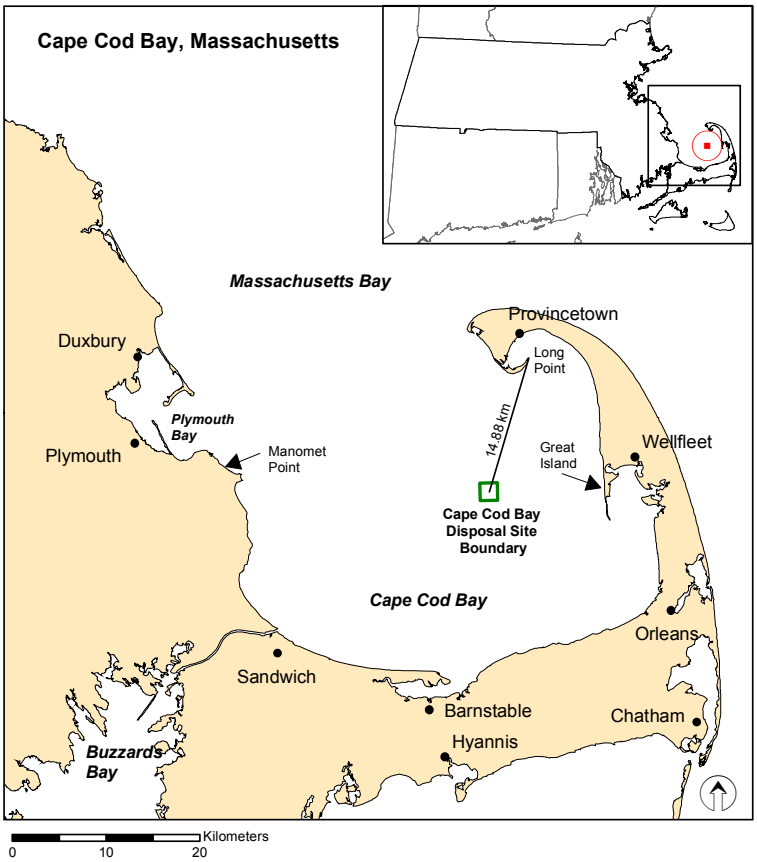
Monitoring Survey at the Cape Cod Bay Disposal Site
August 2003

Disposal Area Monitoring System DAMOS



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13. ABSTRACT

The Cape Cod Bay Disposal Site (CCBDS) was monitored as part of the US Army Corps of Engineers New England District Disposal Area Monitoring System (DAMOS) on 19-20 August 2003 and 22, 27-28 August 2003. The 2003 field effort included bathymetric and sediment-profile imaging (SPI) surveys designed to document changes in seafloor topography, evaluate the physical distribution of dredged material and assess the benthic recolonization status associated with recent dredged material disposal activity. Disposal site data were compared with nearby reference area data and historical data from the May 1996 and August 2001 CCBDS surveys.

Two distinct disposal mounds were evident at CCBDS: Mound A, formed by the disposal of 112,000 m^3 of dredged material in late 1994 to early 1995 and an additional 2600 m^3 of dredged material placed in Fall, 2002, and Mound B, formed by the disposal of 324,000 m^3 of dredged material placed between June 1996 and December 2000, and 185,000 m^3 of dredged material placed between October 2001 and January 2002. Survey results indicated Mound A had a maximum height of approximately 1 m above the surrounding seafloor, with little change in mound dimensions since the previous survey. Survey results indicated Mound B had increased in height approximately 1.5 m since the previous survey, forming an elongated mound with a maximum height of approximately 5.5 m above the surrounding seafloor. The benthic community at Mound A exhibited slower-than-expected recovery, manifested by relatively shallow RPD depths and the presence of Stage I only assemblages in replicate SPI images. Stage III communities were present in at least one replicate image at every station, indicating patchy but advancing benthic recovery. The benthic community at Mound B showed expected recovery eighteen months following cessation of disposal. A comparison of historical and present survey results at the reference stations suggested an apparent decline in ambient benthic habitat conditions, however a preliminary review of long-term MWRA benthic data at nearby stations indicated stable benthic conditions over the 11-year period of record. Therefore seasonal variations in benthic conditions, natural variation or analysis techniques rather than an actual decline in conditions were likely responsible for the variations in the benthic habitat data.

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EXECUTIVE SUMMARY

A monitoring survey was conducted at the Cape Cod Bay Disposal Site (CCBDS), as part of the Disposal Area Monitoring System (DAMOS), from 19 to 28 August 2003. The August 2003 field effort consisted of bathymetric and sediment-profile imaging surveys designed to document changes in seafloor topography, evaluate the physical distribution of dredged material, and assess the recovery of the benthic community within CCBDS relative to ambient sediment conditions.

The bathymetric survey was conducted over the eastern two-thirds of CCBDS, and revealed relatively flat topography, no natural features and three dredged material disposal mounds. Two distinct mounds were identified in CCBDS; Mound A in the southeast quadrant and Mound B in the northeast quadrant. A less distinct mound was identified near the center of the site, at the location of the historic Wellfleet Disposal Area.

Mound A was formed in late 1994 to early 1995 by the disposal of 112,000 m^3 of dredged material. In November 2002, an additional 2600 m^3 of dredged material was placed at Mound A. Three monitoring surveys have been performed in the eight years following the initial disposal: 1996, 2001 and 2003. The 2003 survey indicated that Mound A has a maximum height of approximately 1 m above the surrounding seafloor and an approximate footprint 450 m in diameter. There was little change in the mound height and lateral extent between the 2001 and 2003 surveys.

Eight years following cessation of disposal activities at Mound A, the recovery of the benthic community in 2003 was slower than expected. Relatively shallow RPD depths and presence of Stage I only assemblages in some 2003 replicates resulted in a median OSI of +4, lower than the Mound A OSI in 1996 (+11) and 2001 (+5), and lower than the 2003 reference area OSI (+6). However, Stage III infauna were present in at least one replicate at all stations, indicating patchy, but advancing recolonization over the mound. CCBDS lies within the *Molpadia oolitica* community of Cape Cod Bay; this relatively large Stage III species is found in low densities (2 to 6 individuals per m^2), and produces feeding voids at depths of 20 cm or more. This intermittent occurrence of *M. oolitica* makes the abundance of this species difficult to document with the relatively few SPI stations that were occupied over Mound A. A more intensive monitoring survey is recommended to monitor the apparent inhibited recovery and more fully characterize benthic recolonization status of Mound A.

Mound B was formed by the disposal of 324,000 m^3 of dredged material, placed between June 1996 and December 2000, and an additional 185,000 m^3 of dredged material placed between October 2001 and January 2002. The August 2003 survey

results indicated that Mound B was approximately 1.5 m higher than indicated in the August 2001 survey. A new mound apex was created to the southeast, forming an elongated mound with an approximate height of 5.5 m above the surrounding seafloor. The footprint of the mound had an approximate diameter of 600 m, comparable to that measured in the 2001 survey. Side slopes near the apex of Mound B were relatively steep, and it is recommended that no additional dredged material be placed in the vicinity of the peak of the mound.

The benthic community on Mound B showed recovery with Stage III assemblages present in 42% of the replicates, a mean RPD of 1.3 cm and a median OSI of +5. Benthic conditions appeared to be stressed relative to the reference conditions (Stage III assemblages in 60% of the replicates, mean RPD = 2.3 cm and median OSI=+6) eighteen months following the cessation of disposal events, however benthic recovery is consistent with expectations at this site. It is recommended that Mound B be resampled in the future to continue to monitor benthic habitat recovery.

In the August 2003 survey, Cape Cod Bay Reference Station (CCBRS) was the only reference area surveyed to provide characterization of ambient conditions. Based on the 1996, 2001 and 2003 SPI surveys at CCBRS, there was an apparent decline in ambient benthic conditions (1996 OSI = +10, 2001 OSI = +7, 2003 OSI = +6) due to shallowing RPD depths and decreasing appearance of Stage III infauna. However, sample numbers are not sufficient for a significance test of these results. A preliminary review of long-term MWRA benthic data at two stations (including one at the location of CCBRS) indicated stable benthic conditions in Cape Cod Bay over the 11-year period of record. The apparent decline in ambient benthic community could be due to analysis techniques, seasonal variations in benthic conditions, or natural variation or recovery patterns of Cape Cod Bay that differ from other disposal locations within the DAMOS program. Further study is recommended to better understand the trends observed in the SPI data at the reference area.

1.0 INTRODUCTION

A monitoring survey was conducted at the Cape Cod Bay Disposal Site in August 2003 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS). DAMOS is a comprehensive monitoring and management program designed and conducted to ensure environmental protection of open-water dredged material disposal sites throughout the New England region. An introduction to the DAMOS Program and the Cape Cod Bay Disposal Site, including a brief description of previous dredged material disposal activities and previous monitoring surveys at this site, is provided below.

Disposal site boundaries are established to provide a management area for placement of dredged material on the seafloor. Barge operators are given specific coordinates (and often visible lighted buoys) within these disposal boundaries to navigate to and release their cargo of dredged material. In practice, it is expected that disposal will occur in a cluster around these target coordinates (or buoys) and that some dredged material is lost in the water column during release. The Clean Water Act Section (404)(b)(1) provides guidelines for the discharge of dredged material and defines the "discharge point" as the point within the disposal site (including both the bottom surface area and any overlying volume of water) at which the dredged material is released. The Marine Protection, Research, and Sanctuaries Act Section 102 defines the release zone as a locus of points 100 m around the barge from beginning to end of the discharge (40 CFR Section 227.28). Monitoring objectives recognize that the site boundary is a target area for release at the water's surface, and that during descent and placement some dredged material may extend across the boundary on the seafloor.

1.1 Overview of the DAMOS Program

For over 25 years, the USACE NAE has collected and evaluated disposal site data throughout New England. Patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented based on these data. The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal activities are promptly identified and addressed (Germano et al. 1994). Monitoring surveys are designed to collect data that will allow evaluation of the environmental status of each disposal site, relative both to conditions at the site after recent disposal of dredged material and to conditions observed in nearby reference areas

unaffected by disposal activities. The results of each monitoring survey are evaluated to determine the next step in the process of managing each specific disposal site.

DAMOS monitoring surveys are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor. Typical DAMOS surveys include bathymetric measurements and sediment-profile imaging (SPI). Sequential bathymetric measurements are made to determine the location and accumulation or loss of dredged material placed at a given site. SPI surveys are performed to support evaluation of benthic habitat conditions. DAMOS monitoring surveys may also feature additional types of data collection activities, such as side-scan sonar or sediment coring, as deemed appropriate to achieve specific survey objectives. The longevity of the DAMOS Program and the periodic nature of the monitoring have resulted in a long-term record for many of the disposal sites.

1.2 Introduction to the Cape Cod Bay Disposal Site

The Cape Cod Bay Disposal Site (CCBDS) is a regional dredged material disposal site located in the waters off Massachusetts (Figure 1-1). CCBDS is situated in Cape Cod Bay, approximately 15 km southwest of Provincetown Harbor and 26 km east of Plymouth. CCBDS is defined as a 1.85 x 1.85 km area on the seafloor centered at coordinates 41° 54.406' N, 70° 13.268' W (NAD 83).

CCBDS is characterized by a relatively flat seafloor with no natural bathymetric features (Figure 1-2). The seafloor slopes gently to the northwest across the site, with water depths ranging from 28 m in the southeast corner to 31.5 m in the northwest corner (all depths relative to Mean Lower Low Water (MLLW)). Two distinct dredged material disposal mounds were identified previously in CCBDS (SAIC 2003). Mound A is located in the southeast quadrant of the site, and Mound B is located in the northeast quadrant (Figure 1-2). A less distinct dredged material mound was observed at the center of CCBDS, at the location of the historic Wellfleet Disposal Site.

1.3 Historic Dredged Material Disposal Activity

Dredged material disposal has occurred at the location of the present day CCBDS for over 30 years. The historic Wellfleet Disposal Site received dredged material in the 1970s and 1980s (Figure 1-2). During this period, an estimated total of 172,900 m^3 of dredged material was placed at the site (SAIC 2003). A steady increase in dredging volume in the harbors surrounding Cape Cod Bay led to the establishment of the Cape

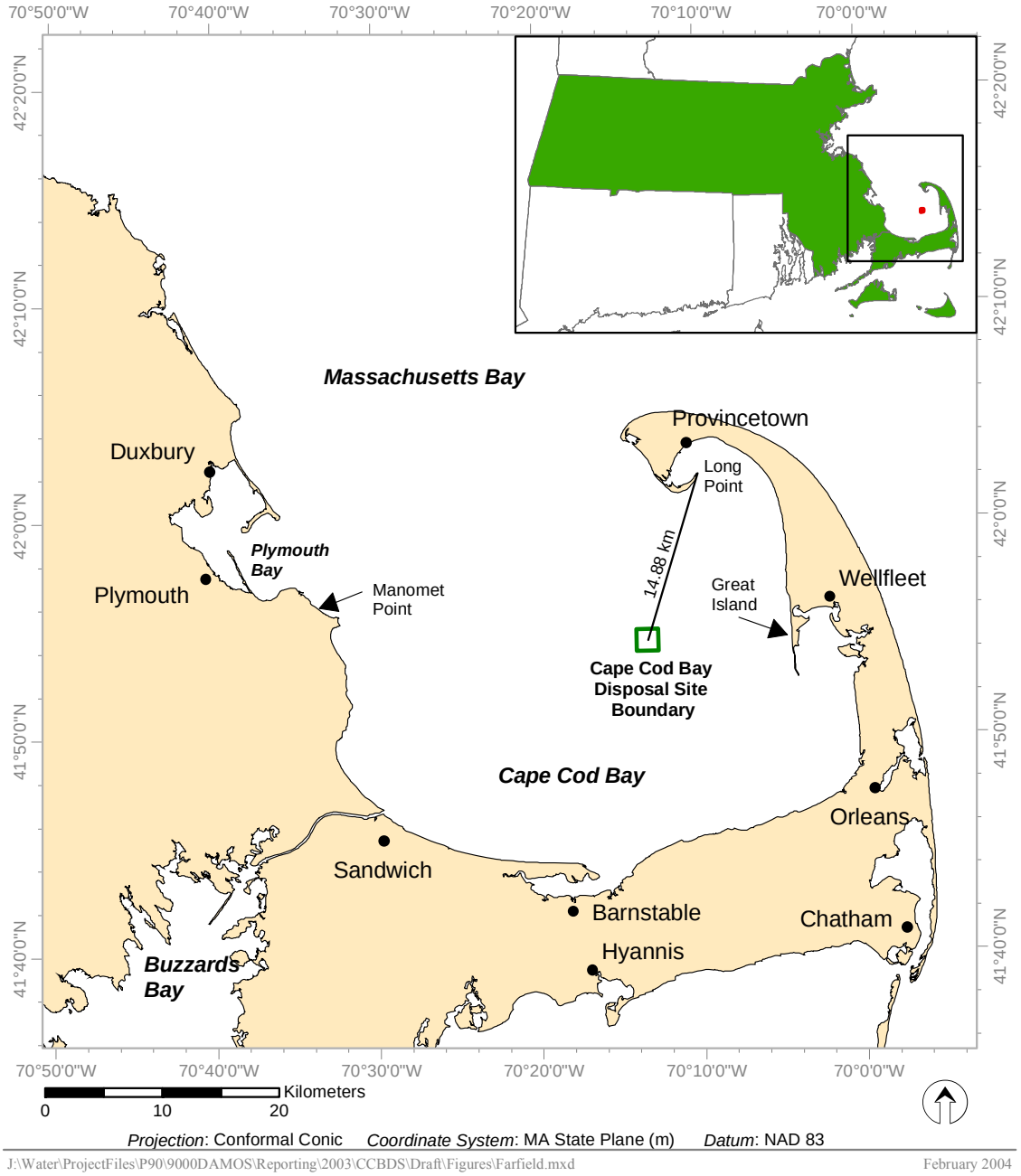


Figure 1-1. Location of the Cape Cod Bay Disposal Site

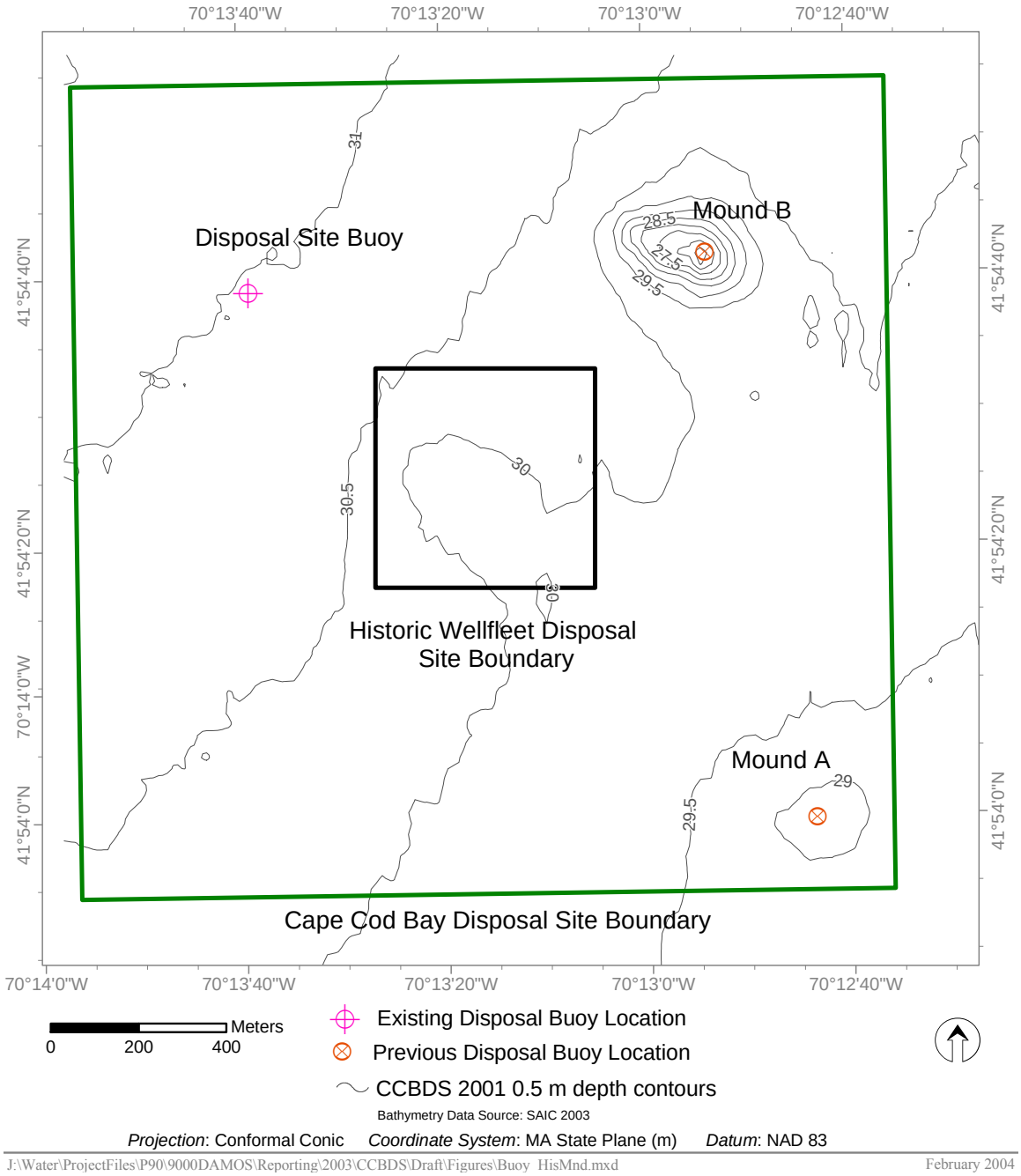


Figure 1-2. CCBDS with disposal mounds and buoys indicated

Cod Bay Disposal Site in 1990, managed jointly by the USACE NAE and the Massachusetts Department of Environmental Management (now the Department of Conservation and Recreation). Disposal activity at CCBDS did not begin until 1994. Between November 1994 and January 1995, 112,000 m^3 of fine-grained dredged material from Wellfleet Harbor was placed in the southeast quadrant of the site, forming Mound A (CR Environmental 1997). In 1996, disposal was shifted to the northeast quadrant of the site, and approximately 324,000 m^3 of dredged material was placed there between June 1996 and December 2000 forming Mound B (SAIC 2003). Sediments placed at Mound B were dredged from Wellfleet, Plymouth, Sesuit, and Duxbury Harbors.

1.4 Historic CCBDS Monitoring Events

An initial post-disposal survey, including bathymetry, side-scan sonar, and sediment-profile imaging was performed at Mound A in 1995, with the objective of delineating the areal extent and height of the disposal mound (CR Environmental 1997). A second survey was performed in May 1996 to document bathymetric and benthic habitat changes one year following cessation of disposal events. Data collected during this survey included bathymetry, side-scan sonar, and SPI. Three reference sites were included during the 1996 survey: the Cape Cod Bay Reference Site (CCBRS), the Northwest Reference Site (NW REF), and the Southwest Reference Site (SW REF) (Figure 1-3). Bathymetry and SPI surveys were conducted at CCBRS, a previously established reference site. SPI surveys were conducted at the other two sites to assess their suitability for designation as reference areas.

A third survey was performed in August 2001 to collect bathymetric data over the entire CCBDS, and SPI data over Mound A and Mound B (SAIC 2003). This survey revealed three dredged material disposal mounds, including Mounds A and B and the less defined mound at the historic Wellfleet Disposal Site. Mound A was found to have an apex 0.6 m above the seafloor, and the SPI survey found that benthic recolonization was proceeding more slowly than expected (SAIC 2003). Mound B was found to have an apex 4 m above the seafloor and a corresponding water depth of 27.5 m (MLLW). At Mound B, the benthic community was observed to be recovering as would be expected for a recently disturbed area (SAIC 2003).

1.5 Recent Dredged Material Disposal Activity

Recent disposal activity (between the previous site survey in August 2001 and the current survey in August 2003) placed approximately 193,000 m^3 of dredged material in

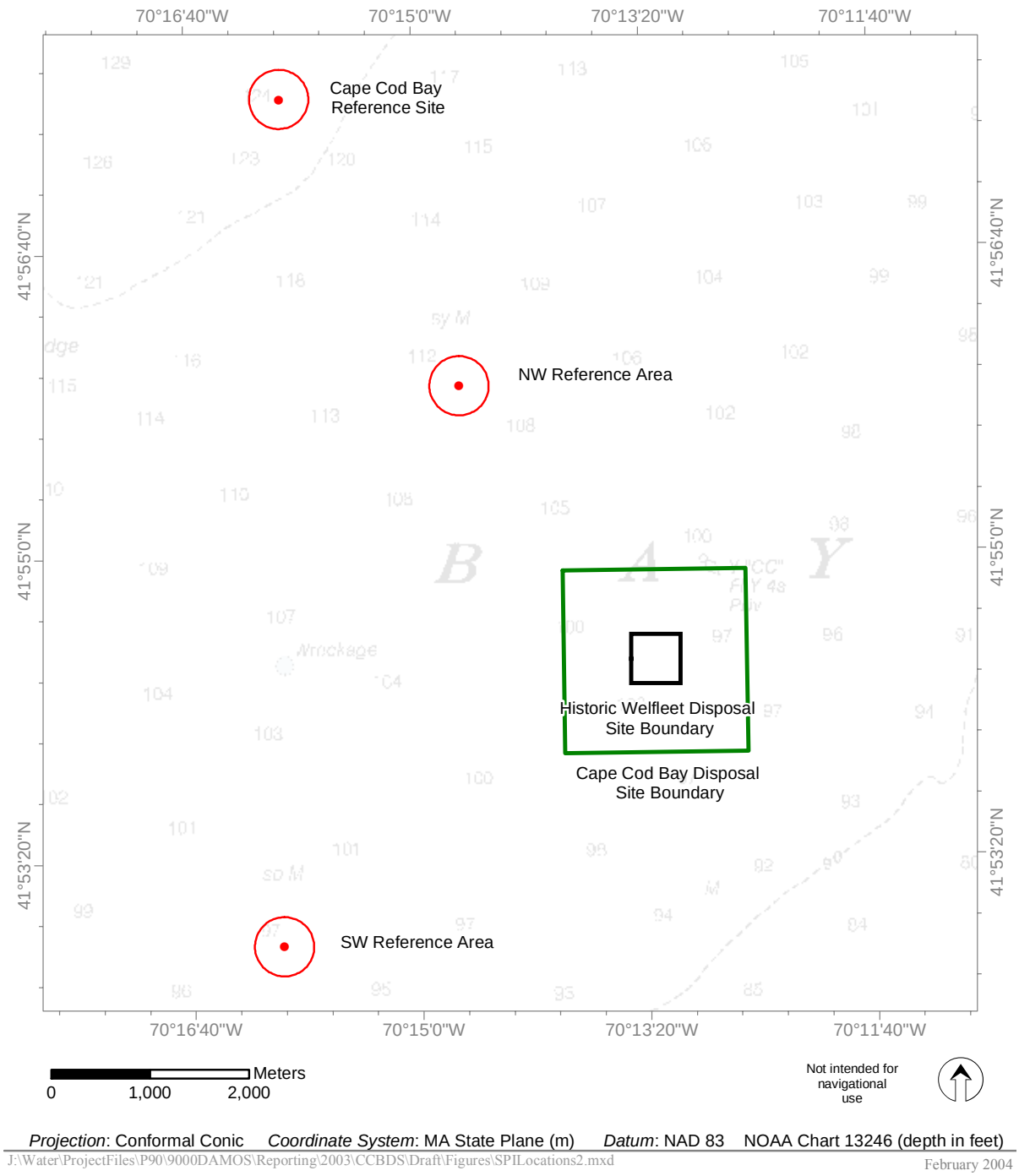


Figure 1-3. CCBDS with reference areas sampled for current and past surveys indicated

CCBDS (Figure 1-4, Table 1-1). Most of this material (185,300 m^3) was placed between October and December 2001 at Mound B in the northeast quadrant of the site. Sediment placed on Mound B was dredged from Wellfleet Harbor, Fiddlers Cove, New Bedford Yacht Club, and the Cape Cod Canal. In August 2002, the disposal marker buoy was moved into the northwest quadrant of CCBDS, where 5200 m^3 of sediment from Provincetown Harbor was placed in November 2002. Following reports of slow benthic habitat recovery (based on the August 2001 survey), the CCBDS target disposal location was shifted back to Mound A, specifically the western and southwestern portion of the mound (Figure 1-4). Only three disposal events, totaling 2600 m^3 of sediment, have occurred following this return to Mound A. It should be noted that the sediment volumes presented in Table 1-1 and Figure 1-4 are considered approximate, as they are based on estimates of the volume of material in the barges towed to the site for disposal. A complete record of recent disposal events is provided in Appendix A.

1.6 Survey Objectives

The August 2003 survey at CCBDS was designed to document changes in seafloor topography over Mounds A and B, to assess benthic recolonization status in response to recent dredged material disposal activity at Mound B, and to perform a follow-up assessment on the slower-than-expected recolonization at Mound A.

The design of the August 2003 survey allowed assessment of the following expectations:

- The size and shape of Mound A, as characterized by the footprint and height, will be similar to that measured in 2001, with little to no apparent consolidation. Small amounts of recently disposed dredged material may be detectable in the southwestern quadrant of the mound.

- Eight years after the disposal of the 112,000 m^3 of dredged material that formed Mound A, sediments at that site will support an advanced benthic community relative to the 2001 survey, with RPD depths, frequency of Stage II or III assemblages, and OSI values comparable to those of CCBRS.

- The 185,300 m^3 of sediment placed in the northeast corner of CCBDS since the August 2001 survey will result in an increase in the height and lateral dimensions of Mound B.

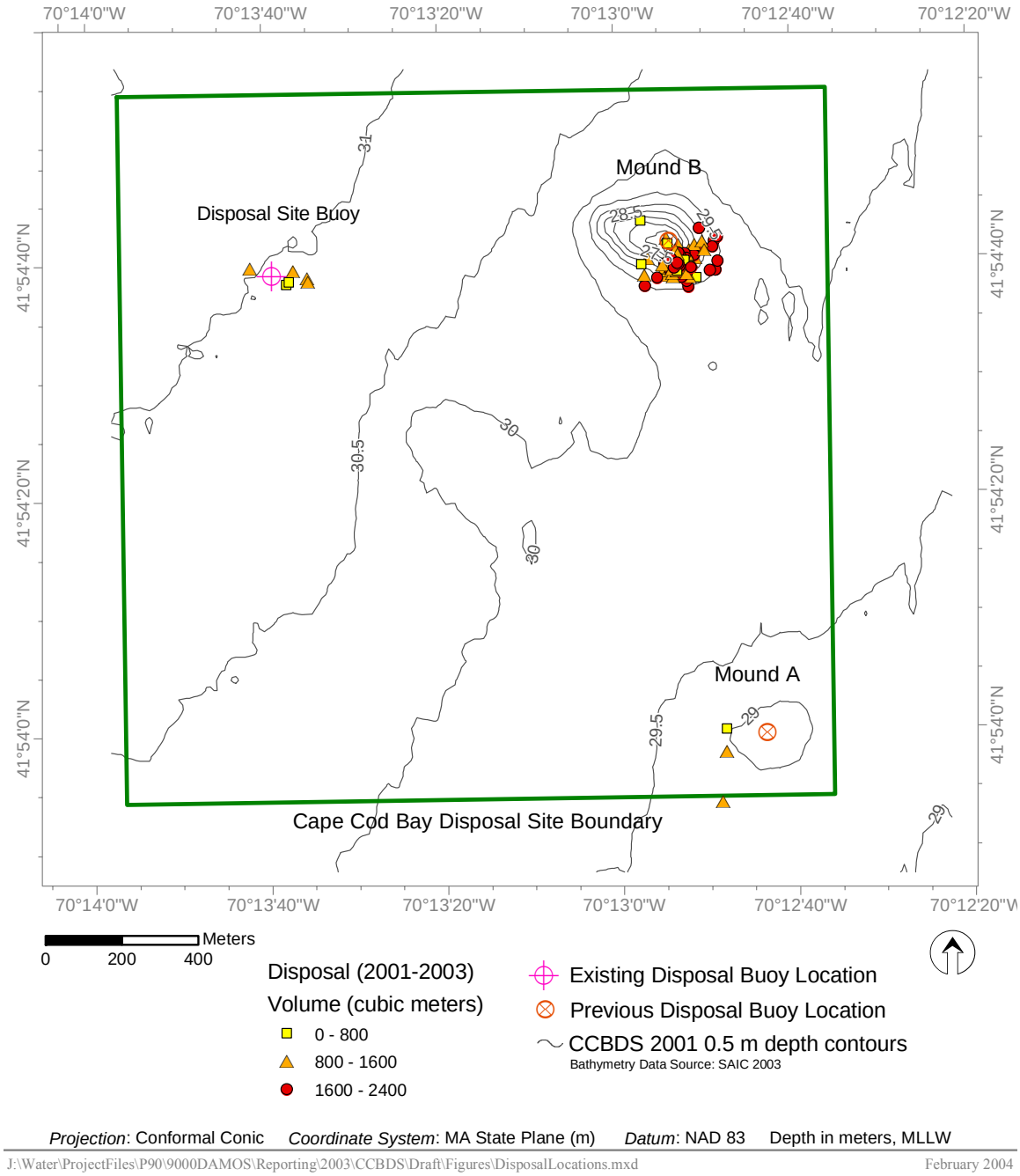


Figure 1-4. CCBDS with recent DM disposal locations indicated

Table 1-1.

Summary of Disposal Activity at CCBDS between August 2001 and August 2003

Source Project	Estimated Scow Volume Disposed (m^3)		
	Mound A	Mound B	DEM Buoy
Wellfleet Harbor		143,489	
Provincetown Harbor	2,561		5,211
Fiddlers Cove		497	
New Bedford Yacht Club		3,425	
Cape Cod Canal		37,845	
Total	2,561	185,257	5,211

- Eighteen months after disposal, sediments at Mound B will support some Stage II and Stage III communities and will display relatively deep RPD depths, with resulting OSI values indicative of only a moderate to slightly disturbed habitat relative to the CCBRS reference area.

2.0 METHODS

The August 2003 survey at the Cape Cod Bay Disposal Site (CCBDS) was performed by a team of investigators from ENSR International, CR Environmental, and R. J. Diaz & Daughters. The survey was performed 19–28 August 2003 and included bathymetry and sediment-profile imaging (SPI). Field activities are summarized in Table 2-1, and an overview of the methods used to collect survey data as well as methods used to process and analyze the data is provided below. A detailed description of methodology and related terminology can be found in ENSR (2004).

2.1 Navigation and On-Board Data Acquisition

Positional data, comprised of horizontal positioning (x- and y-dimensional data) and time (t-dimensional data), were collected using a Trimble AG 132 Differential Global Positioning System (DGPS). This system received and processed satellite and land-based beacon data and provided real-time vessel position, typically to sub-meter accuracy. Coastal Oceanographics', Inc. HYPACK® hydrographic survey software was used to acquire, integrate, and store all positional data from the DGPS as well as bathymetric and station data. The HYPACK® software also displayed real-time vessel position, bathymetric data, and SPI stations over an electronic chart of the study area, thus enabling survey scientists to review and evaluate survey data on a real-time basis.

2.2 Bathymetry

Bathymetry surveys provide measurements of water depth that, when processed, can be used to map the seafloor topography. The processed data can also be compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool in the DAMOS Program for mapping the distribution of dredged material at disposal sites.

2.2.1 Bathymetric Data Acquisition

The 2003 bathymetry survey was conducted over a 1200 x 2100 m area, representing approximately the eastern two-thirds of CCBDS (Figure 2-1). The survey area included the two primary dredged material disposal mound areas of interest, Mound A and Mound B. The bathymetry survey was conducted on 19 and 20 August 2003 aboard the *R/V Cyprinodon*. A total of 90 survey lines, each 25 m apart, were occupied

Table 2-1.

Summary of Field Activities at CCBDS in August 2003

Survey Type	Date	Summary
Bathymetry	19–20 August 2003	Area: 1200 x 2100 m Lines: 49 Spacing: 25 m
Sediment-Profile Imaging	22, 27–28 August 2003	Stations: 31 26 inside CCBDS 5 reference

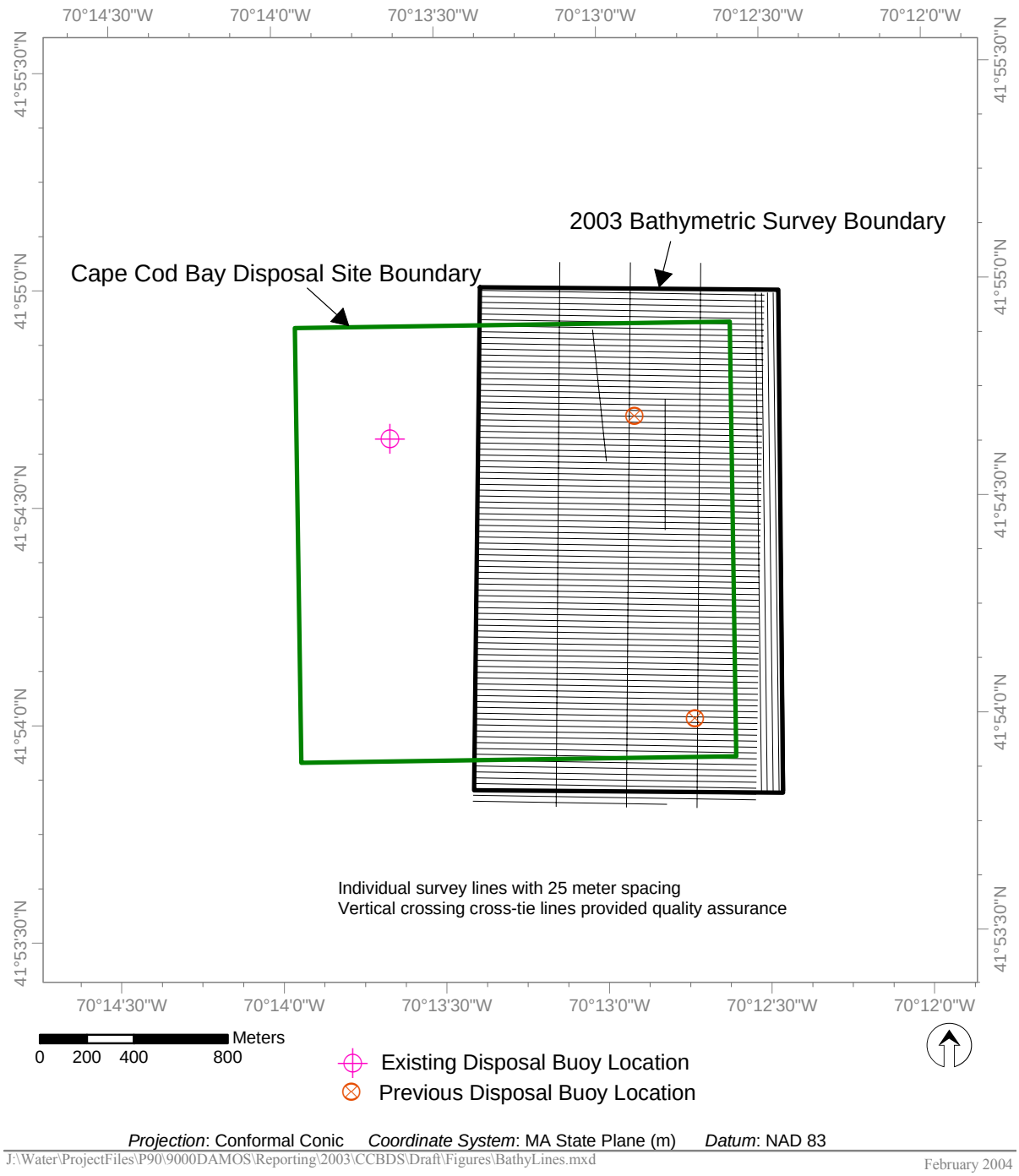


Figure 2-1. Bathymetric survey lines at CCBDS, August 2003

as part of the survey (Figure 2-1). In addition, several perpendicular cross-tie lines were occupied to assess data quality.

The bathymetry survey was conducted using an Ocean Data Equipment Corporation (ODEC) MF500 precision echo sounder outfitted with a narrow (3°) beam, 200-kHz transducer. The accuracy of this system was approximately 0.1% of the water depth, or approximately 3 cm in the waters of CCBDS. The system was calibrated at the dock prior to each survey day. In addition, local measurements of temperature and salinity were taken *in-situ* each day using a Seabird Instruments, Inc. SEACAT-19 CTD. Local tidal water level data were recorded at a project benchmark established by a MA-Registered Land Surveyor in Provincetown Harbor using a pressure transducer (InSitu, Inc. Mini-Troll®). These ancillary measurements were used to process the bathymetric data.

2.2.2 Bathymetric Data Processing

The bathymetric data were processed using the HYPACK® software program and included corrections for tidal conditions, local speed of sound, acquisition system latency, and spurious data points. Tidal correction consisted of transforming the raw measurements of depth below the transducer to seafloor elevation measurements relative to Mean Lower Low Water (MLLW) using the locally collected tidal elevation data. The speed of sound during performance of the survey was calculated from local temperature and salinity measurements and used to correct the bathymetric data. Corrections were applied for acquisition system latency to account for positional errors related to small time delays between the actual DGPS and echo sounder measurements and the digital recording. The bathymetric data were also reviewed for spurious data points (clearly unrealistic measurements resulting from signal interference), and these points were removed.

2.2.3 Bathymetric Data Analysis

Bathymetric data were analyzed to gain a better understanding of the existing conditions at the site and for comparison with previous surveys to document changes in seafloor topography. For this survey, the corrected bathymetric data were analyzed using a combination of the contouring and surface plotting software program, Surfer® 8.0 and the GIS-based software package ArcView® 8.3. Using Surfer®, the processed CCBDS 2003 data were gridded to a cell size of 25 m^2, consistent with the bathymetric grid

created for the previous (August 2001) survey (SAIC 2003). Once gridded, bathymetric contour lines were displayed using ArcView®.

Surfer® was also used to calculate a depth difference grid based on the August 2001 and the September 2003 bathymetric data sets. This grid was calculated by subtracting interpolated depth estimates of September 2003 from the August 2001 depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcView®.

2.3 Sediment-Profile Imaging

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves an underwater frame/camera system that can photograph a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites.

2.3.1 SPI Data Acquisition

The 2003 SPI survey design included 31 stations: 26 stations within CCBDS and five at CCBRS (Table 2-2, Figure 2-2). At Mound A, 13 stations corresponding to the stations sampled during the August 2001 survey (SAIC 2003) were sampled along two transects in a cross-shaped pattern (Figure 2-2). Thirteen stations along two transects in a cross pattern were also sampled at Mound B. Station locations at Mound B differed from the August 2001 locations because the spacing between stations was increased to better capture the expected enlarged footprint. CCBRS, located approximately 6 km to the northwest of the site, was sampled to provide a basis of comparison between CCBDS sediment conditions and the ambient sediment conditions in Cape Cod Bay. Five reference stations were selected randomly within a 300-m radius of the center of CCBRS (Table 2-2, Figure 2-2).

The SPI survey was initiated on 22 August 2003 aboard the *R/V Cyprinodon* and, after a weather delay, was completed on 27–28 August 2003 aboard the *F/V Christopher Andrew*. At each station, the vessel was positioned at the target coordinates and the three replicates were collected within a defined station tolerance of 10 m. Three replicate

Table 2-2.

CCBDS Sediment-Profile Image Sampling Locations, August, 2003

Area	Station	Latitude (N)	Longitude (W)	Area	Station	Latitude (N)	Longitude (W)
Mound A	ACTR	41° 53.977'	70° 12.691'	Reference	REF1	41° 57.625'	70° 16.001'
	A110N	41° 54.031'	70° 12.690'		REF2	41° 57.574'	70° 15.807'
	A200N	41° 54.085'	70° 12.688'		REF3	41° 57.505'	70° 15.881'
	A300N	41° 54.141'	70° 12.688'		REF4	41° 57.424'	70° 15.897'
	A100E	41° 53.978'	70° 12.619'		REF5	41° 57.399'	70° 16.085'
	A200E	41° 53.976'	70° 12.546'				
	A300E	41° 53.975'	70° 12.474'				
	A100S	41° 53.923'	70° 12.692'				
	A200S	41° 53.869'	70° 12.693'				
	A300S	41° 53.816'	70° 12.694'				
	A100W	41° 53.978'	70° 12.763'				
	A200W	41° 53.980'	70° 12.835'				
	A300W	41° 53.981'	70° 12.907'				
Mound B	BCTR	41° 54.685'	70° 12.899'				
	B140N	41° 54.760'	70° 12.899'				
	B280N	41° 54.836'	70° 12.896'				
	B420N	41° 54.911'	70° 12.895'				
	B140S	41° 54.609'	70° 12.901'				
	B280S	41° 54.533'	70° 12.903'				
	B420S	41° 54.458'	70° 12.904'				
	B140E	41° 54.683'	70° 12.798'				
	B280E	41° 54.682'	70° 12.697'				
	B420E	41° 54.681'	70° 12.596'				
	B140W	41° 54.686'	70° 13.001'				
	B280W	41° 54.687'	70° 13.102'				
	B420W	41° 54.688'	70° 13.203'				

Note: All coordinates NAD83.

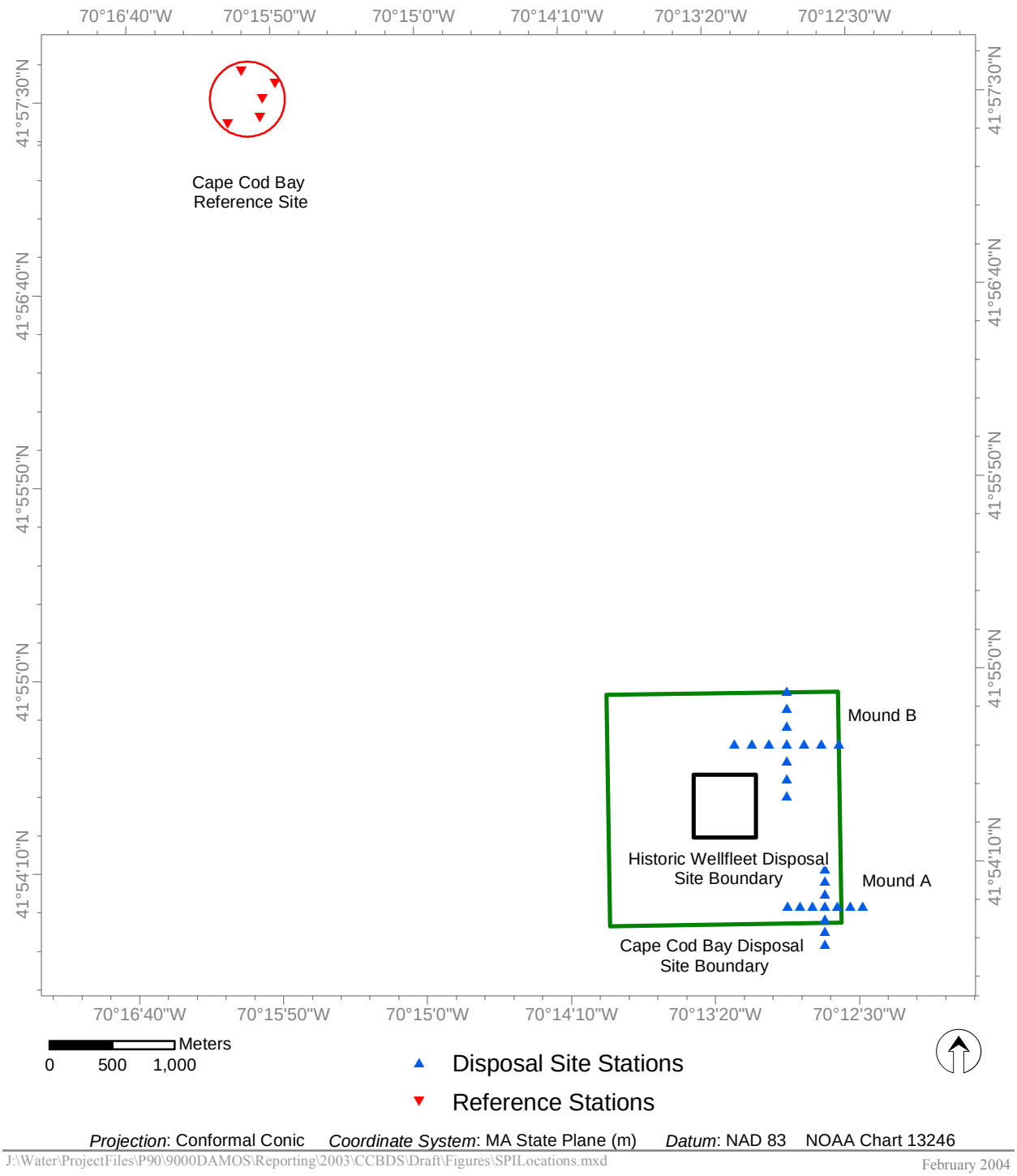


Figure 2-2. SPI sampling stations at CCBDS, August 2003

sediment-profile images were collected at each of the 31 stations for characterization of small-scale variability.

A modified Hulcher SPI system outfitted with a Minolta Dimage 7i, 5.2-megapixal digital camera was used for this survey. Digital images were recorded to a microdrive unit. The camera was equipped with a top-side video feed to allow observation of the sediment profile in real time to ensure satisfactory quality of the captured images. In addition, an underwater video camera was attached to the frame and connected to the surface via the video feed, thus providing a plan view of the seafloor in real time to assist with camera placement. This video signal was recorded on 8-mm videotape.

2.3.2 SPI Data Analysis

Computer-aided analysis of each SPI image provided measurement of the following standard set of parameters:

Sediment Type—The sediment grain size major mode and range were estimated visually from the images using a grain-size comparator at a similar scale. Results were reported using the phi scale; a conversion to other grain size scales is provided in Appendix B. The presence and thickness of disposed dredged material was also assessed by inspection of the images.

Penetration Depth—The depth to which the camera penetrates into the seafloor was measured to provide an indication of the sediment density or bearing capacity.

Surface Boundary Roughness—Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Computer image-analysis software was used to calculate the roughness measure. Analysis also included interpretation of the source (biological or physical) of the roughness.

Apparent Redox Potential Discontinuity (RPD) Depth—RPD provides a measure of the oxygen conditions within sediment pore waters. The RPD depth was measured by assessing color and reflectance boundaries within the images.

Infaunal Successional Stage—Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this

sequence has been divided subjectively into three stages (Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing what types of species or organism-related activities were apparent in the images.

Organism-Sediment Index (OSI)—OSI is a summary parameter incorporating the apparent mean RPD depth, successional stage, and presence of methane or low oxygen. This index is a convenient summary statistic to map disturbance gradients in benthic habitats (Revelas et at. 1987; Table 2-3).

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping individual values.

Table 2-3.

Calculation of the SPI Organism-Sediment Index (OSI)

Parameter	Index Value
A. Mean RPD Depth (choose one)	
0.00 cm	0
0.01 – 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)	
Azoic	-4
Stage I	1
Stage I – II	2
Stage II	3
Stage II – III	4
Stage III	5
Stage I on III	5
Stage II on III	5
C. Chemical Parameters (choose all that apply)	
Methane Present	-2
No/Low Dissolved Oxygen	-4
Organism-Sediment Index (OSI) = Total of above indices (A+B+C)	
Range of possible OSI values is -10 to +11	

3.0 RESULTS

3.1 Bathymetry

3.1.1 Existing Bathymetry

The August 2003 bathymetric survey results for CCBDS were consistent with earlier survey results, showing a relatively flat seafloor with no significant natural bathymetric features (Figure 3-1). Three disposal mounds were evident (Figure 3-1): two distinct dredged material disposal mounds (Mound A and Mound B, discussed below) and the less distinct mound at the location of the historic Wellfleet Disposal Site. The historic mound rose approximately 0.5 m above the surrounding seafloor with a very gradual slope. The natural seafloor sloped gently from the southeast to the northwest across the survey area, with depths ranging from approximately 29 m in the southeast to 30.5 m in the northwest portion of the survey area (Figure 3-1, note that all depths are reported as MLLW).

Mound A

Mound A is located in the southeast quadrant of CCBDS (Figure 3-1). It is the older of the two distinct disposal mounds, formed primarily from disposals occurring between November 1994 and January 1995 (SAIC 2003). Mound A was generally conical in shape, with an approximate base diameter of 450 m. The minimum water depth on the apex of the mound was 28.2 m and surrounding water depths averaged 29.2 m, indicating the maximum observed mound height was approximately 1 m above the surrounding seafloor. Mound A appeared relatively flat and stable, with an approximate side slope of $<0.6^{o}$ (grade of $<1\%$).

Mound B

Mound B is located in the northeast quadrant of CCBDS (Figure 3-2). The minimum water depth at the apex of Mound B was approximately 24.5 m, while surrounding water depths averaged 30 m, indicating a maximum observed mound height of approximately 5.5 m above the surrounding seafloor. Mound B was well defined with an elongated shape, extending along a northwest-southeast axis. The base of the mound measured approximately 560 m along the long axis by 375 m along the short axis. At its steepest point, along the upper eastern and southern sides, the face slope was

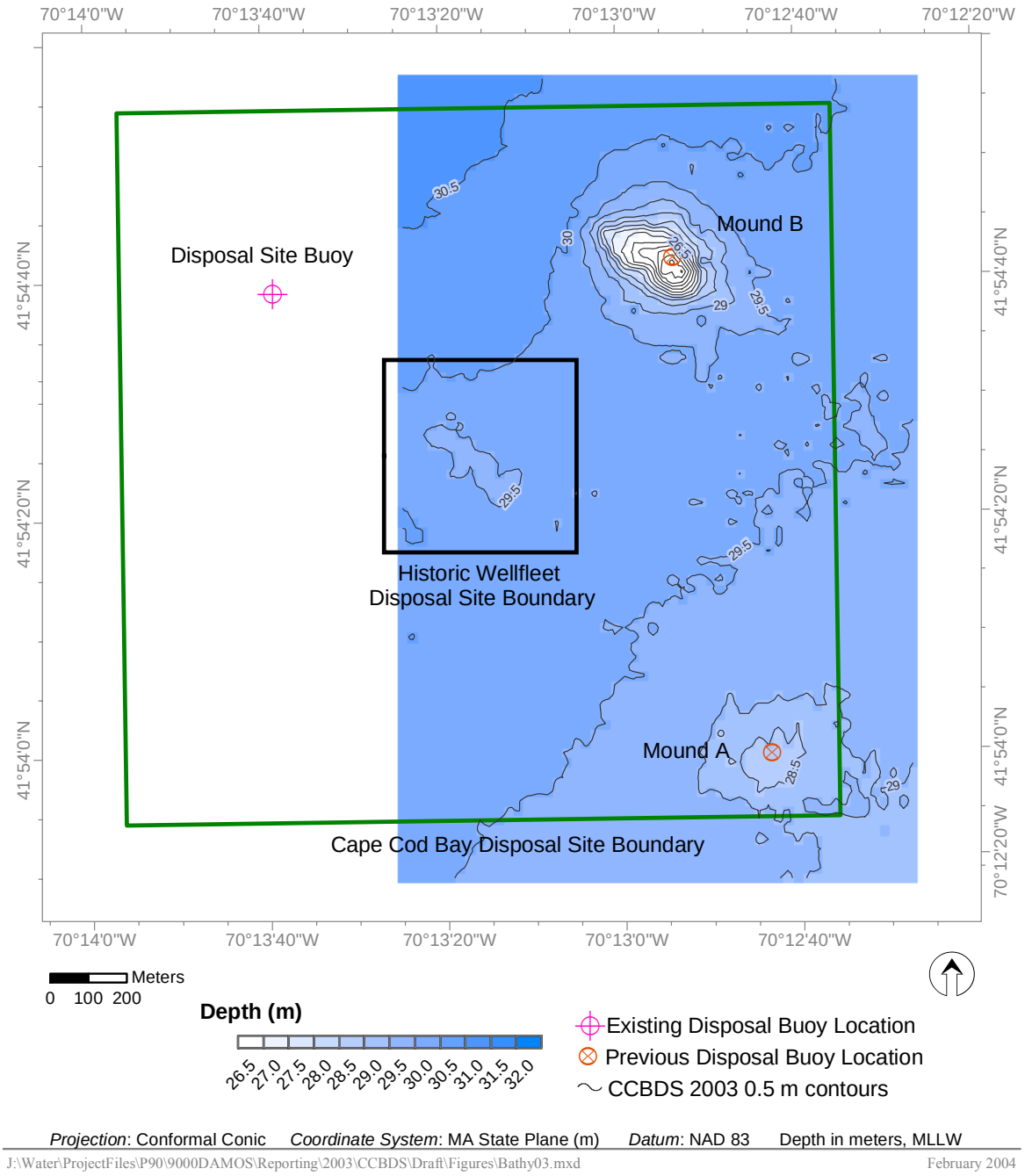


Figure 3-1. Bathymetric contour map of CCBDS survey area, August 2003 (0.5-m contour intervals)

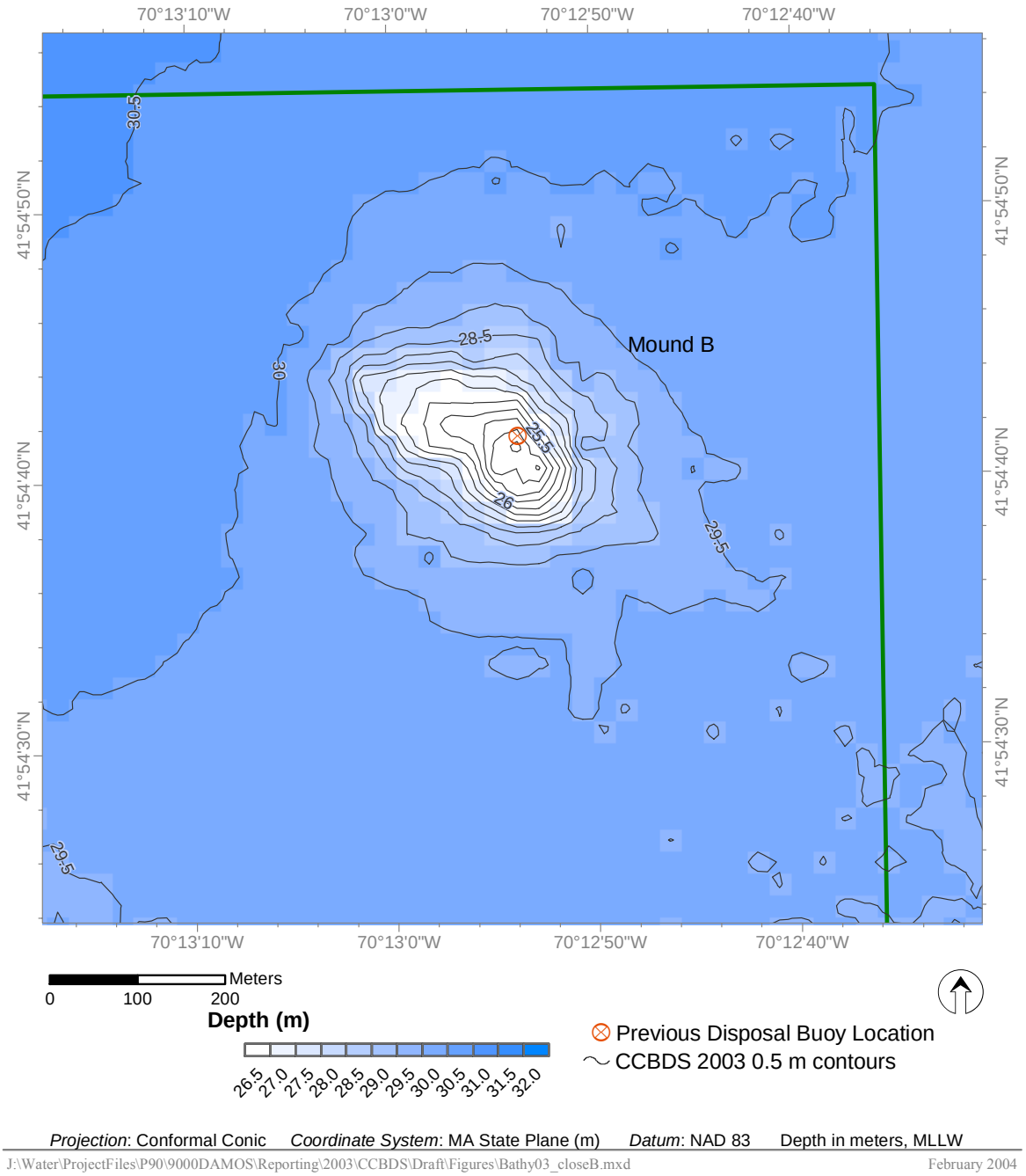


Figure 3-2. Bathymetric contour map of Mound B at CCBDS, August 2003 (0.5-m contour intervals)

approximately 5° (grade of 8%). The slopes of the northern and western faces were much shallower, ranging from 1° to 2.5° (grades of 2% to 4.5%).

3.1.2 Comparison with Previous Bathymetry

The bathymetric contour map developed from the 2001 survey data (SAIC 2003) revealed bathymetric features similar to those found in 2003, including a gently sloping seafloor, distinct Mounds A and B, and a less distinct mound in the center at the location of the historic Wellfleet Disposal Site (Figure 3-3).

The most obvious difference between the 2001 and 2003 surveys was the continued development of Mound B in the northeast quadrant of the site (Figure 3-4). Mound B increased in total height approximately 1.5 m between 2001 and 2003, with a 4 m height increase observed along the flank of the original mound (Figure 3-5). A new apex of the mound was created to the southeast, resulting in a more elongated shape than in the 2001 survey.

At Mound A, the depth difference comparison revealed a small area of decreased water depth on the western side of the mound in the area where limited disposal had occurred since the previous survey. Other features that appeared in the depth difference map were probably small-scale survey artifacts, rather than actual bathymetric differences between the two surveys. These apparent depth differences are attributed to small differences in the track lines between the surveys as well as differences in bathymetric data processing methodology (e.g., the application of tidal correction data and/or data interpolation methodology).

3.2 Sediment-Profile Imaging

Three replicate SPI images were obtained and analyzed at each of the 31 sampling locations (13 at Mound A, 13 at Mound B, and five at the CCBRS). The SPI survey results were used to assess the distribution of dredged material and to evaluate the recovery and status of the benthic infaunal community. Summaries for the reference area are presented in Section 3.2.1 below, followed by results for Mound A and Mound B in Sections 3.2.2 and 3.2.3, respectively. Section 3.2.4 provides a comparison of conditions at the mounds with ambient reference. Complete results are presented in Appendix B.

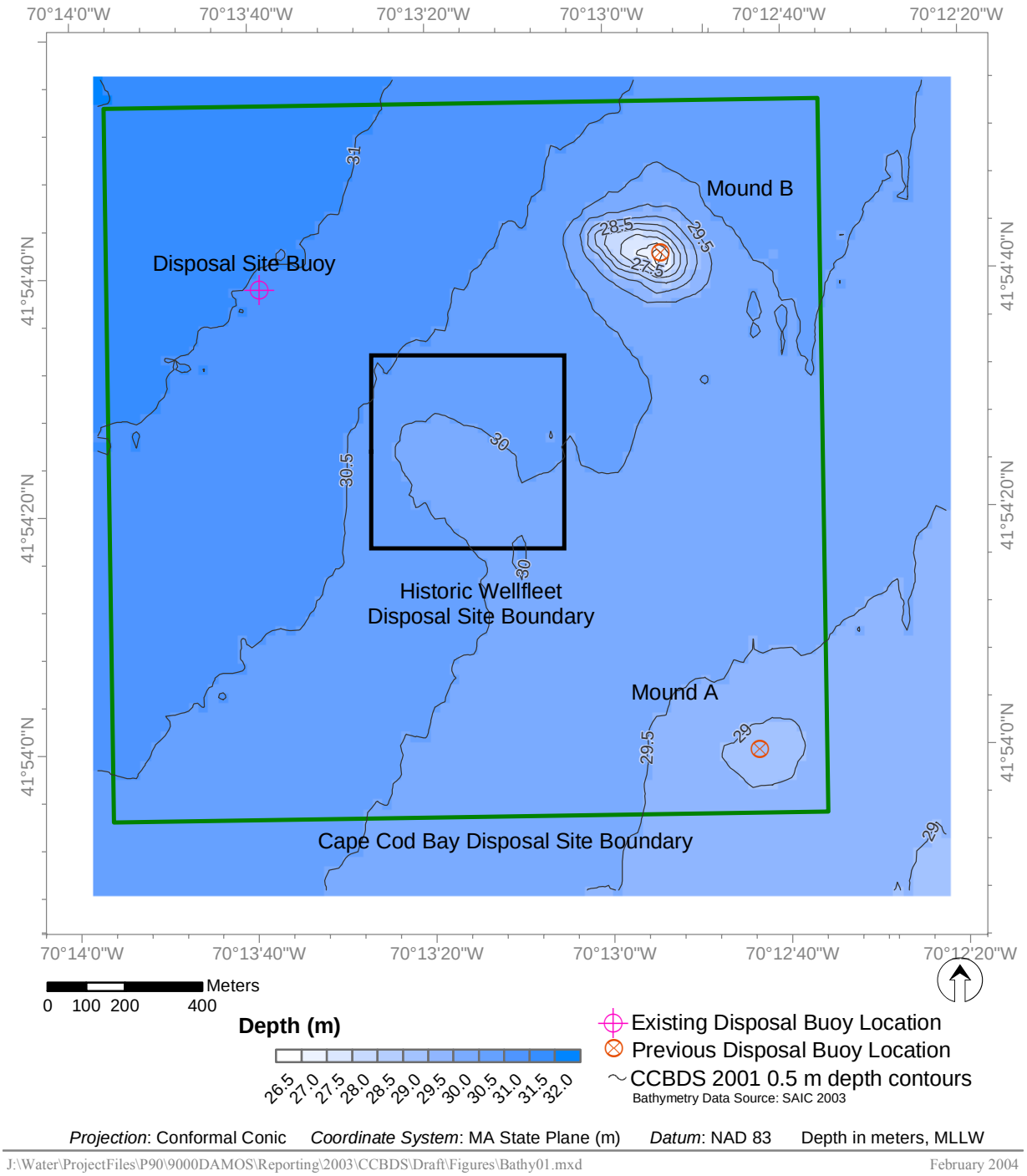


Figure 3-3. Bathymetric contour map of CCBDS, August 2001 (0.5-m contour intervals)

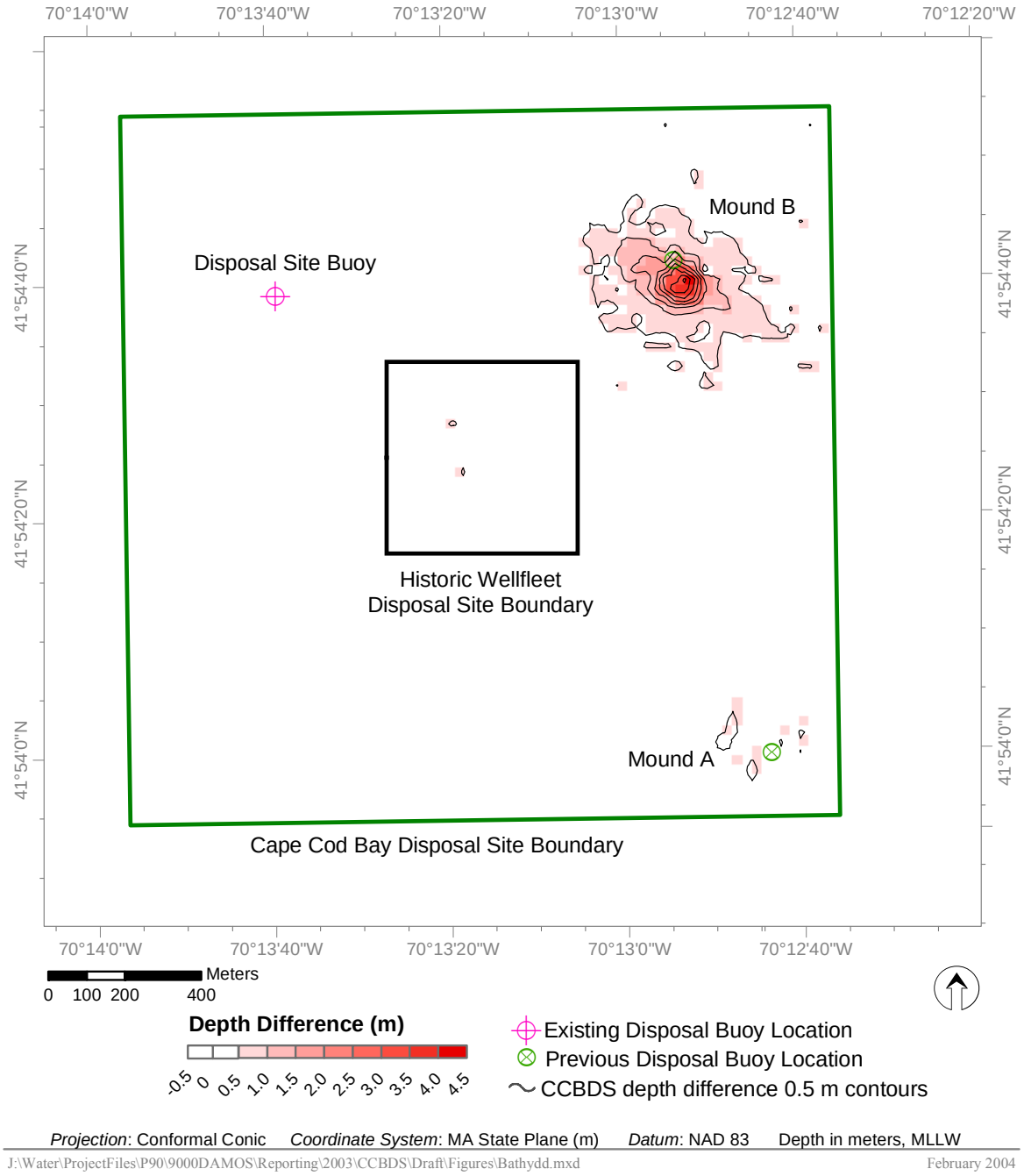
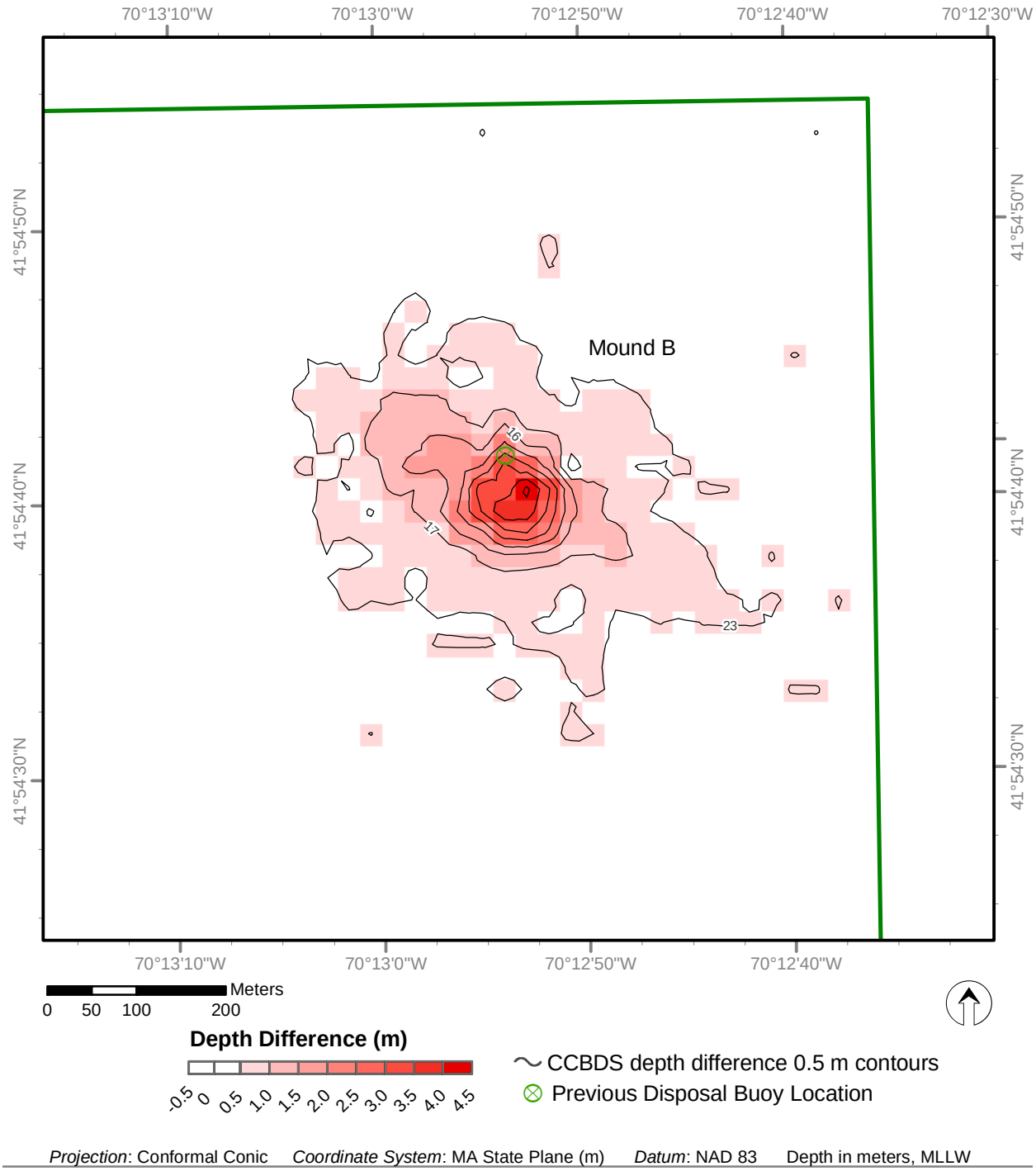


Figure 3-4. Depth difference contour map of CCBDS: August 2001 vs. August 2003 survey results (0.5-m contour intervals)



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83 Depth in meters, MLLW

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Figure 3-5. Depth difference contour map of Mound B at CCBDS: August 2001 vs. August 2003 survey results (0.5-m contour intervals)

3.2.1 Cape Cod Bay Reference Site

Sediment Physical Characteristics

Surface sediments at the Cape Cod Bay Reference Site (CCBRS) were silt/clay muds with a grain size major mode at each station >4 phi (Table 3-1). No dredged material was detected in SPI images from any of the reference stations. A typical replicate image from Station REF4 showing high-reflectance silt/clay sediment is presented in Figure 3-6. The mean camera prism penetration depth at CCBRS was 15 cm, and the mean boundary roughness, which was related to biological processing of the surface, was 1.4 cm.

Biological Conditions and Benthic Recolonization Status

The reference area was dominated by advanced successional states consisting of Stage I on III and Stage II–III infauna (Table 3-1, Figure 3-7). Six replicates (40%) showed no evidence of subsurface feeding voids. The implications of this finding are discussed in Section 4.1 below.

Observed RPD depths were fairly well developed; mean apparent RPD depths ranged from 1.2 to 2.8 cm and averaged 2.3 cm. (Table 3-1). Mean RPD depths were greater than 2.0 cm at four of the five CCBRS stations (Figure 3-8). Median OSI values were ≥ +6 at four of the five reference stations (Figure 3-9); the lowest median OSI (+5) was found at REF1 (Table 3-1). The median OSI values ranged from +5 to +9, which is indicative of a mosaic of moderately disturbed and undisturbed benthic habitats.

Comparison with Previous Surveys

A comparison of SPI results for the stations located in CCBRS indicates that the decline in benthic biological conditions identified between the 1996 and 2001 surveys has persisted to the 2003 survey (Table 3-2). In the 1996 survey, the mean RPD depth was 4.2 cm, compared with 1.9 cm in 2001 and 2.3 cm in 2003. In the 1996 survey, nearly all (97%) of the reference area replicates had evidence of Stage III infauna. In later surveys, the percentage of replicates with evidence of Stage III infauna was 92% (2001) and 60% (2003). The median OSI was +10 in 1996, compared with values of +7 and +6 in 2001 and 2003, respectively. The decline in OSI values from 1996 to 2001 was primarily due to decreased RPD depths, whereas the decline from 2001 to 2003 was due to a decline in Stage III assemblages.

Table 3-1.

Summary of SPI Results for CCBDS Reference Stations, August 2003

Area	Station	MEAN PRISM Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	SUCCESSIONAL STAGES PRESENT (no. of replicates)	Median OSI
Reference	REF 1	13.9	>4	2.5	Stage I-II (1), Stage I (1), Stage I on III (1)	5
	REF 2	14.8	>4	2.7	Stage I-II (2), Stage II on III (1)	6
	REF 3	14.7	>4	1.2	Stage I on III (1), Stage II on III (1), Stage I-II (1)	6
	REF 4	15.6	>4	2.4	Stage I on III (2), Stage I-II (1)	9
	REF 5	16.8	>4	2.8	Stage I on III (3)	9
Average		15.2		2.3		NA
Median		NA		NA		6
Minimum		13.9		1.2		5
Maximum		16.8		2.8		9

NA: Not applicable

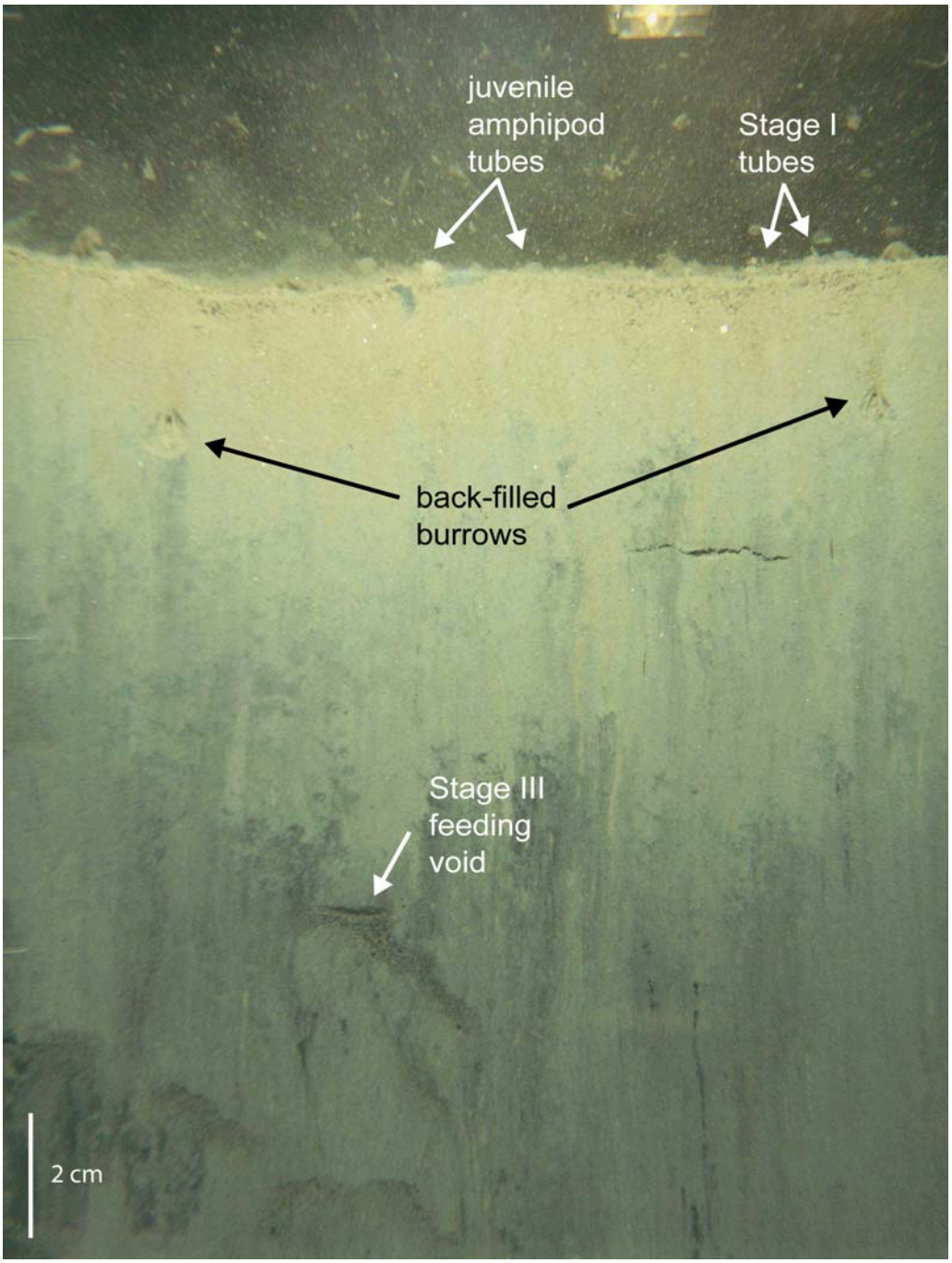


Figure 3-6. SPI image from Station REF4-1 showing a few amphipod tubes on the sediment surface, two backfilled burrows, and an active Stage III feeding void. Mean RPD depth 2.3 cm; Stage I on III; OSI = 9. Image width is 16 cm.

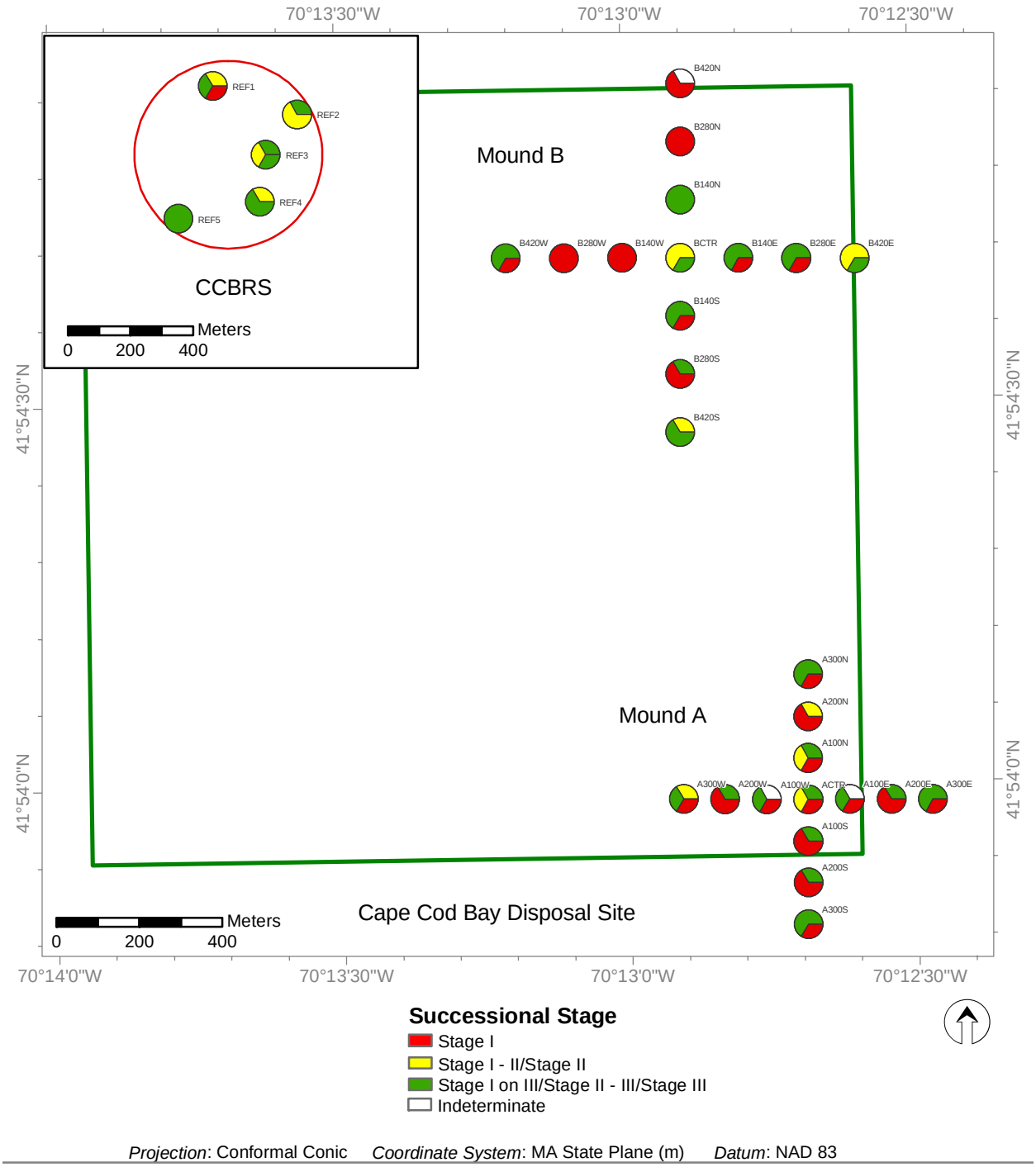
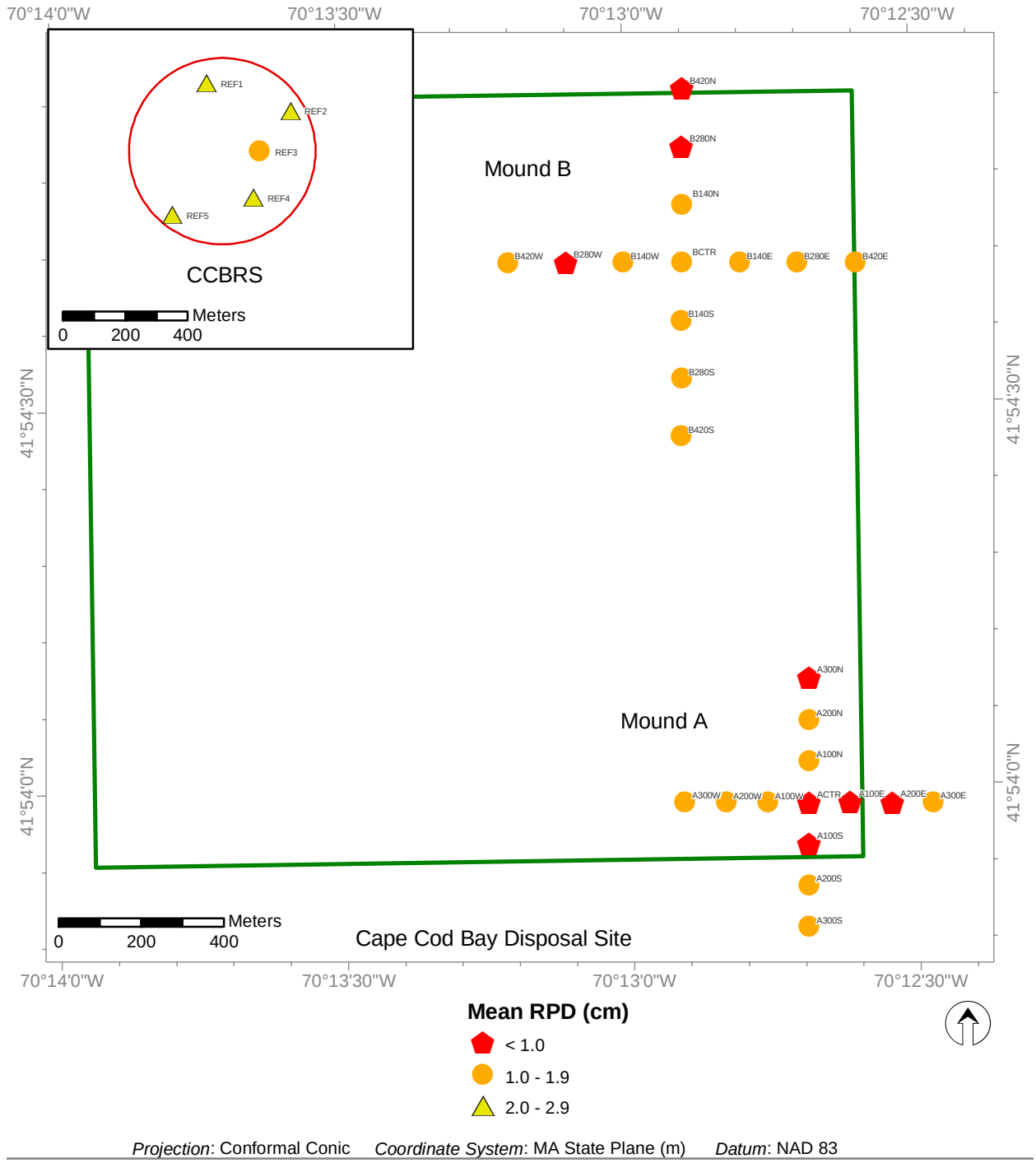


Figure 3-7. Infaunal successional stages at CCBDS and CCBRS, August 2003



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83

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Figure 3-8. Mean RPD depths at CCBDS and CCBRS, August 2003

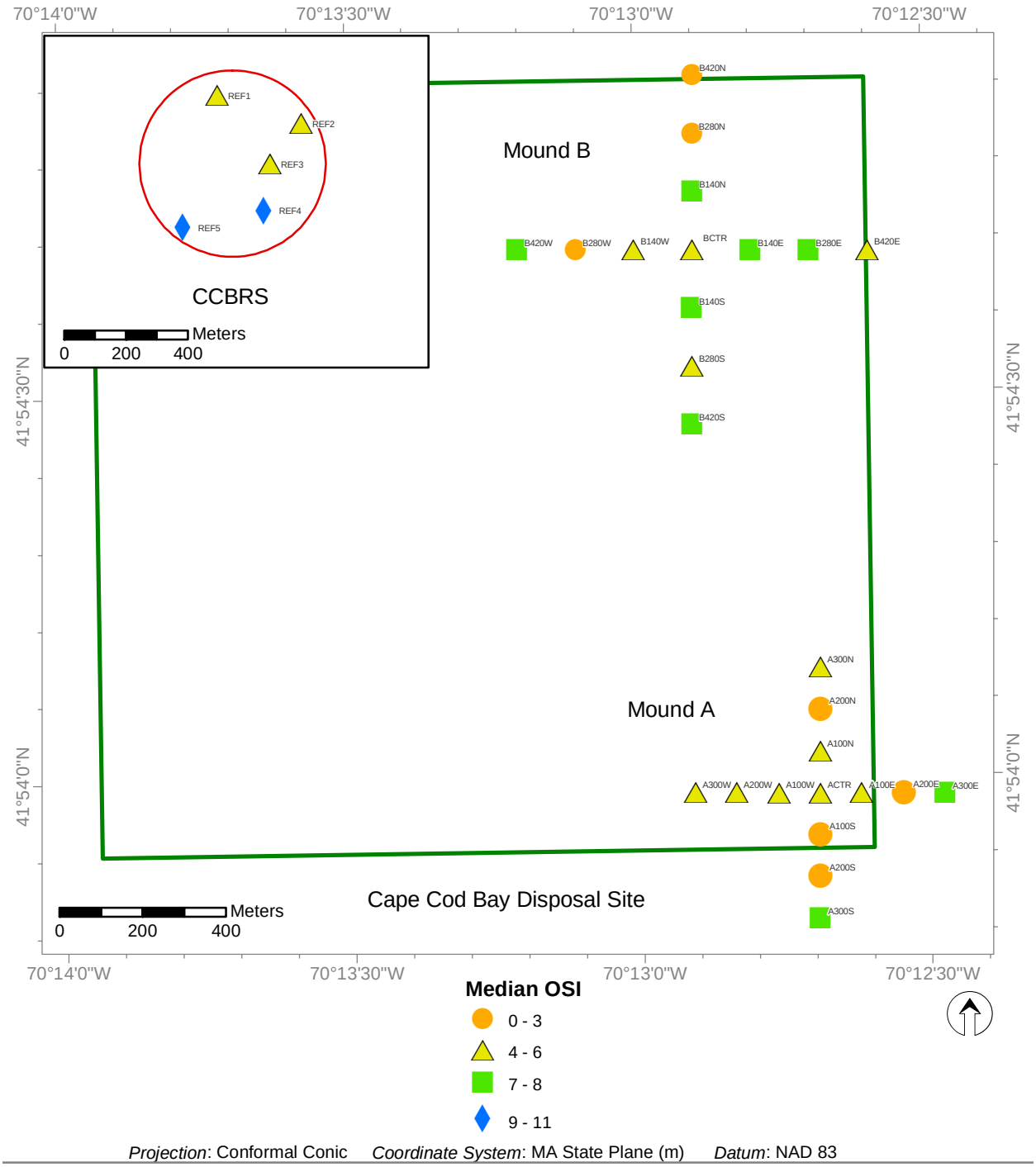


Figure 3-9. Median OSI values at CCBDS and CCBRS, August 2003

Table 3-2.

Comparison of 1996, 2001, and 2003 Sediment Biological Conditions at CCBDS and CCBRS

Area	Year	Mean RPD, in cm (range)	Percentage of Replicate Images with Stage III	Median OSI (range)
CCBRS	1996	4.2 (1.7–7.5)	97	+10 (+5.5 to +11)
	2001	1.9 (0.8–3.1)	92	+7 (+6 to +9)
	2003	2.3 (1.2–2.8)	60	+6 (+5 to +9)
CCBDS Mound A	1996	5.5 (3.1–8.4)	67	+11 (+5 to +11)
	2001	1.9 (0.6–3.0)	31	+5 (+2 to +8.5)
	2003	1.2 (0.7–1.8)	41	+4 (+2 to +8)
CCBDS Mound B	2001	2.2 (1.4–3.7)	52	+6.5 (+3 to +9)
	2003	1.3 (0.3–1.8)	42	+5 (+1.5 to +8)

3.2.2 Mound A

Dredged Material Distribution and Sediment Physical Characteristics

Dredged material thickness was greater than the penetration depth of the camera prism at all Mound A stations except A300E, one replicate at A300W, and two replicates at A300S (Table 3-3, Figure 3-10). At A300E, only ambient sediments were observed, with no indication of dredged material. Stations A300W and A300S displayed a patchy distribution of dredged material, with images showing either ambient sediment or dredged material to below the penetration depth of the camera. Two stations also showed a relatively new layer of dredged material overlaying older dredged material: two replicates each at A300W (13.6 cm over older dredged material, Figure 3-11) and A200S (14.2 cm over older dredged material).

Most of the dredged material at Mound A consisted of silt/clay (>4 phi) occasionally mixed or layered with sand. Dark pieces of fibrous woody tissue (lignin) were observed in 17 replicates (Figure 3-12, Station A200W). Wood fibers are commonly encountered in sediments dredged from nearshore channels and harbors, particularly when they are located downstream from historical or active wood processing facilities. Mound A sediments were relatively soft, with a mean camera penetration depth of about 17 cm. The mean boundary roughness was 1.6 cm. The source of this boundary roughness was evenly divided between physical and biological processes.

Biological Conditions and Benthic Recolonization Status

Mean apparent RPD depths were fairly shallow, ranging from 0.7 to 1.8 cm (Table 3-3, Figure 3-13), with a mean of 1.2 cm. Stations with RPD depths less than 1 cm were generally concentrated near the center of the mound (ACTR, A100E, A200E, and A100S) and at one station at the northern edge of the sampling transect (A300N).

A mosaic of successional stages was observed at Mound A (Figure 3-14), suggesting a patchily disturbed benthic environment. Stage III successional fauna were found in at least one replicate at all but one station (A200N), indicating that head-down deposit-feeding taxa were broadly re-established and community recovery was occurring. However, Stage I conditions (i.e., presence of Stage I fauna, absence of Stage II and III) were found in at least one replicate at every station, indicating recent or persistent disturbance. Within-station variability was generally large: at three stations, three

Table 3-3.

Summary of 2003 SPI Results for CCBDS Mound A Stations

Station	Mean Prism Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	Successional STAGES PRESENT (no. of replicates)	Median OSI	Mean Total DM Thickness (cm)
A100E	14.6	>4	0.9	Stage I on III (1), Stage I (1), IND (1)	4.5	>14.59
A100N	19.4	>4	1.8	Stage I (1), Stage II (1), Stage II on III (1)	5	>19.39
A100S	16.8	>4	0.9	Stage I (2), Stage I on III (1)	2	>16.81
A100W	18.7	>4	1.3	IND (1), Stage II on III (1), Stage I (1)	5.5	>18.65
A200E	15.6	>4	0.9	Stage I (2), Stage 1 on III (1)	2	>15.63
A200N	18.0	>4	1.6	Stage I (2), Stage I-II (1)	3	>18.04
A200S	16.5	>4	1.3	Stage I (2), Stage I on III (1)	3	>16.46
A200W	18.9	>4	1.5	Stage I (2), Stage I on III (1)	4	>18.9
A300E	16.8	>4	1.8	Stage I on III (2), Stage I (1)	8	Ambient
A300N	17.8	>4	0.7	Stage I on III (2), Stage I (1)	4	17.75
A300S	15.7	>4	1.3	Stage I on III (2), Stage I (1)	7	Ambient
A300W	15.6	>4	1.2	Stage I (1), Stage I on III (1), Stage I-II (1)	4	>15.1
ACTR	17.1	>4	0.8	Stage I (1), Stage II (1), Stage II on III (1)	5	>17.08
Mean	16.9		1.2		NA	
Median	NA		NA		4	
Minimum	13.9		0.7		2	
Maximum	19.8		1.8		8	

DM: Dredged Material. NA: Not Applicable

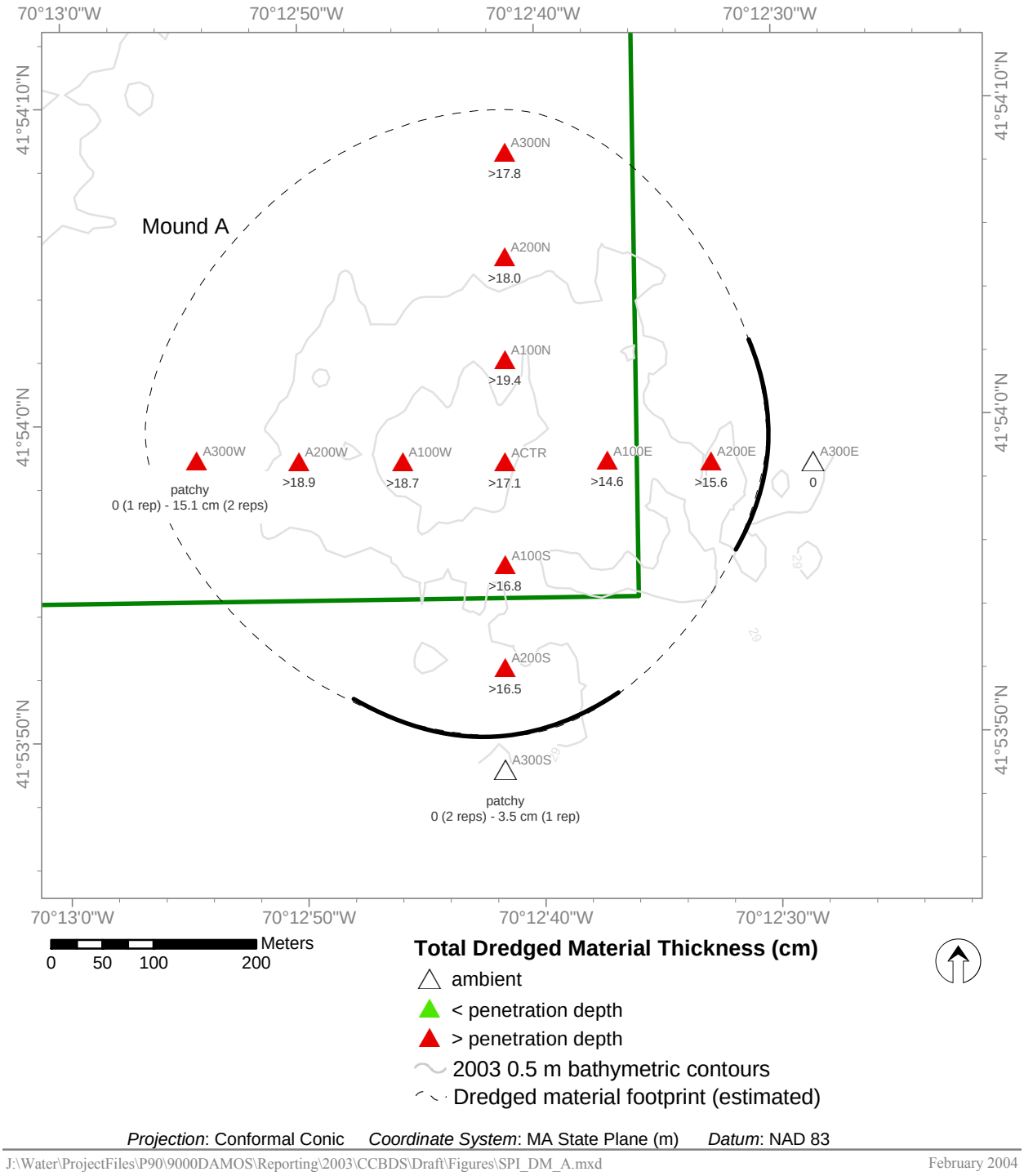


Figure 3-10. Total dredged material thickness at Mound A, CCBDS, August 2003

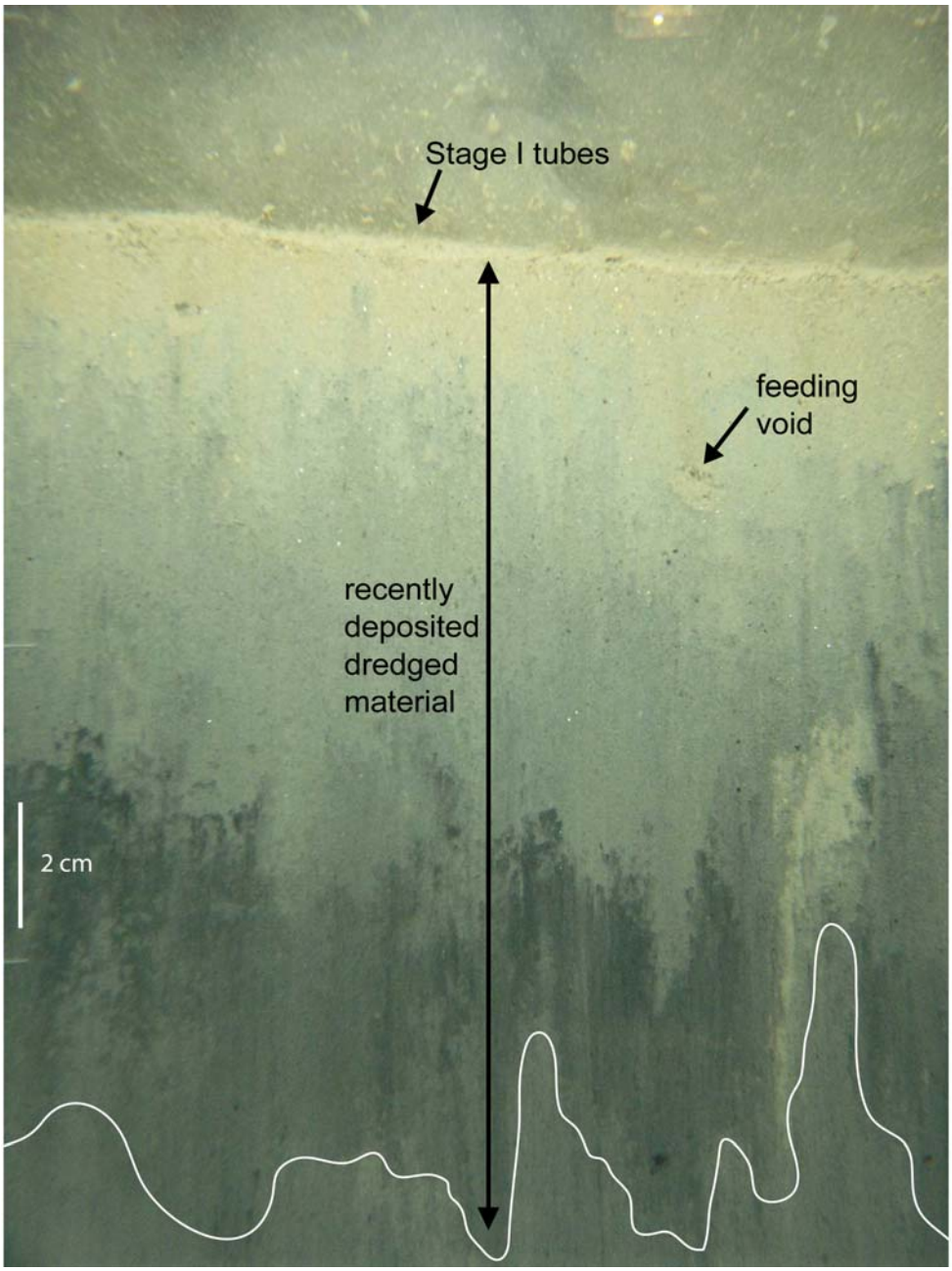


Figure 3-11. SPI image from Station A300W_2B showing dredged material extending beyond camera penetration depth. The bottom of the darker sulfidic layer indicates the depth (mean depth = 15 cm) of a more recent deposition. Stage I tubes have recolonized the sediment surface and several active Stage III feeding voids (depths of 1.6 and 3.4 cm) are present. RPD = 1.1 cm; Stage I on III; OSI=7. Image width is 16 cm.

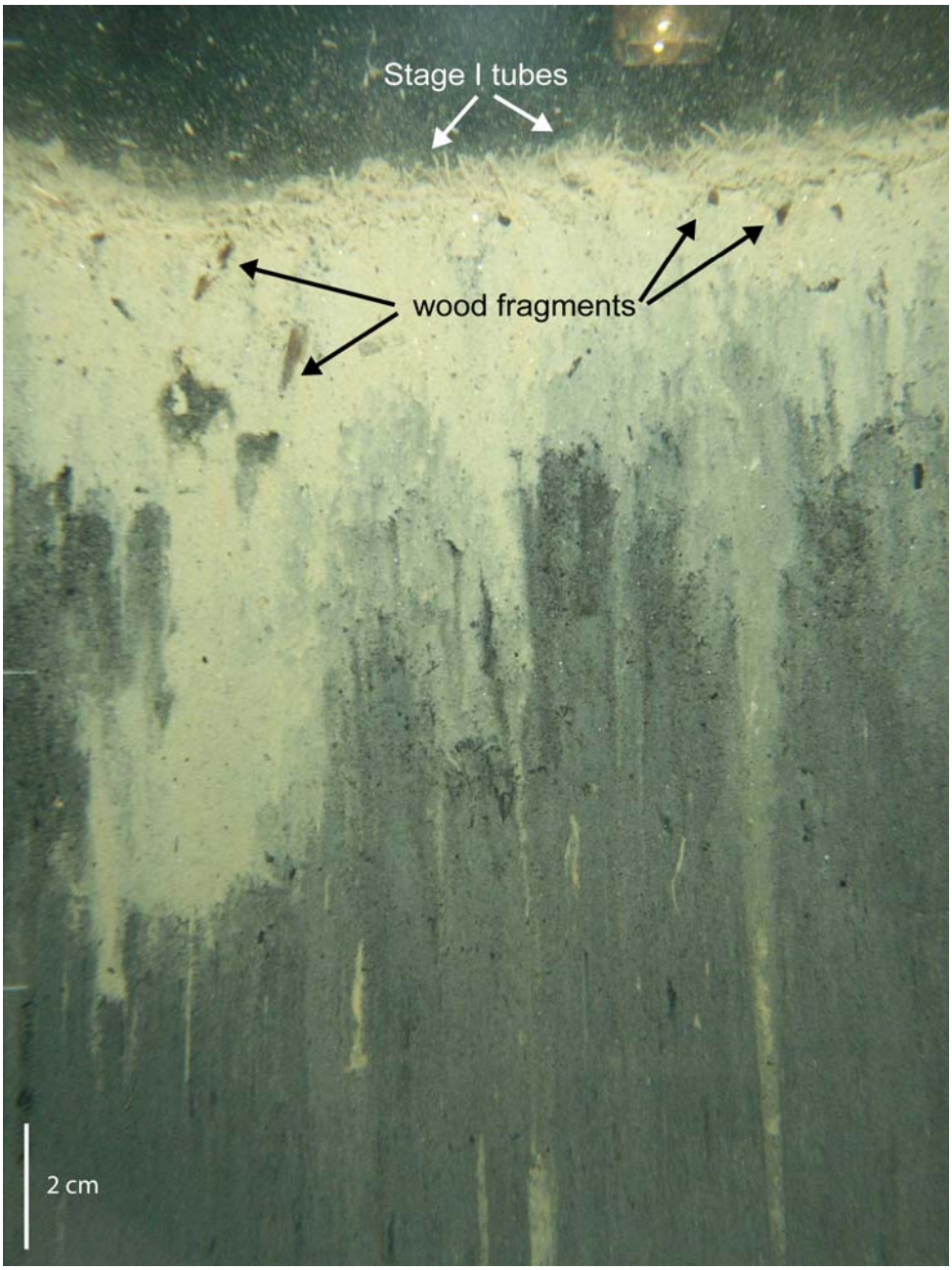
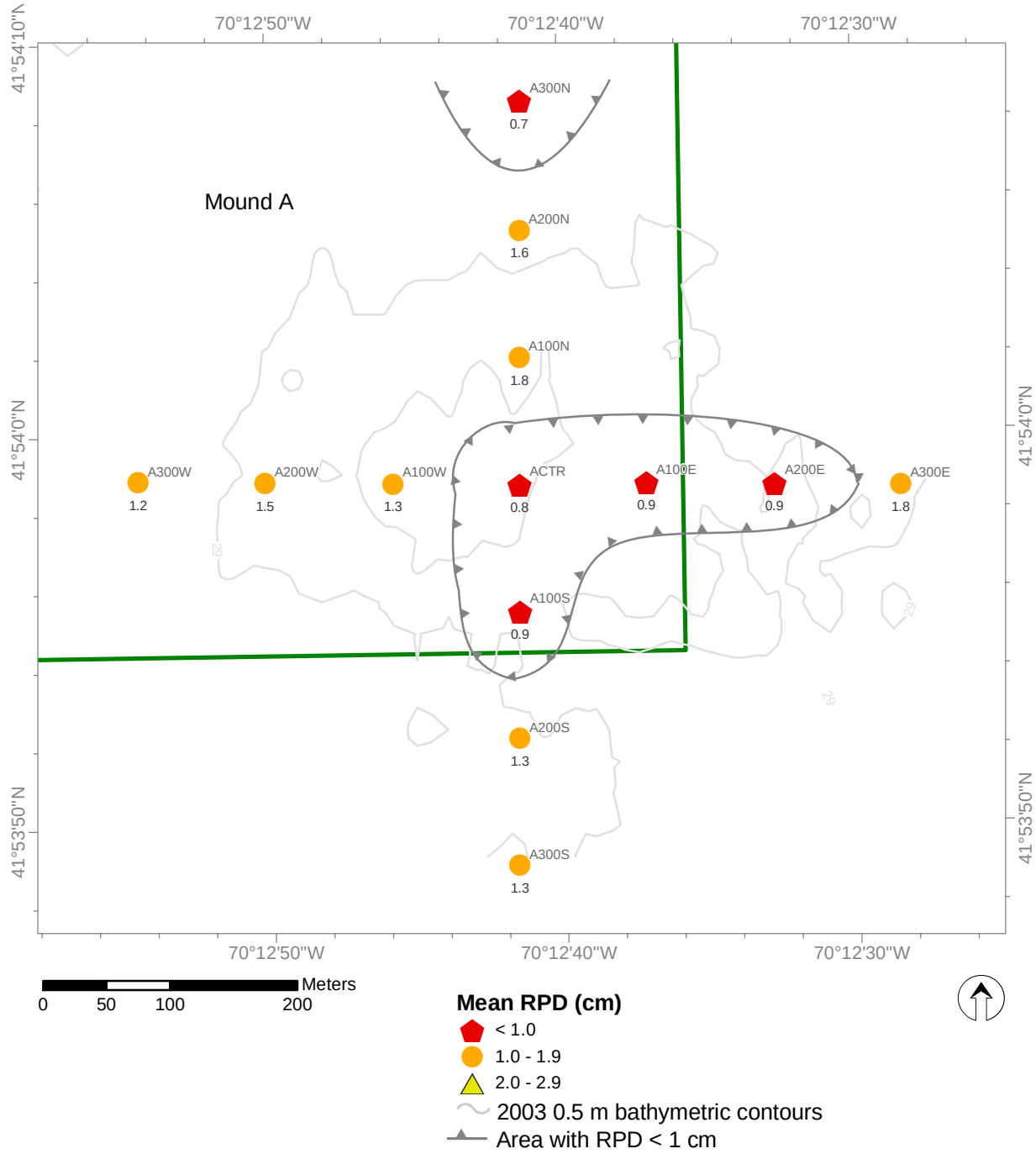


Figure 3-12. SPI image from Station A200W_1B showing dredged material extending to beyond the penetration depth of the camera. Large particles of lignin (a plant-derived polymer) are scattered throughout the upper 4 cm. A thick Stage I tube mat covers the sediment surface. RPD=1.2 cm; Stage I; OSI=3. Image width is 16 cm.



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83

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Figure 3-13. Mean RPD depths at Mound A, CCBDS, August 2003

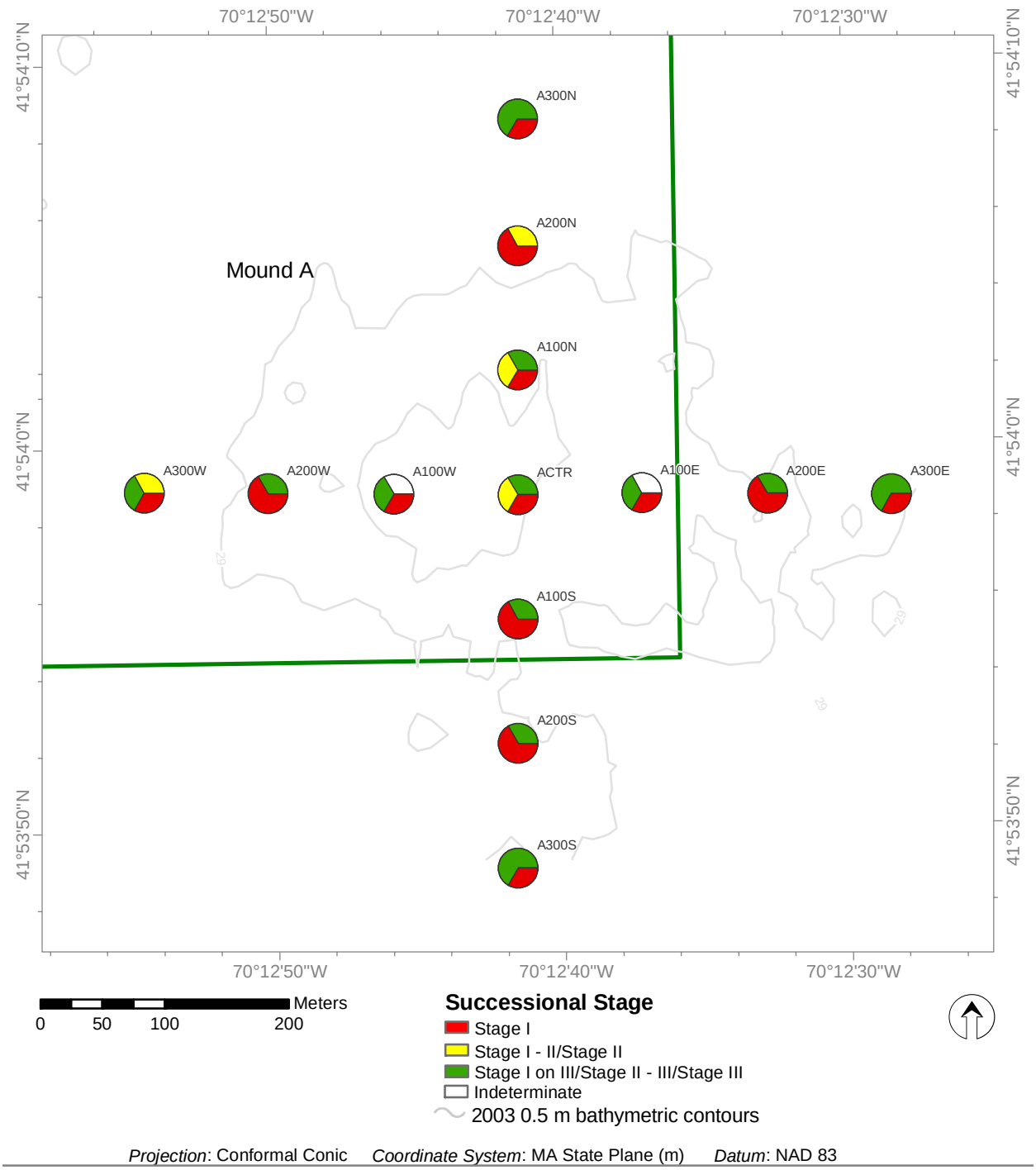


Figure 3-14. Infaunal successional stages at Mound A, CCBDS, August 2003

different successional stages were observed in the three replicate samples (e.g., at ACTR, the three replicates were designated as Stage I, Stage II, and Stage II-III; Figure 3-15). Small-scale patchiness in recolonization is reflected in the patchy distribution of colonizing amphipods (Stage II) over the mound surface, but the presence of Stage I conditions alongside Stage III conditions throughout the survey area is the strongest evidence of patchy disturbance.

All stations located on dredged material at Mound A had median OSI values ≤ +6, indicative of a disturbed benthic environment (Figure 3-16). Stations located on ambient sediment (Stations A300E and A300S) had median OSI values of +8 and +7, respectively, suggestive of a less-disturbed benthic environment.

Comparison with Previous Surveys

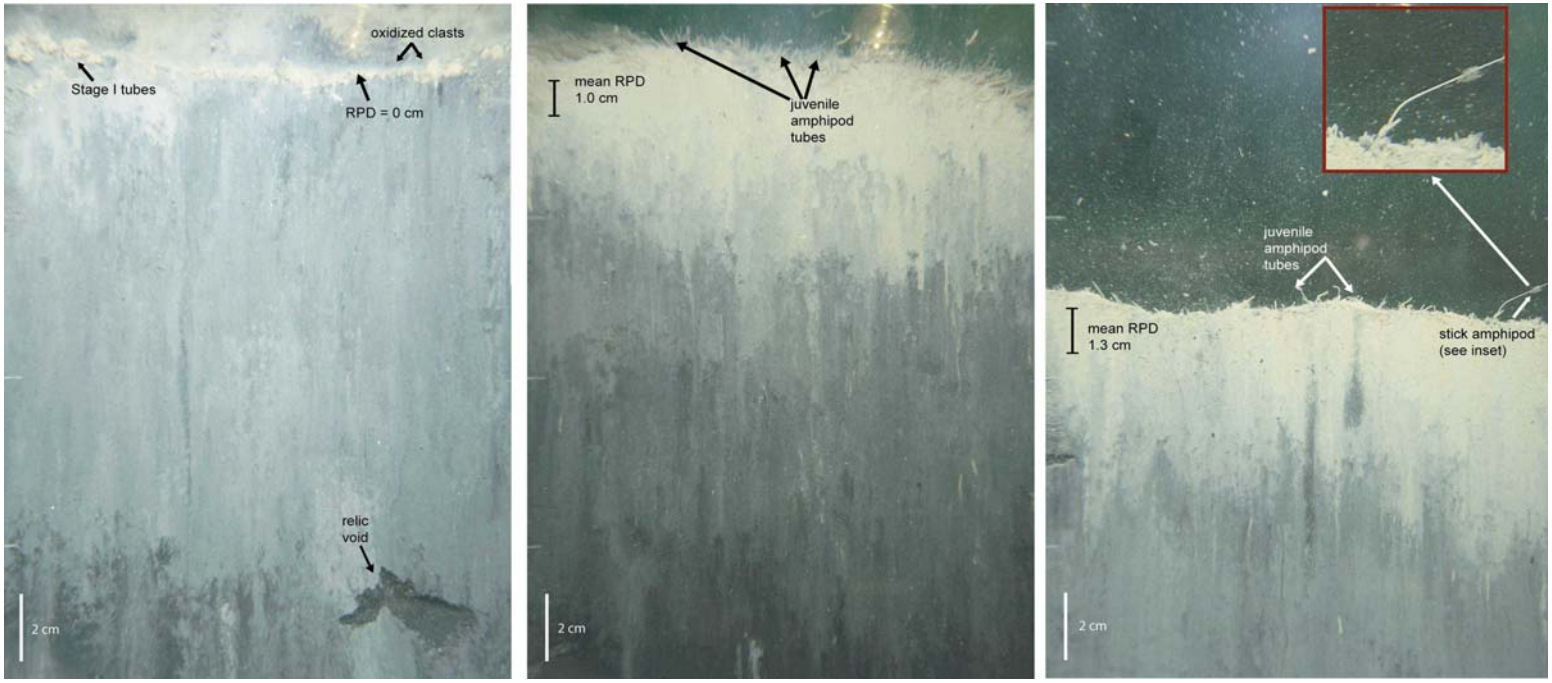
The 2003 SPI survey occupied the same set of stations over Mound A as the 2001 survey. The overall distribution of dredged material mapped by the two surveys was quite similar, with an eastern boundary between Stations A200E and A300E, and northern and western boundaries extending beyond the sampling stations (Figure 3-10). One exception was that in 2003 dredged material appeared to extend 100–200 m farther south than in 2001, with a thick layer identified at Station A200S (where no dredged material was identified in 2001) and a thin layer identified in one replicate at Station A300S.

Three SPI surveys of Mound A have been conducted in the seven years since the original formation of the mound: in 1996 (CR Environmental 1997), 2001 (SAIC 2003), and the current 2003 survey. A station-by-station comparison of RPD and OSI for the 2001 and 2003 surveys suggested that benthic habitat conditions were similar between the two surveys (Figure 3-17) and that values of mean RPDs, median OSIs, and percentage of replicates with evidence of Stage II infauna in 2003 continued to be lower than those measured in the 1996 survey (Table 3-2).

3.2.3 Mound B

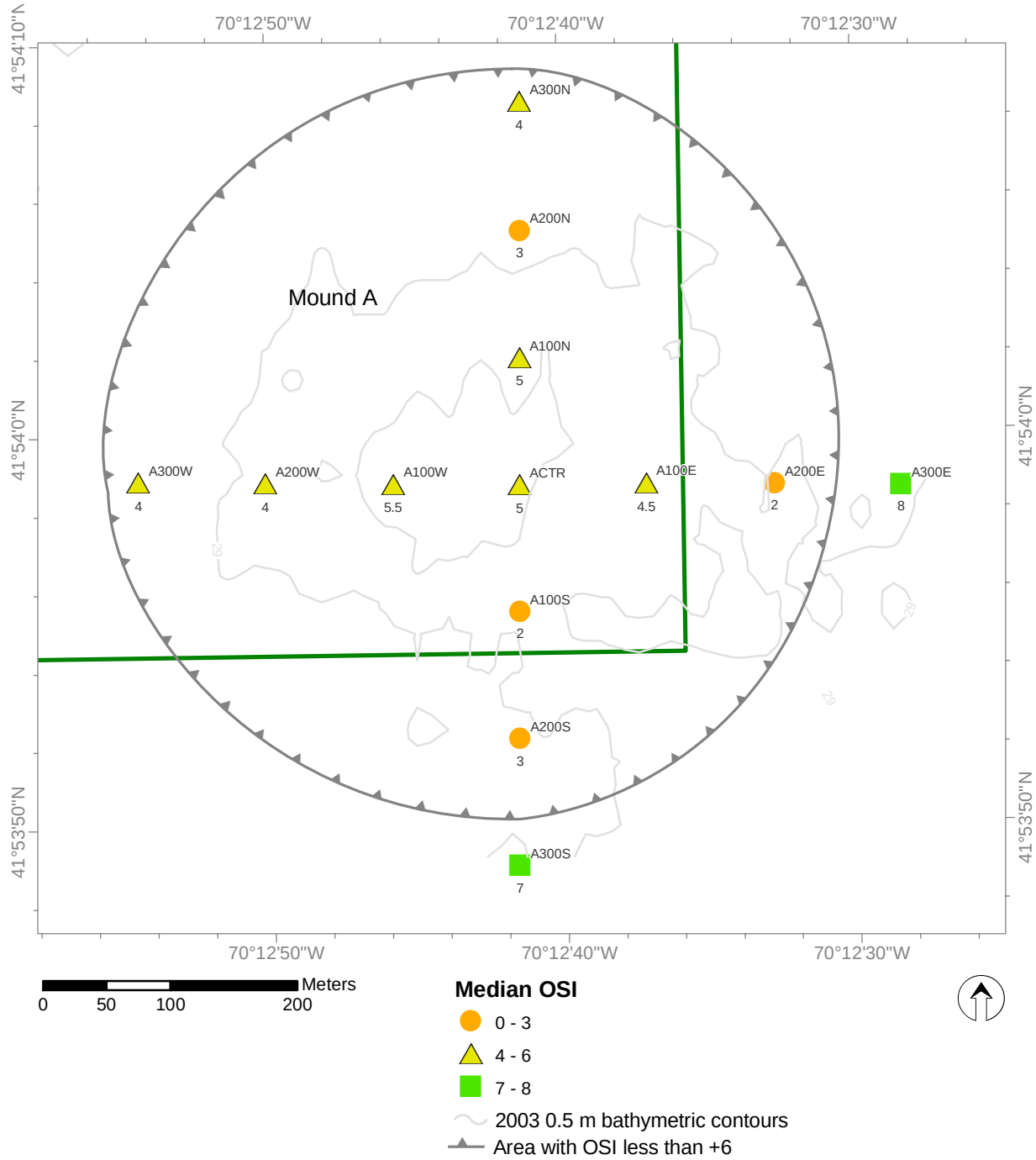
Dredged Material Distribution and Sediment Physical Characteristics

Dredged material was seen in all SPI images except those from Stations B420W, B420E, and B420S, where ambient bottom conditions were observed (Table 3-4, Figure 3-18). One image of the three taken at Station B420S showed evidence of older dredged



A B C

Figure 3-15. SPI images from ACTR showing variability at the center of Mound A. Recent dredged material extends beyond the penetration depth of the camera in all three cases. (A) ACTR_3B. The sediment surface appears erosional and is covered with small oxidized clasts with only a very few Stage I tubes visible. The large dark void at depth is no longer active. RPD=0 cm; Stage I; OSI=1. (B) ACTR_1B. A thick mat of juvenile amphipod tubes covers the sediment surface. RPD = 1.0 cm; Stage II; OSI = 5. (C) ACTR_2B. The tube mat at the surface is composed of Stage I and only a very few Stage II amphipod tubes. The tall tube on the right is made and occupied by a "stick amphipod" in the family Podoceridae. An active Stage III feeding void is present at 5 cm depth. RPD=1.3 cm; Stage II on III; OSI=7. Image widths are all 16 cm.



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83

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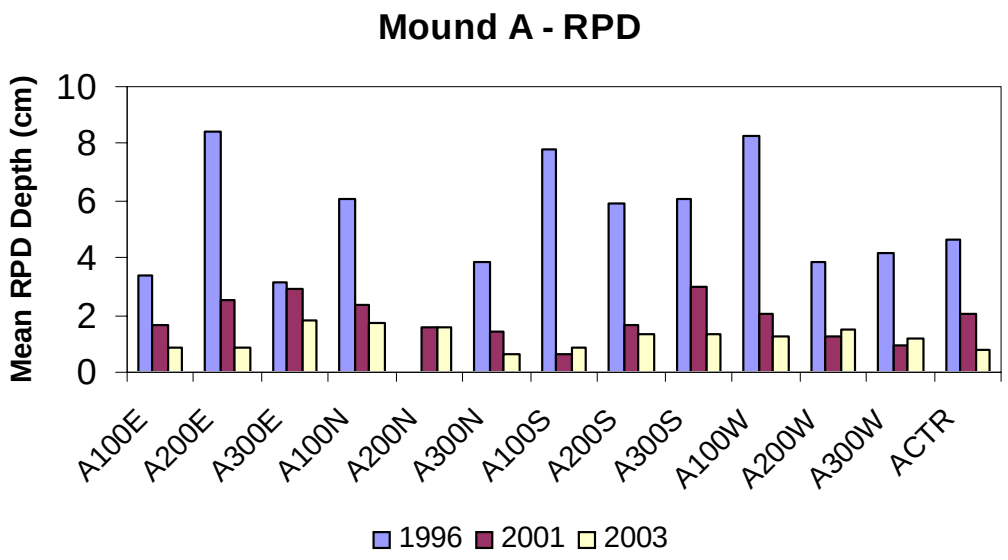
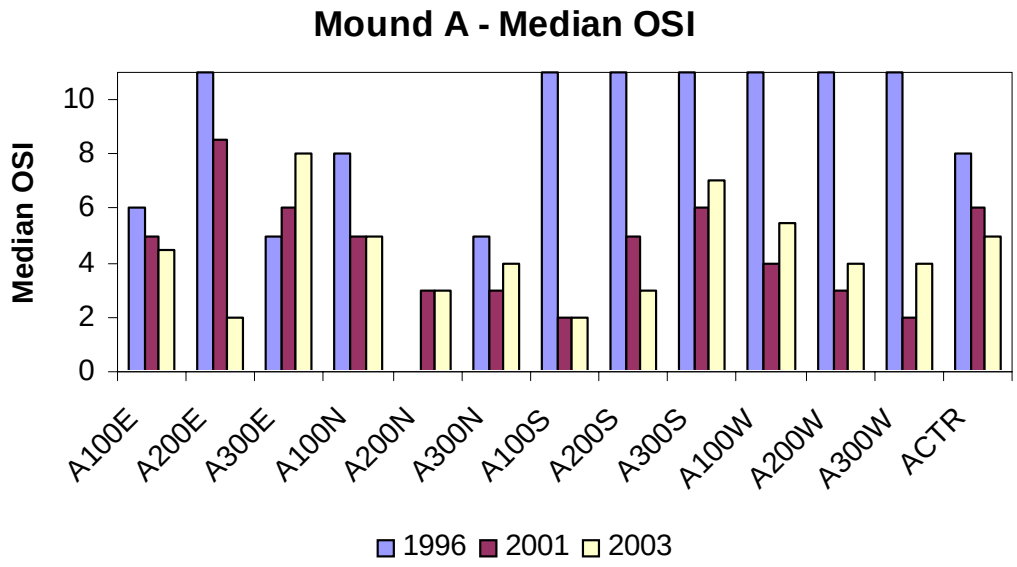
Figure 3-16. Median OSI values at Mound A, CCBDS, August 2003





Note: 2001 and 2003 stations were offset from 1996 stations by 100 m

Figure 3-17. Sediment biological conditions at Mound A, CCBDS, in 1996, 2001 and 2003

Table 3-4.

Summary of 2003 SPI Results for CCBDS Mound B Stations

Station	Mean Prism Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	Successional Stages present (no. of replicates)	Median OSI	Mean Total DM Thickness (cm)
B140E	11.7	>4	1.8	Stage I on III (2), Stage I (1)	7	>12.25
B140N	19.1	>4	1.3	Stage I on III (3)	7	>19.07
B140S	10.5	>4	1.4	Stage I on III (2), Stage I (1)	7	>10.51
B140W	16.0	>4	1.6	Stage I (3)	4	>16.02
B280E	18.0	>4	1.0	Stage I (1), Stage I on III (2)	7	>18.02
B280N	16.2	>4	0.9	Stage I (3)	2	>16.22
B280S	15.1	>4	1.8	Stage I (2), Stage I on III (1)	4	>15.08
B280W	17.8	>4	0.3	Stage I (3)	1.5	>17.82
B420E	17.0	>4	1.2	Stage I-II (2), Stage I on III (1)	5	Ambient
B420N	14.5	>4	0.8	Stage I (2), IND (1)	2.5	>14.44
B420S	17.5	>4	1.7	Stage I on III (2), Stage I-II (1)	8	Ambient
B420W	16.1	>4	1.5	Stage I on III (2), Stage I (1)	7	Ambient
BCTR	4.4	>4	1.0	Stage I-II (2), Stage I on III (1)	4	>4.37
Mean	14.9		1.3		NA	
Median	NA		NA		5	
Minimum	4.4		0.3		1.5	
Maximum	19.1		1.8		8	

DM: Dredged Material. NA: Not applicable

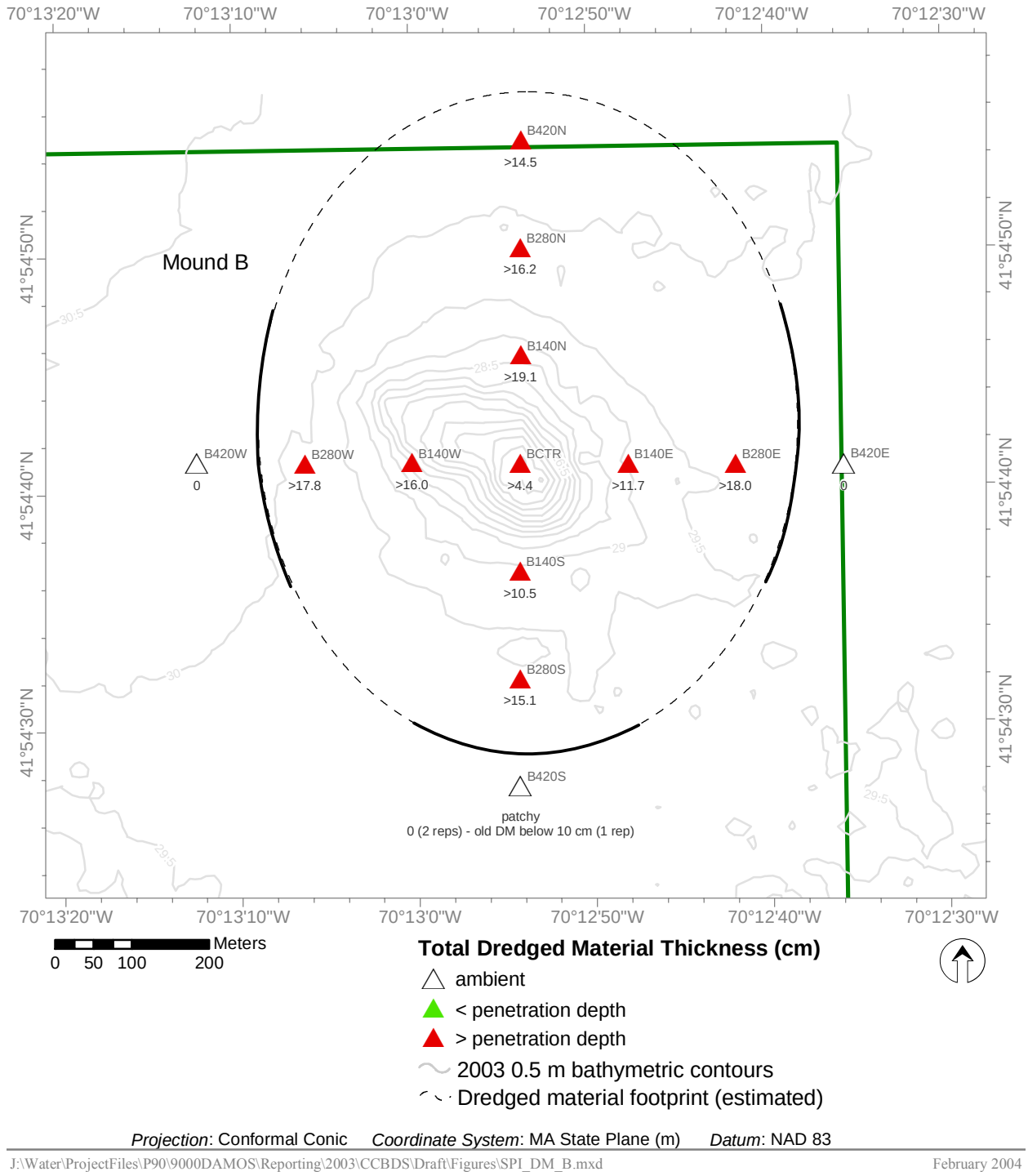


Figure 3-18. Total dredged material thickness at Mound B, CCBDS, August 2003

material below a depth of 10 cm. Dredged material apparently extended north of station B420N, as indicated by the 14+ cm of dredged material observed in SPI images from that station. Where dredged material was present, it was thicker than the penetration depth of the camera prism. The visual signature of dredged material consisted of low-reflectance silt/clay (>4 phi) occasionally mixed or layered with sand. Examples of the appearance of dredged material textures at Stations B140S and B420N are presented in Figure 3-19. Images taken at five stations showed relatively new layers of dredged material on top of older dredged material, with the mean thickness of the newer material equal to 3.9 cm (Station B420N), 8.0 cm (Station B280S), 12.2 cm (Station B280E), 12.4 cm (Station B280W), and 13.4 cm (Station B280N). An example of the layered dredged material at Station B280S is presented in Figure 3-20.

Overall mean penetration depth at Mound B was approximately 15 cm, suggesting relatively soft sediments, and mean boundary roughness was 1.4 cm. Biological features such as feeding mounds or pits dominated this small-scale relief. Thirty-one station replicates provided information about the source of this relief, with 27 replicates (87%) dominated by biological roughness.

Biological Conditions and Benthic Recolonization Status

The mean apparent RPD depths at most stations at Mound B were between 1.0 and 2.0 cm (Table 3-4, Figure 3-21). Stations where mean RPD depths were lowest (< 1.0 cm) were located in the northwest quadrant of the mound (Stations B420N, B280N, and B280W).

A wide range of macrofauna and successional stages was present at Mound B (Figure 3-22). Macrofauna seen at Stations B420S and B140E included brittle stars and sand dollars, respectively (Figures 3-23 and 3-24). Nine stations showed evidence of Stage III infauna, and three stations showed evidence of Stage II infauna. However, four stations (Stations B420N, B280N, B280W, and B140W, which include those noted above with thin mean apparent RPD depths) were populated only by Stage I pioneers.

The overall distribution of OSI showed that five of the six stations with median values greater than +6 were located either on ambient sediment (Stations B420W and B420S) or near the mound center (Stations B140N, B140E, and B140S) (Figure 3-25). The sixth station (Station B280E) was east of the mound center but at a location where dredged material was observed. The remaining stations had median OSI values ranging from +1.5 to +5. The distinctly patchy recolonization may be related to patchiness of recently deposited dredged material. The lowest OSI value (+1) found at Mound B was at Station B280W_2B (Figure 3-26A). Several replicate samples had OSI values of +2; for example, Station B280N_2B (Figure 3-26B).

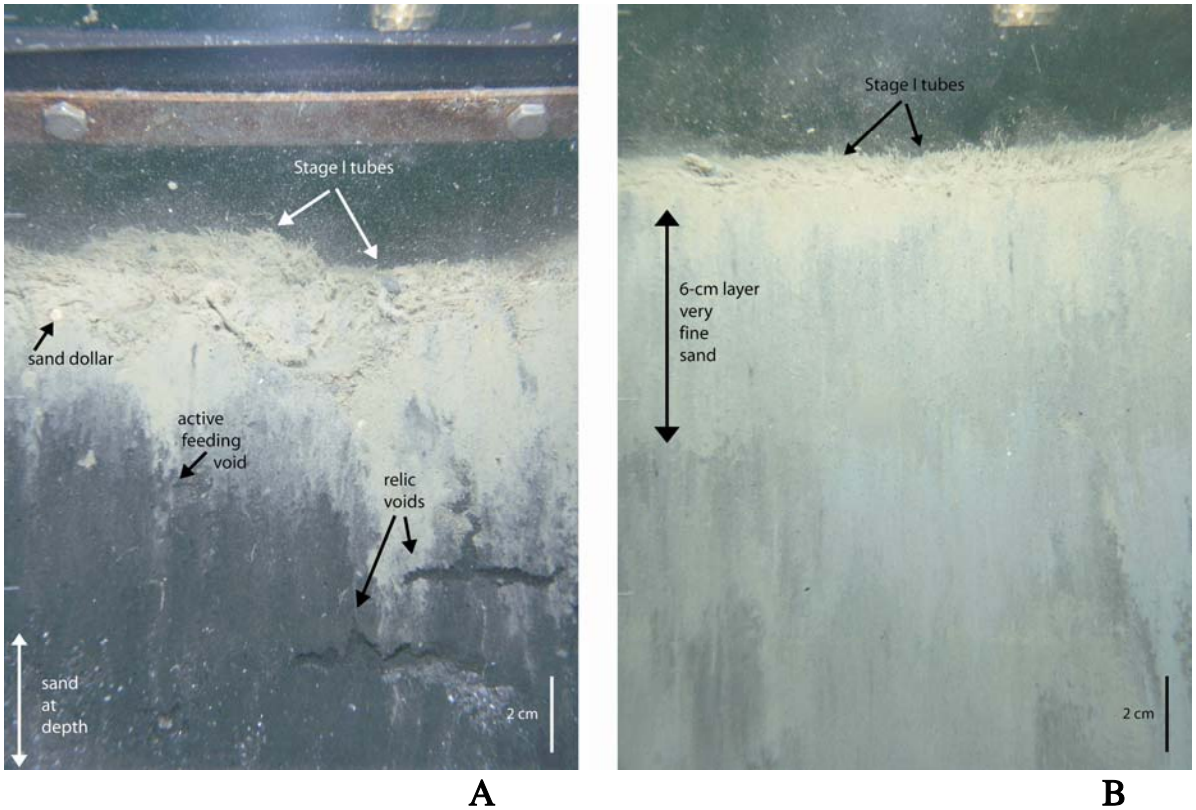


Figure 3-19. SPI images that show layers of dredged material extending beyond the camera penetration depth. (A) Station B140S_1B. This image reveals poorly-sorted sediment, with at least 4 cm of sand at depth. The surface bears a thick Stage I tube mat as well as a small sand dollar (*Echinarachnius parma*). One small active feeding void is present. Mean RPD depth = 0.8 cm; Stage I on III; OSI=7. (B) Station B420N_3B. A 6-cm-thick layer of very fine sand covers two layers of older dredged material. A thick Stage I tube mat covers the sediment surface. Mean RPD depth = 0.8 cm; Stage I; OSI=3. Image widths are 16 cm.

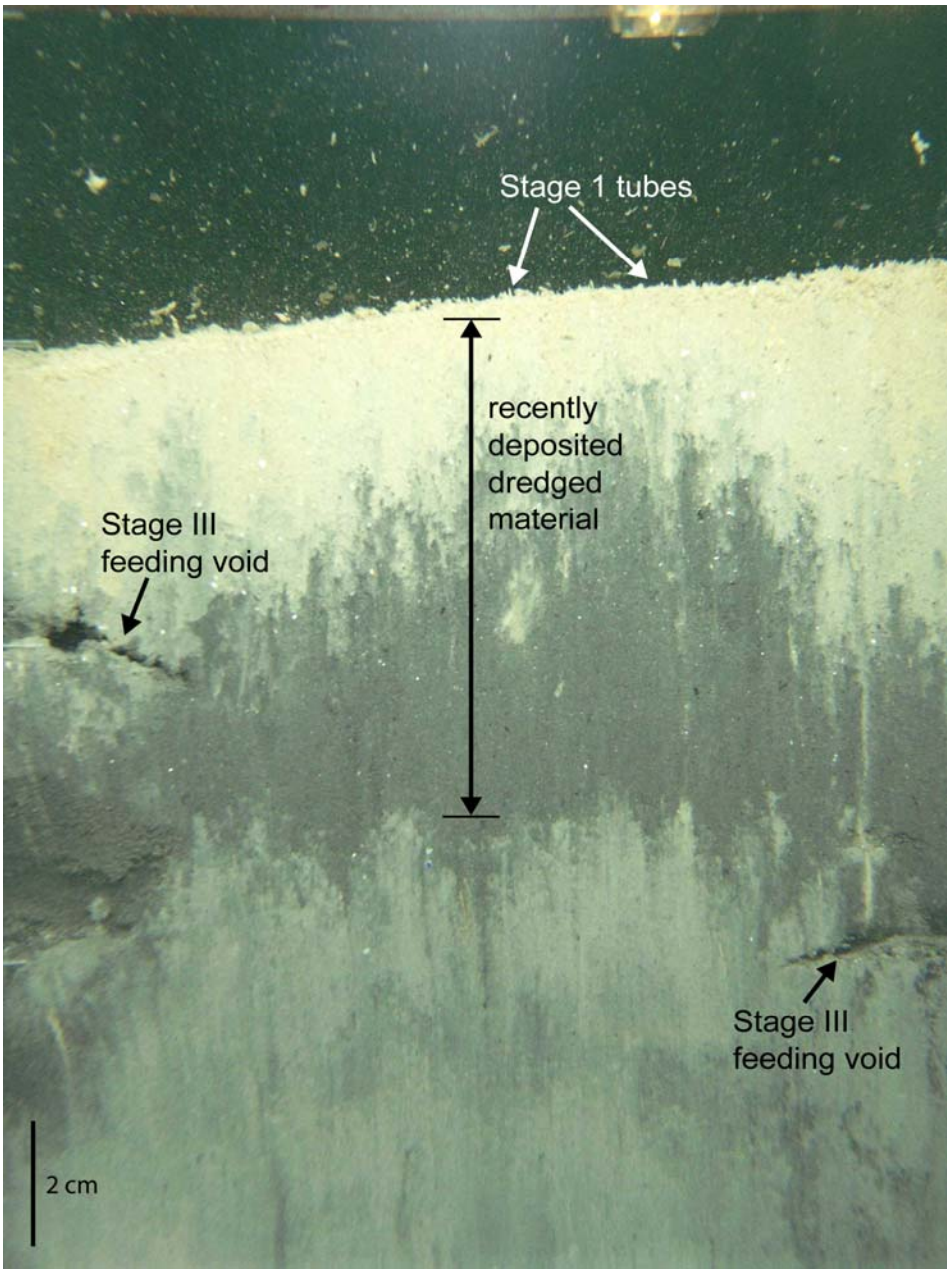
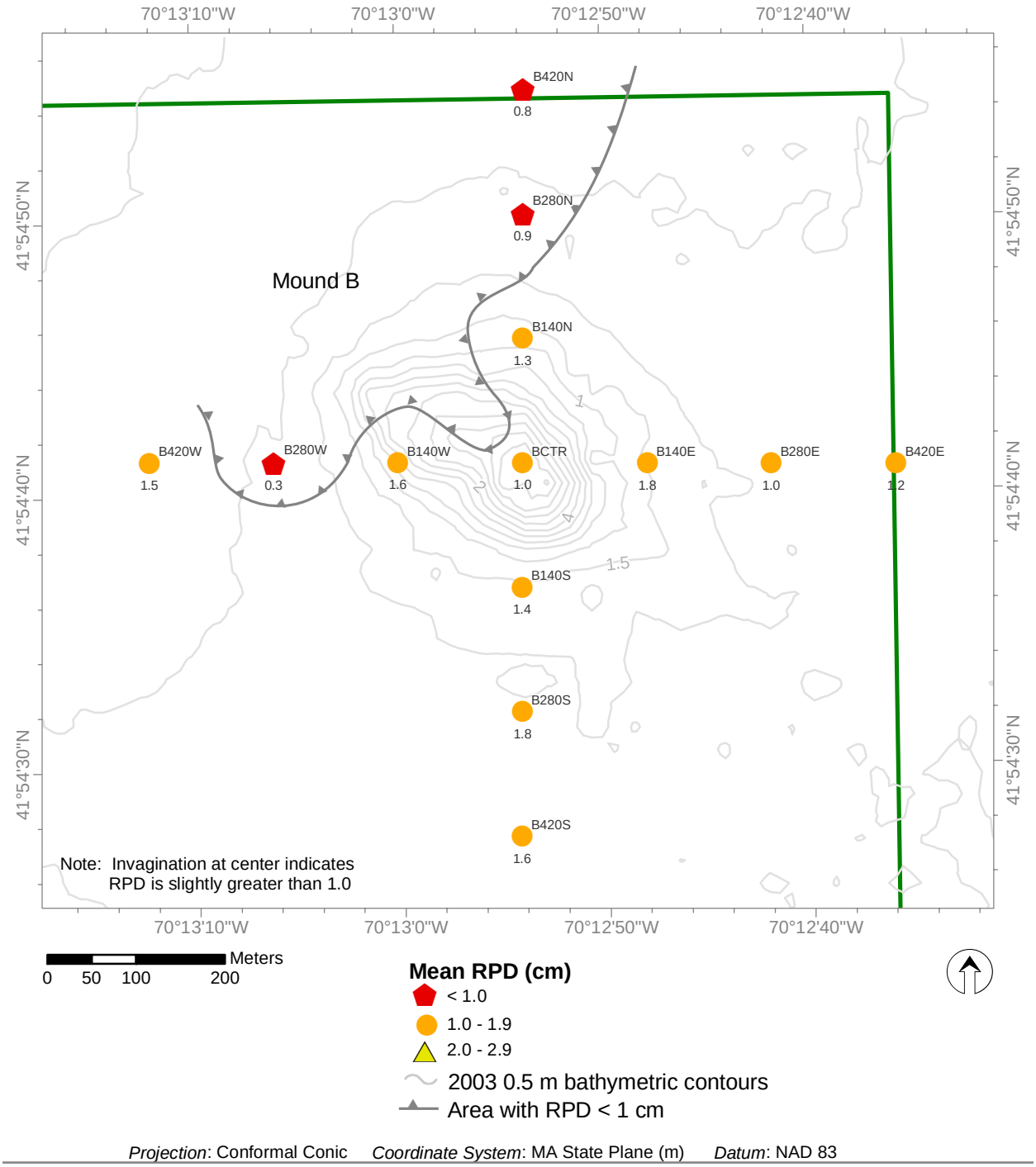


Figure 3-20. SPI image from B280S_1B showing old dredged material extending beyond the penetration depth of the camera. More recent dredged material extends to a mean depth of 9.2 cm (to bottom of dark sulfidic layer). Stage I tubes are present on the surface. Several active Stage III feeding voids are present. Mean RPD depth = 2.1 cm; Stage I on III; OSI = 8. Image width is 16 cm.



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83

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Figure 3-21. Mean RPD depths at Mound B, CCBDS, August 2003

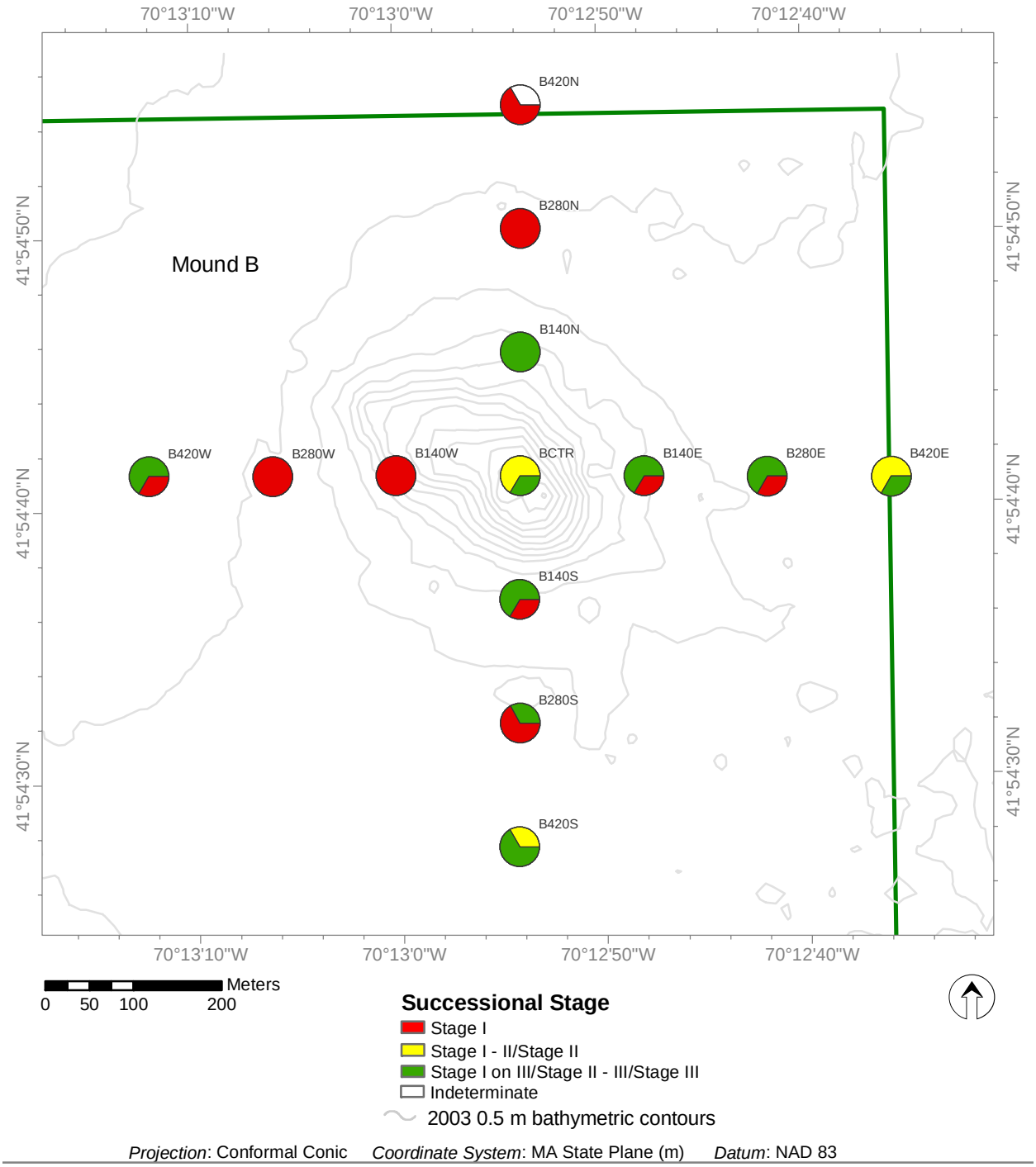
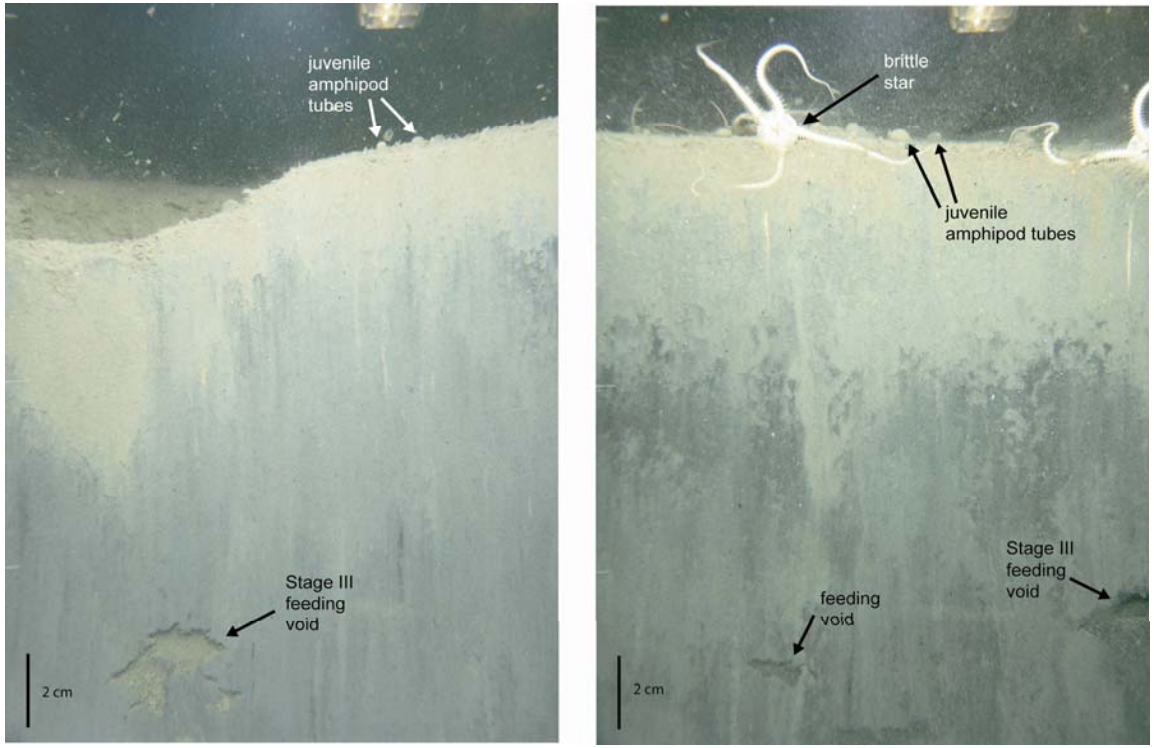


Figure 3-22. Infaunal successional stages at Mound B, CCBDS, August 2003



A

Figure 3-23. SPI images from Station B420S showing ambient sediment to depth, a very few amphipod tubes on the surface along with Stage I tubes, and several active Stage III feeding voids. (A) B420S_1B. Surface relief may be due to *Molpadia oolitica* (a deeply burrowing sea cucumber) mound. Mean RPD depth = 1.5 cm; Stage I on III; OSI=8. (B) B420S_2B. Ophiuroid brittle stars (probably *Ophiura sarsi*) on the surface have arms extending into the sediment. Mean RPD depth = 2.1 cm; Stage I on III; OSI=8. Image widths are 16 cm.

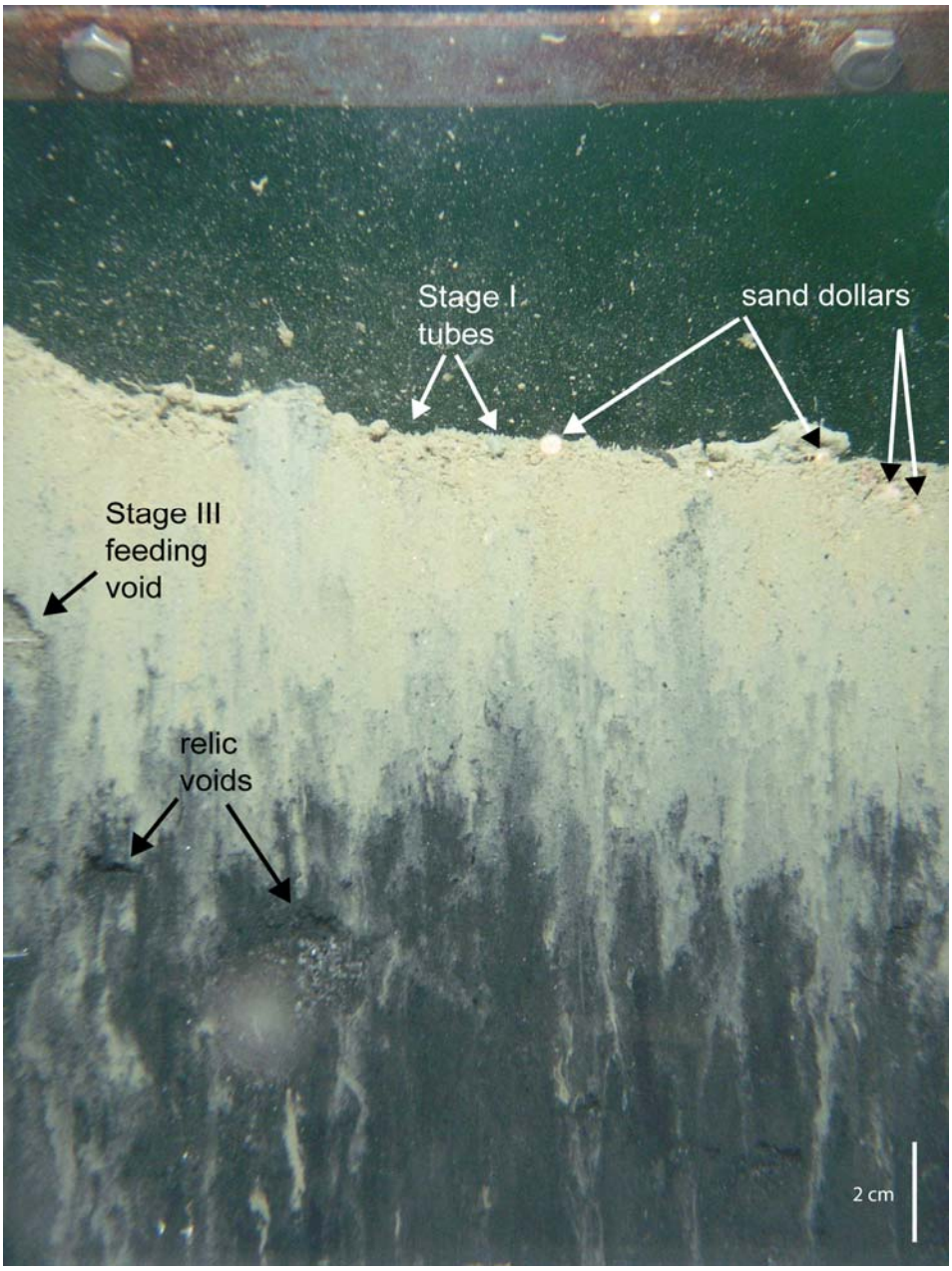
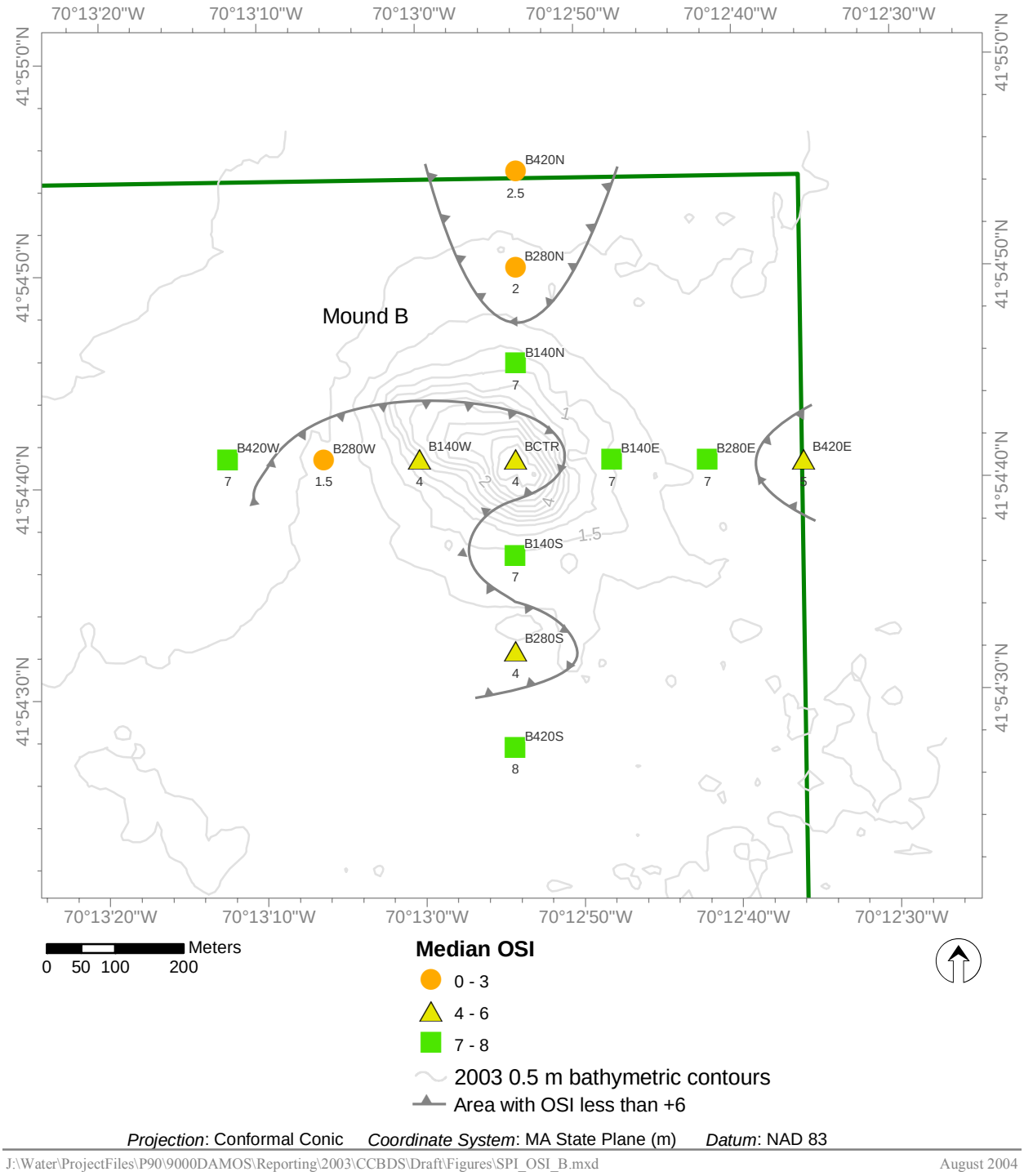


Figure 3-24. SPI image from Station B140E_2B showing dredged material extending beyond the camera penetration depth. Relic voids can be seen in the dark sulfidic layer. An active Stage III feeding void is present at a depth of 4 cm. Stage I tubes are present on the sediment surface along with five sand dollars (*Echinarachnius parma*). Mean RPD depth = 1.4 cm; Stage I on III; OSI=7. Image width is 16 cm.



Projection: Conformal Conic *Coordinate System*: MA State Plane (m) *Datum*: NAD 83

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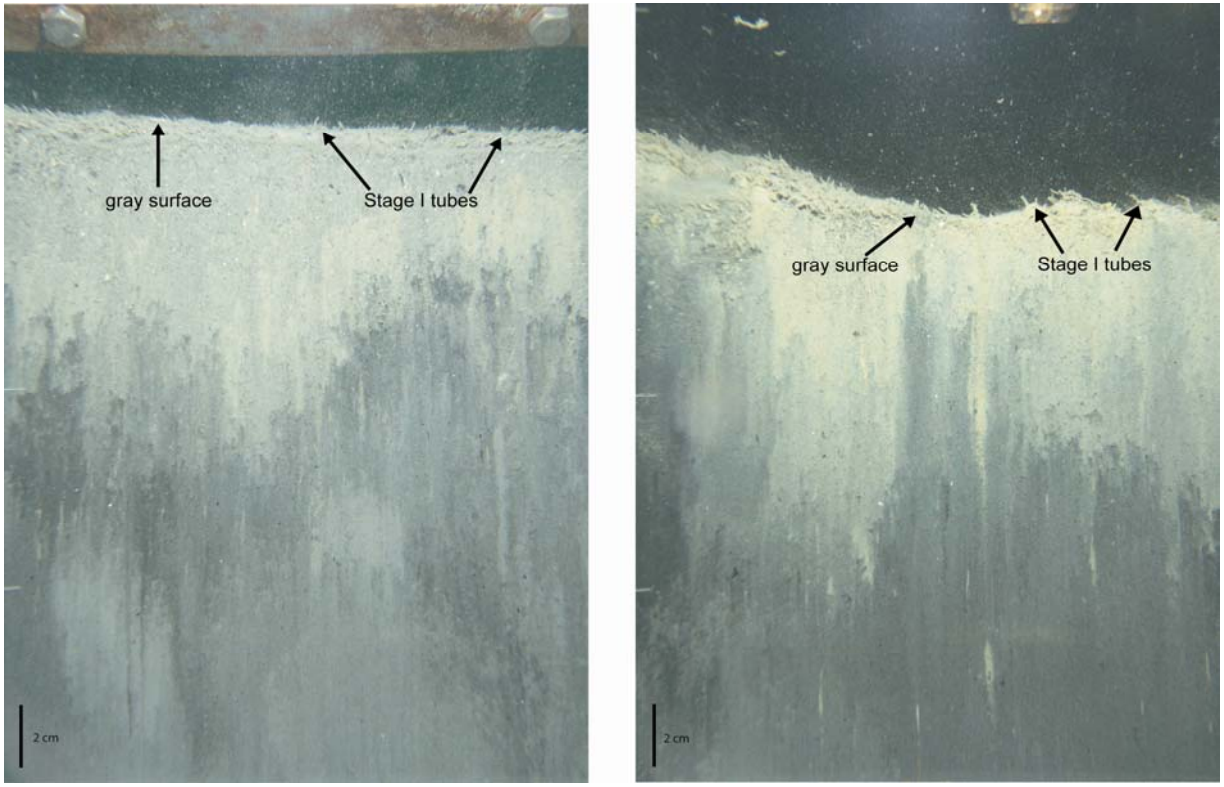
Figure 3-25. Median OSI values at Mound B, CCBDS, August 2003



A

Figure 3-26. SPI images showing examples of a gray sediment surface resulting in low OSI values. In both images, the surface is covered with a thick Stage I tube mat and old dredged material extends beyond the penetration depth of the camera; a more recent layer of sand over mud extends to a mean depth of about 13 cm. (A) At station B280W_2B, the entire sediment surface is gray. RPD=0 cm; Stage I; OSI=1. (B) At station B280N_2B, only a portion of the sediment surface is gray. RPD=0.6 cm; Stage I; OSI=2.

Comparison with Previous Surveys

Although station locations sampled in the 2001 and the 2003 Mound B surveys were not coincident, they were laid out along similar transects and therefore allow for comparison of results. Despite the placement of 185,000 m^3 of dredged material since the 2001 survey, the overall dredged material footprint in 2003 (Figure 3-18) is comparable to that mapped in 2001 (SAIC 2003).

The distribution of mean apparent RPD depths (with the lowest observed in the center and in the northwest quadrant of the mound) was similar in both the 2001 and 2003 surveys, but the mean RPD was 0.9 cm shallower in 2003 compared with 2001 (Table 3-2). Median OSI was variable over the mound in both surveys with a median OSI of +5 in 2003 compared with +6.5 in 2001.

3.2.4 Comparison of CCBDS with CCBRS Conditions

All stations at Mound A, Mound B, and CCBRS had the same major mode grain size (>4 phi). Sediments were generally silt/clay, with some sand observed at Mound A and Mound B stations.

Benthic conditions at Mound A and Mound B were generally indicative of disturbed habitat compared with conditions at CCBRS. Both the mean RPD and median OSI were lower at the mounds (Table 3-2, Figures 3-8 and 3-9). Stage III infauna were present at only 41% and 42% of the replicates at Mound A and Mound B, respectively, compared with 60% of the reference area replicates (Figure 3-7). Stage I only was observed in a large number of the replicates at Mound A and Mound B (over 40%) compared with only one replicate at CCBRS.

4.0 DISCUSSION

The primary objectives of the August 2003 survey at CCBDS were to document any changes in dredged material distribution and bathymetry at Mounds A and B since August 2001 and to assess the status of benthic recolonization at Mounds A and B relative to reference area conditions and previous surveys. At Mound A, recolonization apparently had been slow prior to 2001, and small amounts of dredged material (2600 m^3) were disposed there prior to the 2003 survey. Mound B received substantial amounts of dredged material (185,300 m^3) prior to this survey. Seafloor topography, dredged material distribution, and benthic recolonization at Mounds A and B and CCBRS were characterized with bathymetric surveys and SPI surveys in 1996 (Mound A only), 2001, and 2003.

4.1 Cape Cod Bay Reference Site

Three reference areas were surveyed in 1996: in addition to the established reference area (CCBRS), two additional areas (NW REF and SW REF) were surveyed to determine if they were suitable reference sites (CR Environmental 1997). These two areas were established at reference sites, and all three areas were surveyed in 2001.

In 1996, NW REF and CCBRS showed evidence of advanced successional stages, relatively deep RPD depths, and OSI values indicative of an unstressed benthic habitat (SAIC 2003). Benthic conditions at SW REF were also indicative of an unstressed habitat, although the mean RPD depth and median OSI were lower than at NW REF or CCBRS (Table 4-1). In 2001, RPD depths and OSI values at NW REF and CCBRS were slightly lower than in 1996 (comparable with those observed at SW REF in 1996), and all reference stations had comparable benthic conditions. It is important to note that 13 stations (and 30 replicates) were surveyed at each reference area in 1996, while only four stations at NW REF and SW REF and five stations at CCBRS were surveyed in 2001, precluding direct tests of significance.

In the 1996 analysis, the observed decline in OSI values at CCBRS was attributed in part to a possible overestimation of RPD depths (SAIC 2003). The decline in OSI values at both CCBRS and NW REF may have also resulted from seasonal variation in oxygen demand. The 1996 survey was performed in May and the 2001 survey was performed in August. SPI parameters change over an annual cycle related to seasonal changes in water temperature (i.e., metabolic rates), primary production cycles, benthic recruitment, and reaction rates within sediment pore water, sediment particulate phases, and overlying water. Physical disturbance, such as trawling, may also be more evident later in the summer and contribute to degraded benthic habitat conditions relative to springtime conditions.

Table 4-1.

Comparison of 1996, 2001, and 2003 Sediment Biological Conditions at CCBRS

Area	Year	Mean RPD	Median OSI	Number of Stations
NW REF	1996	4.1	10	13
	2001	3.2	8	4
	2003	--	--	--
SW REF	1996	2.4	7	13
	2001	2.6	8.5	4
	2003	--	--	--
CCBRS	1996	4.2	10	13
	2001	1.9	7	5
	2003	2.3	6	5

In 2003, only CCBRS was surveyed to provide ambient data from a reference area. Therefore, to provide the most appropriate comparison in the following discussion, only CCBRS data from the 1996 and 2001 surveys are considered. Comparisons of the CCBRS SPI data indicate that benthic biological conditions may have degraded between the 1996, 2001, and 2003 surveys. The mean RPD depth increased slightly between the 2001 and 2003 surveys, from 1.9 cm to 2.3 cm, but the percentage of replicates with evidence of Stage III infauna decreased from 92% in 2001 to 60% in 2003. The median OSI decreased from +7 in 2001 (indicative of undisturbed to slightly disturbed conditions) to +6 in 2003 (indicative of moderately disturbed or stressed conditions). Although the intensity of sampling in reference areas in 2003 was not sufficient to permit tests of statistical significance of this apparent degradation with respect to data collected on previous surveys, the 2003 results could suggest a potential long-term, regional decline in benthic habitat conditions.

To evaluate the possibility of a regional decline in benthic conditions in Cape Cod Bay, available long-term benthic and sediment data was briefly reviewed. The Massachusetts Water Resources Authority (MWRA) has performed extensive monitoring at two stations in Cape Cod Bay since 1992 as part of their Harbor and Outfall Monitoring (HOM) Program (Figure 4-1). A comprehensive analysis of 11 years of sampling was recently prepared by Maciolek et al. (2003). MWRA Station FF06 is approximately 1.5 km to the west of CCBDS, and FF07 is to the north of CCBDS, corresponding to the location of CCBRS. These stations are in the *Molpadia* biofacies reported by Rhoads and Young (1971a, b), with benthic conditions comparable to those at CCBDS and the reference areas.

The MWRA benthic monitoring consists of three replicate 0.04-m^2 grabs taken at each of these two stations every August. This sampling schedule thus captures the peak of infaunal densities following spring recruitment and growth and is consistent with the 2001 and 2003 DAMOS surveys. For most of the 11-year period, the dominant infaunal species were the polychaetes *Cossura longocirrata* (family Cossuridae) and *Euchone incolor* (family Sabellidae). These species were also important components of the benthic fauna identified as part of studies conducted by the Coastal Zone Management (CZM) for the Environmental Impact Report used to support the designation of CCBDS (Milliman and Maciolek 1987).

The simplest indicator of organic enrichment available in MWRA bulk sediment data is total organic carbon (TOC). Data from Stations FF06 and FF07 indicate no apparent trends (neither increases nor decreases) in TOC over the 11-year period. However, sediment nutrient chemistry is complicated and other data available for these MWRA stations (and nearby water quality stations), such as chemistry, sedimentology,

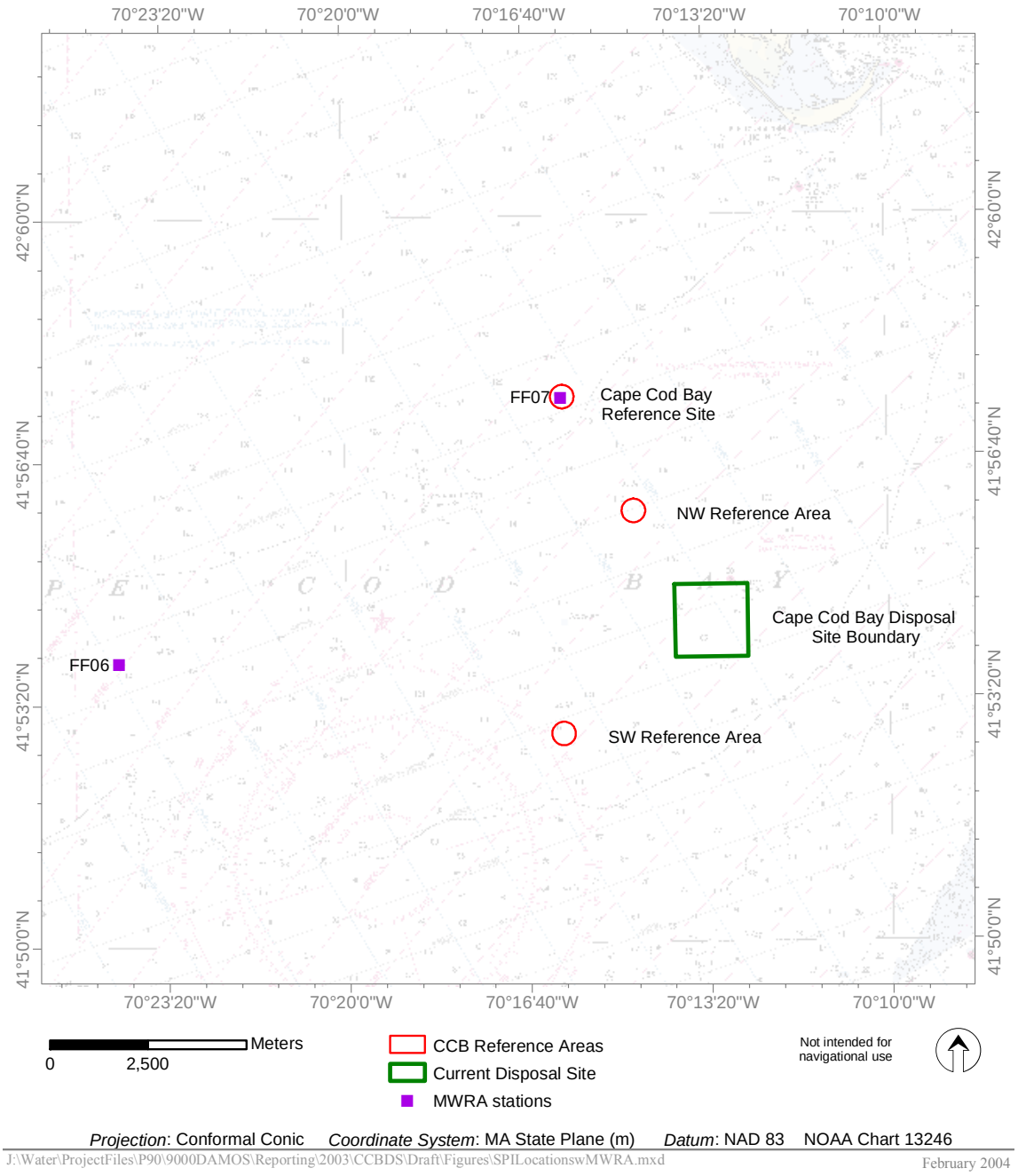


Figure 4-1. Location of MWRA Benthic Monitoring Stations in Cape Cod Bay

water quality, and detailed benthic biology including species richness and diversity, could provide additional insight into regional conditions in Cape Cod Bay.

To explore potential trends in the benthic community, infaunal density, the total number of individuals per sample, was calculated from the MWRA data at FF06 and FF07. Densities at the two stations were variable, showing both declining and stable trends at various times during the 11-year period of record. In the most recent data collected in August 2003 (MWRA, unpublished), infaunal densities were the highest ever recorded in the program. These results suggest that while the dominant infaunal species have remained more or less the same over 11 years of monitoring, the densities of these and other species are variable. There is no clear indication in the MWRA benthic biological data that there is stress impacting benthic habitat conditions either regionally or specifically in CCBRS. The cause of the apparent decline in benthic conditions manifested in the SPI data is not clear, nor is it clear that there has been an actual decline in benthic conditions, rather than a natural variation.

It was noted in Section 3.2.1 that 40% of CCBRS replicates showed no apparent feeding voids at depth (a Stage III criterion). Because of the small sample size at CCBRS (5 stations /15 replicates), the significance of this finding cannot be tested. The reference area lies within the *Molpadia oolitica* (Holothuroidea) biofacies of Cape Cod Bay. These large, vertically oriented holothurians can produce feeding voids at a depth of 20 cm or more (Rhoads and Young 1971a; 1971b). Because *M. oolitica* occurs in relatively low densities of only 2 to 6 individuals per m^3 and is patchily distributed, it is difficult to capture in grab samples or SPI images. If the camera penetration depth is less than the mean feeding depth, feeding voids would not be observed in SPI images; however, the camera may not even have sampled these feeding structures. The irregular occurrence of *M. oolitica* could also account for some of the patchiness observed in successional stages as well as the low percentage of replicates with Stage III infauna. A more intensive sampling program in this habitat is necessary to determine patch size and distribution of Stage III organisms. Finally, even at low densities, *M. oolitica* can produce substantial bioturbation rates that would affect RPD values, although these may be patchily distributed as well (Rhoads and Young 1971b).

4.2 Mound A

The following disposal and monitoring events occurred at Mound A:

- November 1994 to January 1995: Creation of Mound A by the disposal of 112,000 m^3 of dredged material

- May 1996: First Year Monitoring Survey
- August 2001: Monitoring Survey
- November 2002: Disposal of 2600 m^3 of dredged material in the southwest quadrant
- August 2003: Monitoring Survey

4.2.1 Dredged Material Distribution

Prior to the 1996 survey at CCBDS, 112,000 m^3 of dredged material was placed at Mound A. There were no additional disposal events at Mound A until November 2002, when 2600 m^3 of dredged material was placed there. The disposal was targeted at locations on the western portion of Mound A, which had exhibited the most significant decline in benthic conditions based on the 2001 OSI results (SAIC 2003).

The 2003 bathymetric survey detected a dredged material disposal mound with a diameter of approximately 450 m (up to 10 cm thick) and an approximate height of 1 m above the surrounding seafloor. A dredged material footprint with an approximate diameter of 600 m (>1 cm thick) was detected with the SPI data. This footprint was generally similar to that mapped from the 1996 and 2001 survey data. Dredged material observed in the 2003 survey that was not observed in the 2001 survey in the southern portion of Mound A could be from the recent disposals in November 2002. Reported disposal coordinates suggested that these disposal events were located too far from the Stations with apparently new dredged material, however if the actual disposal location were off by 100 m, these disposal events could be the source of the new dredged material observed in the southern portion of Mound A. Bathymetry in the 2001 and 2003 surveys indicated a localized increase in seafloor elevation of 0.5–1 m in the vicinity of the most recent disposal events. No apparent consolidation or loss of dredged material was indicated by the depth difference comparison.

In the three SPI surveys (1996, 2001, and 2003) ambient sediments were detected at the east and south perimeters of the sampling grid (Stations A300E and A300S). In the 2001 survey, ambient sediment was detected at Station A200S, while dredged material was detected at this station in 2003. In both the 2001 and 2003 surveys, it was often difficult to differentiate between ambient sediment and older, biologically reworked dredged material (SAIC 2003, this report). However, at Station A200S, recent dredged material was visible in two of the replicates and a relic RPD was observed in the third, suggesting some deposition from recent disposal events.

Because only a small volume of dredged material had been placed at Mound A since its formation in 1995, no significant changes in either height or footprint of the dredged material were expected in the 2003 survey. The 2003 bathymetric and SPI survey results support this expectation.

4.2.2 Biological Conditions and Benthic Recolonization

The 2001 SPI survey data indicated that benthic recovery at Mound A was slower than expected (SAIC 2003). A decline in conditions relative to the 1996 survey was reflected in shallower RPD depths and a decline in the presence of Stage III infauna over most of the mound, especially over the southern and western portions (SAIC 2003). Only 31% of the replicates were in a Stage III condition and the mean apparent RPD depth was a shallow 1.9 cm (Table 3-2). A more advanced stage of recovery had been expected in 2001 because relatively healthy benthic conditions had been observed in the 1996 post-disposal survey and no disposal events had occurred at this site in the six years prior to the 2001 survey.

The 2003 SPI survey at Mound A indicated benthic habitat conditions similar to those observed in 2001, and degraded conditions compared with the 2003 reference area results. Between 2001 and 2003, the percentage of replicates with evidence of Stage III infauna increased from 31% to 38%, but the mean RPD depth decreased from 1.9 to 1.2 cm and the median OSI decreased from +5 to +4. The successional stage advanced from only Stage I in 2001 to Stage III present in 2003 at only three stations (Stations A100W, A300W and A100S). These results were counter to the expectation that benthic habitat conditions would improve over the two-year period between surveys and would resemble ambient conditions eight years following creation of the mound.

The reduction in benthic habitat conditions observed between 1996 and 2001 was attributed to several possible causes. Shallow RPD depths could have been caused by high organic carbon levels and subsequent high sediment oxygen demand associated with dredged material following the initial recruitment of pioneering polychaetes that appear on freshly placed sediment (SAIC 2003). In this case, RPD depths would be expected to increase over time, yet a mean decrease was observed between 2001 and 2003. Another proposed explanation for the apparent decline in benthic habitat conditions at Mound A was that the dredged material contained chemical constituents that impaired the expected progression of the benthic community (SAIC 2003). In the early 1990s, environmental testing was performed *in-situ* on the harbor sediment prior to disposal at CCBDS, and results indicated that the material was suitable for unconfined open-water disposal (SAIC 2003). There are several additional factors that suggest that sediment contamination is

not necessarily responsible for the Mound A retrograde: the rapid initial benthic colonization of Mound A observed in the 1996 survey; the presence of retrograded conditions at all locations over the mound; the origin of sediment from several surrounding harbors; the relatively clean condition of the sediments in the Cape Cod harbors; and the comparable conditions of Mounds A and B.

A final potential contributing factor to the benthic habitat retrograde at Mound A that was proposed following the 2001 survey was a regional decline in benthic habitat conditions. This proposed theory was supported by the 2003 SPI data. As discussed above, reference area data indicated deterioration in benthic conditions between the 1996, 2001, and 2003 surveys. An initial review of MWRA benthic community data from two stations in Cape Cod Bay did not suggest any obvious decline in regional benthic habitat conditions in Cape Cod Bay, but a more thorough review of the data would be necessary to elucidate any trends that may be in the data.

In summary, benthic habitat conditions at Mound A have not progressed as expected between the 2001 and 2003 SPI surveys, and, eight years following the cessation of disposal, conditions were still degraded relative to reference conditions. Decreased RPD depths and dominance of patchy successional stage distribution resulted in a median OSI in 2003 that is indicative of a moderately disturbed benthic environment, as it was in 2001. No single cause of the lack of improved conditions at Mound A has been identified, and although no serious biological issues are evident, further study is warranted under the DAMOS tiered monitoring approach. Study recommendations are provided in Section 5.

4.3 Mound B

The following disposal and monitoring events occurred at Mound B:

- June 1996 to December 2000: Creation of Mound B by the disposal of 323,400 m^3 of dredged material
- August 2001: Monitoring Survey
- October 2001 to December 2001: Disposal of 185,300 m^3 of dredged material
- August 2003: Monitoring Survey

4.3.1 Dredged Material Distribution

The 2003 bathymetric survey indicated that Mound B had increased in size following placement of additional dredged material, and a new apex has formed to the southeast. The depth difference map indicated an increase in mound height of approximately 4 m and a mound size of approximately 560 x 375 m. SPI, a technique able to detect the thinner apron of the dredged material mound, indicated that all of the dredged material appeared to be contained within the surveyed stations, with the possible exception of an extension beyond 420 m north of center. Despite the placement of additional dredged material, the mound footprint has maintained its previous dimensions: the footprint mapped in 2003 is comparable to that mapped in 2001 (SAIC 2003).

Based on the placement of a large volume of dredged material on Mound B since the 2001 survey, it was expected that the mound would increase in size and extent. The 2003 bathymetric and SPI survey results indicated that the mound increased in size, as expected, but that the mound footprint maintained its previous extent.

4.3.2 Biological Conditions and Benthic Recolonization

The 2001 SPI survey of Mound B showed a mosaic of successional stages reflecting disposal activities from 1996 to 2000. Since the 2001 survey, the additional dredged material placed at Mound B may have caused a decline in benthic conditions (in successional stage, mean apparent RPD depths, and OSI values; Table 3-4). A substantial volume of dredged material was placed at Mound B 19 to 22 months prior to the 2003 survey. Stage III assemblages were observed in 2003 at several stations where dredged material was evident (Stations BCTR, B140N, B140E, B280E, B140S and B280S), as would be expected in the second-year monitoring survey (Germano et al 1994). When the disposal pattern prior to the 2003 survey is compared with the volume and timing of dredged material placed at Mound B prior to the 2001 survey (Figure 4-2), the extent of recovery observed at Mound B in 2003 is consistent with expectations and with previous observed recovery rates.

The overall distribution of OSI values in the 2003 survey indicated that benthic habitat conditions at Mound B were comparable to those at Mound A. There is a suggestion that some wide-scale unspecified stress may inhibit benthic community development and could prevent progress beyond the current observed conditions. Over the next few years, deepening RPD depths would be anticipated at Mound B, with increased presence of Stage III infauna at all stations across the mound and in a higher percentage of the replicates, with conditions approaching those observed at the reference area.

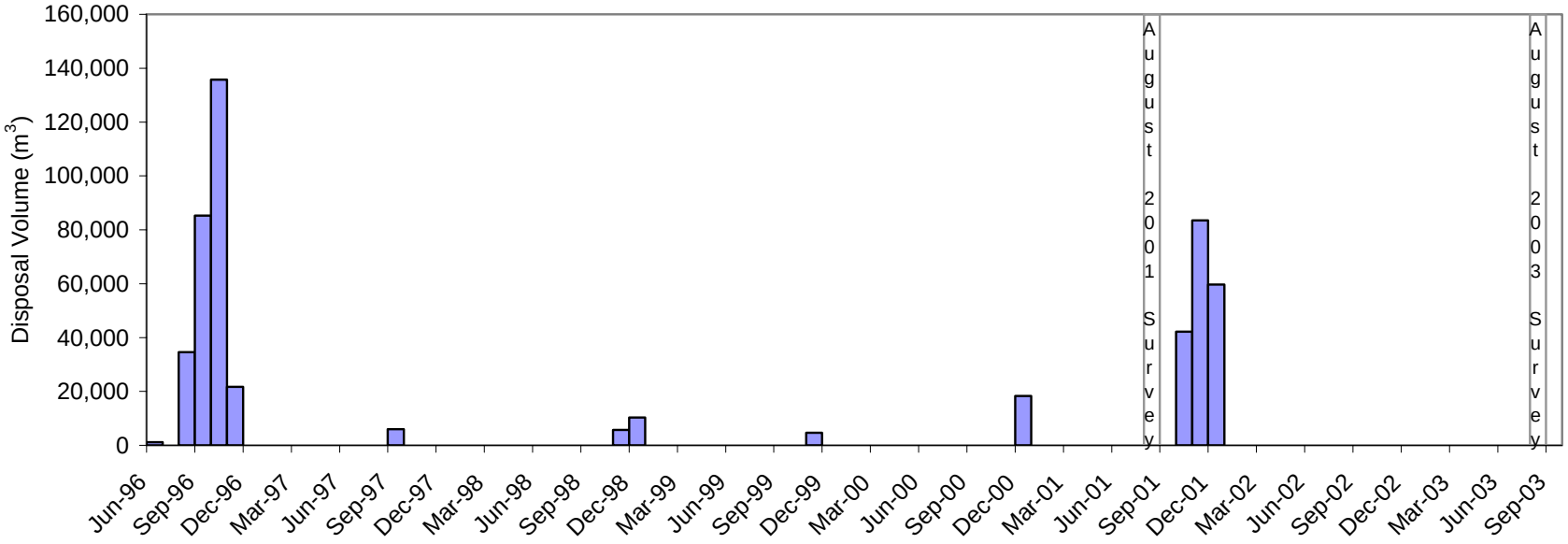


Figure 4-2. Timeline of dredged material disposal at Mound B

5.0 CONCLUSIONS

The August 2003 survey at CCBDS was performed to provide post-disposal bathymetric and SPI data over two mounds at the site: Mound A, where major disposal activity ended in early 1995, but a slower-than-expected recovery was identified in the August 2001 survey; and Mound B, where major disposal activity ended approximately 20 months prior to the survey. The 2003 survey was designed to assess the following specific expectations:

- The size and shape of Mound A, as characterized by the footprint and height, will be similar to that measured in 2001, with little to no apparent consolidation. Small amounts of recent dredged material may be detected in the southwestern quadrant of the mound where limited disposal (2600 m^3) occurred in 2002.

- In the eighth year after disposal, Mound A sediments will support an advanced benthic community relative to the 2001 survey and comparable to CCBRS, with RPD depths, frequency of Stage II or III assemblages and OSI values comparable to those of CCBRS.

- The 185,300 m^3 of sediment placed in the northeast quadrant of CCBDS since the August 2001 survey will result in an increase in height and lateral dimensions of Mound B.

- Twenty months after disposal, sediments at Mound B will support some progression into Stage II and Stage III communities, displaying relatively deep RPD depths, and resulting OSI values indicative of only a moderate to slightly disturbed habitat relative to CCBRS.

With respect to the physical configuration of the mounds, the August 2003 results met the expectations noted above for both Mound A and Mound B. In the southeast quadrant of CCBDS, Mound A was stable in configuration, and was similar in size and shape to that measured in 2001. Following placement of 185,300 m^3 of dredged material in the northeast quadrant of CCBDS in the fall of 2001, Mound B had increased in height by approximately 4 m, for a total mound height of approximately 5.5 m above the surrounding seafloor. Although there was no detectable change in the lateral dimensions of the Mound B footprint, the steeper eastern and southern faces of the mound may eventually result in limited redistribution of material down slope.

With respect to the biological assessment, the results of the August 2003 survey met some but not all of the expectations noted above. Conditions at Mound B are following the expected sequence after cessation of disposal operations, with evidence of a moderate to slightly disturbed habitat. Although there were no serious biological issues identified at Mound A, benthic habitat conditions are similar to those found in 2001 and have not improved as expected.

The results of the August 2003 monitoring at CCBRS were similar to those found in 2001: both data sets indicated degraded benthic conditions in comparison to results from monitoring performed in 1996. This observation raised the possibility that regional conditions might have caused habitat disturbance and slowed recolonization at all sampling stations, including Mounds A and B. The intensity of sampling at the reference area in 2003 was not sufficient to permit tests of significance of this apparent degradation with data from previous surveys. An initial review of MWRA data from two stations in Cape Cod Bay indicated long-term stability in benthic community structure, sediment grain size, and total organic carbon. As a result, questions remain about the significance of the SPI results and the slower-than-expected recovery at Mound A. Specific conclusions and recommendations regarding the reference area and Mounds A and B are presented below.

5.1 Reference Stations and Regional Considerations

The SPI data suggested a decline in benthic habitat conditions at both CCBRS and CCBDS. However, when interpreting the data, consideration should be given to sampling design and analytical methodology, as well as to the benthic community expected at the site. The spatial density of SPI sampling at CCBRS was not sufficient to test the significance of the 2003 results or to determine Stage III distribution definitively. The Stage III benthic community characteristic of this region of Cape Cod Bay is dominated by the deep-burrowing holothurian *Molpadia oolitica*. If camera penetration depth is less than the mean feeding depth, feeding voids will most likely not be observed in SPI images. Because *M. oolitica* occurs in relatively low-density populations and is patchy in distribution, it can be difficult to document in grab samples or SPI images. Hence, spatially intensive sampling may be required in this habitat to determine patch size and distribution of this dominant Stage III organism.

To explore the cause of this apparent decline in conditions and address reference area sampling issues, the following recommendations are proposed:

R1) Reanalyze the SPI images from CCBRS from all three sampling surveys (1996, 2001, 2003) to establish whether a bias toward measurement of deeper apparent RPD depths in the 1996 survey resulted in higher OSI values. If reanalysis determines a bias in any year of sampling, reanalyze the SPI images from Mound A from all three years and Mound B from 2001 and 2003 (if applicable).

R2) Control the seasonal variation expected in SPI survey results. The large apparent change in SPI results in both reference and disposal sites between 1996 and 2001–2003 could be due to the difference in the survey seasons. All future surveys to assess benthic recolonization should be conducted in mid- to late summer when benthic metabolic rates are highest, primary production is relatively low, benthic recruitment has taken place, sediment-mediated reaction rates are at a seasonal high, and organism-sediment relationships are best developed (i.e., high bioturbation rates). Holding the survey season constant will allow observed inter-annual changes to be evaluated with more confidence.

R3) Ensure that future SPI surveys include three reference areas and increase the total number of SPI reference stations to match the number of stations on each mound, to allow better estimation of organism-sediment conditions on the ambient bottom and a statistically robust comparison of reference area conditions with CCBDS conditions.

R4) Consider sampling MWRA FF06, a location where a long-term database of biology, sediment grain size, and TOC data exists, to facilitate the establishment of broader regional baseline conditions.

R5) Review existing regional benthic and water quality data to explore the structure of the benthic community relative to successional paradigms, water and sediment chemistry (particularly nutrient loading), and the current status of the keystone species *Molpadia oolitica* populations in Cape Cod Bay. Summarize the available background data specifically for the DAMOS program. Available sources of data to be reviewed include the on-going MWRA monitoring program (e.g., Maciolek et al. 2003), annual MWRA Outfall Monitoring Overview reports and earlier historical surveys of Cape Cod Bay (Milliman and Maciolek 1987; Rhoads and Young 1971a, 1971b; Young et al. 1971). A review of the bottom video recorded during the August 2003 SPI survey could provide documentation of the existence and frequency of *Molpadia* mounds in the vicinity of the SPI stations.

5.2 Mound A

Older sediment deposits were documented at Mound A in the southeast quadrant of CCBDS. The size and extent of Mound A has not changed significantly since the 2001 survey. Recent disposal of dredged material was sufficiently low in volume (2600 m^3) that it was detected at only one SPI station.

Benthic habitat conditions at Mound A have not improved as expected since the 2001 survey. Failure of the benthic community to exhibit continued recovery several years following the completion of disposal activities leads to Tier 2 analysis in the DAMOS monitoring and management protocol, an evaluation to determine if physical attributes of the mound have changed. The Tier 2 null hypothesis is:

Ho: The sediment grain-size major mode on the disposal mound is not different from the ambient seafloor.

Bathymetric and SPI results from the 2003 survey indicate that the mound has maintained a stable configuration and that sediment grain size (as evident in SPI imagery) shows negligible difference from ambient conditions. There is insufficient data from reference areas to provide a robust test of significance of no difference among means, but the conservative approach is to assume no physical disturbance and proceed to Tier 3 assessment. A Tier 3 analysis within the DAMOS monitoring and management protocol incorporates sampling and laboratory analysis targeted at the locations of poor recruitment. Because benthic conditions are generally patchy over Mound A, with no one area exhibiting significantly poorer conditions, there is no strong indication that chemical contamination is the primary cause of the inhibited recovery at Mound A. The following recommendation is proposed for Mound A:

R6) Review the permit data for disposal at Mound A and design an appropriate sampling program to supply statistically valid levels of representativeness for reference areas and Mound A. An appropriate approach, given the lack of any distinct gradient in conditions on the mound, would be to establish a 600-m diameter around Mound A and each of three reference areas (CCBRS, NW REF, SW REF). Twenty SPI stations would be occupied randomly within each circle, with three replicates taken at each station. Random grab samples of sediment should also be collected to be archived for analysis of sediment chemistry and bulk sediment properties or composite bioassays in the event that the SPI results proved conclusive of a difference in recolonization between Mound A and

reference conditions. If no statistically significant differences in the SPI data are found between reference areas and Mound A, and the results still suggest a stressed community, further studies including a review of the management approach at this disposal site may be warranted. Additional studies could include benthic biology grab sampling and/or surface imaging/videography using a "bounce" camera, an ROV, or a towed sled camera to assess the abundance of *M. oolitica*, whose distinct mounds at the sediment surface may be used to identify and enumerate these holothurians and their associated fauna.

5.3 Mound B

The August 2003 survey indicated that the 185,300 m^3 of dredged material recently placed at Mound B resulted in a larger mound, with an approximate height of 5.5 m above the surrounding seafloor. The dredged material footprint has not expanded following the additional disposal events, and remains at approximately 600 m diameter. The mound had relatively steep slopes along the eastern and southern faces, and this material could be redistributed during severe storm events. Based on this observation, the following recommendation is proposed for Mound B:

R7) Additional material should not be disposed in the vicinity of the peak of Mound B to avoid formation of steep slopes.

Mound B has exhibited adequate recovery in benthic habitat conditions in the 20 months following the completion of disposal activities; however, SPI data indicated the continued stressed conditions over the mound. Based on these results, combined with the concern over observations at Mound A and the reference areas, the following recommendation is proposed for Mound B:

R8) Resurvey the SPI stations at Mound B in a randomized circle design (as in R5 above) in one to two years to monitor the progress of benthic habitat recovery.

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Appendix A

Disposal Barge Log Summary for CCBDS
August 2001 to August 2003

Project Name: WELLFLEET HARBOR
Permittee: TOWN OF WELLFLEET
Permit Number: 199800874

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
10/2/2001	1,500	1,147	41.91090	-70.21505	75 FT	NW
10/3/2001	1,500	1,147	41.91093	-70.21468	100 FT	NW
10/4/2001	1,450	1,109	41.91113	-70.21563	150 FT	NW
10/5/2001	1,450	1,109	41.91093	-70.21502	75 FT	NW
10/5/2001	1,500	1,147	41.91117	-70.21502	75 FT	NW
10/8/2001	1,500	1,147	41.91096	-70.21502	150 FT	NW
10/9/2001	1,500	1,147	41.91084	-70.21500	75 FT	NW
10/10/2001	1,500	1,147	41.91085	-70.21484	50 FT	NW
10/11/2001	1,500	1,147	41.91084	-70.21490	50 FT	NW
10/11/2001	1,500	1,147	41.91075	-70.21492	50 FT	NW
10/12/2001	1,500	1,147	41.91073	-70.21515	100 FT	NW
10/12/2001	1,500	1,147	41.91095	-70.21471	50 FT	NW
10/13/2001	1,500	1,147	41.91093	-70.21471	25 FT	NW
10/14/2001	1,500	1,147	41.91120	-70.21480	50 FT	N
10/14/2001	1,500	1,147	41.91087	-70.21481	40 FT	NW
10/15/2001	1,500	1,147	41.91100	-70.21474	30 FT	NW
10/15/2001	1,500	1,147	41.91092	-70.21468	40 FT	NW
10/16/2001	1,500	1,147	41.91082	-70.21468	100 FT	NW
10/16/2001	1,500	1,147	41.91080	-70.21477	50 FT	NW
10/19/2001	1,500	1,147	41.91087	-70.21477	35 FT	NW
10/19/2001	1,500	1,147	41.91105	-70.21468	25 FT	NW
10/20/2001	1,500	1,147	41.91100	-70.21475	40 FT	NW
10/20/2001	1,500	1,147	41.91090	-70.21480	50 FT	NW
10/21/2001	1,500	1,147	41.91092	-70.21467	25 FT	NW
10/22/2001	1,500	1,147	41.91100	-70.21474	50 FT	NW
10/22/2001	1,500	1,147	41.91082	-70.21481	100 FT	NW
10/23/2001	1,500	1,147	41.91084	-70.21468	75 FT	NW
10/24/2001	1,500	1,147	41.91085	-70.21468	25 FT	NW
10/24/2001	1,500	1,147	41.91100	-70.21468	75 FT	NW
10/28/2001	1,500	1,147	41.91160	-70.21503	100 ft	NW
10/29/2001	1,500	1,147	41.91098	-70.21468	75 ft	NW
10/29/2001	1,500	1,147	41.91108	-70.21468	25 ft	NW
10/30/2001	1,500	1,147	41.91107	-70.21480	75 ft	NW
10/30/2001	1,500	1,147	41.91118	-70.21475	50 ft	NW
10/31/2001	1,500	1,147	41.91103	-70.21463	75 ft	NW
10/31/2001	1,400	1,070	41.91096	-70.21468	25 ft	NW
11/1/2001	1,500	1,147	41.91100	-70.21477	25 ft	NW
11/1/2001	1,500	1,147	41.91102	-70.21484	25 ft	NW
11/2/2001	1,500	1,147	41.91107	-70.21480	50 ft	NW
11/3/2001	1,500	1,147	41.91102	-70.21468	50 ft	NW
11/3/2001	1,500	1,147	41.91100	-70.21484	50 ft	NW
11/4/2001	1,500	1,147	41.91093	-70.21490	75 ft	NW
11/4/2001	1,500	1,147	41.91084	-70.21468	25 ft	NW
11/5/2001	1,500	1,147	41.91082	-70.21468	50ft	NW
11/8/2001	1,500	1,147	41.91093	-70.21508	75	NW

Project Name: WELLFLEET HARBOR (Continued)
Permittee: TOWN OF WELLFLEET
Permit Number: 199800874

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
11/8/2001	1,500	1,147	41.91103	-70.21468	50	NW
11/10/2001	1,500	1,147	41.91133	-70.21432	100	NW
11/10/2001	1,500	1,147	41.91145	-70.21467	75 FT	NW
11/12/2001	1,500	1,147	41.91098	-70.21468	25	NW
11/13/2001	1,500	1,147	41.91093	-70.21484	25	NW
11/14/2001	1,500	1,147	41.91070	-70.21484	100	NW
11/14/2001	1,500	1,147	41.91105	-70.21500	50	NW
11/15/2001	1,500	1,147	41.91078	-70.21485	100	NW
11/15/2001	1,270	971	41.91118	-70.21468	125	NW
11/16/2001	1,500	1,147	41.91123	-70.21468	25	NW
11/17/2001	1,500	1,147	41.91098	-70.21516	50	NW
11/18/2001	1,500	1,147	41.91084	-70.21468	50	NW
11/18/2001	1,500	1,147	41.91085	-70.21468	25	NW
11/27/2001	1,500	1,147	41.91093	-70.21468	0	
11/28/2001	1,500	1,147	41.91093	-70.21468	0	
11/28/2001	1,500	1,147	41.91093	-70.21468	0	
11/29/2001	1,500	1,147	41.91093	-70.21468	0	
11/29/2001	1,500	1,147	41.91093	-70.21468	0	
11/30/2001	1,500	1,147	41.91093	-70.21468	0	
11/30/2001	1,500	1,147	41.91093	-70.21468	0	
12/3/2001	1,500	1,147	41.91093	-70.21468	0	
12/3/2001	1,500	1,147	41.91093	-70.21468	0	
12/4/2001	1,500	1,147	41.91093	-70.21468	0	
12/4/2001	1,500	1,147	41.91093	-70.21468	0	
12/5/2001	1,500	1,147	41.91093	-70.21468	0	
12/6/2001	1,500	1,147	41.91093	-70.21468	0	
12/7/2001	1,500	1,147	41.91093	-70.21468	0	
12/10/2001	1,500	1,147	41.91093	-70.21468	0	
12/11/2001	1,500	1,147	41.91093	-70.21468	0	
12/12/2001	1,500	1,147	41.91093	-70.21468	0	
12/16/2001	1,500	1,147	41.91093	-70.21468	0	
12/17/2001	1,500	1,147	41.91093	-70.21468	0	
12/17/2001	1,500	1,147	41.91093	-70.21468	0	
12/18/2001	1,500	1,147	41.91093	-70.21468	0	
12/19/2001	1,500	1,147	41.91093	-70.21468	0	
12/20/2001	1,500	1,147	41.91093	-70.21468	0	
12/26/2001	1,500	1,147	41.91093	-70.21468	0	
12/26/2001	1,500	1,147	41.91093	-70.21468	0	
Total Dredged Material Volume	124,070	94,858				

Project Name: PROVINCETOWN HARBOR
Permittee: TOWN OF PROVINCETOWN
Permit Number: 199802651

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
11/5/2002	665	508	41.91063	-70.22704	150ft	SE
11/5/2002	800	612	41.91069	-70.22697	100ft	SE
11/9/2002	1,200	917	41.91070	-70.22636	125ft	
11/12/2002	1,500	1,147	41.91102	-70.22818	75ft	WNW
11/15/2002	1,400	1,070	41.91077	-70.22639	90ft	E
11/19/2002	1,250	956	41.91096	-70.22683	75ft	E
11/25/2002	1,200	917	41.89950	-70.21336	0	
11/26/2002	750	573	41.90002	-70.21335	0	
11/30/2002	1,400	1,070	41.89833	-70.21350	0	
Total Dredged Material Volume	10,165	7,772				

Project Name: FIDDLERS COVE
Permittee: FIDDLERS COVE MARINA
Permit Number: 200001365

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
10/17/2001	650	497	41.91084	-70.21470	7 FT	
Total Dredged Material Volume	650	497				

Project Name: NEW BEDFORD YACHT CLUB
Permittee: NEW BEDFORD YACHT CLUB
Permit Number: 200001668

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
10/31/2001	650	497	41.91080	-70.21470	50 FT	SE
11/2/2001	480	367	41.91067	-70.21410	100 FT	SE
11/5/2001	550	421	41.91100	-70.21584	150 FT	NW
11/9/2001	650	497	41.91202	-70.21585	175 FT	SW
11/19/2001	500	382	41.91147	-70.21500	75	
11/26/2001	550	421	41.91095	-70.21435	0	
12/1/2001	550	421	41.91108	-70.21447	0	
12/3/2001	550	421	41.91090	-70.21477	0	
Total Dredged Material Volume	4,480	3,425				

Project Name: CAPE COD CANAL
Permittee: MIRANT CANAL
Permit Number: 200101946

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
11/30/2001	2,593	1,982	41.91096	-70.21507	0	
11/30/2001	2,629	2,010	41.91125	-70.21478	0	
11/30/2001	2,538	1,940	41.91100	-70.21510	0	
12/1/2001	2,447	1,871	41.91123	-70.21445	0	
12/1/2001	2,538	1,940	41.91108	-70.21436	0	
12/1/2001	2,885	2,206	41.91058	-70.21440	0	
12/1/2001	2,520	1,927	41.91112	-70.21440	0	
12/1/2001	2,739	2,094	41.91075	-70.21465	0	
12/1/2001	2,300	1,758	41.91088	-70.21463	0	
12/2/2001	2,428	1,856	41.91100	-70.21455	0	
12/2/2001	1,917	1,466	41.91070	-70.21432	0	
12/2/2001	2,319	1,773	41.91122	-70.21463	0	
12/2/2001	2,502	1,913	41.91085	-70.21492	0	
12/3/2001	2,501	1,912	41.91077	-70.21439	0	
12/3/2001	2,337	1,787	41.91067	-70.21457	0	
12/3/2001	2,209	1,689	41.91117	-70.21458	0	
12/3/2001	1,698	1,298	41.91105	-70.21426	0	
12/4/2001	2,081	1,591	41.91077	-70.21442	N/A	
12/4/2001	2,483	1,898	41.91090	-70.21427	N/A	
12/5/2001	2,246	1,717	41.91125	-70.21467	0	
12/5/2001	1,588	1,214	41.91132	-70.21475	0	
Total Dredged Material Volume	49,498	37,844				

Project Name: WELLFLEET HARBOR
Permittee: TOWN OF WELLFLEET
Permit Number: 200101989

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
11/8/2001	2,200	1,682	41.91084	-70.21350	100	NE
11/8/2001	2,200	1,682	41.91067	-70.21533	100	W
11/9/2001	2,200	1,682	41.91084	-70.21350	100	E
11/12/2001	2,200	1,682	41.91084	-70.21367	100	E
11/13/2001	2,250	1,720	41.91105	-70.21343	100	E
11/14/2001	2,250	1,720	41.91153	-70.21353	100	NE
11/14/2001	2,100	1,606	41.91162	-70.21343	100	NE
11/15/2001	2,100	1,606	41.91048	-70.21574	100	W
11/15/2001	2,100	1,606	41.91045	-70.21436	100	S
11/16/2001	1,500	1,147	41.91113	-70.21413	100	S
11/17/2001	2,200	1,682	41.91138	-70.21391	100	E
11/18/2001	2,100	1,606	41.91138	-70.21358	100	E
11/18/2001	2,100	1,606	41.91183	-70.21400	100	E
11/19/2001	2,100	1,606	41.91120	-70.21416	100	E
11/19/2001	1,800	1,376	41.91145	-70.21415	100	E
11/20/2001	1,900	1,453	41.91075	-70.21575	100	W
11/20/2001	1,900	1,453	41.91152	-70.21390	100	E
11/21/2001	1,900	1,453	41.91133	-70.21384	100	E
11/23/2001	1,900	1,453	41.91084	-70.21467	0	
11/24/2001	1,900	1,453	41.91084	-70.21470	0	
11/24/2001	1,900	1,453	41.91092	-70.21465	0	
11/25/2001	1,900	1,453	41.91087	-70.21471	0	
11/26/2001	1,900	1,453	41.91087	-70.21487	0	
11/27/2001	2,600	1,988	41.91112	-70.21490	0	
11/28/2001	2,600	1,988	41.91093	-70.21463	0	
11/29/2001	2,800	2,141	41.91093	-70.21477	0	
11/30/2001	800	612	41.91084	-70.21471	0	
12/1/2001	3,000	2,294	41.91090	-70.21481	0	
12/2/2001	2,600	1,988	41.91098	-70.21467	0	
12/3/2001	2,600	1,988	41.91102	-70.21470	0	
Total Dredged Material Volume	63,600	48,626				

Appendix B

Sediment-Profile Image Results for CCBDS August 2003 Survey

Table B-1
Grain Size Scale for Sediments

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

Table B-2
Sediment-Profile Image Results for Mound A Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
A100E	1B	8/28/2003 14:32	13.73	14.74	14.51	1.01	IND	13.73	14.74	>14.51		>4	2 to 1	>4	IND	IND	IND	0	0	0	0	--	0.0	0	No	IND	IND	DM>PD; Sand dollar at surf., worm at depth; RPD indeterminate;
A100E	2A	8/28/2003 14:33	11.51	11.84	11.69	0.33	Bio	11.51	11.84	>11.69		>4	1 to 0	>4	0.56	3.11	1.29	0	0	0	0	--	0.0	0	No	Stage I on III	7	DM>PD; Void at 5.1cm; Lignin present
A100E	3B	8/28/2003 14:36	16.85	18.66	17.50	1.81	Phys	16.85	18.66	>17.50		>4	1 to 0	>4	0.00	2.05	0.46	0	0	0	0	--	0.2	0	No	Stage I	2	DM>PD; Sulfidic patches at depth;
A100N	1B	8/28/2003 13:50	16.58	18.87	17.98	2.29	Bio	16.58	18.87	>17.98		>4	3 to 2	>4	0.74	4.48	2.98	0	0	0	0	--	0.4	0	No	Stage I	5	DM>PD; Burrow; Puzzle fabric from burrow at 11.9 cm; Lignin present
A100N	2B	8/28/2003 13:50	19.99	20.79	20.25	0.80	Phys	19.99	20.79	>20.25		>4	3 to 2	>4	0.00	3.38	0.48	0	0	0	0	--	0.0	0	No	Stage II	4	DM>PD; Worm at 2.24cm; Relic voids at 9.21 & 13.35, juv. amphi. tubes; Lignin present
A100N	3B	8/28/2003 13:51	19.67	20.79	19.95	1.12	Bio	19.67	20.79	>19.95		>4	1 to 0	>4	0.00	4.30	1.82	0	0	0	0	--	0.2	0	No	Stage II on III	8	DM>PD; Tiny worms near surface; Burrow; Void at 2.6, relic at 6.3; juv. amphi. tubes; Lignin present
A100S	1B	8/28/2003 13:38	13.17	14.00	13.77	0.83	Bio	13.17	14.00	>13.77		>4	3 to 2	>4	0.00	0.00	0.00	0	0	0	0	--	0.0	0	No	Stage I	1	DM>PD; Upper 5 cm, very fine sand;
A100S	2B	8/28/2003 13:38	18.54	18.86	18.67	0.32	Phys	18.54	18.86	>18.67		>4	3 to 2	>4	1.28	2.58	1.95	0	0	0	0	--	0.2	0	No	Stage I on III	8	DM>PD; Feeding void at 5 cm depth;
A100S	3B	8/28/2003 13:39	17.44	19.04	17.99	1.60	Phys	17.44	19.04	>17.99		>4	3 to 2	>4	0.00	1.87	0.70	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; RPD patchy, thin, sulf. patch deep, upper 6.5 cm fine sand; erosional;
A100W	2B	8/28/2003 14:42	17.32	19.43	18.27	2.11	IND	17.32	19.43	>18.27		4 to 3	1 to 0	>4	IND	IND	IND	0	0	0	0	--	0.0	0	No	IND	IND	DM>PD; RPD indeterminate, surface disturbed; Lignin present
A100W	3B	8/28/2003 14:42	17.53	18.18	17.72	0.65	Phys	17.53	18.18	>17.72		>4	2 to 1	>4	0.00	1.90	0.90	0	0	0	0	--	0.2	0	No	Stage I	3	DM>PD; 2 sand dollars at surface; No feeding voids; Lignin present
A100W	4C	8/28/2003 14:43	19.43	20.26	19.96	0.83	Bio	19.43	20.26	>19.96		>4	2 to 1	>4	0.12	2.73	1.59	0	0	0	0	--	0.0	0	No	Stage II on III	8	DM>PD; Lg. voids at 3 & 4.1 cm, many amphi. tubes; Lignin present
A200E	1B	8/28/2003 14:26	13.73	14.21	13.90	0.48	Phys	13.73	14.21	>13.90		>4	3 to 2	>4	0.00	0.68	0.06	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; Sand dollar at surface; 2 cm sand over mud (S/M); erosional; Lignin present
A200E	2B	8/28/2003 14:27	15.25	16.79	15.63	1.54	IND	15.25 (?)	16.79 (?)	>15.63 (?)		>4	3 to 2	>4	0.53	3.06	2.00	0	0	0	0	--	0.0	0	No	Stage I on III	8	DM?>PD; Tiny worm at 2 cm ; Sulfidic patches at depth; Void at 3.2cm;
A200E	3B	8/28/2003 14:27	16.76	18.21	17.38	1.45	Phys	16.76	18.21	>17.38		>4	1 to 0	>4	0.00	1.48	0.54	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; 2 sand dollars at surface; RPD patchy; funnel pit, 3 cm sand over mud;

Table B-2
Sediment-Profile Image Results for Mound A Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
A200N	2B	8/28/2003 13:55	16.70	18.72	17.39	2.02	Bio	16.70	18.72	>17.39		>4	3 to 2	>4	0.36	3.47	2.12	4.06	8.13	6.01	0	--	0.2	0	No	Stage I-II	5	DM>PD; Thin worm at 9 cm; Relic RPD at 9 cm depth, upper 4 cm is fine sand; Juv. amphipod tubes?; Lignin present
A200N	3B	8/28/2003 13:56	19.13	20.79	19.99	1.66	Bio	19.13	20.79	>19.99		>4	2 to 1	>4	0.44	2.52	1.32	4.92	7.53	6.48	0	--	0.2	0	No	Stage I	3	DM>PD; Worm at 4.7cm; Relic RPD at 10 cm depth, upper 7 cm is fine sand; Relic voids; Lignin present
A200N	4B	8/28/2003 13:57	14.21	20.23	16.74	6.02	IND	14.21	20.23	>16.74		>4	3 to 2	>4	0.03	3.41	1.26	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD; Surf. Disturbed, shelter fabric; No feeding voids; Lignin present
A200S	1B	8/28/2003 13:33	16.20	16.85	16.45	0.65	IND	16.20	16.85	>16.45	14.02	>4	4 to 3	>4	0.00	2.79	0.83	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD? recent DM to 14.02 cm depth; Thin worms at 4 & 13, 3 sand dollars; Sulfidic patch at 10 cm depth (DM?);
A200S	2B	8/28/2003 13:33	17.29	17.98	17.51	0.69	Bio	17.29	17.98	>17.51	14.39	>4	3 to 2	>4	0.56	2.85	1.86	0	0	0	0	--	0.2	0	No	Stage I on III	8	DM>PD? recent DM to 14.39 cm depth; Worm at 3 cm; Upper 2 cm is very fine sand; Lg. void at 9.9 cm;
A200S	3B	8/28/2003 13:34	14.86	15.99	15.43	1.13	Bio	14.86	15.99	>15.43		>4	3 to 2	>4	0.24	2.73	1.24	0	0	0	0	--	0.2	0	No	Stage I	3	DM>PD; Thin worms at 12 cm; Relic RPD at 4.5 cm depth;
A200W	1B	8/28/2003 14:49	17.35	17.98	17.56	0.63	Phys	17.35	17.98	>17.56		>4	2 to 1	>4	0.00	2.14	1.24	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD; Worm at 10.4 cm; No feeding voids; Lignin present
A200W	2B	8/28/2003 14:49	19.22	20.29	19.80	1.07	Bio	19.22	20.29	>19.80		>4	1 to 0	>4	0.00	2.52	1.55	0	0	0	0	--	0.0	0	No	Stage I on III	8	DM>PD; Voids at 4.2 5.9 & 6.4cm; Lignin present
A200W	3A	8/28/2003 14:50	18.84	20.20	19.34	1.36	Phys	18.84	20.20	>19.34		>4	3 to 2	>4	0.00	2.64	1.61	0	0	0	0	--	0.2	0	No	Stage I	4	DM>PD; Sulfidic at depth; Lignin present
A300E	1B	8/28/2003 14:20	15.99	18.15	17.12	2.16	Bio	Ambient ?	Ambient ?	Ambient ?		>4	3 to 2	>4	0.06	4.09	2.36	0	0	0	0	--	0.0	0	No	Stage I on III	9	Ambient?; Voids at 10.4 & 12.9 cm, a few lg. amphi. tubes; Egg masses with stalks on surface
A300E	2B	8/28/2003 14:21	16.5	19.25	17.72	2.75	IND	Ambient ?	Ambient ?	Ambient ?		>4	3 to 2	>4	IND	IND	IND	0	0	0	0	--	0.3	0	No	Stage I	IND	Ambient?; Worm at depth; Surface disturbed, hit previous footprint?;
A300E	3B	8/28/2003 14:21	15.28	15.75	15.52	0.47	Phys	Ambient ?	Ambient ?	Ambient ?		>4	3 to 2	>4	0.00	3.59	1.19	0	0	0	0	--	0.0	0	No	Stage I on III	7	Ambient?; Feeding voids at 2-3 cm, a few amphi. tubes; Eggs? on surface

Table B-2
Sediment-Profile Image Results for Mound A Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
A300N	1B	8/28/2003 14:03	16.64	17.26	16.93	0.62	Phys	16.64	17.26	16.93	Obscured	>4	3 to 2	>4	IND	IND	IND	0	0	0	0	--	0.0	0	No	Stage I on III	IND	DM>PD; pull-away hides recent DM ; Pull away obscured RPD, erosional (est. 5 mm); stranded tubes; Voids at 3.3 & 6cm; Lignin present
A300N	2	8/28/2003 14:04	14.42	17.26	15.74	2.84	IND	14.42	17.26	15.74		>4	2 to 1	>4	0.00	1.84	0.54	0	0	0	0	--	0.0	0	No	Stage I on III	6	DM>PD; Upper 6 cm, very fine sand (phi 4-3); Feeding void at 6 cm, a few juv. amphi. tubes; Lignin present
A300N	3C	8/28/2003 14:07	20.2	21.54	20.59	1.34	Phys	20.2	21.54	20.59		>4	1 to 0	>4	0.00	1.87	0.79	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; Relic RPD at 4-5.5 cm depth; upper 4 cm is fine sand (phi 3-2); Lignin present
A300S	1A	8/28/2003 13:25	11.95	13.79	12.76	1.84	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.21	4.00	1.66	0	0	0	0	--	0.0	0	No	Stage I on III	8	Ambient; A few amphipod tubes; Voids at 4.5 and 10 cm, a few amphi. tubes;
A300S	2B	8/28/2003 13:26	18.72	19.76	18.97	1.04	Bio	Upper 3.5 cm?	Upper 3.5 cm?	Upper 3.5 cm?		>4	3 to 2	>4	0.00	2.02	0.85	0	0	0	0	--	0.2	0	No	Stage I	3	Upper 3.5 cm DM?; Thin worms at 6 and 17 cm depth; Sulfidic patch at 9 cm depth, upper 3.5 cm is very fine sand - DM?; Shell bits in upper 5 cm
A300S	3B	8/28/2003 13:27	13.11	17.59	15.39	4.48	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.00	2.14	1.41	0	0	0	1	0.4	0.2	0	No	Stage I on III	7	Ambient; Edge of Molpadia mound?; Void at 1.4 cm depth, a few amphipod tubes; Stick amphipod (podocerid)
A300W	1B	8/28/2003 14:58	13.08	15.31	13.71	2.23	Phys	13.08	15.31	>13.71	12.18	>4	3 to 2	>4	0.39	3.06	1.82	0	0	0	0	--	0.0	0	No	Stage I	4	DM>PD; recent DM to 12.18 cm depth; Large nepthys at 7.42 cm; Sulfidic patches at depth;
A300W	2B	8/28/2003 14:59	16.08	17.09	16.49	1.01	Phys	16.08	17.09	>16.49	14.95	>4	3 to 2	>4	0.30	3.00	1.09	0	0	0	0	--	0.0	0	No	Stage I on III	7	DM>PD; recent DM to 14.95 cm depth; Sulfidic layer at depth; Voids at 1.6 & 3.4 cm; 4 layers; yellow, lt. gray, black, gray
A300W	4C	8/28/2003 15:00	14.95	18.04	16.73	3.09	IND	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.00	1.93	0.75	0	0	0	0	--	0.0	0	No	Stage I-II	3	Ambient; Sulfidic patches at depth, possible Molpadia mound; A few amphipod tubes; 2 egg masses
ACTR	1B	8/28/2003 13:43	17.96	19.84	19.31	1.88	Bio	17.96	19.84	>19.31		>4	3 to 2	>4	0.00	1.54	1.00	0	0	0	0	--	0.4	0	No	Stage II	5	DM>PD; Juv. amphipod? mat;

Table B-2
Sediment-Profile Image Results for Mound A Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
ACTR	2B	8/28/2003 13:43	11.63	12.96	12.34	1.33	Phys	11.63	12.96	>12.34		>4	4 to 3	>4	0.00	2.41	1.32	0	0	0	0	--	0.0	0	No	Stage II on III	7	DM>PD; Slight erosion, stranded tubes; Void at 5 cm, amphi. tubes?; Stick amphipod (podocerid)
ACTR	3B	8/28/2003 13:44	19.07	20.65	19.61	1.58	Phys	19.07	20.65	>19.61		>4	3 to 2	>4	0.00	0.00	0.00	0	0	0	5	0.3	0.0	0	No	Stage I	1	DM>PD; Tiny worms at 4.8cm; Erosional with clasts; Tiny worms at 4.8 cm, relic voids;

Table B-3
Sediment-Profile Image Results for Mound B Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
B140E	1B	8/28/2003 12:30	10.44	11.12	10.67	0.68	Bio	10.44	11.12	>10.67		>4	4 to 3	>4	0.59	3.41	1.91	0	0	0	0	--	0.0	0	No	Stage I on III	8	DM>PD; Holothurian? at surf, worm at 5 cm; Bottom 4 cm very sulfidic; Void at 4, relic void at 7 cm depth;
B140E	2B	8/28/2003 12:31	12.52	14.86	13.28	2.34	Phys	12.52	14.86	>13.28		>4	3 to 2	>4	0.00	3.14	1.42	0	0	0	0	--	0.1	0	No	Stage I on III	7	DM>PD; 5 sand dollars; ; Sulfidic below 6.3 cm, erosional?; Feeding void at 4 cm (left), 3 relic voids;
B140E	3B	8/28/2003 12:32	10.95	11.87	11.23	0.92	Bio	10.95	11.87	>11.23		>4	3 to 2	>4	0.36	2.88	1.96	0	0	0	0	--	0.3	0	No	Stage I	4	DM>PD; 2 sand dollars at surface; Sulfidic below 6 cm; A few relic voids?;
B140N	1B	8/28/2003 11:47	16.01	18.30	17.20	2.29	Bio	16.01	18.30	>17.20		>4	3 to 2	>4	0.00	2.76	1.25	0	0	0	0	--	0.0	0	No	Stage I on III	7	DM>PD; Mostly sulfidic below RPD; Voids at 5.5 and 9.0 cm depth;
B140N	2B	8/28/2003 11:48	17.80	19.84	19.36	2.04	Bio	17.80	19.84	>19.36		>4	3 to 2	>4	0.59	2.97	1.45	0	0	0	0	--	0.0	0	No	Stage I on III	7	DM>PD; Sand dollar on surface; Sulfidic below RPD, abandoned pit burrow?; Voids at 4.1 and 9.7 cm depth;
B140N	3B	8/28/2003 11:48	20.26	20.94	20.65	0.68	Bio	20.26	20.94	>20.65		>4	3 to 2	>4	0.03	2.64	1.28	0	0	0	0	--	0.0	0	No	Stage I on III	7	DM>PD; Sand dollar on surface; Sulfidic below RPD; Voids at 13.0 and 13.9 cm depth;
B140S	1B	8/28/2003 11:26	11.84	12.55	12.22	0.71	IND	11.84	12.55	>12.22		>4	1 to 0	>4	0.09	2.58	0.81	0	0	0	1	0.4	0.0	0	No	Stage I on III	7	DM>PD; Sand dollar on surface; Sulfidic below 2.3 cm, poorly sorted, sand at depth, physical SR?; Relic voids, void at 7 cm on left;
B140S	2B	8/28/2003 11:27	10.65	12.34	10.93	1.69	Phys	10.65	12.34	>10.93		>4	2 to 1	>4	0.09	4.60	2.23	0	0	0	8	0.8	0.2	0	No	Stage I on III	8	DM>PD; Sulfidic below RPD, burrow leading to void; Small void at depth ;
B140S	3B	8/28/2003 11:28	8.13	8.63	8.38	0.50	Bio	8.13	8.63	>8.38		>4	4 to 3	>4	0.12	2.70	1.16	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD; Sand dollar + holothurian on surface; Sulfidic below RPD;
B140W	1A	8/28/2003 12:39	12.67	15.19	13.60	2.52	IND	12.67	15.19	>13.60		>4	3 to 2	>4	0.00	2.67	1.16	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD; Burrowing anemone at 5.3 cm; Sulfidic below 4 cm, burrowing anemone?; Shell pieces in upper 7 cm
B140W	2B	8/28/2003 12:39	13.67	15.42	14.54	1.75	Bio	13.67	15.42	>14.54		>4	3 to 2	>4	0.36	2.85	1.72	0	0	0	0	--	0.2	0	No	Stage I	4	DM>PD; Worm in burrow; Long, thin burrows; Small relic voids at 8 and 13 cm depth;

Table B-3
Sediment-Profile Image Results for Mound B Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
B140W	3D	8/28/2003 12:40	19.37	20.73	19.93	1.36	Bio	19.37	20.73	>19.93		>4	4 to 3	>4	0.71	2.97	1.89	0	0	0	0	--	0.2	0	No	Stage I	4	DM>PD; Sand dollar on surface; Small relic void at 11 cm depth; 3 layers; yellow+gray (6.8), black (3.8), gray (8.7)
B280E	1B	8/28/2003 12:22	14.80	15.34	14.95	0.54	Phys	14.80	15.34	>14.95	6.70	>4	2 to 1	>4	0.03	0.83	0.37	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; recent DM to 6.7 cm depth; Arenaceous forams; Sulfidic middle layer below RPD to 6.9 cm depth, erosional; 3 layers; light (2.3), black (4.5), gray below 6.9 cm
B280E	2B	8/28/2003 12:23	19.43	21.36	20.52	1.93	Bio	19.43	21.36	>20.52	15.00	4 to 3	3 to 2	>4	0.33	2.34	1.31	0	0	0	0	--	0.3	0	No	Stage I on III	7	DM>PD; recent DM to 15.00 cm depth; Sand dollar at surf., enteropneust?; Lg. sulfidic patches from 9 to 17 cm depth, enteropneust?; Tiny void at 6.5 cm depth; 4 layers; light, gray, black, gray; fish eggs? (2)
B280E	3B	8/28/2003 12:23	18.01	19.22	18.61	1.21	Bio	18.01	19.22	>18.61	14.77	>4	4 to 3	>4	0.00	2.73	1.45	0	0	0	0	--	0.2	0	No	Stage I on III	7	DM>PD; recent DM to 14.77 cm depth; Sulf. partial layer 4 cm thick below 9 cm, lg. burrow to feeding void; Void at 4 cm depth in burrow; 4 layers in a V, yellow, gray, black, gray; fish egg? (1);
B280N	1B	8/28/2003 11:55	17.71	19.61	18.51	1.90	IND	17.71	19.61	>18.51	15.00	>4	3 to 2	>4	0.00	5.58	1.60	0	0	0	0	--	0.0	0	No	Stage I	4	DM>PD; recent DM to 15.00 cm depth; Small sand dollar at surf.; Sulf. Patch, two burrow pits at surf., mounds from burrows?; black layer to 13-19 cm depth
B280N	2B	8/28/2003 11:56	14.39	16.34	15.07	1.95	IND	14.39	16.34	>15.07	13.08	>4	3 to 2	>4	0.00	2.14	0.57	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; recent DM to 13.08 cm depth; Tube mats; black layer to 11-16 cm depth
B280N	3B	8/28/2003 11:56	14.51	15.87	15.08	1.36	Bio	14.51	15.87	>15.08	12.09	>4	2 to 1	>4	0.06	0.98	0.40	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; recent DM to 12.09 cm depth; Polychaete near surface; Relic void? at 10 cm depth; 3 layers; yellow+lt gray (8.6), black (3.7), lt gray (3)

Table B-3
Sediment-Profile Image Results for Mound B Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
B280S	1B	8/28/2003 11:15	15.22	16.73	15.94	1.51	Bio	15.22	16.73	>15.94	9.22	>4	3 to 2	>4	1.10	3.89	2.12	0	0	0	0	--	0.3	0	No	Stage I on III	8	DM>PD; recent DM to 9.22 cm depth; Voids at 4.5, 9.5, 10.9 cm depth; 3 layers; yellow (4.2), black (4.7), gray (7)
B280S	2B	8/28/2003 11:16	12.22	16.17	14.42	3.95	Bio	12.22 (?)	16.17 (?)	>14.42 (?)	3.81	>4	3 to 2	>4	0.00	2.64	1.23	0	0	0	0	--	0.0	0	No	Stage I	3	DM?>PD; recent DM to 3.81 cm depth; Sulfidic patch nr. surface; possible Molpadia burrow/pit; Slurry in pit on left from Molpadia?
B280S	3B	8/28/2003 11:16	14.45	15.60	14.88	1.15	Bio	14.45	15.60	>14.88	10.81	>4	3 to 2	>4	0.65	2.94	2.14	0	0	0	0	--	0.3	0	No	Stage I	4	DM>PD; recent DM to 10.81cm depth; 3 layers; yellow+lt gray (5.6), dk gray (6.9), lt gray (2.4)
B280W	2B	8/28/2003 12:48	16.46	16.93	16.67	0.47	Bio	16.46	16.93	>16.67	13.32	>4	2 to 1	>4	0.00	0.00	0.00	0	0	0	0	--	0.0	0	No	Stage I	1	DM>PD; recent DM to 13.32 cm depth ; A few amphipod tubes; Mottled sulf. patches 5.6-9.5 cm; RPD layer - very fine to fine sand; 4-5 layers; gray, yellow, gray, black, gray
B280W	3B	8/28/2003 12:48	16.94	18.78	17.86	1.84	IND	16.94	18.78	>17.86	11.07	>4	2 to 1	>4	IND	IND	IND	0	0	0	0	--	0.0	0	No	Stage I	IND	DM>PD; recent DM to 11.07 cm depth; RPD indeterminate, surface disturbed; 3 layers; yellow+gray (6.3), black (4.8), gray (6.7)
B280W	4B	8/28/2003 12:49	18.15	19.25	18.94	1.10	IND	18.15	19.25	>18.94	12.83	>4	4 to 3	>4	0.00	1.66	0.58	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; recent DM to 12.83 cm depth; Sand dollar on surtace; Relic? Burrow; 3 layers, yellow+gray (7.78), black (5.5), gray (6.7)
B420E	1A	8/28/2003 12:14	14.98	16.14	15.49	1.16	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.98	3.00	2.14	0	0	0	0	--	0.3	0	No	Stage I-II	5	Ambient; Ophiuroid on surf., Nephtys at 11.2; Sulfidic patch at depth; A few amphipod tubes;
B420E	2B	8/28/2003 12:15	17.74	18.30	18.07	0.56	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.03	2.28	1.12	0	0	0	0	--	0.0	0	No	Stage I-II	4	Ambient; RPD patchy; burrow funnel pit; A few amphipod tubes;
B420E	3B	8/28/2003 12:15	17.20	17.83	17.38	0.63	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.03	2.05	0.46	0	0	0	0	--	0.0	0	No	Stage I on III	6	Ambient; Slight pull-away; Feeding void at 9.5 cm, a few amphi. tubes; A few arenaceous forams on surf.

Table B-3
Sediment-Profile Image Results for Mound B Stations at CCBDS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
B420N	1B	8/28/2003 12:01	13.11	14.33	13.88	1.22	IND	13.11	14.33	>13.88	2.28	>4	3 to 2	>4	IND	IND	IND	0	0	0	0	--	0.0	0	No	IND	IND	DM>PD; recent DM to 2.28 cm depth; Sand dollar on surface; RPD indeterminate; disturbed; 4 layers; to bottom of black (2), gray (2), black (2.8), gray (6.1)
B420N	2B	8/28/2003 12:01	12.99	14.21	13.25	1.22	Phys	12.99	14.21	>13.25	1.54?	>4	4 to 3	>4	0.12	1.99	0.69	0	0	0	0	--	0.0	0	No	Stage I	2	DM>PD; recent DM? to 1.54 cm depth; Sand dollar on surface; Erosional;
B420N	3B	8/28/2003 12:02	15.96	16.70	16.21	0.74	Bio	15.96	16.70	>16.21	7.79	>4	4 to 3	>4	0.03	1.31	0.82	0	0	0	0	--	0.0	0	No	Stage I	3	DM>PD; recent DM to 7.79 cm depth; Upper 6 cm is very fine sand; 3 patchy layers inc. sulf. (7+11.8) cm and gray
B420S	1B	8/28/2003 11:05	14.27	17.83	15.94	3.56	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.24	3.14	1.52	0	0	0	0	--	0.2	0	No	Stage I on III	8	Ambient; Molpadia mound?; Lg. void at 11.7 cm, a few amphi. tubes;
B420S	2B	8/28/2003 11:05	16.79	17.53	17.26	0.74	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.65	2.49	1.57	0	0	0	0	--	0.0	0	No	Stage I on III	8	Ambient; Two lg. ophiuroids on surface; Feeding voids at 14.5, 17.3, few amphi. tubes;
B420S	3B	8/28/2003 11:08	18.95	19.96	19.26	1.01	Bio	Old DM? below 10 cm depth				>4	3 to 2	>4	0.33	3.56	1.85	0	0	0	0	--	0.2	0	No	Stage I-II	5	Old DM? below 10 cm depth; Sulfidic patches below 12 cm depth; A few juv. amphi. tubes;
B420W	1A	8/28/2003 12:55	15.5	16.94	16.20	1.44	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.30	2.37	1.45	0	0	0	0	--	0.2	0	No	Stage I on III	7	Ambient; Filled-in void at 11.2 cm depth;
B420W	2B	8/28/2003 12:56	12.81	15.63	14.92	2.82	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.00	23.17	2.13	0	0	0	1	0.5	0.2	0	No	Stage I on III	8	Ambient; Void at 2.1 cm depth, a few amphi. tubes;
B420W	3B	8/28/2003 12:57	16.40	17.32	17.08	0.92	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.15	2.14	1.02	0	0	0	0	--	0.1	0	No	Stage I	3	Ambient; A few thin worms deep;
BCTR	2B	8/28/2003 11:38	6.79	7.39	7.17	0.60	Bio	6.79	7.39	>7.17		>4	3 to 2	>4	15.00	2.08	1.19	0	0	0	0	--	0.0	0	No	Stage I-II	4	DM>PD; Slight pull-away; A few amphipod tubes;
BCTR	3B	8/28/2003 11:39	2.73	3.06	2.86	0.33	Bio	2.73	3.06	>2.86		4 to 3	3 to 2	>4	0.68	1.93	1.37	0	0	0	0	--	0.0	0	No	Stage I-II	4	DM>PD; Penetration too low to see Stage III's; sl. pull-away; A few amphipod tubes; Fish egg? (1)
BCTR	4B	8/28/2003 11:39	2.64	3.44	3.08	0.80	IND	2.64	3.44	>3.08		>4	2 to 1	4 to 3	0.03	1.16	0.50	0	0	0	0	--	0.0	0	No	Stage I on III	6	DM>PD; Low penetration; Small voids at 1-2 cm, a few amphipods?; Some shell hash

Table B-4
Sediment-Profile Image Results for Reference Area Stations at CCBRS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
REF 1	1A	8/28/2003 9:14	7.50	7.92	7.69	0.42	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.44	3.06	1.86	0	0	0	0	--	0.1	0	No	Stage I-II	5	Ambient; Thin worm nr. burrow at 5 cm depth; A few juvenile amphipod tubes; Fish egg? (1)
REF 1	3B	8/28/2003 9:20	16.49	17.68	16.87	1.19	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	1.36	3.71	2.47	0	0	0	0	--	0.2	0	No	Stage I	5	Ambient; Closed feeding void?; Fish egg? (1)
REF 1	4B	8/28/2003 9:20	16.37	17.95	17.17	1.58	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.59	5.61	3.25	0	0	0	0	--	0.3	0	No	Stage I on III	10	Ambient; Thin worms at 7 cm depth; Small void at 1.5 cm depth; Fish eggs? (2)
REF 2	1B	8/28/2003 9:34	12.52	13.20	12.92	0.68	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	1.69	3.59	2.74	0	0	0	0	--	0.2	0	No	Stage I-II	6	Ambient; Small worm at 7 cm depth nr. burrow; Thin burrow; Juvenile amphipod tubes;
REF 2	2B	8/28/2003 9:35	15.54	18.84	16.89	3.30	IND	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.80	4.63	2.54	0	0	0	0	--	0.2	0	No	Stage I-II	6	Ambient; Closed feeding voids? a few juv. amphi. tubes;
REF 2	4B	8/28/2003 9:44	14.27	15.04	14.55	0.77	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	1.60	3.77	2.75	0	0	0	0	--	0.2	0	No	Stage II on III	9	Ambient; T'hin worms at 6 cm depth; Tiny void at 7 cm depth, Many juv. amphi. tubes;
REF 3	1B	8/28/2003 9:55	14.15	15.60	14.59	1.45	Bio	Ambient	Ambient	Ambient		4 to 3	4 to 3	>4	0.00	2.20	0.59	0	0	0	0	--	0.2	0	No	Stage I on III	6	Ambient; Worm on surf., thin worms at 7 cm; Slight pull-away; Tiny void & relic void at 9; few juv. amphi. tubes;
REF 3	2B	8/28/2003 9:56	13.94	14.81	14.35	0.87	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	1.16	3.41	2.21	0	0	0	0	--	0.2	0	No	Stage II on III	8	Ambient; Tiny void at 1 cm depth, many juv. amphi. tubes;
REF 3	3B	8/28/2003 9:56	14.71	15.51	15.02	0.80	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.12	1.99	0.84	0	0	0	0	--	0.2	0	No	Stage I-II	4	Ambient; A few amphipod tubes; No feeding voids;
REF 4	1	8/28/2003 10:08	16.08	16.88	16.41	0.80	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	0.50	3.47	2.29	0	0	0	3	0.4	0.2	0	No	Stage I on III	9	Ambient; A few thin worms at 5 cm depth; 2 back-filled burrows at 2 cm depth; Feeding voids at 10.2 & 12.9, few amphi. tubes;
REF 4	2B	8/28/2003 10:08	13.67	14.48	14.02	0.81	Bio	Ambient	Ambient	Ambient		>4	4 to 3	>4	1.13	3.08	1.93	0	0	0	0	--	0.5	0	No	Stage I-II	5	Ambient; Thin worms at 6 cm ; A few juvenile amphipod tubes; Fish egg? (1)
REF 4	3B	8/28/2003 10:09	16.05	16.64	16.34	0.59	Bio	Ambient	Ambient	Ambient		4 to 3	4 to 3	>4	0.24	4.95	3.04	0	0	0	0	--	0.5	0	No	Stage I on III	10	Ambient; Lg. feeding void at 12.6, a few amphi. tubes;
REF 5	2	8/28/2003 10:19	14.30	15.43	14.81	1.13	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.33	5.72	2.97	0	0	0	3	0.4	0.2	0	No	Stage I on III	9	Ambient; 3 thin worms deep near burrow; 9 cm long burrow; Void at 2.1 cm depth, a few amphi. tubes;

Table B-4
Sediment-Profile Image Results for Reference Area Stations at CCBRS

Station	Replicate	Date/Time	Min Penetration (cm)	Max Penetration (cm)	Mean Penetration (cm)	Boundary Roughness (cm)	BR Process (Bio/Phys)	Min Dredged Material Thickness (cm)	Max Dredged Material Thickness (cm)	Mean Dredged Material Thickness (cm)	Recent Dredged Material Thickness (cm)	Min Grain Size (phi)	Max Grain Size (phi)	Major Mode Grain Size (phi)	Min RPD (cm)	Max RPD (cm)	Mean RPD (cm)	Min Redox Rebound (cm)	Max Redox Rebound (cm)	Mean Redox Rebound (cm)	# Clasts	Mean Clast diameter (cm)	Pell Layer (cm)	Methane Presence	Low DO	Successional Stage	OSI	Comments
REF 5	3B	8/28/2003 10:20	16.64	20.82	18.15	4.18	Bio	Ambient	Ambient	Ambient		>4	3 to 2	>4	0.83	5.10	2.58	0	0	0	0	--	0.3	0	No	Stage I on III	9	Ambient; Feeding void at 8.1 cm, a few amphi. tubes;
REF 5	4B	8/28/2003 10:20	16.14	19.10	17.42	2.96	IND	Ambient	Ambient	Ambient		>4	3 to 2	>4	1.25	3.92	2.70	0	0	0	0	--	0.2	0	No	Stage I on III	9	Ambient; Feeding void at 12.4 cm, a few amphi. tubes;