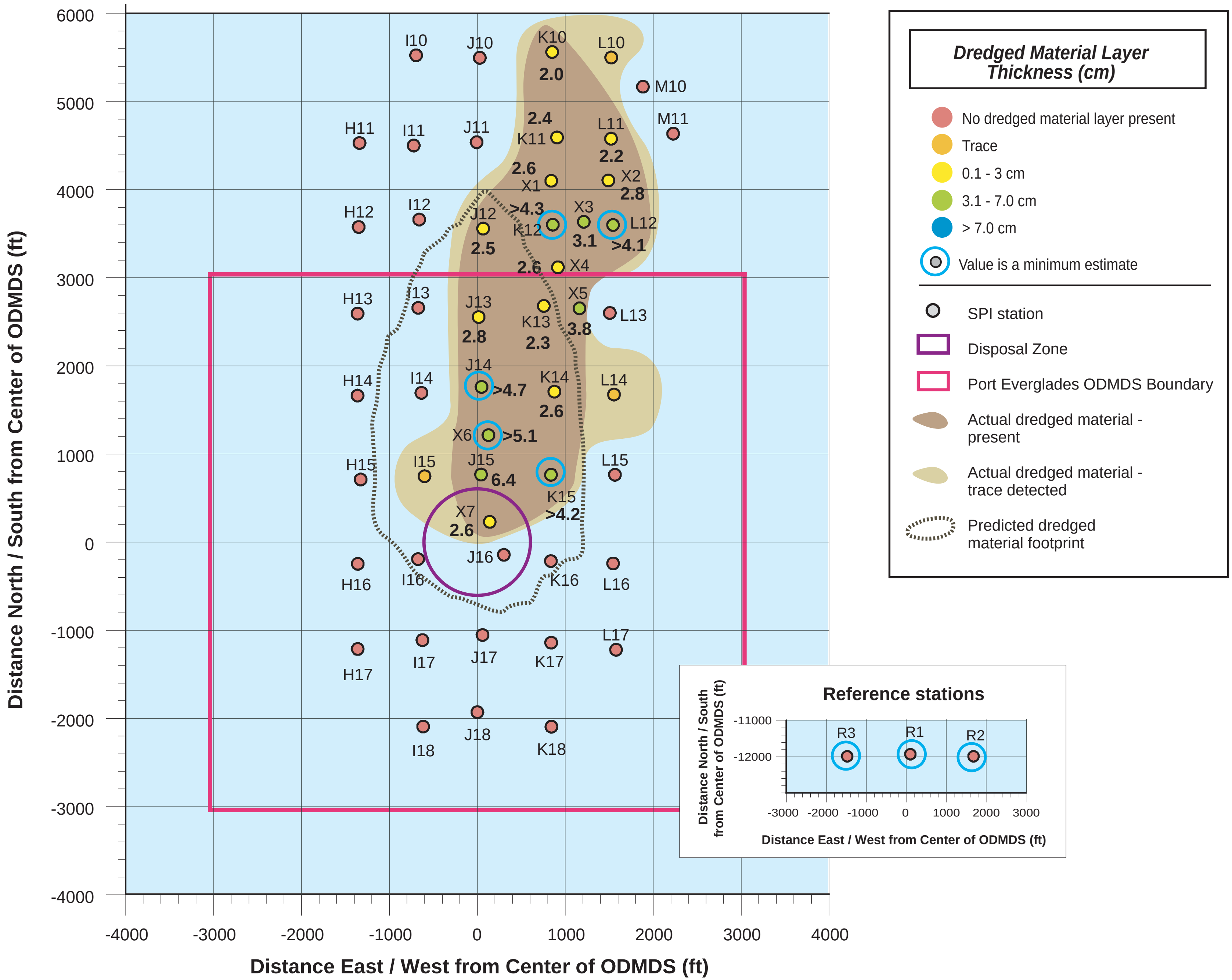


Figure 4-1: Actual distribution of dredged material based on analysis of sediment profile images as compared with modeled results for the Port Everglades Harbor ODMDS.

APPENDIX A

Plan-view Image Analysis Results

Station	Rep	Biogenic mounds	Feeding pits/furrows	Tracks	Burrow openings	Sea stars	Crabs	Rocks	Ripples	DM?
J10	3	17	5	0	60	1	0	0	0	N
J11	1	5	4	0	14	0	0	0	0	N
J12	2	2	7	0	20	0	0	0	0	N
J13	3	5	3	0	10	3	0	0	0	Y
J14	3	7	4	0	3	2	0	0	0	Y
J15	3	0	0	0	8	2	1	15	0	Y
J16	2	5	2	0	7	1	0	0	0	N
J17	1	6	3	0	10	3	0	0	0	N
J18	3	2	5	0	14	1	0	0	0	N
L13	2	0	4	0	8	1	0	0	0	N
R1	2	4	2	0	7	1	0	0	0	N
R2	2	0	0	0	30	0	0	0	0	N
R3	1	0	0	0	34	1	0	0	0	N

Station	Comment
J10	Ambient silty fine sand; many small holes (burrow openings); clumps of dead seagrass; biogenic mounds
J11	Ambient silty fine sand; prominent feeding pits/burrow depressions?; many small tubes; dead eelgrass clumps
J12	Ambient silty fine sand; one-half of image obscured by suspended sed; pits w/ holes=burrow openings?
J13	Change in texture=sandier than previous=DM; 3 sea stars
J14	Sandier than ambient=DM; a few indistinct pits and mounds; 2 sea stars
J15	Much coarser than ambient=gravel+sand; many beer+soda cans; indistinct burrow openings
J16	Ambient silty fine sand; pieces of dead drift eelgrass; indistinct burrow openings; one sea star
J17	Ambient silty fine sand; pieces of dead drift eelgrass; 3 sea stars; indistinct cluster of small holes=burrow openings
J18	Ambient silty fine sand; small indistinct mounds+small holes=burrow openings; 1 sea star
L13	Ambient silty fine sand; some coarser sand=trace DM influence?; many small tubes
R1	Ambient silty fine sand; small holes=burrow openings; 1 sea star; small surface tubes?
R2	Ambient silty fine sand; many small holes=burrow openings; many small surface tubes?
R3	Ambient silty fine sand; many small hles=burrow openings; small surface tubes?

APPENDIX B

Sediment Profile Image Analysis Results

Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles
PE-H11	1B	5/22/2006	16:49	14.4	4 to 3	2	>4	>4 to 2	64.5	4.5	4.0	5.0	1.0	p	>64.5	4.5	Y	>4.0	>5.0	0	None
PE-H11	2B	5/22/2006	16:51	14.42	4 to 3	0	>4	>4 to 0	67.9	4.7	3.9	6.4	2.5	p	>67.8	4.7	Y	>3.9	>6.4	0	None
PE-H11	3B	5/22/2006	16:52	14.43	4 to 3	1	>4	>4 to 1	63.7	4.4	3.9	4.9	0.9	p	>63.7	4.4	Y	>3.9	>4,9	0	None
PE-H12	1B	5/22/2006	17:15	14.42	4 to 3	1	>4	>4 to 1	78.1	5.4	5.3	5.7	0.4	p	>78.1	5.4	Y	>5.3	>5.7	0	None
PE-H12	2B	5/22/2006	17:16	14.42	4 to 3	1	>4	>4 to 1	56.4	3.9	3.6	4.4	0.8	p	>53.4	3.9	Y	>3.6	>4.4	0	None
PE-H12	3B	5/22/2006	17:17	14.42	4 to 3	1	>4	>4 to 1	75.1	5.2	4.7	6.2	1.5	p	>75.1	5.2	Y	>4.7	>6.2	0	None
PE-H13	1B	5/21/2006	20:50	14.42	4 to 3	1	>4	>4 to 1	54.0	3.7	3.2	4.1	0.9	p	>54.0	3.7	Y	>3,2	>4.1	0	None
PE-H13	2B	5/21/2006	20:52	14.42	4 to 3	0	>4	>4 to 0	53.6	3.7	3.0	4.1	1.2	p	>53.6	3.7	Y	>3.0	>4.1	0	None
PE-H13	3B	5/21/2006	20:52	14.42	4 to 3	0	>4	>4 to 0	52.9	3.7	3.3	4.0	0.7	p	>52.9	3.7	Y	>3.2	>4.0	0	None
PE-H14	1B	5/22/2006	17:43	14.42	4 to 3	1	>4	>4 to 1	62.7	4.3	4.1	4.8	0.7	p	>62.7	4.3	Y	>4,1	>4,8	0	None
PE-H14	2B	5/22/2006	17:44	14.42	>4 to 3	1	>4	>4 to 1	56.9	3.9	3.5	4.3	0.8	b	>57.0	3.9	Y	>3.5	>4.3	0	None
PE-H14	3A	5/22/2006	17:45	14.42	4 to 3	1	>4	>4 to 1	48.7	3.4	2.7	3.8	1.0	b	>48.7	3.4	Y	>2.7	>3.8	0	None
PE-H15	1B	5/21/2006	21:29	14.42	>4 to 3	2	>4	>4 to 2	71.0	4.9	3.7	5.7	2.0	p	>71.0	4.9	Y	>3.7	>5.6	0	None
PE-H15	2B	5/21/2006	21:29	14.42	4 to 3	2	>4	>4 to 2	59.0	4.1	3.8	4.5	0.7	b	>59.0	4.1	Y	>3.8	>4.4	0	None
PE-H15	3B	5/21/2006	21:30	14.4	4 to 3	2	>4	>4 to 2	58.5	4.1	3.8	5.0	1.2	b	>58.5	4.1	Y	>3.8	>5.0	0	None
PE-H16	1B	5/22/2006	18:08	14.42	4 to 3	1	>4	>4 to 1	50.4	3.5	3.1	4.0	0.9	p	>50.4	3.5	Y	>3.1	>4.0	0	None
PE-H16	2B	5/22/2006	18:08	14.4	4 to 3	1	>4	>4 to 1	52.4	3.6	3.2	4.3	1.1	b	>52.4	>3.6	Y	>3.2	>4.3	0	None
PE-H16	3B	5/22/2006	18:09	14.44	4 to 3	1	>4	>4 to 1	52.3	3.6	3.2	4.1	0.9	b	>52.3	>3.6	Y	>3.2	>4.1	0	None
PE-H17	1B	5/22/2006	18:34	14.4	4 to 3	2	>4	>4 to 2	44.0	3.1	2.5	4.2	1.7	p	>44.0	3.1	Y	>2.5	>4.2	0	None
PE-H17	2B	5/22/2006	18:35	14.42	>4 to 3	2	>4	>4 to 2	61.9	4.3	3.8	4.6	0.8	b	>62.0	4.3	Y	>3.8	>4.6	0	None
PE-H17	3B	5/22/2006	18:36	14.42	4 to 3	2	>4	>4 to 2	47.8	3.3	2.5	4.0	1.5	b	>47.8	3.3	Y	>2.5	>4.0	0	None
PE-I10	1B	5/22/2006	0:15	14.4	4 to 3	2	>4	>4 to 2	65.9	4.6	4.1	5.0	1.0	p	>65.9	4.6	Y	>4.1	>5.0	0	None
PE-I10	2B	5/22/2006	0:16	14.4	4 to 3	2	>4	>4 to 2	58.3	4.0	3.7	4.6	0.9	b	>58.3	4.0	Y	>3.7	>4.6	0	None
PE-I10	3B	5/22/2006	0:17	14.42	4 to 3	1	>4	>4 to 1	63.0	4.4	3.6	4.8	1.2	p	>63.0	4.4	Y	>3.6	>4.8	0	None
PE-I11	1B	5/22/2006	0:46	14.42	4 to 3	0	>4	>4 to 0	51.0	3.5	3.0	3.9	0.8	b	>51.0	3.5	Y	>3.0	>3.9	0	None
PE-I11	2A	5/22/2006	0:47	14.42	4 to 3	1	>4	>4 to 1	46.6	3.2	2.6	3.8	1.3	p	>46.6	3.2	Y	>2.6	>3.8	0	None
PE-I11	3B	5/22/2006	0:48	14.42	4 to 3	1	>4	>4 to 1	58.8	4.1	2.8	4.6	1.8	p	>58.8	4.1	Y	>2.8	>4.6	0	None
PE-I12	1B	5/22/2006	1:13	14.42	4 to 3	0	>4	>4 to 0	65.3	4.5	3.8	5.1	1.3	b	>65.2	4.5	Y	>3.8	>5.1	0	None
PE-I12	2B	5/22/2006	1:15	14.42	4 to 3	1	>4	>4 to 1	87.4	6.1	4.4	7.9	3.5	p	>87.4	6.1	Y	>4.4	>7.8	0	None
PE-I12	3B	5/22/2006	1:16	14.4	>4 to 3	1	>4	>4 to 1	68.6	4.8	3.7	5.2	1.4	p	>68.6	4.8	Y	>3.7	>5.2	0	None
PE-I13	1B	5/21/2006	20:25	14.4	4 to 3	0	>4	>4 to 0	47.6	3.3	2.7	4.2	1.5	p	>47.6	3.3	Y	>2.6	>4.2	0	None
PE-I13	2B	5/21/2006	20:27	14.42	3 to 2	1	>4	>4 to 1	53.1	3.7	3.1	4.3	1.2	p	>53.1	3.7	Y	>3.1	>4.3	0	None
PE-I13	3B	5/21/2006	20:28	14.42	3 to 2	0	>4	>4 to 0	58.9	4.1	3.1	5.1	2.1	p	>58.9	4.1	Y	>3.0	>5.1	0	None
PE-I14	1B	5/22/2006	1:48	14.42	4 to 3	0	>4	>4 to 0	56.7	3.9	2.9	4.6	1.6	b	>56.7	3.9	Y	>2.9	>4.6	0	None
PE-I14	2B	5/22/2006	1:50	14.42	4 to 3	0	>4	>4 to 0	52.5	3.6	3.6	3.8	0.3	b	>52.5	3.6	Y	>3.6	>3.8	0	None
PE-I14	3B	5/22/2006	1:51	14.42	4 to 3	0	>4	>4 to 0	61.8	4.3	3.9	4.5	0.6	b	>61.8	4.3	Y	>3.9	>4.5	0	None
PE-I15	1B	5/21/2006	21:52	14.42	4 to 3	1	>4	>4 to 1	59.0	4.1	3.8	4.5	0.6	b	>59.0	4.1	Y	>3.8	>4.4	0	None
PE-I15	2B	5/21/2006	21:53	14.42	4 to 3	0	>4	>4 to 0	71.0	4.9	4.4	5.3	0.9	b	>71.0	4.9	Y	>4.4	>5.3	0	None
PE-I15	3B	5/21/2006	21:54	14.42	4 to 3	1	>4	>4 to 1	66.3	4.6	4.3	4.9	0.6	b	>66.2	4.6	Y	>4.3	>4.9	0	None
PE-I16	1A	5/22/2006	2:24	14.42	4 to 3	2	>4	>4 to 2	54.1	3.8	3.4	4.1	0.7	b	>54.1	3.8	Y	>3.4	>4.1	0	None
PE-I16	2B	5/22/2006	2:25	14.42	4 to 3	1	>4	>4 to 1	54.4	3.8	3.6	4.1	0.5	b	>54.4	3.8	Y	>3.6	>4.1	0	None

Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles
PE-I16	3B	5/22/2006	2:26	14.42	4 to 3	-1	>4	>4 to -1	58.8	4.1	3.4	4.8	1.3	b	>58.8	4.1	Y	>3.4	>4.8	0	None
PE-I17	1B	5/22/2006	2:58	14.42	4 to 3	1	>4	>4 to 1	59.8	4.1	2.8	5.0	2.3	p	>59.8	4.1	Y	>2.7	>5.0	0	None
PE-I17	2B	5/22/2006	2:58	14.44	4 to 3	0	>4	>4 to 0	75.4	5.2	4.6	6.1	1.5	b	>75.4	5.2	Y	>4.6	>6.1	0	None
PE-I17	3B	5/22/2006	2:59	14.4	4 to 3	1	>4	>4 to 0	61.5	4.3	1.3	5.2	3.8	ind	>61.5	4.3	Y	>1.3	>5.2	0	None
PE-I18	1B	5/22/2006	3:29	14.42	4 to 3	0	>4	>4 to 0	48.2	3.3	2.5	4.0	1.6	p	>48.2	3.3	Y	>2.5	>4.0	0	None
PE-I18	2B	5/22/2006	3:30	14.42	4 to 3	2	>4	>4 to 2	64.3	4.5	4.0	5.1	1.1	b	>64.2	4.5	Y	>4.0	>5.1	0	None
PE-I18	3B	5/22/2006	3:30	14.4	4 to 3	1	>4	>4 to 1	54.8	3.8	3.3	4.4	1.1	b	>54.8	3.8	Y	>3.3	>4.4	0	None
PE-J10	1B	5/21/2006	17:59	14.42	4 to 3	1	>4	>4 to 1	64.8	4.5	4.2	4.7	0.4	b	>64.8	4.5	Y	>4.2	>4.7	0	None
PE-J10	2B	5/21/2006	18:00	14.4	4 to 3	1	>4	>4 to 1	38.4	2.7	2.5	3.2	0.7	b	>38.4	2.7	Y	>2.5	>3.2	0	None
PE-J10	3B	5/21/2006	18:01	14.42	4 to 3	0	>4	>4 to 0	75.8	5.3	4.7	5.6	1.0	b	>75.8	5.3	Y	>4.6	>5.6	0	None
PE-J11	1B	5/21/2006	16:43	14.42	4 to 3	0	>4	>4 to 0	57.3	4.0	3.7	4.4	0.7	p	>57.3	4.0	Y	>3.7	>4.4	0	None
PE-J11	2B	5/21/2006	16:44	14.42	4 to 3	1	>4	>4 to 0	65.9	4.6	3.6	5.6	2.0	p	>65.9	4.6	Y	>3.6	>5.6	0	None
PE-J11	3B	5/21/2006	16:46	14.42	4 to 3	0	>4	>4 to 0	58.8	4.1	3.3	4.7	1.4	p	>58.8	4.1	Y	>3.3	>4.7	0	None
PE-J12	1B	5/21/2006	16:15	14.42	4 to 3	0	>4	>4 to 0	57.4	4.0	3.7	4.4	0.7	p	>57.4	4.0	Y	>3.7	>4.4	0	None
PE-J12	2B	5/21/2006	16:15	14.42	3 to 2/4 to 3	0	>4	>4 to 0	60.6	4.2	4.0	4.3	0.3	p	>60.6	4.2	Y	>4.0	>4.3	0	None
PE-J12	3B	5/21/2006	16:17	14.42	3 to 2/4 to 3	0	>4	>4 to 0	53.4	3.7	3.3	4.1	0.9	p	>53.4	3.7	Y	>3.2	>4.1	0	None
PE-J13	1B	5/21/2006	15:38	14.42	3 to 2/4 to 3	1	>4	>4 to 1	68.7	4.8	4.5	5.3	0.8	b	>68.7	4.8	Y	>4.5	>5.3	0	None
PE-J13	2A	5/21/2006	15:39	14.42	3 to 2	0	>4	>4 to 0	50.5	3.5	2.8	3.9	1.0	b	>50.5	3.5	Y	>2.8	>3.9	0	None
PE-J13	3B	5/21/2006	15:40	14.42	3 to 2	-1	>4	>4 to -1	61.5	4.3	4.1	4.4	0.3	b	>61.5	4.3	Y	>4.1	>4.4	0	None
PE-J14	1B	5/21/2006	15:08	14.42	3 to 2	-1	>4	>4 to -1	67.2	4.7	4.0	5.6	1.6	p	27.73	1.9	N	0.9	2.9	0	None
PE-J14	2A	5/21/2006	15:10	14.42	3 to 2	<-1	>4	>4 to <-1	54.5	3.8	3.6	4.1	0.5	p	>54.5	3.8	Y	>3.6	>4.1	0	None
PE-J14	3B	5/21/2006	15:11	14.42	3 to 2	<-1	>4	>4 to <-1	57.1	4.0	3.5	4.5	1.0	p	>57.0	4.0	Y	>3.5	>4.4	0	None
PE-J15	1B	5/21/2006	14:38	14.40	4 to 3	0	>4	>4 to 0	107.6	7.5	6.9	8.4	1.5	p	15.52	1.1	N	0	2.23	0	None
PE-J15	2B	5/21/2006	14:40	14.42	4 to 3	-1	>4	>4 to -1	113.5	7.9	7.6	8.2	0.6	p	11.45	0.8	N	0	1.64	0	None
PE-J15	3B	5/21/2006	14:41	14.42	4 to 3	0	>4	>4 to 0	95.2	6.6	6.0	7.9	1.9	p	17.04	1.2	N	0	3.32	0	None
PE-J16	1B	5/21/2006	14:14	14.42	4 to 3	2	>4	>4 to 2	66.1	4.6	4.0	5.0	1.0	b	>66.1	4.6	Y	>4.0	>5.0	0	None
PE-J16	2B	5/21/2006	14:16	14.40	4 to 3	2	>4	>4 to 2	60.0	4.2	3.9	4.7	0.8	b	>60.0	4.2	Y	>3.9	>4.7	0	None
PE-J16	3B	5/21/2006	14:17	14.42	4 to 3	2	>4	>4 to 2	66.1	4.6	4.3	4.9	0.7	b	>66.1	4.6	Y	>4.2	>4.9	0	None
PE-J17	1B	5/21/2006	13:35	14.40	4 to 3	2	>4	>4 to 2	57.7	4.0	3.1	4.3	1.2	b	>57.7	4.0	Y	>3.1	>4.3	0	None
PE-J17	2B	5/21/2006	13:37	14.42	4 to 3	0	>4	>4 to 2	58.5	4.1	3.8	4.4	0.6	b	>58.5	4.1	Y	>3.8	>4.4	0	None
PE-J17	3B	5/21/2006	13:38	14.42	>4 to 3	2	>4	>4 to 2	96.3	6.7	6.1	7.4	1.3	b	>96.3	6.7	Y	>6.1	>7.4	0	None
PE-J18	1B	5/21/2006	13:07	14.40	>4 to 3	2	>4	>4 to 2	67.5	4.7	3.9	5.6	1.7	b	>67.5	4.7	Y	>3.9	>5.6	0	None
PE-J18	2B	5/21/2006	13:08	14.42	4 to 3	2	>4	>4 to 2	57.8	4.0	3.6	4.4	0.8	b	>57.8	4.0	Y	>3.6	>4.4	0	None
PE-J18	3B	5/21/2006	13:08	14.42	4 to 3	2	>4	>4 to 2	59.0	4.1	3.2	4.9	1.8	p	>59.0	4.1	Y	>3.2	>4.9	0	None
PE-K10	1B	5/22/2006	9:15	14.40	4 to 3	1	>4	>4 to 2	60.8	4.2	3.9	4.5	0.6	b	>60.8	4.2	Y	>3.9	>4.5	0	None
PE-K10	2B	5/22/2006	9:17	14.42	4 to 3	0	>4	>4 to 0	60.9	4.2	3.6	4.7	1.1	p	>60.9	4.2	Y	>3.6	>4.7	0	None
PE-K10	3B	5/22/2006	9:18	14.42	4 to 3	1	>4	>4 to 1	64.5	4.5	3.9	4.8	0.9	b	>64.5	4.5	Y	>3.9	>4.8	0	None
PE-K11	1B	5/22/2006	9:45	14.42	3 to 2	-1	>4	>4 to -1	50.3	3.5	2.7	3.8	1.1	b	>50.3	3.5	Y	>2.7	>3.8	0	None

Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles
PE-K11	2B	5/22/2006	9:46	14.40	3 to 2	0	>4	>4 to 0	58.1	4.0	3.6	4.4	0.8	b	>58.1	4.0	Y	>3.6	>4.4	0	None
PE-K11	3B	5/22/2006	9:47	14.42	3 to 2	0	>4	>4 to 0	51.8	3.6	3.3	3.9	0.6	b	>51.8	3.6	Y	>3.3	>3.9	0	None
PE-K12	1B	5/22/2006	10:08	14.42	3 to 2	-1	>4	>4 to -1	51.1	3.5	2.9	4.0	1.1	b	>51.1	3.5	Y	>2.9	>4.0	0	None
PE-K12	2A	5/22/2006	10:09	14.42	3 to 2	-1	>4	>4 to -1	46.2	3.2	2.4	3.6	1.2	b	>46.2	3.2	Y	>2.4	>3.6	0	None
PE-K12	3B	5/22/2006	10:10	14.42	4 to 3	<-1	>4	>4 to <-1	63.8	4.4	3.9	5.4	1.5	p	>63.8	4.4	Y	>3.9	>5.4	0	None
PE-K13	1B	5/21/2006	19:58	14.40	3 to 2/>4 to 3	<-1	>4	>4 to <-1	53.1	3.7	3.4	4.1	0.7	p	>53.1	3.7	Y	>3.4	>4.1	0	None
PE-K13	2B	5/21/2006	19:59	14.42	3 to 2/>4 to 3	<-1	>4	>4 to <-1	52.5	3.6	3.0	4.2	1.2	p	>52.5	3.6	Y	>3.0	>4.2	0	None
PE-K13	3B	5/21/2006	20:00	14.42	3 to 2	<-1	>4	>4 to <-1	46.1	3.2	2.8	3.4	0.6	p	>46.1	3.2	Y	>2.8	>3.4	0	None
PE-K14	1A	5/22/2006	10:35	14.42	4 to 3	-1	>4	>4 to -1	56.4	3.9	3.6	4.2	0.6	b	>56.4	3.9	Y	>3.6	>4.2	0	None
PE-K14	2B	5/22/2006	10:36	14.42	4 to 3	-1	>4	>4 to -1	55.7	3.9	3.3	4.4	1.0	b	>55.7	3.9	Y	>3.3	>4.4	0	None
PE-K14	3B	5/22/2006	10:37	14.42	4 to 3	-1	>4	>4 to -1	52.3	3.6	3.2	3.8	0.6	b	>52.3	3.6	Y	>3.2	>3.8	0	None
PE-K15	1B	5/21/2006	22:19	14.42	4 to 3	-1	>4	>4 to -1	47.2	3.3	2.4	4.4	2.0	p	>47.2	3.3	Y	0.93	>4.4	0	None
PE-K15	2A	5/21/2006	22:19	14.42	4 to 3	1	>4	>4 to 1	41.5	2.9	2.2	4.2	2.0	b	>41.5	2.9	Y	>2.2	>4.2	0	None
PE-K15	3B	5/21/2006	22:20	14.42	4 to 3	0	>4	>4 to 0	50.1	3.5	3.0	4.0	1.0	b	>50.1	3.5	Y	>3.0	>4.0	0	None
PE-K16	1B	5/22/2006	11:01	14.42	4 to 3	1	>4	>4 to 1	47.6	3.3	1.2	5.3	4.1	b	>47.6	3.3	Y	>1.2	>5.3	0	None
PE-K16	2B	5/22/2006	11:02	14.42	>4 to 3	2	>4	>4 to 2	58.2	4.0	3.7	4.5	0.8	b	>58.2	4.0	Y	>3.7	>4.5	0	None
PE-K16	3B	5/22/2006	11:04	14.42	4 to 3	2	>4	>4 to 2	82.3	5.7	5.4	6.4	1.0	b	>82.2	5.7	Y	>5.4	>6.4	0	None
PE-K17	1B	5/22/2006	11:04	14.40	4 to 3	1	>4	>4 to 1	61.7	4.3	3.7	5.0	1.4	b	>61.7	4.3	Y	>3.7	>5.0	0	None
PE-K17	2B	5/22/2006	11:28	14.42	4 to 3	2	>4	>4 to 2	57.5	4.0	3.5	4.2	0.8	b	>57.5	4.0	Y	>3.5	>4.2	0	None
PE-K17	3B	5/22/2006	11:29	14.40	4 to 3	2	>4	>4 to 2	62.8	4.4	3.3	4.6	1.3	b	>62.8	4.4	Y	>3.3	>4.6	0	None
PE-K18	1B	5/22/2006	11:51	14.42	4 to 3	2	>4	>4 to 2	56.9	3.9	3.2	4.6	1.4	b	>56.9	3.9	Y	>3.2	>4.6	0	None
PE-K18	2B	5/22/2006	11:52	14.42	4 to 3	2	>4	>4 to 2	49.9	3.5	3.0	4.4	1.4	b	>50.0	3.5	Y	>3.0	>4.4	0	None
PE-K18	3B	5/22/2006	11:53	14.42	4 to 3	2	>4	>4 to 2	77.2	5.4	5.0	5.9	0.9	b	>77.2	5.4	Y	>5.0	>5.9	0	None
PE-L10	1B	5/22/2006	19:38	14.42	4 to 3	0	>4	>4 to 0	63.4	4.4	4.1	4.7	0.6	b	>63.4	4.4	Y	>4.1	>4.7	0	None
PE-L10	2B	5/22/2006	19:39	14.42	4 to 3	0	>4	>4 to 0	60.3	4.2	3.7	4.6	0.8	b	>60.2	4.2	Y	>3.7	>4.6	0	None
PE-L10	3B	5/22/2006	19:40	14.42	4 to 3	-1	>4	>4 to 0	38.1	2.6	2.3	3.1	0.8	b	>38.0	2.6	Y	>2.3	>3.1	0	None
PE-L11	1B	5/22/2006	12:58	14.42	3 to 2	0	>4	>4 to 0	45.5	3.2	2.7	3.4	0.7	b	>45.4	3.2	Y	>2.7	>3.4	0	None
PE-L11	2B	5/22/2006	13:00	14.42	4 to 3	-1	>4	>4 to -1	53.8	3.7	3.3	4.3	1.1	b	>53.8	3.7	Y	>3.2	>4.3	0	None
PE-L12	2B	5/22/2006	13:30	14.42	3 to 2	<-1	>4	>4 to <-1	44.6	3.1	2.8	3.5	0.6	b	>44.6	3.1	Y	>2.8	>3.5	0	None
PE-L12	3B	5/22/2006	13:31	14.42	3 to 2	-1	>4	>4 to -1	59.4	4.1	3.6	4.7	1.1	b	>59.4	4.1	Y	>3.6	>4.7	0	None
PE-L13	1B	5/21/2006	18:33	14.42	4 to 3	0	>4	>4 to 0	49.5	3.4	2.7	3.9	1.2	p	>49.5	3.4	Y	>2.7	>3.9	0	None
PE-L13	2B	5/21/2006	18:34	14.42	4 to 3	<-1	>4	>4 to <-1	53.6	3.7	3.2	4.5	1.3	b	>53.6	3.7	Y	>3.2	>4.4	0	None
PE-L13	3B	5/21/2006	18:35	14.42	4 to 3	-1	>4	>4 to -1	63.8	4.4	3.7	5.1	1.5	b	>63.8	4.4	Y	>3.7	>5.1	0	None
PE-L14	1B	5/22/2006	14:09	14.40	4 to 3	2	>4	>4 to 2	57.8	4.0	3.7	4.5	0.8	b	>57.8	4.0	Y	>3.7	>4.4	0	None
PE-L14	2B	5/22/2006	14:11	14.42	4 to 3	-1	>4	>4 to -1	56.5	3.9	3.6	4.2	0.6	b	>56.5	3.9	Y	>3.6	>4.2	0	None
PE-L14	3B	5/22/2006	14:12	14.42	4 to 3	-1	>4	>4 to -1	53.8	3.7	3.4	4.3	0.9	b	>53.8	3.7	Y	>3.4	>4.3	0	None
PE-L15	1B	5/21/2006	22:43	14.42	4 to 3	1	>4	>4 to 1	51.1	3.5	3.1	3.7	0.6	b	>51.1	3.5	Y	>3.1	>3.7	0	None
PE-L15	2A	5/21/2006	22:44	14.42	4 to 3	1	>4	>4 to 1	47.6	3.3	2.2	4.0	1.7	b	>47.6	>3.3	Y	>2.2	>3.9	0	None
PE-L15	3B	5/21/2006	22:45	14.42	4 to 3	1	>4	>4 to 1	51.3	3.6	3.1	4.2	1.1	b	>51.3	>3.6	Y	>3.1	>4.2	0	None
PE-L16	1B	5/22/2006	14:55	14.42	4 to 3	1	>4	>4 to 1	50.8	3.5	3.1	3.9	0.8	b	>50.8	>3.5	Y	>3.1	>3.9	0	None
PE-L16	2B	5/22/2006	14:55	14.42	4 to 3	1	>4	>4 to 1	54.9	3.8	3.1	4.2	1.1	b	>54.9	>3.8	Y	>3.1	>4.2	0	None
PE-L16	3B	5/22/2006	14:55	14.42	4 to 3	1	>4	>4 to 1	51.9	3.6	3.0	4.1	1.1	b	>51.9	>3.6	Y	>3.0	>4.1	0	None
PE-L17	1B	5/22/2006	15:49	14.42	4 to 3	1	>4	>4 to 1	56.3	3.9	3.4	4.3	0.9	b	>56.3	>3.9	Y	>3.4	>4.3	0	None
PE-L17	2B	5/22/2006	15:51	14.42	4 to 3	1	>4	>4 to 1	69.9	4.8	4.4	5.3	0.9	b	>70.0	>4.8	Y	>4.4	>5.3	0	None

Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles
PE-L17	3B	5/22/2006	15:53	14.42	4 to 3	1	>4	>4 to 1	54.0	3.7	3.5	3.9	0.4	b	>54.0	>3.7	Y	>3.5	>3.9	0	None
PE-M10	1B	5/22/2006	20:17	14.42	4 to 3	-1	>4	>4 to -1	50.1	3.5	2.8	4.1	1.3	b	>50.1	>3.5	Y	>2.8	>4.1	0	None
PE-M10	2B	5/22/2006	20:18	14.42	4 to 3	-1	>4	>4 to -1	54.2	3.8	2.0	4.8	2.8	p	>54.2	>3.8	Y	>2.0	>4.8	0	None
PE-M10	3B	5/22/2006	20:18	14.42	4 to 3	0	>4	>4 to 0	57.5	4.0	3.2	4.4	1.2	b	>57.5	>4.0	Y	>3.2	>4.4	0	None
PE-M11	1B	5/22/2006	20:40	14.42	4 to 3	-1	>4	>4 to -1	71.8	5.0	4.2	5.7	1.5	b	>71.8	>5.0	Y	>4.2	>5.6	0	None
PE-M11	2B	5/22/2006	20:41	14.42	4 to 3	-1	>4	>4 to -1	61.8	4.3	3.8	4.6	0.8	b	>61.8	>4.3	Y	>3.8	>4.6	0	None
PE-M11	3B	5/22/2006	20:42	14.42	4 to 3	-1	>4	>4 to -1	45.8	3.2	2.6	3.6	1.0	b	>45.8	>3.2	Y	>2.6	>3.6	0	None
PE-X1	1B	5/22/2006	21:07	14.42	3 to 2	<-1	>4	>4 to <-1	50.8	3.5	3.1	3.7	0.7	b	>50.8	>3.5	Y	>3.1	>3.7	0	None
PE-X1	2B	5/22/2006	21:08	14.42	3 to 2	<-1	>4	>4 to <-1	51.1	3.5	2.7	4.1	1.4	p	>51.1	>3.5	Y	>2.7	>4.1	0	None
PE-X1	3B	5/22/2006	21:08	14.42	3 to 2	-1	>4	>4 to -1	49.6	3.4	3.0	3.8	0.7	b	>49.6	>3.4	Y	>3.0	>3.8	0	None
PE-X2	1B	5/22/2006	21:26	14.42	3 to 2/4 to 3	0	>4	>4 to 0	65.4	4.5	3.9	5.3	1.5	b	>65.4	>4.5	Y	>3.9	>5.3	0	None
PE-X2	2B	5/22/2006	21:27	14.40	3 to 2/4 to 3	<-1	>4	>4 to <-1	59.2	4.1	3.7	4.3	0.6	b	>59.2	>4.1	Y	>3.7	>4.3	0	None
PE-X2	3B	5/22/2006	21:28	14.42	3 to 2	-1	>4	>4 to -1	50.2	3.5	2.6	3.9	1.3	b	>50.2	>3.5	Y	>2.6	>3.9	0	None
PE-X3	1B	5/22/2006	21:50	14.40	3 to 2	-1	>4	>4 to -1	50.1	3.5	3.0	3.7	0.7	b	>50.1	>3.5	Y	>3.0	>3.7	0	None
PE-X3	2A	5/22/2006	21:50	14.42	3 to 2	-1	>4	>4 to -1	53.4	3.7	3.3	4.0	0.6	b	>53.4	>3.7	Y	>3.3	>3.9	0	None
PE-X3	3B	5/22/2006	21:51	14.42	3 to 2/4 to 3	<-1	>4	>4 to <-1	73.7	5.1	4.7	5.3	0.6	b	>73.7	>5.1	Y	>4.7	>5.3	0	None
PE-X4	1B	5/22/2006	22:13	14.42	4 to 3	-1	>4	>4 to -1	59.3	4.1	3.4	4.7	1.3	b	>59.3	>4.1	Y	>3.4	>4.6	0	None
PE-X4	2B	5/22/2006	22:14	14.42	3 to 2	-1	>4	>4 to -1	45.2	3.1	2.8	3.4	0.6	b	>45.2	>3.1	Y	>2.8	>3.4	0	None
PE-X4	3B	5/22/2006	22:15	14.40	3 to 2	<-1	>4	>4 to <-1	52.1	3.6	3.2	3.9	0.7	b	>52.1	>3.1	Y	>3.2	>3.9	0	None
PE-X5	1B	5/22/2006	22:37	14.42	3 to 2	<-1	>4	>4 to <-1	39.2	2.7	2.1	3.1	1.0	b	>39.2	>2.7	Y	>2.1	>3.1	0	None
PE-X5	2B	5/22/2006	22:38	14.42	3 to 2	<-1	>4	>4 to <-1	51.1	3.5	3.1	3.8	0.7	b	>51.1	>3.5	Y	>3.1	>3.8	0	None
PE-X5	3B	5/22/2006	22:39	14.42	3 to 2/4 to 3	<-1	>4	>4 to <-1	70.6	4.9	4.5	5.2	0.8	b	>70.6	>4.9	Y	>4.4	>5.2	0	None
PE-X6	1B	5/22/2006	23:05	14.42	>4 to 3	-1	>4	>4 to -1	76.4	5.3	4.8	5.7	0.9	b	9.85	0.7	N	0	2.02	0	None
PE-X6	2B	5/22/2006	23:06	14.42	>4 to 3	<-1	>4	>4 to <-1	62.1	4.3	4.1	4.5	0.4	b	13.1	0.9	N	0	2.15	0	None
PE-X6	3B	5/22/2006	23:06	14.42	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	0	None
PE-X7	1B	5/22/2006	23:26	14.42	>4 to 3	1	>4	>4 to 1	84.0	5.8	5.3	6.3	1.0	b	>84.0	>5.8	Y	>5.3	>6.3	0	None
PE-X7	2B	5/22/2006	23:27	14.42	3 to 2/4 to 3	0	>4	>4 to 0	56.4	3.9	3.4	4.4	1.0	b	>56.4	>3.9	Y	>3.4	>4.4	0	None
PE-X7	3B	5/22/2006	23:28	14.42	4 to 3	0	>4	>4 to 0	91.8	6.4	5.4	7.2	1.8	b	>91.8	>6.4	Y	>5.4	>7.2	0	None
PE-R1	1B	5/21/2006	11:19	14.42	4 to 3	2	>4	>4 to 2	51.6	3.6	2.8	4.2	1.5	b	>51.6	>3.6	Y	>2.8	>4.2	0	None
PE-R1	2B	5/21/2006	11:20	14.42	4 to 3	1	>4	>4 to 1	59.0	4.1	3.4	4.7	1.3	b	>59.0	>4.1	Y	>3.4	>4.7	0	None
PE-R1	3B	5/21/2006	11:23	14.42	4 to 3	1	>4	>4 to 1	62.9	4.4	3.9	4.6	0.7	b	>62.9	>4.4	Y	>3.9	>4.6	0	None
PE-R2	1B	5/21/2006	12:07	14.42	4 to 3	1	>4	>4 to 1	61.8	4.3	4.0	4.6	0.6	b	>61.8	>4.3	Y	>4.0	>4.6	0	None
PE-R2	2B	5/21/2006	12:08	14.42	4 to 3	1	>4	>4 to 1	60.4	4.2	3.9	4.6	0.8	b	>60.4	>4.2	Y	>3.9	>4.6	0	None
PE-R2	3B	5/21/2006	12:10	14.42	4 to 3	1	>4	>4 to 1	70.5	4.9	4.6	5.2	0.6	b	>70.5	>4.9	Y	>4.6	>5.2	0	None
PE-R3	1B	5/21/2006	9:58	14.42	4 to 3	1	>4	>4 to 1	64.5	4.5	3.6	5.4	1.8	p	>64.5	>4.5	Y	>3.6	>5.4	0	None
PE-R3	2B	5/21/2006	10:00	14.42	4 to 3	1	>4	>4 to 1	79.1	5.5	5.1	5.8	0.7	p	>79.1	>5.5	Y	>5.1	>5.8	0	None
PE-R3	3B	5/21/2006	10:01	14.42	4 to 3	1	>4	>4 to 1	66.4	4.6	4.3	5.0	0.7	b	>66.4	>4.6	Y	>4.3	>5.0	0	None

Station	REP	Low DO?	DM?	DM lyr thickness	Feeding Void #	SUCCESS. STAGE	OSI	COMMENT
PE-H11	1B	n	N		0	Stage 2 on 3	11	Ambient very fine sand>pen; sand is silty w/ homogenous color+texture; large+small surface tubes; no rpd contrast=RPD>pen; biogenic mound=Stg 3
PE-H11	2B	n	N		0	Stage 2 to 3	10	Ambient very fine to fine sand>pen; silt component; small shell frags; no rpd contrast=RPD>pen; numerous lrg+small tubes@sed surf;tubes in farfield counted
PE-H11	3B	n	N		0	Stage 2 on 3	11	Ambient silty very fine to fine sand>pen; homogenous color+texture=no rpd contratst; a few v. small worms@depth; numerous diverse surface tubes
PE-H12	1B	n	N		0	Stage 2	9	Ambient silty very fine to fine sand>pen; homogenous color+texture; subtle vertical "streaks" of silty-clay sediment; little evidence of subsurface bio; numerous diverse surface tubes
PE-H12	2B	n	N		0	Stage 2	9	Ambient silty very fine to fine sand>pen; homogenous color+texture; one very shallow void@right??; small to moderate # of tubes@sed surfce
PE-H12	3B	n	N		0	Stage 2	9	Ambient silty very fine to fine sand>pen; vertical streaks/patches of silt-clay=minor dragdown artifact?; one small subsurface worm lwr left+biogenic mound=Stg 3; numerous diverse surface tubes
PE-H13	1B	n	N		0	Stage 2 on 3	10	Ambient silty very fine to fine sand>pen; homogenous color+texture=no rpd contrast; little subsurface bio; floccy sed surface w/ numerous tubes
PE-H13	2B	n	N		0	Stage 2 on 3	10	Ambient silty very fine to fine sand>pen; homogenous color+texture; slightly darker color than previous images; biogenic tunneling in upper 2-4 cm; lrg+small surf tubes+biogenic mound=2 on 3
PE-H13	3B	n	N		0	Stage 2	8	Ambient silty very fine to fine sand>pen; uneven texture=alternating patches of silt, very fine and fine sand; numerous diverse surface tubes
PE-H14	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color and texture; no rpd contrast; numerous different kinds of surface tubes; no obvious subsurface bio.
PE-H14	2B	n	N		0	Stage 2 to 3	10	Ambient silty very fine sand>pen; homogenous color+texture; burrow@depth left; numerous lrg+small surface tubes
PE-H14	3A	n	N		0	Stage 2 to 3	9	Ambient silty very fine to fine sand>pen; homogenous color+texture; subsurface worm@far right edge; Ampelisca-like tubes (?) + worm tubes@surf
PE-H15	1B	n	N		0	Stage 2 on 3	11	Ambient very silty very fine sand>pen; homogenous color+texture; larger-bodied worm@depth=Stage 3; numerous lrg+small surface tubes
PE-H15	2B	n	N		0	Stage 2 on 3	11	Ambient fine to very fine sand w/ some silt>pen; homogenous color+texture; numerous surface tubes=worms+a few Ampelisca
PE-H15	3B	n	N		0	Stage 2 on 3	11	Ambient silty very fine sand>pen; homogenous color+texture; numerous surface worm tubes+biognic mound=Stg 2 on 3
PE-H16	1B	n	N		0	Stage 2 to 3	9	Ambient silty very fine to fine sand>pen; homogenous color+somewhat homo. texture (some patchiness); worm tubes+Ampelisca tubes in farfield
PE-H16	2B	n	N		1	Stage 2 on 3	11	Ambient silty very fine to fine sand>pen; homogenous color+somewhat homo. texture (some patchiness); assorted tubes; 2 feeding voids/subsurface burrows. Void is located between 2.4 - 2.7 cm below SWI
PE-H16	3B	n	N		0	Stage 2 on 3	11	Ambient silty very fine to fine sand>pen; homogenous color+somewhat homo. texture (some patchiness); assorted tubes; subsurface burrows
PE-H17	1B	n	N		0	Stage 2 to 3	9	Ambient fine to very fine sand>pen; minor silt component; homogenous color; numerous thick ornate worm tubes or draped w/ floccy material=Stg 3
PE-H17	2B	n	N		0	Stage 2 on 3	11	Ambient silty very fine to fine sand>pen; homogenous color+texture; larger-bodied subsurface worm+thick tubes+biogenic mound=2 on 3; numerous surface worm tubes draped w/ floc
PE-H17	3B	n	N		0	Stage 2 to 3	9	Ambient silty v. fine to fine sand>pen; homogenous color+texture; numerous thick and small surface tubes+subsurface burrow lwr right=Stage 1 on 3
PE-I10	1B	n	N		0	Stage 2 to 3	10	Ambient very silty fine to very fine sand>pen; shallow void or worm@right; homogenous color w/ clayey streaks; numerous surface worm tubes; biogenic mound?
PE-I10	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine to very sand>pen; homogenous color+texture; many surface tubes=worms and many Ampelisca of different sizes
PE-I10	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine to very fine sand>pen; homogenous color+texture; piece of decayed eelgrass@SWI; small worm tubes@surf; numerous v. small subsurface worms; biogenic mound
PE-I11	1B	n	N		0	Stage 2 on 3	10	Ambient silty fine to very fine sand>pen; homogenous color+texture; numerous surface tubes nearfield+farfield; biogenic mounds farfield=Stg 3
PE-I11	2A	n	N		0	Stage 2	8	Ambient silty fine to very fine sand>pen; homogenous color+texture; floccy surface+numerous floccy tubes nearfield+farfield
PE-I11	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color+texture; numerous surface tubes lrg and small some w/ floccy material; biogenic mound
PE-I12	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color; small worms@depth; vertical burrow or dragdown@left??; biogenic mound farfield w/ underlying burrow+floccy surface w/ many tubes near+far=Stg 3
PE-I12	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine to very fine sand>pen; homogenous color+texture; little subsurface bio; many surface tubes; sand ripple?
PE-I12	3B	n	N		0	Stage 2 on 3	11	Ambient very silty very fine sand>pen; higher silt content then previous rep; several v. small voids@right=Stg 3 (indistinct); numerous floccy surface tubes, mostly farfield
PE-I13	1B	n	N		0	Stage 2	8	Ambient silty very fine to fine sand>pen; dragdown of shell or rock@center?; dark streaks@left=?? trace DM influence?; numerous floccy/ornate tubes@surf, many in farfield
PE-I13	2B	n	N		0	Stage 2	8	Ambient fine sand>pen; some silt but looks coarser than previous image; homogenous color+texture; sed surface floccy w/ numerous tubes, many in farfield
PE-I13	3B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; dark patch@right=trace DM influence?; piece of decayed eelgrass; numerous floccy tubes@sed surf; burrow/worms@depth
PE-I14	1B	n	N		0	Stage 2 to 3	10	Ambient silty very fine to fine sand>pen; some silt-clay patches; homogenous color; floccy surface w/ dense larger distinct surface tubes=Stg 3; possible burrow@right
PE-I14	2B	n	N		0	Stage 2 to 3	9	Ambient silty very fine to fine sand w/ shell frags>pen; homogenous color; floccy surface w/ assorted tubes; a few small worms@depth
PE-I14	3B	n	N		0	Stage 2 on 3	11	Ambient silty very fine to fine sand>pen; homogenous color w/ some silt-clay patches; subsurface worm@left+many assorted surface tubes=Stg 2 on 3
PE-I15	1B	n	Trace	NA	0	Stage 2	9	Ambient silty fine to very fine sand>pen; slightly darker horizon in upper 2-3 cm and dark patch=trace DM; floccy surface w/ many assorted tubes; small worms@depth
PE-I15	2B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; v. slightly darker upper 2-3 cm=?; worms@depth and many assorted worm tubes@SWI
PE-I15	3B	n	N		0	Stage 2	9	Ambient very silty fine sand>pen; homogenous color+texture; piece of decayed eelgrass@left; floccy surface w/ many assorted tubes
PE-I16	1A	n	N		0	Stage 2	8	Ambient silty very fine sand>pen; homogenous color+texture; little subsurface bio; floccy surface w/ many assorted tubes (many in farfield not counted)
PE-I16	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; biogenic mound in farfield+many assorted surface tubes=Stage 2 on 3; floccy

Station	REP	Low DO?	DM?	DM lyr thickness	Feeding Void #	SUCCESS. STAGE	OSI	COMMENT
PE-I16	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; biogenic mound in farfield left+one worm@z lwr right+many assorted surf tubes=2 on 3
PE-I17	1B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; slightly coarser texture-between 4-3 and 3-2 sand; very floccy sed surface=difficult to count tubes; burrow opening@right?; worm@depth; biogenic mound?
PE-I17	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; at least 2 small subsurface worms; v. floccy surface w/ many tubes; biogenic mound?
PE-I17	3B	n	N		0	Stage 2	9	Ambient silty fine to very fine sand>pen; uniform light color w/ patches of silt-clay; high roughness=camera disturbance artifact; floccy surf w/ many tubes
PE-I18	1B	n	N		0	Stage 2 on 3	10	Ambient silty fine to very fine sand>pen; uniform light color w/ silt-clay patches; little subsurface bio; assorted worm and Ampelisca tubes
PE-I18	2B	n	N		0	Stage 2	9	Ambient silty fine to very fine sand>pen; uniform color+texture; little subsurface bio; floccy surface w/ many assorted tubes; dragdown of filamentous plant matter@left
PE-I18	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine to very fine sand>pen; uniform color+patches of silt-clay; center mound=biogenic; dragdown decayed eelgrass@left; v. floccy surface=many tubes; thick tubes+biogenic mound=Stage 3 present
PE-J10	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; uniform color+texture; many surface tubes+several biogenic mounds in farfield=evidence of Stage 3
PE-J10	2B	n	N		0	Stage 2 on 3	9	Ambient silty fine to very fine sand>pen; slightly darker sand than previous images; a few small worms@z; many surface tubes, particularly in farfield
PE-J10	3B	n	N		0	Stage 2	9	Ambient silty fine to very fine sand>pen; homogenous color+texture; a few small worms@z; many surface tubes, esp. in farfield
PE-J11	1B	n	N		0	Stage 2	9	Ambient silty fine to very fine sand>pen; slightly darker in upper 2-4 cm; vertical "patches" of silt-clay; farfield descending away from camera=low # tubes
PE-J11	2B	n	N		0	Stage 2	9	Ambient silty fine to very fine sand>pen; homogenous color+texture; cloudy water column=hard to see/count tubes; little subsurface bio
PE-J11	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; sand looks slightly darker and coarser (more 3-2 fraction); small worms@z; appears to be many tubes but water turbid
PE-J12	1B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; slightly darker+coarser; sed surface descending in farfield=few tubes; vertical "patches" of silt-clay and fine sand; subsurface worm
PE-J12	2B	n	Y	2.61	0	Stage 2 to 3	10	Muddy fine sand DM over ambient silty very fine sand; DM is darker and has higher 3-2 sand content, with whitish shell frags; subtle contact between lyrs; floccy surface w/ tubes
PE-J12	3B	n	Y	2.48	0	Stage 2 to 3	9	Muddy fine sand DM w/ small white shell frags over ambient silty very fine sand; subtle layering=DM darker w/ faint reduced streaks; floccy surface w/ tubes' some subsurface worms
PE-J13	1B	n	Y	2.26	0	Stage 2	9	Muddy fine sand DM w/ white sand grains+shell frags over ambient silty very fine sand; subtle layering=DM darker w/ clay "streaks"; small subsurface worms+many surface tubes=2 to 3
PE-J13	2A	n	Y	2.68	0	Stage 2	8	Muddy fine sand DM w/ white sand grains+shell frags over ambient silty very fine sand; v. subtle layering; DM has clay patches; floccy masses@SWI=worm tube clusters or just org matter?
PE-J13	3B	n	Y	3.6	0	Stage 2	9	Muddy fine sand DM w/ white sand grains+shell frags over ambient silty very fine sand; point of contact between lyrs@very bottom of image; subsurface worms+surface tubes=2 to 3; decayed eelgrass
PE-J14	1B	n	Y	>5.6	0	Stage 2 on 3	8	Muddy fine sand DM w/ white sand grains/shell frags>pen; planview trigger wire in image; streaks of dark/reduced sed@depth; some subsurface worms+many assorted surface tubes
PE-J14	2A	n	Y	>4.1	0	Stage 2	9	Muddy fine sand DM w/ white sand grains+shell frags>pen; faint reddish streaks@depth; many surface tubes, esp in farfield
PE-J14	3B	n	Y	>4.4	0	Stage 2	9	Muddy fine sand DM w/ white sand grains+shell frags>pen; dark streaks=sed color and not gechemical=rpd>pen(?); floccy surface w/ moderate # of assorted tubes
PE-J15	1B	n	Y	5.52	0	Stage 2 to 3	6	Muddy very fine sand DM over ambient silty fine sand; DM lyr much darker than underlying sed; white sand grains@bottom of DM lyr; many small subsurface worms in DM lyr+many surface tubes; rpd=??
PE-J15	2B	n	Y	7.06	0	Stage 2 to 3	6	Dark muddy very fine sand DM over ambient light-colored silty fine sand; DM lyr has significant dark brown patches; fine sand w/ white grains@bottom of DM lyr; v. dense small worms in DM+many surf tubes
PE-J15	3B	n	Y	6.62	0	Stage 2 to 3	6	Dark muddy very fine sand DM over ambient light-colored silty fine sand; contact between lyrs right@bottom of image=inferred from other 2 reps; v. dense tiny worms within DM+many surface tubes
PE-J16	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color+texture; a few small subsurface worms+many assorted surface tubes, including thicker tubes=2 on 3
PE-J16	2B	n	N		0	Stage 2 on 3	11	Ambient silty very fine sand>pen; homogenous color+texture; a few v. small worms@depth; many assorted surface tubes, most in farfield (not counted); farfield tubes are thick
PE-J16	3B	n	N		0	Stage 2 on 3	11	Ambient silty very fine sand>pen; homogenous color+texture; 1 visible thin worm@depth; many assorted thick and thin surface tubes
PE-J17	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color+texture; a few small thin subsurface worms; many assorted surface tubes, many in farfield (not counted)
PE-J17	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color+texture; a few subsurface worms; many assorted surface tubes, including many thicker, Stg 3 tubes
PE-J17	3B	n	N		0	Stage 2 on 3	11	Ambient very silty fine sand>pen; homogenous color+texture=little rpd contrast; biogenic mounds in farfield; many assorted surface tubes
PE-J18	1B	n	N		0	Stage 2 on 3	11	Ambient very silty fine sand>pen; homogenous color+some variation in texture (mud vs. sand); biogenic mounds; many assorted worm tubes, one large/tall tube
PE-J18	2B	n	N		0	Stage 2 on 3	11	Ambient very silty fine sand>pen; homogenous color+texture; very dense and assorted surface tubes; some subsurface bio
PE-J18	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; many surface tubes, esp. in farfield; larger Stg 3 tube
PE-K10	1B	n	Y	1.74	0	Stage 2	9	Thin layer of darker silty fine sand DM w/ white grains+shell frags over ambient silty fine sand; DM lyr subtle; winch wire in image; many assorted surface tubes
PE-K10	2B	n	Y	2.31	0	Stage 2 to 3	10	Thin layer of darker silty fine sand DM w/ white grains+shell frags over ambient silty fine sand; patches of darker sed w/in DM; small subsurface worms and surface tubes
PE-K10	3B	n	Y	2.05	0	Stage 2 to 3	10	Thin lyr of darker silty fine sand DM w/ white grains over ambient silty fine sand; sand in DM lyr obscured behind clay patches; thickness measured at far right; subsurface wrms+surf tubes
PE-K11	1B	n	Y	>3.8	0	Stage 2 to 3	9	DM>pen; DM=darker silty fine sand w/ distinct clay patches, white sand grains+small white shell frags; subsurface worms+many assorted surf tubes

Station	REP	Low DO?	DM?	DM lyr thickness	Feeding Void #	SUCCESS. STAGE	OSI	COMMENT
PE-K11	2B	n	Y	2.7	0	Stage 2 to 3	10	Surf lyr of DM over ambient silty fine sand; DM=darker mud matrix w/ sand having white grains+white shell frgs; subsurface worms+surface worm tubes
PE-K11	3B	n	Y	2.08	0	Stage 2	8	Surf lyr of DM over ambient silty fine sand; DM=slightly darker matrix w/ sand w/ white sand grains+shell frags; many assorted surf tubes
PE-K12	1B	n	Y	>4.0	0	Stage 2 on 3	10	DM>pen; DM=matrix of somewhat darker silt w/ fine sand having white grains+shell frags; subsurface worms+surf. worm tubes; distinct long tubes=long body w/ frilly top
PE-K12	2A	n	Y	>3.6	0	Stage 2 on 3	10	DM>pen; DM=darker silt w/ fine sand w/ white grains+shell frags; floccy masses of tubes or organic matter@sed surf; distinct long tubes; subsurface worms; biogenic mound in farfield
PE-K12	3B	n	Y	>5.4	0	Stage 2 on 3	11	DM>pen; DM=poorly sorted mix of silt, fine sand and shell frags (many white shell frags); some small subsurface worms+many distinct surface tubes=long body w/ frilly tops; biogenic mound(?)
PE-K13	1B	n	Y	2.22	0	Stage 2 to 3	9	Thin lyr of DM over ambient silty fine sand; DM=darker w/ white sand grains+white shell frags; small subsurface worms+some surf tubes, mostly farfield; winch wire in farfield; blue glass?
PE-K13	2B	n	Y	2.36	0	Stage 2 to 3	9	Thin lyr of DM over ambient silty fine sand; DM=darker w/ white sand grains+white shell frags; small subsurface worms; worm+blood@right?; floccy matter@sed surf; some surf tubes
PE-K13	3B	n	Y	>3.4	0	Stage 2 to 3	9	DM>pen; possible DM over ambient but layering hard to see; DM=darker matrix w/ white sand+shell frags; distinct surf tubes=long w/ frilly tendrils
PE-K14	1A	n	Y	2.55	0	Stage 2 on 3	11	DM over ambient silty fine sand; DM=darker silt-clay w/ white sand grains+shell frags; biogenic mound; subsurface worms+many surf tubes
PE-K14	2B	n	Y	2.75	0	Stage 2 to 3	10	DM over ambient silty fine sand; DM=darker w/ darker patches+white sand grains+white shell frgs; subtle layering; small subsurface worms+many worm tubes, esp. farfield
PE-K14	3B	n	Y	2.61	0	Stage 2 to 3	9	DM over ambient silty fine sand: DM=darker patches+white grains+shell frags; small subsurface worms+many assorted surf tubes
PE-K15	1B	n	Y	>4.4	0	Stage 2	8	DM>pen; DM=silty fine sand w/ dark patches+white sand grains+white shell frags; high BR=?; small subsurf. worms+surface worm tubes
PE-K15	2A	n	Y	>4.2	0	Stage 2	7	DM>pen; DM=darker-colored silty sand w/ dark patches+white grains+shell frags; small subsurface worms+many surf tubes; larger surf tubes
PE-K15	3B	n	Y	>4.0	0	Stage 2	8	DM>pen or 1-2 cm surf layer??; DM=dark patches w/ white shell frags; high biogenic mound farfield?; many surf tubes, some longer/larger
PE-K16	1B	n	N		0	Stage 2 to 3	9	Ambient silty very fine to fine sand>pen; mostly homogenous color+texture; biogenic pit?; a few subsurf. worms+many surface tubes; floccy surface
PE-K16	2B	n	N		0	Stage 2 to 3	10	Ambient very silty very fine sand>pen; homogenous color+texture; subsurface worms+some surf worm tubes; v. floccy surface=obscures tubes
PE-K16	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; subsurface worms+many surface worm tubes
PE-K17	1B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; many assorted surface tubes; biogenic mound in nearfield
PE-K17	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; not many subsurface worms but many assorted surf tubes
PE-K17	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine to very fine sand>pen; homogenous color+texture; few subsurface worms but many assorted surf tubes
PE-K18	1B	n	N		0	Stage 2	9	Ambient very silty fine sand>pen; homogenous color+texture; little obvious subsurface bio but many assorted surf tubes
PE-K18	2B	n	N		0	Stage 2	8	Ambient silty fine sand>pen; homogenous color+texture; dragdown of vegetation (eelgrass)@right?; biogenic mound; many assorted surface tubes
PE-K18	3B	n	N		0	Stage 2 to 3	10	Ambient very silty fine sand>pen; homogenous color+texture; a few small subsurface worms+many assorted surf tubes; small biogenic mound center?
PE-L10	1B	n	Trace (?)	NA	0	Stage 2 to 3	10	Ambient silty fine sand>pen; trace DM or actual layer?? Subtle darker sed w/ some white sand grains; Assorted surf tubes
PE-L10	2B	n	Trace (?)	NA	0	Stage 2 to 3	10	Ambient silty fine sand>pen; trace DM=darker sed in upper 2-4 cm and white sand grains; subsurface worms+many assorted surface tubes
PE-L10	3B	n	Trace	NA	0	Stage 2	7	Ambient silty fine sand>pen; white sand grains+white small shell frags=trace DM; many small subsurface worms+many assorted surf tubes
PE-L11	1B	n	Y	2.35	0	Stage 2	8	DM over ambient silty fine sand; layering indistinct=DM>pen?; DM=darker silt+white sand grains+white shell frags; small subsurface worms+many assorted worm tubes
PE-L11	2B	n	Y	1.96	0	Stage 2	8	DM over ambient silty fine sand; layering indistinct=trace DM only?; DM=some white sand grains+white shell frags; small subsurface worms+many surf tubes
PE-L12	2B	n	Y	>3.5	0	Stage 2	8	DM>pen; DM is darker silt w/ white sand grains+many small white shell frags+darker patches; many surf tubes; distinct long tube-like structures --look like hydroids
PE-L12	3B	n	Y	>4.7	0	Stage 2	9	DM>pen; DM is darker silt w/ white sand grains+white shell frags; distinct surf hydroids
PE-L13	1B	n	N		0	Stage 2	8	Ambient silty fine sand>pen; homogenous color+texture; small subsurface worms+surface worm tubes
PE-L13	2B	n	N		0	Stage 2 to 3	9	Ambient silty fine sand>pen; numerous white shell frags@surf; many larger subsurface worms+distinct surf tubes/stalks
PE-L13	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine to very fine sand>pen; homogenous color+texture; white shells@surf=trace DM influence?; v. small subsurface worms+assorted surf tubes
PE-L14	1B	n	Trace?	NA	0	Stage 2 to 3	10	Ambient silty fine to very fine sand>pen; homogenous color+texture; 1-2 whitish clay clasts=trace DM influence?; small void lwr right; dense assorted surf tubes
PE-L14	2B	n	Trace?	NA	0	Stage 2	9	Ambient silty fine to very fine sand>pen; some darker patches+some white shells=trace DM influence?; small subsurface worms+dense assorted surf tubes
PE-L14	3B	n	Trace?	NA	0	Stage 2	8	Ambient silty fine to very fine sand>pen; one dark patch@right w/white shells=trace DM?; a few small subsurface worms+dense assorted surf tubes
PE-L15	1B	n	N		0	Stage 2 to 3	9	Ambient silty fine sand>pen; homogenous color+some patches of silt vs. sand; small+indistinct burrow/void@right?; assorted surf tubes
PE-L15	2A	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color; slightly patchy texture=silt+sand; larger subsurface worm@right; many assorted surf tubes
PE-L15	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+silty/sandy texture; biogenic mound farfield; a few small subsurface worms+many assorted surf tubes
PE-L16	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; biogenic mound@center nearfield; many assorted surf tubes
PE-L16	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; a few small subsurface worms+many assorted surf tubes; many thick stubby tubes
PE-L16	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; many assorted surf tubes; one larger/longer tube/hyroid@right
PE-L17	1B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; sand has more black grains than previous reps; winch wire disturbance of SWI; many assorted surf tubes
PE-L17	2B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; homogenous color+texture; very few subsurface worms or other bio; many assorted surf tubes

Station	REP	Low DO?	DM?	DM lyr thickness	Feeding Void #	SUCCESS. STAGE	OSI	COMMENT
PE-L17	3B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; homogenous color+texture; unidentified invertebrate on sed surf@center; biogenic mound nearfield left; assorted surf tubes
PE-M10	1B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; homogenous color+texture; some white sand grains+shell frags=minimal trace DM; few subsurface worms+many assorted surf tubes
PE-M10	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; a few white shell frags=faint minimal trace of DM; few subsurface worms; many assorted surf tubes; many thick short tubes
PE-M10	3B	n	N		0	Stage 2	9	Ambient silty fine sand>pen; homogenous color+texture; piece of dead eelgrass@surf; little subsurface bio; assorted surf tubes
PE-M11	1B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; some silty/sandy patchiness; a few white shells=minimal trace DM; many assorted surf tubes+long frilly hyroids in farfield
PE-M11	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; coarser sand present w/ white grains+shell frags=minimal trace DM influence(?); little subsurface bio; biogenic mound farfield left; many assorted surf tubes
PE-M11	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; a few white shellf frags@surf=minimal trace DM influence; little subsurface bio; many assorted surf tubes
PE-X1	1B	n	Y	2.78	0	Stage 2	9	DM over ambient silty fine sand; DM=darker w/ white sand grains+white shell frags; layering indistinct=DM>pen??; many surface tubes/frilly stalks (hyroids?)
PE-X1	2B	n	Y	2.44	0	Stage 2	9	DM over ambient silty fine sand; layering indistinct; DM=darker silty sand w/ white sand grains+small white shell frags; a few small subsurface worms; few to mod. #'s of surface tubes/stalks
PE-X1	3B	n	Y	2.53	0	Stage 2	9	DM over ambient silty fine sand; subtle layering but more distinct than previous 2 reps; DM=darker silt w/ white grains/shell frags; many small subsurface worms; floccy surface w/ a few tubes
PE-X2	1B	n	Y	2.74	0	Stage 2 on 3	11	DM over ambient silty fine sand; clear layering of different grain sizes+color; biogenic mound@left; small worms@depth; mod. #'s of surface tubes, many short+fat
PE-X2	2B	n	Y	2.94	0	Stage 2	9	DM over ambient silty fine sand; subtle layering; DM is darker w/ white sand grains+shell frags; many assorted surface tubes
PE-X2	3B	n	Y	>2.63	0	Stage 2 to 3	10	DM>pen; DM is darker silt w/ clay patches+white sand grains+shell frags; many small subsurface worms+many assorted surf tubes
PE-X3	1B	n	Y	>3.7	0	Stage 2 to 3	10	DM>pen; DM is darker silt w/ dark patches+white sand grains+small white shell frags; a few surface tubes/stalks (hydroids?)
PE-X3	2A	n	Y	3.01	0	Stage 2 to 3	10	DM over ambient silty fine sand; subtle layering; DM is darker w/ white grain+shell frags; subsurface worms+many assorted surf tubes/stalks; numerous frilly hyrdoids
PE-X3	3B	n	Y	3.18	0	Stage 2 to 3	10	DM over ambient silty fine sand; distinct layering; DM=darker, white grains+shell frags; vertical burrow through shells@right?; many surface tubes/stalks=many frilly hydroids
PE-X4	1B	n	Trace	NA	0	Stage 2	9	Possible DM>pen(?) but looks like DM patches mixed w/ ambient silty fine sand; small subsurface worms+many assorted surface tubes
PE-X4	2B	n	Y	>3.4	0	Stage 2	9	DM>pen; DM is darker w/ white sand grains+small white shell frags; small worms@depth+many assorted surf tubes+frilly stalks
PE-X4	3B	n	Y	2.6	0	Stage 2	9	DM over ambient silty fine sand; subtle layering=DM>pen?; DM is darker w/ white sand grains+shells; many assorted surf tubes
PE-X5	1B	n	Y	>3.1	0	Stage 2	9	DM>pen; DM is darker silt w/ white sand grains+many white small shell frags; many small subsurface worms+many surface tubes/frilly stalks
PE-X5	2B	n	Y	>3.8	0	Stage 2	9	DM>pen; DM is darker silt w/ white sand grains+shell frags; piece of dead eelgrass (from inshore) dragged down by camera; many assorted surf tubes+frilly stalks
PE-X5	3B	n	Y	3.84	0	Stage 2 on 3	11	DM over ambient silty fine sand; subtle layering; DM=darker horizon w/ white grains+shell frags; small subsurface worms+surf tubes/frilly stalks
PE-X6	1B	n	Y	>5.6	0	Stage 2	4	DM>pen; DM has very dark patches of silt-clay=reduced sed?? measured shallow RPD; many v. small worms or ? @depth, many concentrated in 1 of the patches; many assorted surf tubes+frilly stalks
PE-X6	2B	n	Y	>4.5	0	Stage 2	5	DM>pen; DM has dark patches of silt-clay+white sand grains+shell frags; many small worms or ?@depth+assorted surf tubes+frilly stalks (hydroids?)
PE-X6	3B	ind	ind	ind	ind	Ind	Ind	No penetration; sed surface in farfield
PE-X7	1B	n	Trace	NA	0	Stage 2 on 3	11	Ambient silty fine to very sand>pen; one vertical patch darker sed=trace DM; biogenic mound farfield; small worms@depth+assorted surf tubes
PE-X7	2B	n	Y	2.57	0	Stage 2 to 3	10	Trace DM layer over ambient silty fine sand; DM=slightly darker w/ white grains+small shell frags; indistinct layering; small worms@z; assorted surf tubes
PE-X7	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; biogenic mound+vertical burrow@left=Stage 3; small subsurface worms+assorted worm tubes
PE-R1	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; planview trigger wire in image; little subsurface bio; many assorted surf tubes+long frilly hydroids(?) in farfield
PE-R1	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; planview wire left; a few small subsurface worms+tunnels(?); many assorted surf tubes+frilly hydroids
PE-R1	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; v. silty; planview wire in image; little subsurface bio; many surface tubes+frilly hydroids
PE-R2	1B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; some silty/sandy patchiness; little subsurface bio; many assorted surf tubes+short (immature?)frilly hydroids
PE-R2	2B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture w/ silty patches; brittle star@SWI@right; many assorted surf tubes/stalks, many w/ distinct branched structure
PE-R2	3B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; larger-bodied burrower@far right=Stage 3; many thin tall surf tubes/stalks
PE-R3	1B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture; mound=likely hang weight artifact w/ displaced surface floc on left; many surface tubes
PE-R3	2B	n	N		0	Stage 2 on 3	11	Ambient silty fine sand>pen; homogenous color+texture (darker than previous rep); larger subsurface worm+large surf tube=Stage 3
PE-R3	3B	n	N		0	Stage 2 to 3	10	Ambient silty fine sand>pen; homogenous color+texture; some silty/sandy patches; a few small subsurface worms+many assorted surf tubes