

Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Jeffrey P. Halka, Acting Director

**COASTAL AND ESTUARINE GEOLOGY
FILE REPORT NO. 09-01**

**Placement, Consolidation, and Erosion Studies
at Open-Water Placement Site 92
2007 – 2008 (Year 10)**

by
**Katherine A. Offerman, MGS
and
William Panageotou, DMP Services, LLC**



Prepared For:
The Maryland Port Administration
(Contract # 599910, PIN #521100-40)
and
U.S. Army Corps of Engineers, Philadelphia District
(W912BU-07-C-002, Option Year 1)

Under Contract To:
Maryland Environmental Service
(Contract # 99-07-35 and 07-07-61)

June 2009

CONTENTS

ABSTRACT	1
PROJECT DESCRIPTION	2
SITE DESCRIPTION	2
PLACEMENT HISTORY	2
PLACEMENT OPERATIONS.....	4
OBJECTIVES	4
METHODS	6
CHRONOLOGY OF ACTIVITIES.....	6
BATHYMETRIC DATA COLLECTION.....	6
BATHYMETRIC INTERPRETATION AND VOLUMETRIC CALCULATIONS.....	7
BOTTOM SEDIMENT SAMPLING	8
RESULTS	11
BATHYMETRIC SURVEYS.....	11
Pre-placement survey	11
Completion survey	11
One-month survey.....	15
Three-month survey	15
Six-month survey	15
Ten-month survey	22
SEDIMENT PROPERTIES.....	22
Foundation sediments	25
Placed sediments.....	25
ANALYSIS OF BATHYMETRIC AND SEDIMENT DATA	26
CONSOLIDATION OF FOUNDATION SEDIMENTS.....	26
DREDGED AND PLACED AMOUNTS.....	28
CONSOLIDATION AND EROSION AFTER PLACEMENT.....	30
SEDIMENT MASS BUDGET	31
CAPACITY USAGE	33
CONCLUSIONS	36
ACKNOWLEDGMENTS	36
REFERENCES	37
APPENDIX	40
PHYSICAL PROPERTIES OF SEDIMENT CORES	40

FIGURES

Figure 1.	Location map of Site 92 and other overboard disposal areas in the northern Chesapeake Bay.....	3
Figure 2.	Location map of Site 92 showing the site boundary, 500-foot setback, designated drop zone, bathymetric tracklines, West Sailing Course, and bottom sediment coring sites	5

Figure 3.	Shepard's (1954) classification of sediment types	11
Figure 4.	Bathymetry prior to sediment placement	12
Figure 5.	Bathymetry at completion of sediment placement.....	13
Figure 6.	Change in bottom elevation between pre-placement and completion of placement.....	14
Figure 7.	Bathymetry at one month	16
Figure 8.	Change in bottom elevation between pre-placement and one month	17
Figure 9.	Bathymetry at three months	18
Figure 10.	Change in bottom elevation between pre-placement and three months.....	19
Figure 11.	Bathymetry at six months.....	20
Figure 12.	Change in bottom elevation between pre-placement and six months	21
Figure 13.	Bathymetry at ten months	23
Figure 14.	Change in bottom elevation between pre-placement and ten months.....	24

TABLES

Table 1.	Chronology of placement and study activities in Site 92.....	6
Table 2.	Coring site collection schedule	25
Table 3.	Change in foundation sediment water content through time	27
Table 4.	Comparison of bulk property and volumetric data using CENAP and NDC reported volumes dredged.....	29
Table 5.	Volumetric analyses of placed sediments through time.....	31
Table 6.	Sediment mass for dredging and placement operations and post- placement period.....	32
Table 7.	Deficit/surplus in sediment mass in tons and percentage	32

Table 8.	Site volume capacity usage	34
Table 9.	Physical properties of foundation sediments prior to placement	41
Table 10.	Physical properties of foundation sediments at completion.....	42
Table 11.	Physical properties of foundation sediments at ten months	43
Table 12.	Physical properties of placed sediments at completion.....	44
Table 13.	Physical properties of placed sediments at ten months	45

EQUATIONS

Equation 1.	Calculation of water content	8
Equation 2.	Calculation of water content relative standard deviation.....	9
Equation 3.	Calculation of bulk density from water content.....	9
Equation 4.	Calculation of porosity from water content	9
Equation 5.	Calculation of void ratio from water content	9
Equation 6.	Calculation of volume changes	10

ABSTRACT

The tenth year (Year 10) of dredged sediment placement at open-water placement Site 92 occurred between November 29, 2007 and February 3, 2008. A clamshell-bucket dredge excavated approximately 0.64 million cubic yards (mcy) of clayey-silt sediment from the Chesapeake & Delaware (C&D) Canal approach channel. The sediment was placed via bottom-release scows into a designated drop zone in the western, central portion of Site 92. Placement occurred in water depths that ranged from -16 to -17 feet (ft.) mean lower low water (MLLW).

The volume of placed sediment identified by Maryland Geological Survey (MGS) at the completion of placement was 0.44 ± 0.10 mcy. This represented a mean volumetric deficit of 0.17 mcy, or 27.6%, after accounting for a bulking factor of 0.95. The total area covered by placed sediment was 0.89 million square yards (msy), or approximately 183.4 acres. The majority of the deposit was 1.0 to 3.0 ft. thick with a maximum thickness of 3.8 ft.

The placed sediments underwent elevation, volumetric, and sediment mass changes during the following ten months. The maximum thickness of the placed sediments decreased by 1.6 ft., from 3.8 ft. at completion of placement to 2.2 ft. at ten months. There was a 46.4 % volumetric reduction at ten months following placement. It was estimated that approximately one-sixth of the volumetric change resulted from consolidation and five-sixths from erosion. During the combined placement and post-placement periods, a sediment mass loss of approximately 58.5% (-179,755 tons) occurred at Site 92.

Year 10 placement utilized 0.24 mcy, or approximately 3%, of the site volume capacity. To date, dredged sediment placement has used approximately 59% of the total site volume capacity, and 41% is available for future placements.

PROJECT DESCRIPTION

Routine dredging of the Chesapeake and Delaware (C&D) Canal approach channel in the northern Chesapeake Bay maintains access to the Port of Baltimore. Portions of the dredged sediments are placed overboard on the Bay bottom in designated placement sites known as the Pooles Island Disposal Sites. The designated sites are south and east of Pooles Island, just to the west of the lower reach of the C&D Canal approach channel (Figure 1). Site 92 is presently utilized for placement. The Site 92 Site Management Team (SMT), consisting of representatives from the U.S. Army Corps of Engineers, Philadelphia District (CENAP), Maryland Port Administration (MPA), Maryland Department of the Environment (MDE), Maryland Environmental Service (MES), and Maryland Geological Survey (MGS) manages the placement sites.

Site Description

Site 92 is approximately 934 acres (ac) in size (Maryland Environmental Service, 1997). The site initially straddled a trough, oriented in a northeast to southwest direction, between Buoy R “6” to the south and Buoy G “7” to the north. This trough, known as the West Sailing Course, is used principally by tugs running without barges and tugs with empty or light-loaded barges. In the northeast direction, the trough opens to variable bottom topography referred to as the high-relief area. Water depths in the high-relief area range from -10 feet to -40 feet (ft.) mean lower low water (MLLW) over very short distances. The southern end of the high-relief area is east of Site 92. The West Sailing Course trough extends to the southwest into shallower water. The western half of former disposal Area G-South is within Site 92.

Placement History

Prior to its initial use in the winter of 1998-1999, Site 92 had an estimated capacity of 7 million cubic yards (mcy). This estimate is the site volume (space) and assumes an idealized placement configuration when brought to the authorized depth of -14 ft. MLLW. Prior to the 2007-2008 placement operations, nine years of dredged sediment placement have occurred in different designated areas of Site 92 utilizing 3.91 mcy of the site volume.

During the first year of placement, 1998-1999 (Year 1), creation of a sediment berm along the northeastern corner of the site (within the West Sailing Course) minimized the potential for the spread of sediment deposited in subsequent placement operations (Panageotou, 2001). Berm placement utilized 0.70 mcy of the initial capacity. Placements during Years 2 through 9 were designated for filling in the southern three-quarters of Site 92 (Panageotou, 2002, 2003, 2004a, 2004b, 2005, 2006, Offerman and Panageotou, 2007, 2008). The objective was to maximize capacity of the site proceeding from the southern end northward.

The second year of placement, 1999-2000 (Year 2), utilized 0.49 mcy of capacity. This placement filled in the southern end of the site and created an enclosed basin within Site 92. The third year of placement, 2000-2001 (Year 3), utilized 1.23 mcy of capacity. The fourth year of placement, 2001-2002 (Year 4), utilized 0.11 mcy of capacity. The fifth year of placement, 2002-2003 (Year 5), utilized 0.10 mcy of capacity. However, ten months after completion of placement in Year 5, Hurricane Isabel caused an estimated 0.17 mcy of erosion from the

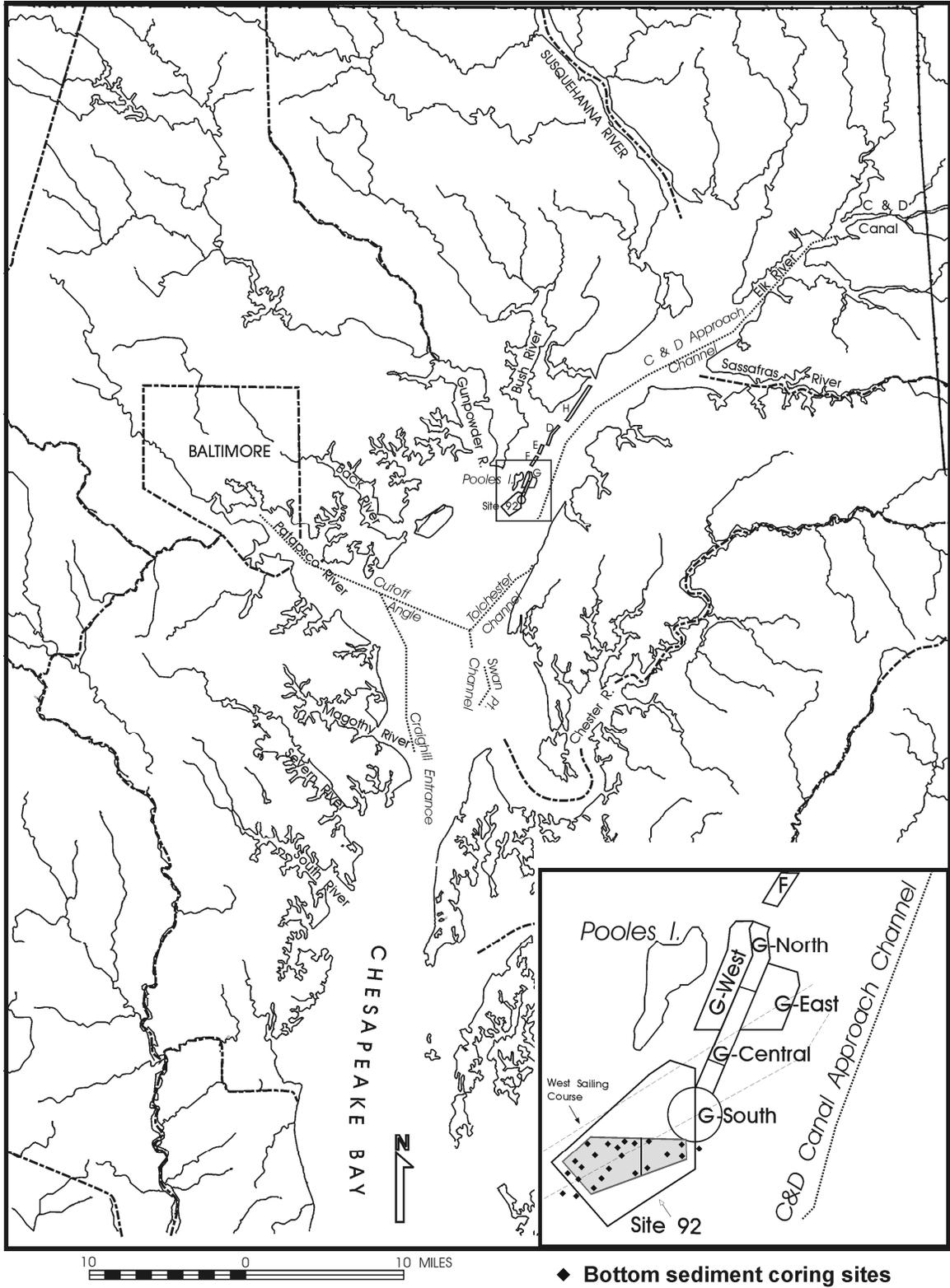


Figure 1. Location of overboard disposal areas in the northern Chesapeake Bay. Site 92 is presently utilized for placement. Designated drop zone is shaded. Light dotted lines indicate position of dredged shipping channels.

placement site. The erosion resulted in a net capacity gain of 0.07 mcy. The sixth year of placement, 2003-2004 (Year 6), utilized 0.49 mcy of capacity in the center section. Placement during 2004-2005 (Year 7) also took place in the center section of Site 92 and utilized 0.70 mcy of capacity. The eighth year of placement, 2005-2006 (Year 8), utilized 0.33 mcy of capacity in the northern, central portion of Site 92. Placement during 2006-2007 (Year 9) also utilized 0.33 mcy of capacity in the northern portion of Site 92.

Placement Operations

The tenth year of placement, 2007-2008 (Year 10), occurred between November 29, 2007 and February 3, 2008. For Year 10 operations, the SMT delineated a drop zone in the southern, central portion of the site (Figure 2). Southern and northern limits of the drop zone were Maryland State Plane Coordinate System (M.S.P.C.S.) northings 576,200 ft. and 579,400 ft., respectively. The Year 10 drop zone area encompassed approximately 275 acres, and was divided at M.S.P.C.S. easting 1,517,100 into two sections – a western portion with a capacity of approximately 0.75 mcy, and an eastern portion with a capacity of approximately 0.25 mcy. It was intended that placement begin in the westernmost area and proceed to the east. Ultimately, only the western portion of the drop zone (approximately 200 acres) was utilized for placement (herein referred to as the “drop zone”). The drop zone perimeter was setback 300-500 ft. from the site boundary to minimize the potential for the spread of sediment outside the designated site.

Maintenance dredging took place during the winter of 2007-2008 under CENAP contract number W912BU-07-C-0026 with Norfolk Dredging Company (NDC). A clamshell-bucket dredge removed sediments from the channel, and bottom-release scows towed by tugs transported and placed them within the designated drop zone. By the completion of sediment placement, the bottom was not to be shallower than the authorized depth of -14 ft. \pm 0.5 ft. MLLW.

NDC submitted a placement operation plan that divided the designated drop zone into cells measuring 225 ft. by 500 ft. The Year 10 Site Management Report (SMR) details the placement operation plan, scow drop locations, and placement-monitoring plan (Maryland Environmental Service, 2008).

CENAP and NDC both provided estimates of the quantity of dredged sediment based on different measurement techniques. NDC reported that 0.60 mcy was removed from the channel and placed within the designated drop zone. NDC calculated the dredged volume by measuring the quantity of sediment placed per scow load. CENAP reported that 0.69 mcy was removed from the channel by measuring the change between the pre- and post-dredging bathymetric surveys of the channel.

Objectives

As specified in the SMR, placement, consolidation, and erosion studies (PCE) are conducted by MGS on the placed dredged sediments. MPA and CENAP funded the studies, and

Site 92 2007-2008 (Year 10) Placement Site & Study Area

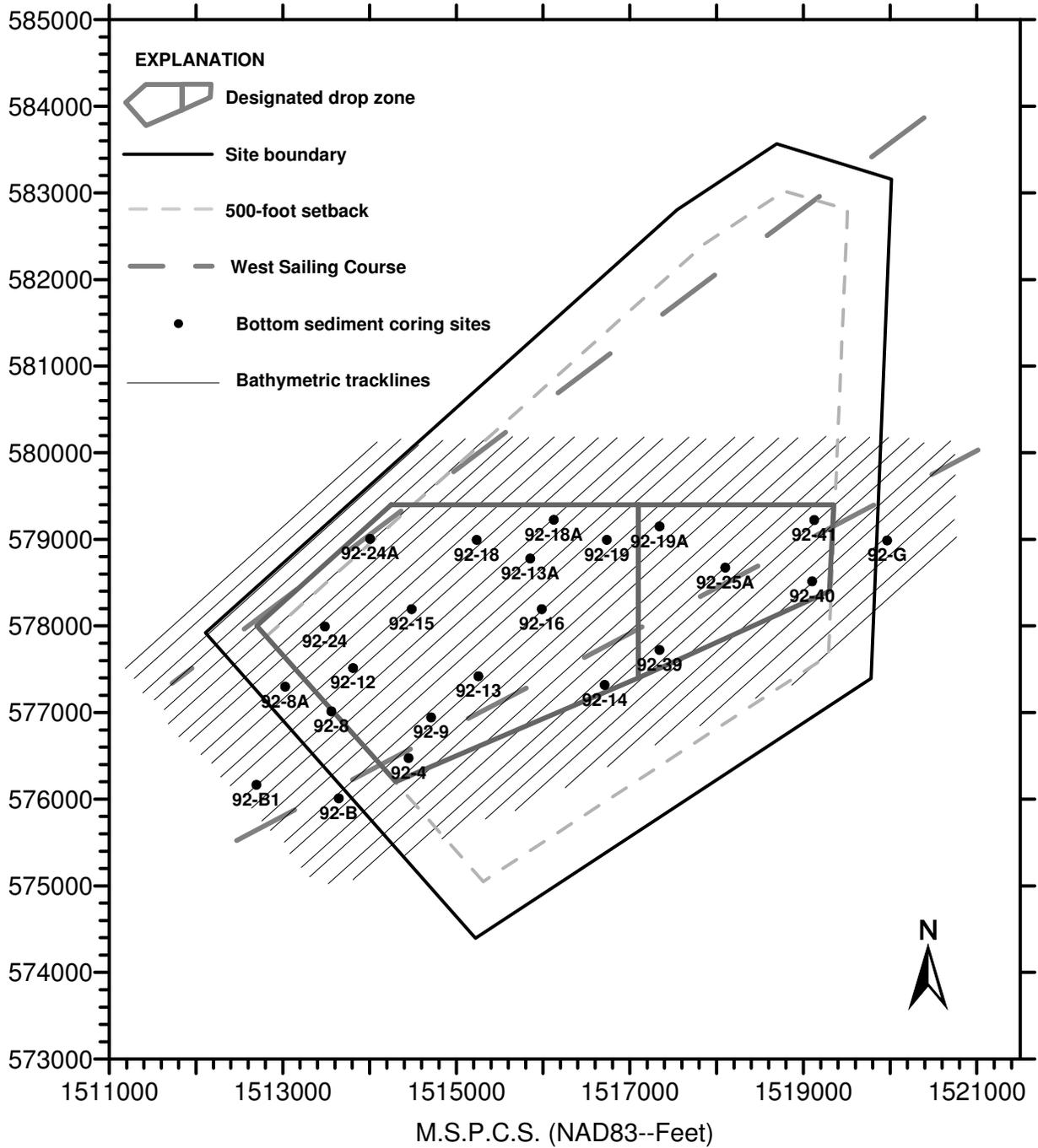


Figure 2. Location map of Site 92 showing designated drop zone, site boundary, 500-foot setback, West Sailing Course, bottom sediment coring sites, and bathymetric tracklines.

MES administered the contract. This document reports on the PCE studies. The specific objectives were to:

- (1) evaluate pre-placement conditions at the designated placement site;
- (2) determine the placement location, thickness, and spatial extent of the deposited dredged sediment and changes in these characteristics through time;
- (3) sample the dredged sediments to determine their physical and bulk properties at the placement site;
- (4) evaluate foundation settlement underlying the placed sediments during the placement and post-placement periods;
- (5) evaluate the quantity of dredged sediment present at the placement site soon after the completion of dredging and placement operations;
- (6) evaluate consolidation and erosion of the placed sediments;
- (7) develop a total sediment mass budget for the placement and post-placement period; and
- (8) update capacity usage.

METHODS

Chronology of Activities

On-site monitoring activities were conducted aboard the Maryland Department of Natural Resources' Research Vessel *Kerhin*. Table 1 lists the chronology of placement and study activities. The proposed schedule called for 1) bathymetric surveys and 2) bottom sediment coring. Bathymetric surveys were scheduled prior to placement, at the completion of placement, and at one month, three months, six months, and ten months after placement. Bottom sediment coring was scheduled prior to placement, at completion of placement, and ten months after placement. If necessary, turbidity plume monitoring from dragging operations is scheduled after completion of placement and prior to the completion bathymetric survey. However, it was determined that post-placement conditions did not warrant dragging operations, and therefore no monitoring of turbidity plumes was required during Year 10 placement operations.

September 24-25, 2007	Bathymetric survey prior to sediment placement
October 2, 2007	Bottom sediment coring prior to sediment placement
November 29, 2007	Scow placement commences
February 3, 2008	Scow placement completed
February 8-9, 2008	Bathymetric survey at completion
February 20, 2008	Bottom sediment coring for completion survey
March 6, 2008	Bathymetric survey at one month
May 7, 2008	Bathymetric survey at three months
August 6, 2008	Bathymetric survey at six months
November 20 & 26, 2008	Bathymetric survey at ten months
December 3, 2008	Bottom sediment coring for ten-month survey

Bathymetric Data Collection

Bathymetric data was collected on tracklines running northeast to southwest in and around

the designated drop zone (Figure 2). The spacing between tracklines was approximately 150 ft. A bathymetric survey was completed prior to placement operations to establish a baseline record of bottom depths. A second survey was completed as soon as possible after placement to establish the initial spatial extent, thickness, and volume of the placed dredged sediment. Subsequent surveys evaluated the bathymetric and volumetric changes of the placed sediments through time.

Raw bathymetric data were collected using Leica 412B survey-grade Differential Global Positioning System (DGPS) and a Furuno FCV-1100L echosounder. DGPS differential corrections broadcast by the United States Coast Guard (USCG) provide a horizontal accuracy of 6.6 ft. to 16.4 ft. Horizontal position was recorded in Maryland State Plane Coordinate System (MSPCS) meters and converted to feet based upon the North American Datum of 1983 (NAD 83).

The Furuno echosounder was calibrated using known vertical measurements before and after each survey. The echosounder generates repetitive acoustic pulses, ten soundings per second, at 200 kilohertz (kHz) for bottom recognition. The acoustic wave reflects off the density gradient differentiating the water column from the bottom sediment. The reflections are then filtered and integrated within the echo-sounder to produce an accurate digital measurement from the transducer to the water/sediment interface every two seconds. A correction for the draft of the vessel was applied by the data logging software, as determined by the “bar check” before the beginning of the survey. At the survey speed of the vessel, a data point was collected approximately every 20 ft. along the survey tracklines. Bathymetry and positioning data were logged to a personal computer at a rate of one point every two seconds.

All depth data presented in this study were referenced to MLLW at the Tolchester Beach location for the 1983-2001 National Tidal Datum Epoch (NTDE). The National Oceanic and Atmospheric Administration/ National Ocean Service (NOAA/NOS) maintains this station. Raw depth data were tidally adjusted by subtracting the Tolchester Beach tide level, recorded at six-minute intervals, from the raw depth data collected on the R/V *Kerhin*. Incorporated into the tidal adjustments was a +20 minute offset from Tolchester Beach to Site 92. The practical resolution of the tidally corrected bathymetric data is ± 2 inches (in.) (Ortt, 1999).

To reduce the error inherent in bathymetric surveys from instrument limitations and from surface modeling interpolation, a controlled reference area was surveyed before and after each survey of the placement area. A secondary adjustment to the tidally corrected data was applied based on the average height measured at the controlled reference area for all of the surveys performed within the study year. Theoretically, this aligns the surfaces to a common plane that might otherwise be offset from the errors inherent in bathymetric surveys. This allows for a higher degree of accuracy when comparing surfaces. Quality Assurance/Quality Control (QA/QC) analyses indicated that the practical resolution of the post-processed bathymetric data after secondary correction application is ± 1 in.

Bathymetric Interpretation and Volumetric Calculations

Interpretation of post-processed bathymetric data utilized Surfer, a commercially available contouring software package (product of Golden Software, Golden, CO). The Triangulation with Linear Interpolation (TIN) method was used to process the adjusted data. This method is based on

the work of Lawson (1977), Lee and Schachter (1980), and Guibas and Stolfi (1985). Data was gridded to a 100 ft. regularly spaced grid in order to facilitate the calculation of volumes and thicknesses of placed dredged sediments. Isopach maps were created using the gridded surfaces and were used to show bottom changes. The vertical resolution of the isopach maps was estimated to be 0.3 ft. This resolution produces a range of uncertainty in the volume calculations that is a function of the area covered by placed sediments. Gravity cores within and outside the placement area provided ground-truthing of the isopach maps.

Bottom Sediment Sampling

Figures 1 and 2 show the bottom sediment sampling sites. Sampling sites inside Site 92 are labeled 92-4, 92-8, 92-8A, 92-9, 92-12, 92-13, 92-13A, 92-14, 92-15, 92-16, 92-18, 92-18A, 92-19, 92-19A, 92-24, 92-24A, 92-25A, 92-39, 92-40, and 92-41. Sampling sites outside Site 92 are labeled 92-B, 92-B1, and 92-G.

Bottom sediments were collected in 2.6 in. diameter cellulose acetate butyrate (CAB) core liners inserted into a Benthos open-barrel gravity corer, model 2171, or a Benthos piston corer, model 2450. The recovered cores were trimmed at the sediment-water interface, capped, and returned to the laboratory for bulk property and grain size analyses.

Sediment cores were first X-rayed in their liners using a TORR-MED medical X-ray unit. Prints of the X-ray images were developed using a Xerox 125 xeroradiograph processor. X-rays of cores facilitate recognition of small-scale internal structures, such as clam and worm burrows or tubes, shells, and gas voids. These characteristics were used to evaluate benthic activity and identify the pre-placement bottom. On a negative xeroradiographic print, less dense material, such as burrows or gas voids, appear darker as compared to denser material, such as shells or sand, which appear lighter.

After the cores were X-rayed, the sediment was extruded from the core liner, split along the axis, photographed, and described. The core was carefully examined to identify the pre- and post-placement sedimentary units. Each sedimentary unit was subsequently sub-sampled in equal volumes at 4 in. intervals along the entire core length, homogenized into a single representative sample, and analyzed for water content and grain size. Analyses were conducted according to MGS standard techniques as outlined in Kerhin and others (1988). Samples used for water content analysis were divided into 0.5 ounce (oz.) to 0.7 oz. portions, dried at 149°F and then weighed. Water content was calculated as the percentage of water weight to the total weight of wet sediment:

$$\% H_2O = \left(\frac{W_w}{W_t} \right) \times 100 \quad (1)$$

where W_w is the weight of water, and W_t is the weight of wet sediment. The water content, as sub-sampled from the homogenized intervals, was assumed to represent the mean water content present in each pre- and post-placement sedimentary unit.

Loss of water from the sediment in the interval between collection and extrusion of the core may cause an underestimation of the water content. Recently placed sediments, contained within the core liner, exhibit a measurable amount of dewatering between the time of collection and analysis

resulting in compaction. Measuring the change in core length prior to extrusion allows the calculation of the amount of water expressed from the sediment subsequent to collection. Water contents calculated in the laboratory were corrected by assuming that this compaction occurred evenly throughout the thickness of the most recently placed sediment layer. The percent water contents reported for the samples represent corrected values.

During collection of fine-grained sediments via open-barrel gravity coring, a significant but generally variable and indeterminable amount of compression (core shortening) also occurs in the sediment due to frictional forces against the inner wall core liner. The shortening of the collected sediment results from a physical thinning caused by lateral extrusion in front of the core (Weaver and Schultheiss, 1983; Blomqvist, 1985). Lateral thinning of sediment ahead of the retained sediments in the corer does not alter the water content (Halka and Panageotou, 1993).

The precision of water content measurements was determined by calculating the relative standard deviation from replicate measurements made on fine-grained sediments collected at disposal Areas D and F in 1991 (Figure 1). For sediment samples collected and analyzed in this manner, the relative standard deviation for percent water content was 4.46% (Halka and Panageotou, 1993). The standard deviation (σ) for any particular water content is:

$$\sigma_{H_2O} = \frac{\% H_2O}{100} \times 4.46 \quad (2)$$

This function yields a plus or minus value (\pm) indicating the general variability in water content for each sediment sample.

Bulk density (ρ_b), porosity (P), and void ratio (e) were calculated from water content utilizing equations (3), (4), and (5) by assuming an average grain density (ρ_s) of 2.65 g/cm³ and saturation of voids with water density (ρ_w) of 1.0 g/cm³. This method is an adaptation of the work of Bennett and Lambert (1971):

$$\rho_b = \frac{W_t}{W_d / 2.65 + W_w} \quad (3)$$

where W_d is the weight of dry sediment.

$$P = \rho_s \frac{\% H_2O}{\rho_s \% H_2O + \rho_w (100 - \% H_2O)} \quad (4)$$

$$e = \frac{V_v}{V_s} \quad (5)$$

where V_v is the volume of voids and V_s is the volume of solids.

The discussion concerning bulk properties focuses on the results of the mean water content analyses. The other properties (bulk density, porosity, and void ratio) – calculated from the water content – are included in Tables 9-13 in the Appendix.

A statistically verifiable change in mean water content over time can be used to definitively quantify volumetric change through time. A t-test compares two water contents at a certain confidence level to determine if the values are statistically different (Davis, 1973; Ott and others, 1978). If the water content values are statistically different, then the percent volume change over a specified time interval can be calculated at the specified confidence level.

The percentage of volumetric change (V_{Δ}) attributable to either bulking (water-loading during dredging and placement) or *in situ* consolidation (dewatering of foundation sediments and post-placement sediments) was determined from the change in porosity over time. Percent volume change can be calculated utilizing equation (6):

$$V_{\Delta} = \frac{1 - P_i}{1 - P_f} \times 100 \quad (6)$$

where P_i is the initial porosity at time one and P_f is the final porosity at time two. The estimated amount of erosion in placed sediments begins by calculating the total sediment volume change from the bathymetric analyses and then subtracting the volume change due to *in situ* consolidation.

Grain-size analysis involved cleaning approximately 1.5 oz. samples in solutions of 10% hydrochloric acid and 15% hydrogen peroxide and subsequent rinsing with deionized water. This process removes soluble salts, carbonates, and organic matter that could interfere with the disaggregation of the individual grains. Subsequent treatment of the samples with a 0.26% solution of the dispersant sodium hexametaphosphate ($(\text{NaPO}_3)_6$) ensured that individual grains did not reaggregate during analysis. Wet sieving through a 4 phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230) separated the sand and mud fractions. The sand fraction was dried and weighed. The finer silt and clay-sized particles were suspended in a 1000 ml [34 oz.] cylinder in a solution of 0.26% sodium hexametaphosphate. The suspension was agitated, and at specified times thereafter, 20 ml [0.7 oz.] pipette withdrawals were made (Carver, 1971; Folk, 1974). The rationale behind this process is that larger particles settle faster than smaller ones. By calculating the settling velocities for different sized particles, times for withdrawal can be determined at which all particles of a specified size will have settled out past the point of withdrawal. Sampling times were chosen to permit the determination of the amount of silt (4 phi) and clay sized (8 phi) particles in the suspension. Withdrawn samples were dried at 149°F and weighed. From these data, the dry weight percentages of sand, silt, and clay were calculated for each sample and classified according to Shepard's (1954) nomenclature (Figure 3).

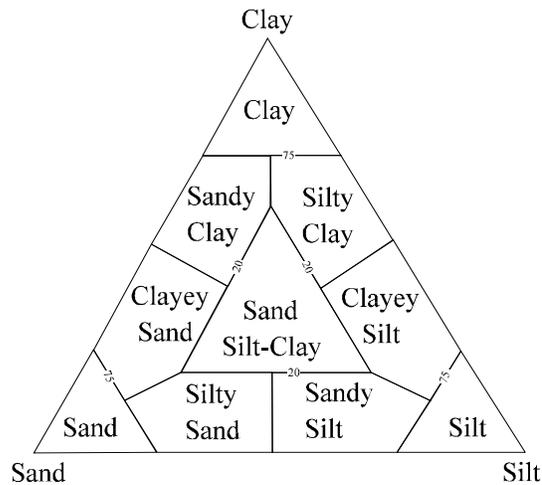


Figure 3. Shepard's (1954) classification of sediment types.

RESULTS

Bathymetric Surveys

Figures 4, 5, 7, 9, 11, and 13 depict the pre- and post-placement bathymetry. The bold, red contour line marks the water depth of -14 ft. MLLW. Figures 6, 8, 10, 12, and 14 depict the bathymetric changes between the pre- and post-placement surveys as isopach maps created from the bathymetric data. The 0.3 ft. contour delineates the minimum change discernable from the bathymetric data.

Pre-placement survey: September 24-25, 2007 (Figure 4)

Water depths over the majority of the designated drop zone were -17 ft. ± 0.5 ft. Water depths decreased slightly to -16 ft. along the southeastern boundary of the drop zone. The bottom is relatively level and shallow in this portion of Site 92. This condition is a result of five years of placement operations. Years 2, 3, and 4 placements occurred in the lower, triangular section of Site 92; Years 5 and 6 placements occurred to the immediate north in a 2,500 ft. wide section.

Completion survey: February 8-9, 2008 (Figures 5 and 6)

After completion of placement, water depths over the majority of the drop zone were -16 ± 1 ft. Three small areas in the central portion of the drop zone exhibited slight sediment "mounding" and water depths of -14 ft. ± 0.5 ft. The area less than -14 ft. occupied an area of 0.006 msy (1.2 ac). Bottom relief in most of the drop zone was 3 ft. or less. Water depths generally increased towards the northeastern portion of the drop zone to a maximum of -17.5 ft.

Placed sediments occupied nearly the entire area of the drop zone, and in some areas extended up to 250 ft. into the setback area. However, no placed sediments were identified beyond the Site 92 boundaries.

Site 92 2007-2008 (Year 10) Bathymetry Prior to Placement September 24-25, 2007

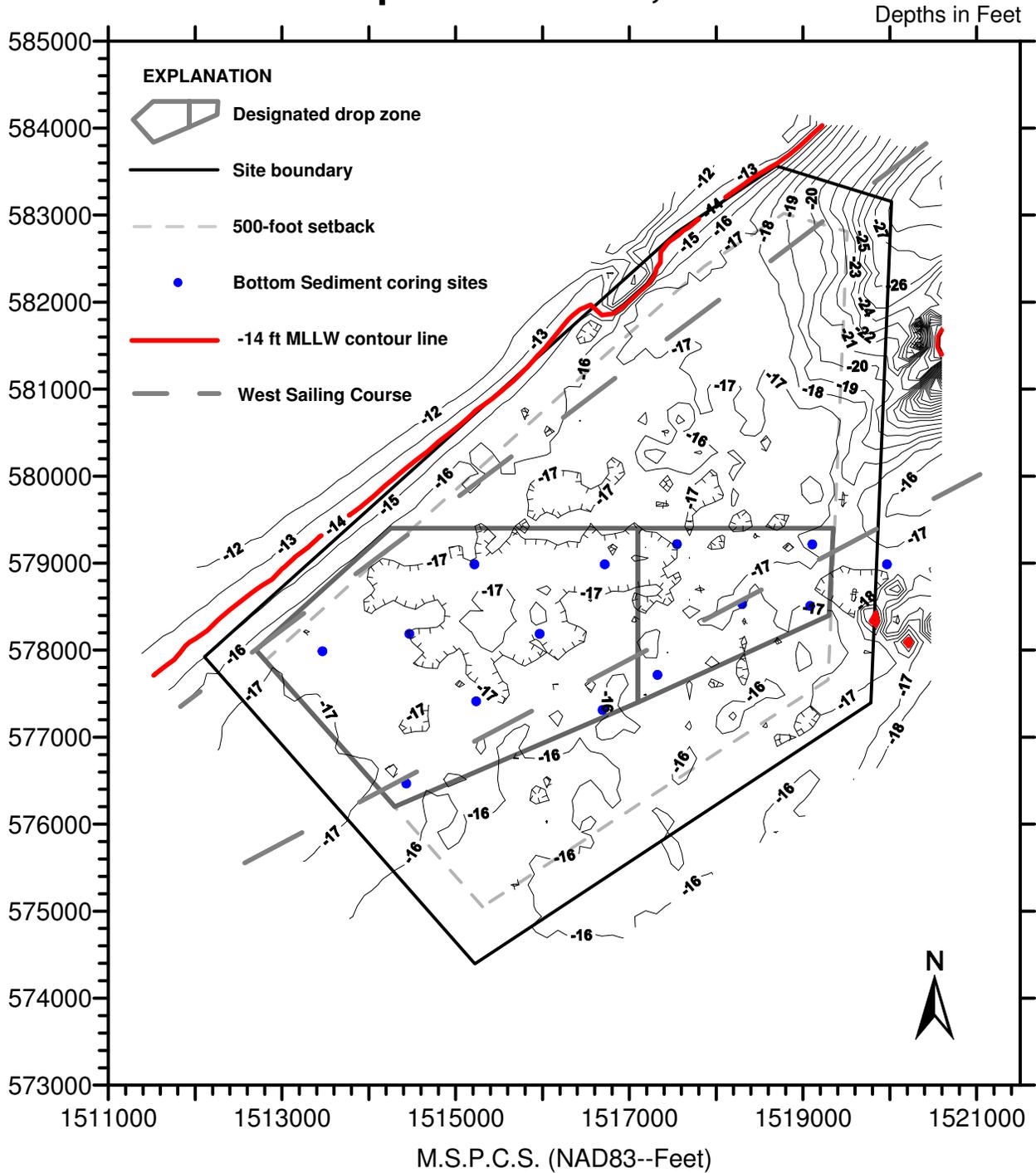


Figure 4. Bathymetry on September 24-25, 2007, prior to sediment placement.

Site 92 2007-2008 (Year 10) Bathymetry at Completion of Placement February 8-9, 2008

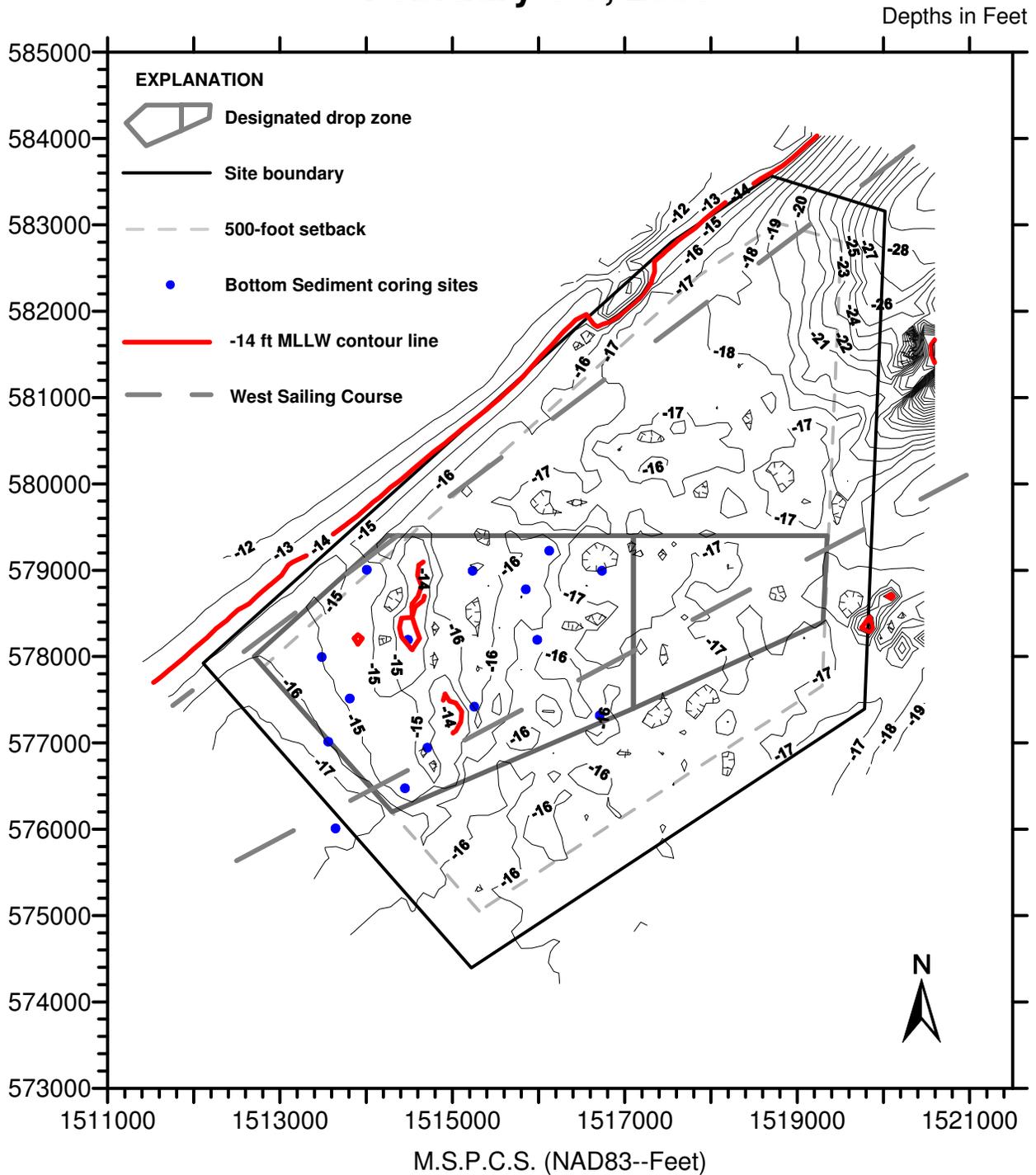


Figure 5. Bathymetry on February 8-9, 2008, after completion of sediment placement.

Site 92 2007-2008 (Year 10) Change in Elevation Pre-Placement vs. Completion of Placement

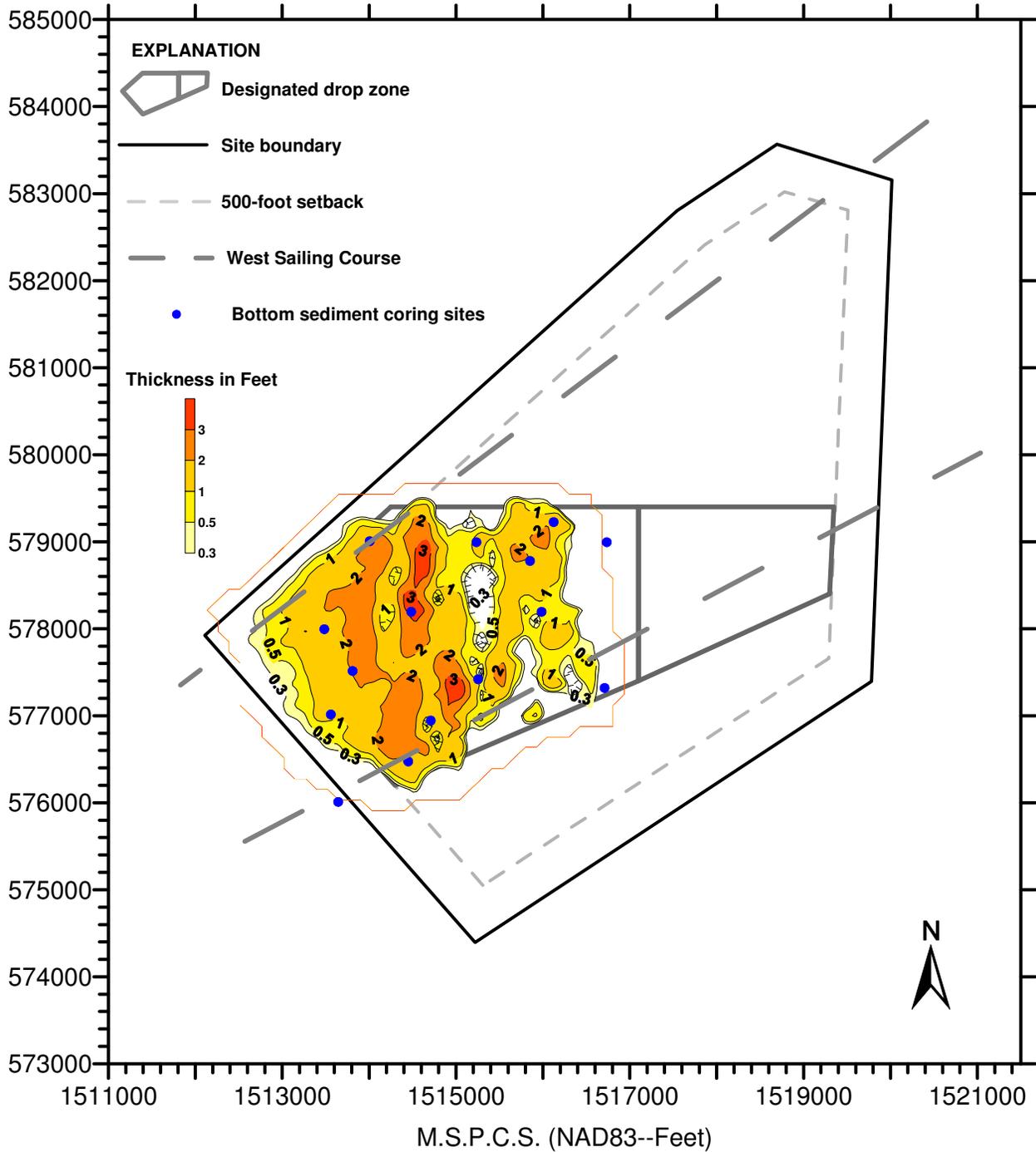


Figure 6. Isopach map showing change in elevation (feet) between pre-placement (September 24-25, 2007) and completion of placement (February 8-9, 2008).

The majority of the deposit was 1.0 ft. to 3.0 ft. thick, with thicknesses increasing to a maximum of 3.8 ft. in the central portion of the drop zone. The completion survey identified a placed sediment volume of 0.44 mcy. The total area covered by placed sediment greater than 0.3 ft. thick was 0.89 million square yards (msy) (183.4 ac), or approximately 20% of the entire Site 92 area.

One-month survey: March 6, 2008 (Figures 7 and 8)

At one month, water depths were very similar to those observed on the completion survey. The three small, “mounded” areas in the central portion of the drop zone were still evident. The deposit “footprint” was very similar to that seen at completion. In one localized area along the southwestern edge of the drop zone, a negligible volume of placed sediment was identified slightly beyond the site boundary. The placed sediment thickness along the southwestern site boundary was approximately 0.3 ft. (4 inches).

The majority of the deposit exhibited thicknesses of 1.0 ft. to 3.0 ft. The thickest part of the deposit was 3.6 ft., occurring in the central portion of the drop zone. The one-month survey identified a placed sediment volume of 0.45 mcy. The total area covered by placed sediment greater than 0.3 ft. thick was 0.88 mcy (182.2 ac).

Three-month survey: June 12, 2007 (Figures 9 and 10)

Minor changes in water depths were observed at three months post-placement. The northern, two small sediment “mounds” were no longer present. The southern sediment mound was still evident but decreased in area. The placed sediment “footprint” was very similar in area to that observed at one month post-placement. In some areas, placed sediments extended varying distances into the setback area; however, no placed sediments were identified beyond the Site 92 boundaries.

The majority of the deposit ranged in thickness from 1.0 ft. to 2.0 ft. with only a small area occupying a thickness of up to 3.1 ft. The three-month survey identified a placed sediment volume of 0.38 mcy. The total area covered by placed sediment greater than 0.3 ft. in thickness was 0.87 mcy (178.9 ac).

Six-month survey: August 6, 2008 (Figures 11 and 12)

At six months, water depths were very similar to those observed at three months post-placement. The -14 ft. sediment “mounds” seen at three months were no longer present. Water depths ranged from -15 ft. to -17 ft. across the drop zone.

The deposit footprint was similar to that seen at 3 months, with the exception of the western portion. Apparently, a thin layer of sediment was redistributed beyond the Site 92 boundary by prevailing northeast to southwest tidal currents extending through the West Sailing Course trough. The placed sediment thickness outside of the Site 92 boundary was approximately 0.5 ft. (4 to 6 inches) or less.

Site 92 2007-2008 (Year 10) Bathymetry at 1 Month Post-Placement March 6, 2008

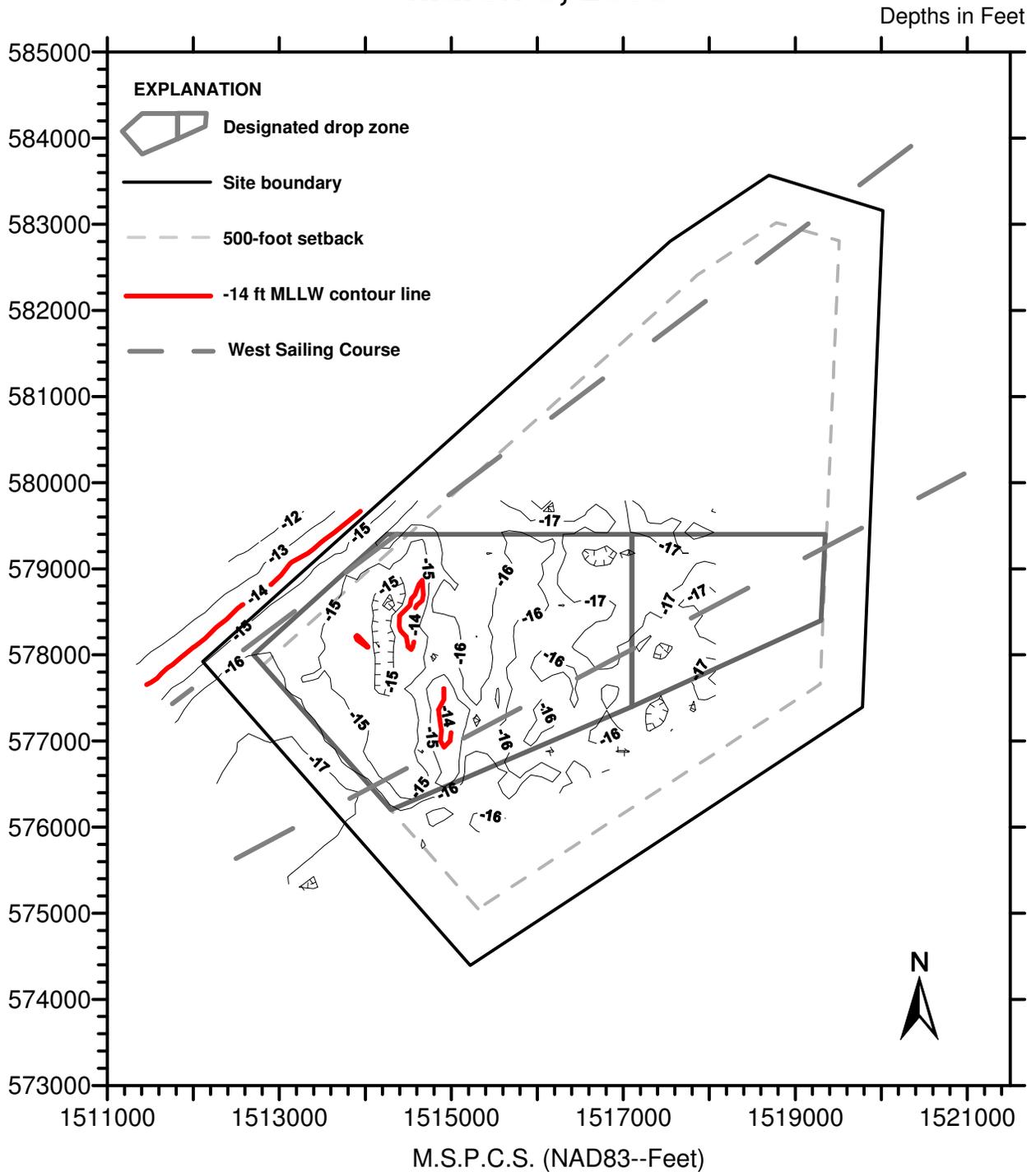


Figure 7. Bathymetry on March 6, 2008, one month after completion of placement.

Site 92 2007-2008 (Year 10) Change in Elevation Pre-Placement vs. 1 Month Post-Placement

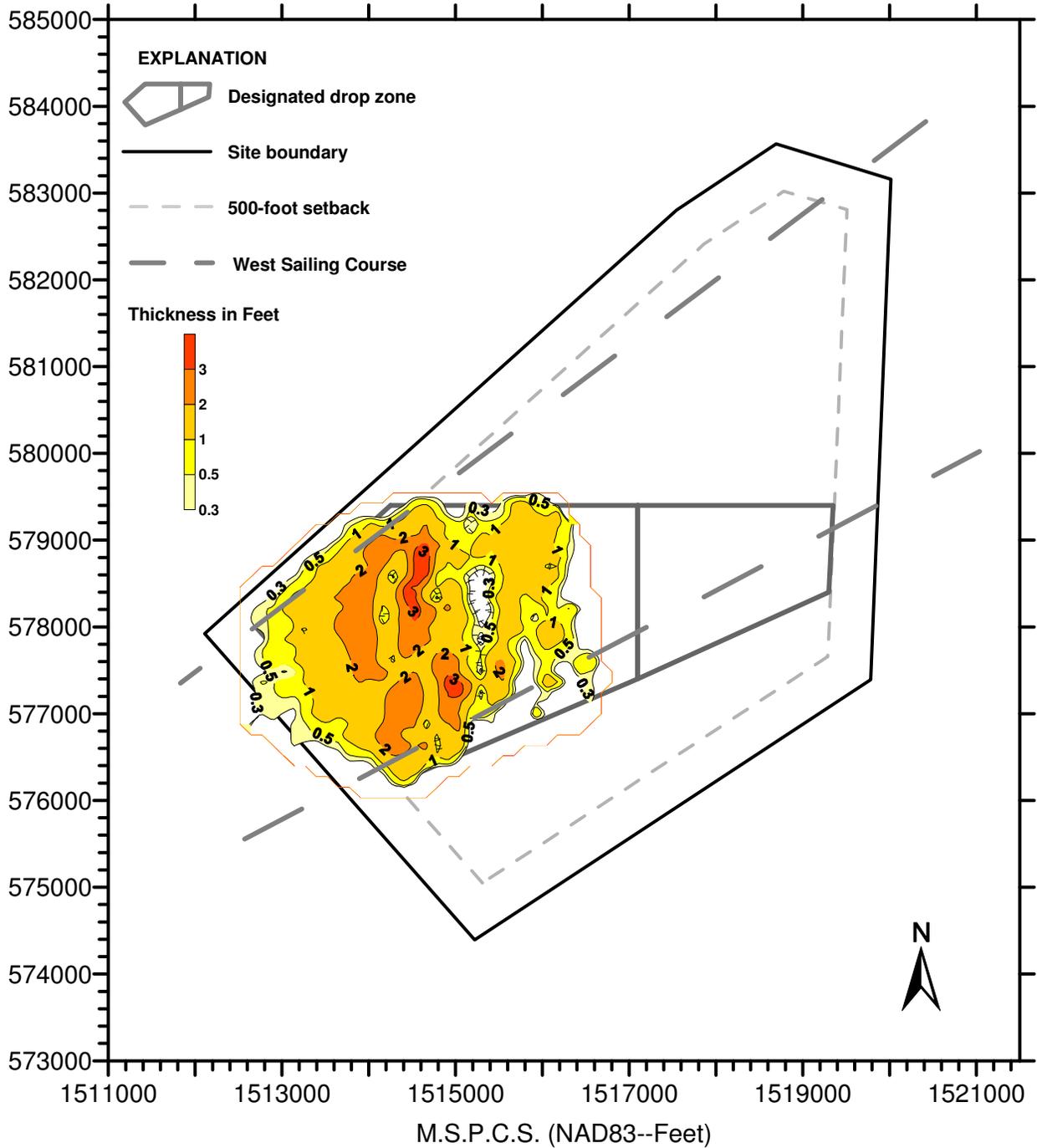


Figure 8. Isopach map showing change in elevation (feet) between pre-placement (September 24-25, 2007) and one month post-placement (March 6, 2008).

Site 92 2007-2008 (Year 10) Bathymetry at 3 Months Post-Placement May 7, 2008

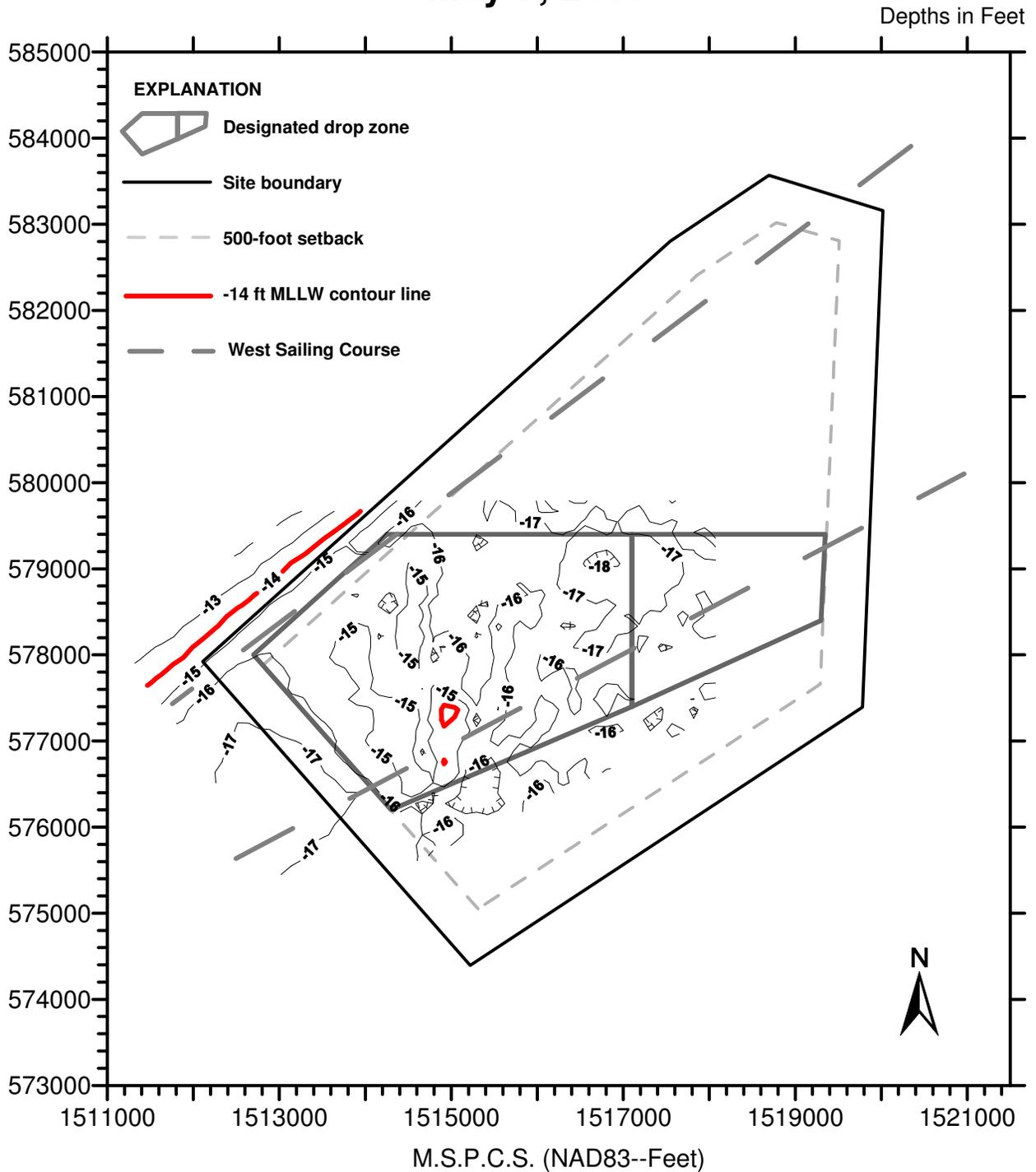


Figure 9. Bathymetry on May 7, 2008, three months after completion of placement.

Site 92 2007-2008 (Year 10) Change in Elevation Pre-Placement vs. 3 Months Post-Placement

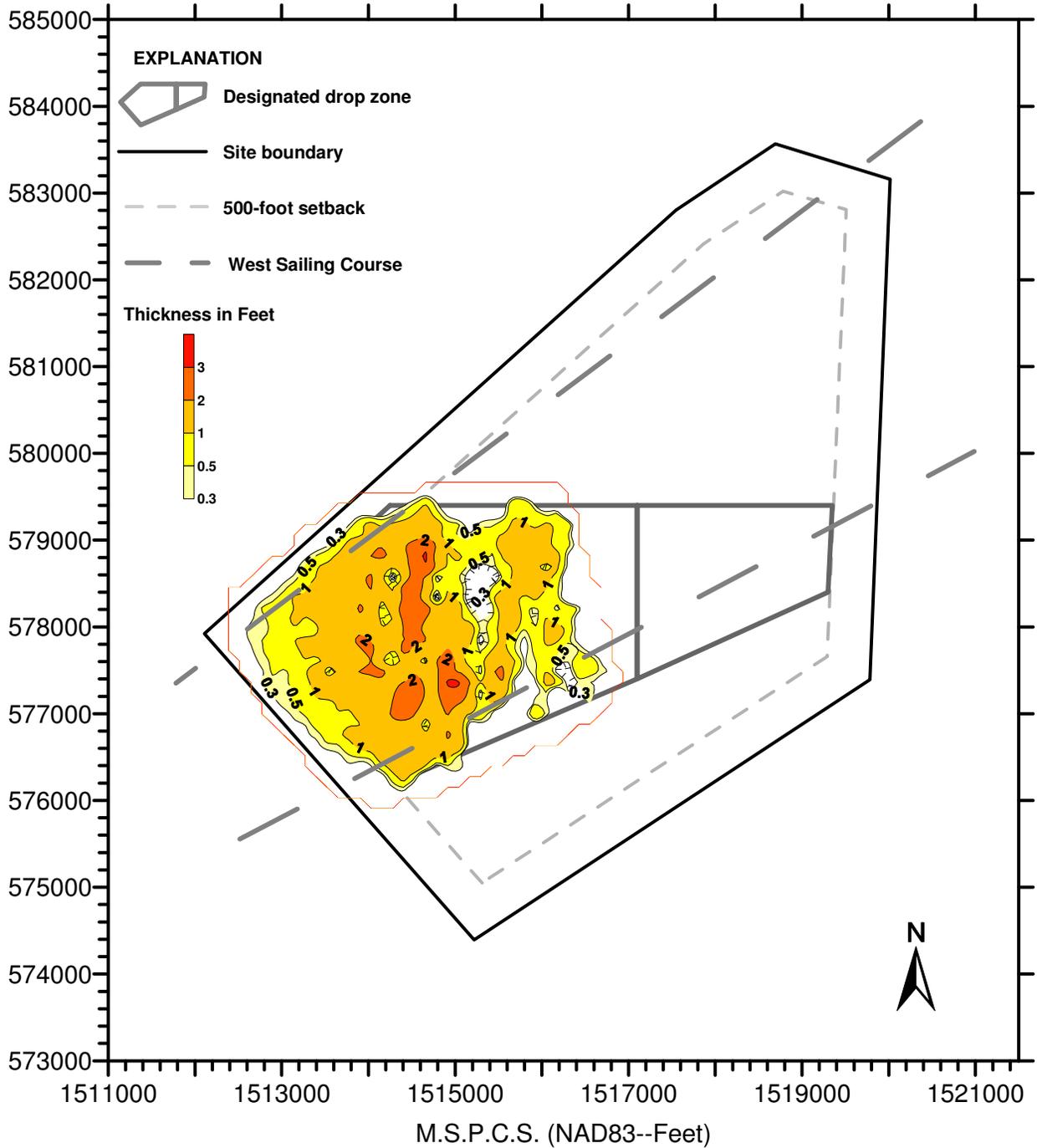


Figure 10. Isopach map showing change in elevation (feet) between pre-placement (September 24-25, 2007) and three months post-placement (May 7, 2008).

Site 92 2007-2008 (Year 10) Bathymetry at 6 Months Post-Placement August 6, 2008

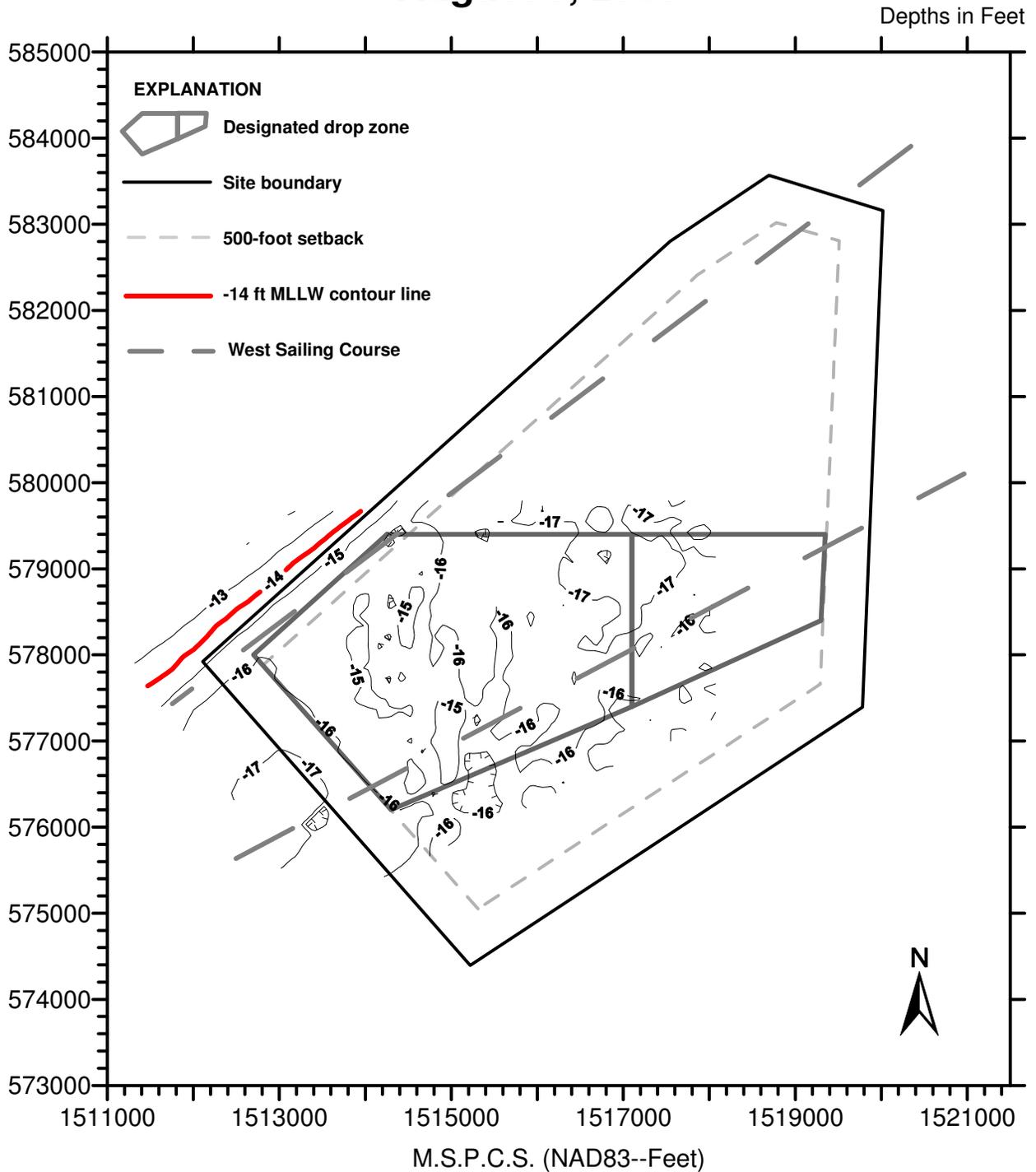


Figure 11. Bathymetry on August 6, 2008, six months after completion of placement.

Site 92 2007-2008 (Year 10) Change in Elevation Pre-Placement vs. 6 Months Post-Placement

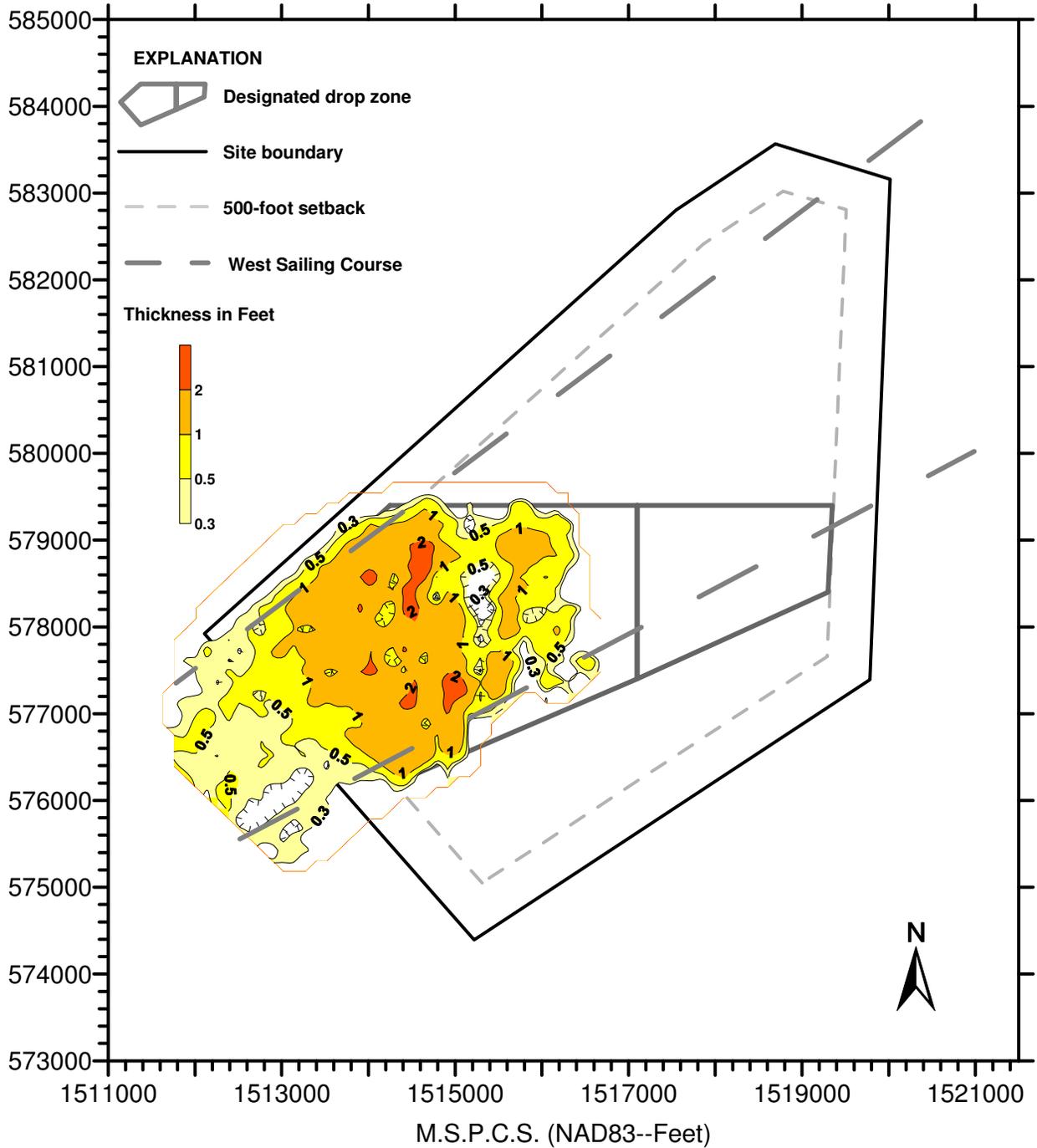


Figure 12. Isopach map showing change in elevation (feet) between pre-placement (September 24-25, 2007) and six months post-placement (August 6, 2008).

The majority of the deposit was less than 2.0 ft. thick, with a maximum thickness of 2.6 ft. in the central portion of the drop zone. The six-month survey identified a placed sediment volume of 0.38 mcy. The total area covered by placed sediment greater than 0.3 ft. in thickness was 1.0 msy (206.6 ac).

Ten-month survey: November 20 & 26, 2008 (Figures 13 and 14)

At ten months post-placement, water depths across the drop zone were slightly deeper than in previous surveys, indicating further settlement and/or erosion of the placed sediments. The greatest changes occurred in the thickest areas of initial placement. Water depths over the majority of the drop zone were mostly -16 ft. to -17 ft., except in the northeast portion where water depths ranged from -17 ft. to -18 ft.

In the western portion of the drop zone, the placed sediments that extended approximately 150 ft. into the setback area were still evident. Only a small portion of the redistributed sediment extending through the West Sailing Course trough beyond the site boundary was identified by ten months. The placed sediment thickness in this area is approximately 0.3 ft. (4 inches).

The majority of the deposit ranged in thickness from 0.3 ft. to 1.0 ft., with a maximum thickness of 2.2 ft. in the southern, central portion of the drop zone. The ten-month survey identified a placed sediment volume of 0.24 mcy. The total area covered by placed sediment greater than 0.3 ft. in thickness was 0.76 msy (156.5 ac).

Sediment Properties

Appendix A, Tables 9 through 13 list the bulk properties and grain size for each core collected prior to placement, at completion of placement, and at ten months after placement. Table 2 lists the sites cored. On the post-placement coring cruises, several coring sites were added to ensure adequate sample coverage in areas likely to recover placed sediments. These core locations were chosen based on scow placement data and preliminary analyses of the isopach data. The core samples aided in the evaluation of placed sediment consolidation and in ground-truthing the bathymetric data.

Figure 4, 5, and 13 show the pre-placement, completion, and ten-month bottom sediment coring site locations overlain on the respective bathymetries. Figures 6 and 14 show the bottom sediment coring sites overlain on the completion and ten-month isopach maps, respectively. For each core, the placed sediment thickness listed may be less than the *in situ* thickness because of core shortening (refer to Methods section). The discussion concerning bulk properties focuses on the results of the mean water content analyses. Bulk density, porosity, and void ratio are also included in the tables for completeness.

Site 92 2007-2008 (Year 10) Bathymetry at 10 Months Post-Placement November 20 & 26, 2008

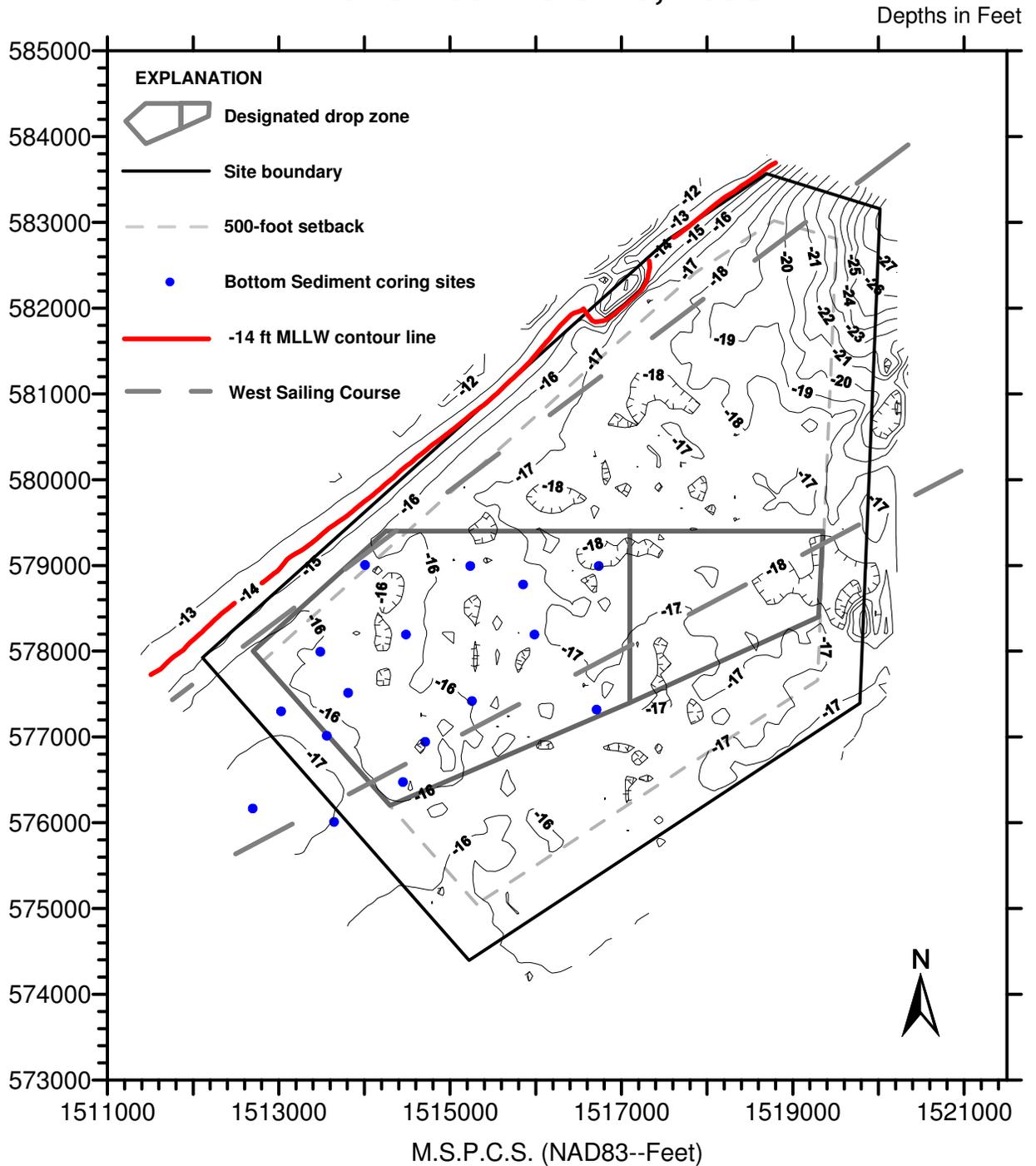


Figure 13. Bathymetry on November 20 & 26, 2008, ten months after completion of sediment placement.

Site 92 2007-2008 (Year 10) Change in Elevation Pre-Placement vs. 10 Months Post-Placement

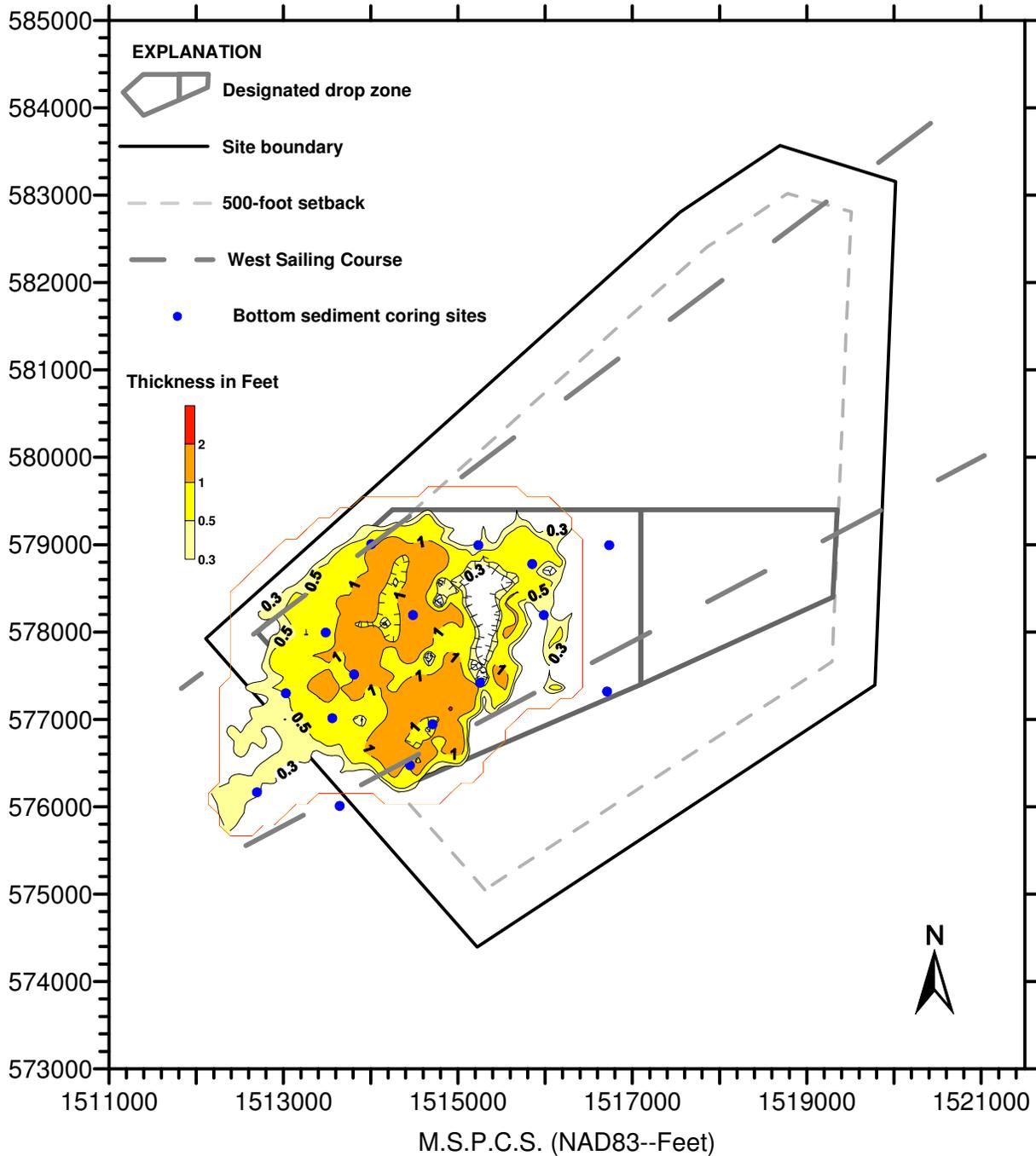


Figure 14. Isopach map showing change in elevation (feet) between pre-placement (September 24-25, 2007) and ten months post-placement (November 20 & 26, 2008).

Table 2. Coring Site Collection Schedule.

Coring Site	4	8	8A	9	12	13	13A	14	15	16	18	18A	19	19A	24	24A	25A	39	40	41	B	B1	G	
Pre-Placement	X					X		X	X	X	X		X	X	X		X	X	X	X			X	
Completion	X	X		X	X	X	X	X	X	X	X	X	X		X	X						X		
Ten-months	X	X	X	X	X	X	X	X	X	X	X		X		X	X						X	X	

Foundation sediments

Bottom sediment coring occurred prior to placement in order to characterize the pre-placement bottom sediments, establish bulk property data to evaluate subsequent foundation consolidation, and facilitate identification of placed dredged sediment. Pre-placement bottom sediments were sampled at 13 locations throughout the central region of Site 92 to ensure adequate coverage in locations where scow placement was likely to occur or potentially spread after placement (Table 2 and Figure 2). One additional site (core 92-G) was sampled outside of the site boundary to aid in ground-truthing the bathymetric data and confirm the absence or presence of placed sediments.

The foundation sediments were primarily olive gray, clayey silt mud (Shepard’s 1954 classification). The sand fraction ranged from 1% to 12%, silt fraction from 50% to 59%, and clay fraction from 30% to 45%. Water contents varied from 41.5% to 56.8%, a range of 15.3%.

Placed sediments

On the completion sampling date, twelve of the fifteen coring sites recovered Year 10 placed sediments of variable thicknesses (cores 92-4, 92-8, 92-9, 92-12, 92-13, 92-13A, 92-15, 92-16, 92-18, 92-18A, 92-24, and 92-24A). The three remaining core sites were devoid of placed sediments (cores 92-14 and 92-19, located within the designated drop zone; and core 92-B, located outside of the Site 92 boundary).

At completion, Year 10 placed sediments were primarily olive gray, clayey silt mud (Shepard’s 1954 classification). The sand content ranged from 0% to 6%, silt from 51% to 60%, and clay from 34% to 49%. The water contents varied from 52.2% to 66.0%, a range of 13.8%.

Ten months after completion of placement, coring recovered placed sediments at these same eight coring sites (cores 92-4, 92-8, 92-9, 92-12, 92-13A, 92-15, 92-16, and 92-18) and one additional coring site, core 92-8A (located within the designated drop zone). The following core sites were devoid of placed sediments: cores 92-13, 92-14, 92-19, 92-24, and 92-24A, located within the designated drop zone; and cores 92-B and 92-B1, located outside of the Site 92 boundary.

Placed sediments recovered during the ten-month coring cruise were very similar to those sediments recovered during the completion cruise. The sand content ranged from 3% to 6%, silt from 52% to 59%, and clay from 35% to 45%. The water contents varied from 50.7% to 61.1%, a range of 10.4%.

The historical average of the mean water content values for the dredged channel sediments (58.12 ±2.34%), Year 10 completion placed sediments (56.56 ±2.68%), and Year 10 ten-month

placed sediments ($54.35 \pm 3.22\%$) were utilized to calculate a bulking factor at completion and consolidation over the post-placement period (Tables 4 and 5).

Analysis of Bathymetric and Sediment Data

This analysis evaluated the QA/QC of the post-processed bathymetric data and the presence of any anomalous trends that would indicate a problematic survey. Gravity cores collected within and outside the placement area provided ground-truth for the isopach maps created from the bathymetric data.

There was a strong correlation at completion and ten months between the absence or presence of placed sediment at the coring locations and the bathymetric data within the limits of resolution. At completion, coring recovered placed sediments at twelve locations (cores 92-4, 92-8, 92-9, 92-12, 92-13, 92-13A, 92-15, 92-16, 92-18, 92-18A, 92-24 and 92-24A). At ten months post-placement, coring recovered placed sediments at nine locations (92-4, 92-8, 92-8A, 92-9, 92-12, 92-13A, 92-15, 92-16, and 92-18). At these locations, the bathymetric data indicated a sediment deposit greater than 0.3 ft. thick.

The following core sites were devoid of placed sediments during the completion coring cruise: cores 92-14 and 92-19 (located inside the designated drop zone) and 92-B (located outside of the Site 92 boundaries). During the final ten-month coring cruise, the following core sites were devoid of placed sediments: 92-13, 92-14, 92-19, and 92-24 (located inside the designated drop zone) and cores 92-B and 92-B1 (located outside of the Site 92 boundaries). With the exception of sites 92-13, 92-24, and 92-B1 (discussed below), placed sediments were not identified in the bathymetric data and isopach maps in these locations.

According to the bathymetric data, core samples taken at three coring sites during the final ten-month cruise – cores 92-13, 92-24, and 92-B1 – should have contained placed sediments of approximately 0.3 ft. to 0.8 ft. thick. However, no placed sediments were identified during the core sediment analysis. Cores 92-13 and 92-B1 are located along the edge of the deposit at the outer limits of the bathymetric data resolution. As such, the lack of placed sediments found at these sites does not diminish the reliability and accuracy of the bathymetry surveys. Core 92-24 should have recovered placed sediments of approximately 0.8 ft. of thickness. However, no placed sediments were identified at this location. It is possible that a small amount of sediment redistribution occurred between the final bathymetric survey and coring cruises (a time span of approximately two weeks), resulting in a lack of placed sediments at a location thought to be covered by the deposit.

Consolidation of Foundation Sediments

Foundation consolidation is routinely evaluated to derive the most accurate placement volumes possible. Dewatering of the foundation sediments is expected to occur through time and result in some consolidation after placement. Without accounting for foundation consolidation, the placed sediment volumes determined through the bathymetric surveys may be underestimated. Foundation consolidation lowers the elevation of the overlying placed sediments and increases the water depths. Accounting for the difference in elevation because of foundation consolidation increases the calculated volume of the placed sediment.

The depth to which foundation consolidation is affected by the overburden of placed sediments is unknown. A combination of variables such as the foundation slope, porosity and permeability of the foundation sediments, and the overlying thickness of the placed sediment contributes to the variability measured in previous placement operations. This study evaluated the upper 1.1 ft. to 2.1 ft. of the foundation layer. This was the maximum thickness that the coring device could penetrate through placed sediments and recover pre-placement foundation sediments in relatively shallow water depths (<16 ft.). Poindexter-Rollings (1990) determined that foundation consolidation should be greatest in the upper portion of the underlying sediment column. Based on that research, it was assumed that if minimal foundation consolidation was identified in the uppermost layer, then it was likely consolidation was negligible below this level.

Four sites were used to evaluate foundation consolidation. These sites were located in areas where the placed sediment thickness ranged from 0.3 ft. to 3.0 ft. Table 3 summarizes the change in mean water content over the three sampling periods.

Table 3. Change in foundation sediment water content through time ¹ .				
placement period	92-4	92-15	92-16	92-18
change in water content (%) between pre-placement (10/2/07) and completion of placement (2/20/08)	-0.5	1.3	-0.9	-4.2
post-placement period	92-4	92-15	92-16	92-18
change in water content (%) between completion of placement (2/20/08) and ten months after placement (12/3/08)	-2.2	-4.8	2.2	1.7

¹ Positive values indicate an increase in water content. Negative values indicate a decrease in water content.

No clear trend was immediately evident from the data in Table 3. The change in the foundation sediment water contents over the sampling periods varied from site to site, ranging from -4.2% to +1.3% during the placement period and -4.8% to +2.2% during the post placement period. The water contents of foundation sediments decreased in 3 out of 4 coring sites between pre-placement and completion of placement (cores 92-4, 92-16, and 92-18). Between completion of placement and ten months after placement, 2 out of 4 coring sites exhibited a decrease in water content (cores 92-4 and 92-15). The variations may have resulted from a combination of factors including the overlying thickness of placed sediments, the porosity and permeability of the foundation sediments, and sampling and analytical errors.

Typically, the station-to-station variations shown in Table 3 can be averaged to develop a general measure of foundation consolidation over the entire placement area. The average of the foundation sediment water content prior to placement was 51.2 ±1.0%; at completion of placement, 50.1 ±2.8%; and 49.4 ±2.0% at ten months after placement. These numbers indicate a decrease in foundation sediment water content between pre-placement and completion of placement, and a slight decrease in water content between completion of placement and ten months following placement.

A t-test was run on the data to determine if the decrease in foundation sediment water contents was statistically significant. The test demonstrated that the average 1.1% decrease in water content between pre-placement and completion, and the average 0.7% decrease in water content

between completion and ten months were not statistically significant. Therefore, foundation consolidation could not be documented over the placement period or the post-placement period, except for the possibility that it occurred in localized areas during and after placement.

Dredged and Placement Amounts

The study evaluated the volumetric quantity of dredged sediment present at the placement site soon after the completion of dredging and placement operations. A volumetric deficit of sediment is expected at completion of placement operations resulting from the following processes during the placement period: (1) suspended sediment loss in primary turbidity plumes during dredging and placement, (2) suspended sediment loss from the resuspension and erosion of placed sediment, and (3) dewatering (consolidation) of the placed sediment. The reported dredged volumes in conjunction with bulk property and bathymetric data collected by MGS were used to account for the placed sediment volume at completion.

Table 4 summarizes the results of the study. Mean values are bolded; bracketed values indicate the possible range as discussed below. The dredged (column *a*) and expected volumes at the placement site (column *e*) are rounded off to the nearest 500 cubic yards. The expected volume at the placement site (column *e*) was determined by multiplying a derived bulking ratio (column *d*) by the reported volume of dredged sediments (column *a*). The bulking ratio is a function of the change in porosities, which is calculated from the mean water contents of the dredged channel sediments (column *b*) and the placed sediments (column *c*). This takes into account the change in volume from both water-loading (bulking) and dewatering (consolidation) of the sediments through time and allows for a more reliable estimation of suspended sediment loss from the placement site. The standard deviation for each water content appears as the \pm component in columns *b* and *c* and results in a possible range for the bulking ratio and the expected volume of sediment at the placement site. The mean sediment volumes identified (column *f*) and accounted for at the placement site (columns *g* and *h*) were calculated based on bathymetric measurements. The possible ranges are due to the limits in vertical resolution inherent in the bathymetric surveys.

NDC reported a total estimated dredged volume of 0.60 mcy based on the sum of all scow loads. CENAP reported a “total removed” sediment volume of 0.69 mcy based on the change between pre- and post-dredging bathymetric surveys in the channel. The difference in the reported quantity of sediment dredged from the channel (column *a*) was approximately 0.09 mcy (approximately ninety thousand cubic yards). Therefore, for column *a*, the average of the two reported dredged volumes (0.64 mcy) is also reported and was used to derive an expected placed sediment volume at completion (column *e*).

Table 4. Comparison of bulk property and volumetric data.							
(a) volume dredged (mcy)	(b) % water content of channel sediment [range]	(c) % water content of placed sediment [range]	(d) bulking ratio from water content data [range]	(e) expected volume of sediment at placement site (mcy) [range]	(f) volume of sediment identified at placement site (mcy) [range]	(g) volume difference identified at placement site (mcy)	(h) volume difference identified at placement site (%)
<u>CENAP</u> 0.69	58.1 ±2.3 [55.8 to 60.4]	56.6 ±2.7 [53.9 to 59.3]	0.95 [0.81 to 1.12]	0.66 [0.56 to 0.77]	0.44 ±0.10 [0.34 to 0.54]	-0.21 [-0.02 to -0.43]	-32.6% [-3.6 to -55.8]
<u>NDC</u> 0.60				0.57 [0.49 to 0.67]		-0.12 [-0.05 to -0.33]	-21.9% [-10.2 to -49.3]
<u>Average</u> 0.64				0.61 [0.52 to 0.72]		-0.17 [-0.02 to -0.38]	-27.6% [-3.8 to 52.8]

The average of the water contents for the channel sediments, $58.1 \pm 2.3\%$, was calculated from 13 previous years of data (column *b*). The placed sediments water content (column *c*) was the average of eight water contents from the cores that recovered placed sediments after completion of placement and ten months following placement (Appendix A, Tables 12 and 13). The average placed sediment water content, $56.6 \pm 2.7\%$, ranged within the averages determined in previous year's studies and is considered reliable. A t-test demonstrated that the decrease in the dredged sediment water content after placement was statistically significant (at the 90% confidence level). Therefore, a bulking ratio of 0.95 was utilized in the volumetric analysis. When the standard deviation of the water contents (columns *b* and *c*) is considered for this year's placement, the bulking ratio could range from 0.81 to 1.12. The range in bulking ratios and volumes identified at the placement site (columns *d*, *f*, *g*, and *h*) are theoretically possible due to the sediment's standard deviation and limits in vertical resolution inherent in the bathymetric surveys. However, utilizing the mean value is the best approximation for accounting purposes.

The placed sediment volume identified at Site 92 from the completion bathymetric survey was 0.44 ± 0.10 mcy. A volume of 0.61 mcy would be expected utilizing the 0.95 bulking ratio and the average of the reported dredged volumes. This represented a mean deficit of 0.17 mcy, or 27.6%, when comparing what MGS identified at the placement site to the average of the reported dredged volumes.

The Year 10 mean volume deficit, 27.6%, is considered slightly lower than the historical ranges generally seen. For example, the deficits in Years 5, 6, 8, and 9 were 32.5%, 31.5%, 31.7%, and 31.5%, respectively. There was only a 8% deficit documented in Year 7; however, this deficit is considered minimal in comparison to the historic values.

Consolidation and Erosion After Placement

The volumetric reductions that occur after placement result from both consolidation due to dewatering and erosion of sediment from the surface of the deposit. The reduction in sediment volume due to consolidation can be estimated from changes in the water content over time. The amount of erosion can be estimated by first calculating the total sediment volume change from the bathymetric data and then subtracting the volume change determined to be due to consolidation.

Table 5, columns *a-b*, summarizes the mean volumes estimated to be present at the completion of placement and at one, three, six, and ten months after placement. The completion volume is the mean of the possible range in volumes identified at completion of placement. Column *c* is the volumetric and percentage cumulative change over time. The associated volumetric changes attributed to consolidation and erosion (columns *f-g*) were estimated from the placed sediment data collected for the completion and ten-month survey dates. The underlying assumption in estimating consolidation and erosion is that the recovered sediment accurately reflects the water content of the *in situ* sediment. Water makes up a relatively large proportion of the bottom sediments by volume, and relatively small differences in the calculated water contents can result in large volume differences. This can affect the analyses in two ways. First, in recently placed sediments, water contents are at their highest and dewatering occurs very rapidly. Because the water contents are at their highest levels, the effect of small water content variations on the volumetric change analyses is greatly magnified in the early stages of dewatering. Calculating dewatering rates over periods of less than approximately three months has yielded ambiguous results in previous studies conducted by MGS (Panageotou and Halka, 1994a, 1994b). Secondly, there exists variability in the water content values over the site. The mean water content value represents the best approximation of the consolidation changes occurring in the sediments over the longer term. The standard deviation of mean water content measurements is shown as the \pm component of the water contents reported in column *e*.

Table 5. Volumetric analyses of placed sediments through time.			
Bathymetric analyses and associated volumetric changes.			
(a) survey	(b) measured volume present (mcy)	(c) cumulative volume change (mcy) (%)	
completion	0.44 ±0.10	0	0
one month	0.45 ±0.10	+0.01	+1.0
three month	0.38 ±0.09	-0.06	-13.3
six month	0.38 ±0.11	-0.06	-15.1
ten month	0.24 ±0.08	-0.20	-46.4
Water content analyses and associated volumetric changes			
(d) survey	(e) average water content (%)	(f) mean volume change due to consolidation (%)	(g) mean volume change due to erosion (%)
completion	56.6 ±2.7	0	0
ten month	54.4 ±3.2	-7.0	-39.4

The in-place volumes identified at one month, three months, six months, and ten months were approximately 0.01, 0.06, 0.06, and 0.20 mcy less, respectively, than the volume identified on the completion survey. At the end of the ten-month post-placement period, 53.6% of the original placed sediment volume remained.

During the post-placement period, the average sediment water content of placed sediments decreased 2.2%, from 56.6% to 54.4%. A t-test indicated that there was a statistically significant change in water contents at a 90% confidence level between completion and ten months. This equated to a 7% volume reduction due to dewatering and consolidation, or approximately one-sixth of the total reduction. The remainder of the volume change attributed to erosion, 39.4%, is approximately five-sixths of the total volumetric reduction.

The Year 10 percent cumulative volume change (-46.4%) is within the historical range. For example, Years 5, 6, 7, 8, and 9 percent cumulative volume changes were 49%, 38%, 26%, 38.5%, and 47.8%, respectively. In addition, the Year 10 percent mean volume change due to consolidation and erosion (7.0 % and 39.4%, respectively) align well with the results from previous years. The percent mean volume change due to consolidation ranged from 0% to 13% during Years 5, 6, 7, 8, and 9. The percent mean volume change due to erosion during those years ranged from 19% to 49%.

Sediment Mass Budget

A sediment mass budget estimates the movement of sediment mass from the placement site during the placement and post-placement periods, which can be recorded as a loss of material. Sediment mass is calculated in tons by multiplying the weight of the solids determined from the bulk property analysis by the volume of placed sediment. A ton is equal to 2,000 pounds. A sediment mass loss is expected at placement and post placement periods from: (1) suspended sediment

dispersed in primary turbidity plumes during dredging and placement operations and (2) from the resuspension and erosion of placed sediment after completion.

Table 6 summarizes the sediment mass calculated from the reported volumes dredged and the sediment mass identified at the completion and ten-month bathymetric surveys. The sources of the sediment mass values are listed. Table 7 presents the differences in sediment mass between the reported tons dredged and the tons identified at Site 92 on the completion survey, for the interval between the completion and ten-month surveys, and for the ten-month survey. Negative values represent the loss of sediment mass. Positive values indicate more sediment mass was identified at the placement site than was reported dredged.

Table 6. Sediment mass for dredging and placement operations and post-placement period.		
	source	tons
sediment mass dredged	CENAP	329,860
	NDC	284,824
	average	307,343
sediment mass identified at completion	MGS	222,192
sediment mass identified at ten months	MGS	127,588

Table 7. Deficit in sediment mass in tons and percentage.				
time-frame	source	CENAP	NDC	average
at completion	reported amount/MGS	-107,668 (-33%)	-62,632 (-22%)	-85,150 (-28%)
completion to ten months	MGS	-94,604 (-43%)		
at ten months	reported amount/MGS	-202,272 (-61%)	-157,236 (-55%)	-179,755 (-59%)

CENAP reported dredged volume results in a 33% deficit of sediment mass at completion (107,668 tons). NDC reported dredged volume results in a 22% deficit of sediment mass (62,632 tons) at completion.

Utilizing the average of the reported dredged volume most likely represents the best estimate of sediment mass loss from the placement site. At completion, there was a 28% deficit (85,150 tons) identified at Site 92. Over the post-placement period, MGS calculated an additional 43% loss (94,604 tons). Over the combined periods, there was a total average sediment mass loss of 59% (179,755 tons). The total loss represents approximately three-fifths of the sediment mass dredged and placed at Site 92.

During the previous nine years of placement, the total percentage sediment mass loss has ranged from 25% to 65%, or approximately from one-quarter to over two-thirds. Specifically, in Years 5, 6, 8, and 9, the total percentage of sediment mass loss was 65%, 52%, 53%, and 60%, respectively. Year 7 was an unusually good year, with a total loss of only 26%. This year's total percentage of sediment loss (59%) appears to be within the historical normal range.

The average annual input of fine-grained sediment from shoreline erosion and the Susquehanna River to the upper bay (during the years without major floods) has been estimated at

1,594,215 tons (Panageotou and others, 1996). This year's dredging operation involved the movement of 307,343 tons of sediment mass from the C&D approach channel to Site 92. By the end of the monitoring period, it was estimated that 179,755 tons were transported from Site 92 and dispersed by prevailing currents over the upper Bay. The sediment mass dispersed over the upper Bay represents 11% of the average annual input of fine-grained sediment from shoreline erosion and the Susquehanna River. Spread evenly over the area covered by fine-grained sediment north of Tolchester (67 mi²), a thickness of 0.08 inches would result from the mass of sediment transported from Site 92 during this monitoring period.

Capacity Usage

Table 8 summarizes the site volume capacity usage at Site 92. Site volume is the available space for placement usage. The estimates assume an idealized placement configuration when brought to the authorized depth of -14 ft. MLLW. Site volume was estimated at 7 mcy prior to Placement Year 1 (column *e*).

In Table 8, of the two reported volume sources (CENAP and contractor), the closest volume to the volume identified by MGS at completion of placement (column *b*) is listed on the top line in column *a* and carried forward for a cumulative total cut volume from the channel. The contractor's dredged volume (indicated by +) is based on the quantity of sediment placed per scow load. CENAP dredged volume (indicated by *) is based on the change between pre- and post-dredging bathymetric surveys in the channel (cut volume). Column *c* lists the measured volume reduction over the post-placement period. Column *d* lists the site volume used at the end of the year on a yearly and cumulative cycle. The final bathymetric surveys determined the volumetric usage and the remaining site volume for future placements.

Table 8. Site volume capacity usage at Site 92 (mcy).									
NTDE	placement year	Reported		Measured Site Volume Use at Placement Site					
		(a)		(b)		(c)	(d)		(e)
		cut volume from channel		site volume used at completion of placement		volume reduction after placement	site volume used at end of year		remaining site volume at end of year ^a
		yearly	cumulative	yearly	cumulative	yearly	yearly	cumulative	cumulative
1960-1978	Year 1 1998 1999	1.09+	1.09	1.04	1.04	0.34	0.70	0.70	6.30
		0.76*							
	Year 2 1999 2000	0.51+	1.60	0.59	1.29	0.10	0.49	1.19	5.81
		0.46*							
	Year 3 2000 2001	1.78*	3.38	1.44	2.63	0.21	1.23	2.42	4.58
		0.91+							
	Year 4 2001 2002	0.30*	3.68	0.19	2.61	0.08	0.11	2.53	4.47
		0.18+							
	Year 5 2002 2003	0.32+	4.00	0.21	2.34	0.11	0.10	2.63 ^b	4.37 ^b
		0.35*						2.23 ^c	4.77 ^c
0.28 ^d								-0.07 ^d	2.06 ^d
Year 6 2003 2004	1.07+	5.07	0.74	2.80	0.25	0.49	2.55	4.45	
	1.08*								
Year 7 2004 2005	1.01+	6.08	0.95	3.50	0.25	0.70	3.25	3.75	
	1.21*								
Year 8 2005-2006	0.68*	6.76	0.53	3.78	0.20	0.33	3.58	3.42	
	0.87+								
Year 9 2006-2007	0.83+	7.59	0.63	4.21	0.30	0.33	3.91	3.09	
	0.88*								
Year 10 2007-2008	0.60+	8.19	0.44	4.35	0.20	0.24	4.15	2.85	
	0.69*								

+ denotes contractor's reported dredged volume (cumulative total = 7.39 mcy).
* denotes CENAP reported dredged volume (cumulative total = 8.19 mcy).
^a initial site volume 7.00 mcy.
^b 1960-1978 National Tidal Datum Epoch (NTDE).
^c updated NTDE decreases column *d* cumulative and increases column *e* by 0.40 mcy prior to Hurricane Isabel.
^d erosion from Hurricane Isabel decreases column *d* and increases columns *c* and *e* by 0.17 ±0.04 mcy.

Years 1 through 4 placements utilized 2.53 mcy of site volume, or 36%, leaving 4.47 mcy. Prior to Year 5 placement, all bathymetric surveys were referenced to MLLW for 1960-1978 NTDE. During Year 5 placement, the NTDE was updated (1983-2001) to reflect changes in mean sea level along the nation's coast. The updated NTDE increased site volume capacity by 0.40 mcy. Year 5 placement utilized 0.10 mcy of site volume, leaving 4.77 mcy. Subsequently, Hurricane Isabel passed through the mid-Atlantic region (16 days prior to Year 6 placement). After Hurricane Isabel, an estimated 0.17 mcy of sediment eroded from Site 92 resulting in a 0.07 mcy net gain of site volume. Therefore, Year 5 placement had a total net gain of 0.47 mcy, or 6.7% of the site volume, leaving 4.94 mcy. Years 6 utilized 0.49 mcy of site volume, leaving 4.45 mcy. Year 7 placement utilized 0.70 mcy of site volume, leaving 3.75 mcy. Year 8 placement utilized 0.33 mcy, leaving 3.42 mcy of site volume. Year 9 placement also utilized 0.33 mcy of site volume, leaving 3.09 mcy of site volume.

Placement in Year 10 utilized 0.24 mcy, leaving 2.85 mcy of site volume. In total, Years 1 through 10 placements used 4.15 mcy of the site volume, or 59%. Therefore, 41% of the placement site is available for future placements assuming an idealized placement configuration when brought to the authorized depth of -14 ft. MLLW.

CONCLUSIONS

CENAP and NDC both provided estimates of the quantity of sediment dredged based on different measurement techniques. CENAP reported a total cut volume of 0.69 mcy. NDC reported 0.60 mcy. The difference in the two reported volumes suggests that the average volume, 0.64 mcy, represents the best estimate of sediment volume dredged.

Placement occurred in the designated drop zone in water depths that ranged from -16 ft. to -17 ft. After completion of placement, most of the drop zone exhibited water depths of -16 ft. \pm 1.0 ft. Placed sediments occupied nearly the entire area of the drop zone, and in some areas extended beyond the drop zone boundaries into the setback area. Three small areas in the drop zone exhibited slight sediment "mounding" and water depths of -14 ft. \pm 0.5 ft. The majority of the deposit was 1.0 to 3.0 ft. thick, with a maximum thickness of 3.8 ft. No placed sediments were identified beyond the Site 92 boundaries.

The total coverage of placed sediment within Site 92 was 0.89 msy, or 183.4 ac. The estimated in-place volume identified at the placement site was 0.44 mcy. This represents a 27.6% deficit when compared to the average of the reported dredged volumes. Subsequent consolidation and erosion processes reduced the in-place volume by 46.4% by ten months following placement.

Water content data indicates that approximately 7%, or one-sixth of the total volumetric reduction was due to consolidation. Approximately five-sixths, or 39.4%, was due to erosion. At ten months after completion of placement, 53.6% of the original placed sediment volume remained in-place.

Over the combined placement and post-placement periods, there was a 59% loss of sediment mass (-179,755 tons) identified at Site 92. The total sediment mass loss represents approximately three-fifths of the dredged amount. The historical range of sediment mass loss has been between one-quarter to two-thirds.

This year's cut volume, 0.64 mcy, utilized 0.24 mcy of the site volume. To date, 4.15 mcy, or 59%, of the site volume was used. Approximately 2.85 mcy of the site volume remains at Site 92 for future placements.

ACKNOWLEDGMENTS

This report was made possible by the combined efforts of the following Maryland Department of Natural Resources personnel: Captain Richard K. Younger, Jr. and First Mate Taylor Woodburn - operators of the *R/V Kerhin*; Jeffrey Halka, Richard Ort, Jr., Stephen VanRyswick, Lamere Hennessee, Heather Quinn, Andrew Staley, and Johanna Carpenter - sediment data collection. The authors gratefully thank Stephen VanRyswick and Johanna Carpenter for their assistance with laboratory analysis and Jeffrey Halka and the SMT Team for their constructive reviews of the original manuscript.

REFERENCES

- Bennett, R.H., and Lambert, D.V.**, 1971, Rapid and reliable technique for determining unit weight and porosity of deep-sea sediments: *Marine Geology*, v. 11, p. 201-207.
- Blomqvist, S.**, 1985, Reliability of core sampling of soft bottom sediment - an *in situ* study: *Sedimentology*, v. 32, p. 605-612.
- Carver, R.E.**, 1971, *Procedures in sedimentary petrology*: New York, Wiley, 653 p.
- Davis, J.C.**, 1973, *Statistics and data analysis in geology*: New York, Wiley, 550 p.
- Folk, R.L.**, 1974, *Petrology of sedimentary rocks*: Austin, Tex., Hemphill Publ. Co., 182 p.
- Guibas, L., and Stolfi, J.**, 1985, Primitives for the manipulation of general subdivisions and the computation of Voronoi diagrams: *ACM Transactions on Graphics*, v. 4, no. 2, p. 74-123.
- Halka, J., and Panageotou, W.**, 1993, The fate of sediments hydraulically deposited in overboard placement sites in the northern Chesapeake Bay: Maryland Geological Survey File Report, 228 p.
- Kerhin, R.T., Halka, J.P., Wells, D.V., Hennessee, E.L., Blakeslee, P.J., Zoltan, N., and Cuthbertson, R.H.**, 1988, The surficial sediments of Chesapeake Bay, Maryland: physical characteristics and sediment budget: Maryland Geological Survey Report of Investigations No. 48, 82 p.
- Lawson, C.L.**, 1977, Software for C^1 surface interpolation, *in* Rice, J., ed. *Mathematical software III*, New York, Academic Press, p. 161-193.
- Lee, D.T., and Schachter, B.J.**, 1980, Two algorithms for constructing a Delaunay triangulation: *International Journal of Computer and Information Sciences*, v. 9, no. 3, p. 219-242.
- Maryland Environmental Service**, 1997, Designation of aquatic dredged material placement Areas G-East and Site 92 for maintenance dredging, inland waterway Delaware River to Chesapeake Bay, Delaware and Maryland northern approach channel: final environmental assessment, 168 p. plus appendices.
- Maryland Environmental Service**, 2005, Monitoring of 2004/2005 dredged material placement at Pooler Island open-water placement Site 92: Year 7, Site Management Report, 18 p. plus appendices.
- Offerman, K.A., and Panageotou, W.**, 2007, Placement, consolidation, and erosion studies at open-placement Site 92, 2005-2006 (Year 8): Maryland Geological Survey File Report No. 07-01, 43 p.

- Offerman, K.A., and Panageotou, W.,** 2008, Placement, consolidation, and erosion studies at open-placement Site 92, 2006-2007 (Year 9): Maryland Geological Survey File Report No. 08-01, 43 p.
- Ott, L., Mendenhall, W., and Larson, R.,** 1978, Statistics - a tool for the social sciences: North Scituate, MA, Duxbury Press, 531 p.
- Ortt, R. A.,** 1999, Analysis of discrepancies and sources of error in the bathymetric surveying results of the Philadelphia Corps of Engineers and the Maryland Geological Survey, unpublished report.
- Panageotou, W.,** 2001, Placement, consolidation, and erosion studies at open-placement Site 92, 1998 - 1999: Maryland Geological Survey File Report No. 01-1, 69 p.
- Panageotou, W.,** 2002, Placement, consolidation, and erosion studies at open-placement Site 92, 1999 - 2000: Maryland Geological Survey File Report No. 02-2, 43 p. plus appendices.
- Panageotou, W.,** 2003, Placement, consolidation, and erosion studies at open-placement Site 92, 2000 - 2001: Maryland Geological Survey File Report No. 02-6, 49 p. plus appendices.
- Panageotou, W.,** 2004a, Placement, consolidation, and erosion studies at open-placement Site 92, 2001 - 2002 (Year 4): Maryland Geological Survey File Report No. 03-06, 53 p. plus appendices.
- Panageotou, W.,** 2004b, Placement, consolidation, and erosion studies at open-placement Site 92, 2002 - 2003 (Year 5): Maryland Geological Survey File Report No. 04-05, 54 p. plus appendices.
- Panageotou, W.,** 2005, Placement, consolidation, and erosion studies at open-placement Site 92, 2003 - 2004 (Year 6): Maryland Geological Survey File Report No. 05-03, 49 p. plus appendices.
- Panageotou, W.,** 2006, Placement, consolidation, and erosion studies at open-placement Site 92, 2004 - 2005 (Year 7): Maryland Geological Survey File Report No. 06-01, 36 p. plus appendices.
- Panageotou, W., and Halka, J.,** 1994a, Studies of dredged sediments placed in open-water sites in the northern Chesapeake Bay, October, 1991 - March, 1992: Maryland Geological Survey File Report No. 94-1, 115 p.
- Panageotou, W., and Halka, J.,** 1994b, Studies of sediments dredged from the approach channel to the Chesapeake and Delaware Canal, December, 1992 - January, 1993 and from the Baltimore Harbor Approaches, November, 1992 - March, 1993: Maryland Geological Survey File Report No. 94-5, 68 p.

- Panageotou, W., Ortt, R., Jr. and Halka, J.**, 1996, Placement, consolidation, and erosion studies of sediments dredged from the approach channel to the Chesapeake and Delaware Canal, November, 1994 - January, 1995: Maryland Geological Survey File Report No. 96-1, 70 p.
- Poindexter-Rollings, M.E.**, 1990, Methodology for analysis of subaqueous sediment mounds: Technical Report D-90-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 110 p. plus appendix.
- Shepard, F.P.**, 1954, Nomenclature based on sand-silt-clay ratios: *Journal of Sedimentary Petrology*, v. 24, p. 151-158.
- U.S. Army Corps of Engineers, Philadelphia District**, 2004, Maintenance dredging, sta. 163+655 to sta. 250+440, inland waterway Delaware River to Chesapeake Bay, Delaware and Maryland, construction solicitation and specifications; IFB DACW61-04-B-0021.
- Weaver, P.P.E., and Schultheiss, P.J.**, 1983, Detection of repenetration and sediment disturbance in open-barrel gravity cores: *Journal of Sedimentary Petrology*, v. 53, p. 649-654.

APPENDIX

Physical Properties of Sediment Cores

Table 9. Physical properties of foundation sediments prior to sediment placement (October 2, 2007).				
Core location	92-4	92-13	92-14	92-15
Sediment thickness in core (ft.)	1.9	1.9	2.4	2.1
Sand/silt/clay fraction (%)	5/56/39	5/56/39	5/53/42	7/55/38
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	50.5 ±2.2	51.5 ±2.3	51.5 ±2.3	52.8 ±2.4
Bulk density (g/cm ³)	1.45 ±0.03	1.43 ±0.03	1.43 ±0.03	1.42 ±0.03
Porosity	0.730 ±0.018	0.737 ±0.018	0.738 ±0.018	0.748 ±0.018
Void ratio	2.7 ±0.3	2.8 ±0.4	2.8 ±0.3	3.0 ±0.3
Core location	92-16	92-18	92-19	92-19A
Sediment thickness in core (ft.)	2.0	1.5	1.5	1.3
Sand/silt/clay fraction (%)	4/55/41	5/55/40	4/54/42	4/55/41
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	51.2 ±2.3	50.3 ±2.2	55.9 ±2.5	50.9 ±2.3
Bulk density (g/cm ³)	1.44 ±0.03	1.45 ±0.03	1.38 ±0.03	1.44 ±0.03
Porosity	0.736 ±0.018	0.729 ±0.018	0.770 ±0.018	0.733 ±0.018
Void ratio	2.8 ±0.3	2.7 ±0.3	3.4 ±0.4	2.8 ±0.3
Core location	92-24	92-25A	92-39	92-40
Sediment thickness in core (ft.)	2.0	1.4	1.8	2.5
Sand/silt/clay fraction (%)	6/57/37	3/57/40	5/55/40	7/50/43
Shepard's (1954) classification	clayey silt	silty clay	clayey silt	clayey silt
Water content (%)	49.7 ±2.2	47.6 ±2.1	50.2 ±2.2	54.3 ±2.4
Bulk density (g/cm ³)	1.46 ±0.03	1.48 ±0.03	1.45 ±0.03	1.40 ±0.03
Porosity	0.724 ±0.018	0.706 ±0.018	0.728 ±0.018	0.759 ±0.018
Void ratio	2.6 ±0.2	2.4 ±0.2	2.7 ±0.3	3.2 ±0.3
Core location	92-41	92-G		
Sediment thickness in core (ft.)	1.6	2.0		
Sand/silt/clay fraction (%)	4/54/42	6/54/40		
Shepard's (1954) classification	clayey silt	clayey silt		
Water content (%)	49.4 ±2.2	52.4 ±2.3		
Bulk density (g/cm ³)	1.46 ±0.03	1.42 ±0.03		
Porosity	0.721 ±0.018	0.745 ±0.018		
Void ratio	2.6 ±0.2	2.9 ±0.3		

Table 10. Physical properties of foundation sediments at completion of placement (February 20, 2008). Foundation sediments overlain by placed sediments are shaded in the core location and sediment thickness rows.

Core location	92-4	92-8	92-9	92-12
Sediment thickness in core (ft.)	1.6	1.6	1.6	1.6
Sand/silt/clay fraction (%)	4/56/40	3/57/40	12/58/30	3/56/41
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	50.0 ±2.2	52.1 ±2.3	41.5 ±1.8	50.2 ±2.2
Bulk density (g/cm ³)	1.45 ±0.03	1.42 ±0.03	1.57 ±0.03	1.45 ±0.03
Porosity	0.726 ±0.018	0.743 ±0.018	0.652 ±0.018	0.728 ±0.018
Void ratio	2.6 ±0.2	2.9 ±0.3	1.9 ±0.1	2.7 ±0.3
Core location	92-13	92-13A	92-14	92-15
Sediment thickness in core (ft.)	1.6	1.6	2.0	1.6
Sand/silt/clay fraction (%)	4/56/40	4/55/41	3/54/43	1/54/45
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	53.0 ±2.4	51.2 ±2.3	51.8 ±2.3	54.1 ±2.4
Bulk density (g/cm ³)	1.41 ±0.03	1.44 ±0.03	1.43 ±0.03	1.40 ±0.03
Porosity	0.749 ±0.018	0.735 ±0.018	0.740 ±0.018	0.758 ±0.018
Void ratio	3.0 ±0.3	2.8 ±0.3	2.8 ±0.3	3.1 ±0.3
Core location	92-16	92-18	92-18A	92-19
Sediment thickness in core (ft.)	1.6	1.6	1.6	1.6
Sand/silt/clay fraction (%)	6/58/36	5/54/41	3/54/43	3/54/43
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	50.4 ±2.2	46.1 ±2.1	51.0 ±2.3	48.1 ±2.1
Bulk density (g/cm ³)	1.45 ±0.03	1.51 ±0.03	1.44 ±0.03	1.48 ±0.03
Porosity	0.729 ±0.018	0.694 ±0.018	0.734 ±0.018	0.710 ±0.018
Void ratio	2.7 ±0.3	2.3 ±0.2	2.8 ±0.3	2.5 ±0.2
Core location	92-24	92-24A	92-B	
Sediment thickness in core (ft.)	1.6	1.6	1.6	
Sand/silt/clay fraction (%)	5/54/41	5/55/40	7/55/38	
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	
Water content (%)	51.5 ±2.3	55.3 ±2.5	56.5 ±2.5	
Bulk density (g/cm ³)	1.43 ±0.03	1.39 ±0.03	1.37 ±0.03	
Porosity	0.738 ±0.018	0.767 ±0.018	0.775 ±0.018	
Void ratio	2.8 ±0.3	3.3 ±0.3	3.4 ±0.4	

Table 11. Physical properties of foundation sediments at ten months (December 3, 2008). Foundation sediments overlain by placed sediments are shaded in the core location and sediment thickness rows.

Core location	92-4	92-8	92-8A	92-9
Sediment thickness in core (ft.)	1.1	1.5	1.6	1.6
Sand/silt/clay fraction (%)	5/57/38	4/59/37	6/54/40	7/58/35
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	47.8 ±2.1	48.4 ±2.2	51.6 ±2.3	49.6 ±2.2
Bulk density (g/cm ³)	1.48 ±0.03	1.47 ±0.03	1.40 ±0.03	1.46 ±0.03
Porosity	0.708 ±0.018	0.713 ±0.018	0.759 ±0.018	0.723 ±0.018
Void ratio	2.4 ±0.2	2.5 ±0.2	3.2 ±0.3	2.6 ±0.2
Core location	92-12	92-13	92-13A	92-14
Sediment thickness in core (ft.)	0.9	1.6	1.6	1.6
Sand/silt/clay fraction (%)	3/57/40	3/55/42	3/54/43	4/52/44
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	50.3 ±2.2	55.1 ±2.5	50.3 ±2.2	53.7 ±2.4
Bulk density (g/cm ³)	1.45 ±0.03	1.39 ±0.03	1.45 ±0.03	1.41 ±0.03
Porosity	0.728 ±0.018	0.764 ±0.018	0.729 ±0.018	0.754 ±0.018
Void ratio	2.7 ±0.3	3.2 ±0.3	2.7 ±0.3	3.1 ±0.3
Core location	92-15	92-16	92-18	92-19
Sediment thickness in core (ft.)	1.1	1.6	1.3	1.6
Sand/silt/clay fraction (%)	4/55/41	3/53/44	7/54/39	3/54/43
Shepard's (1954) classification	silty clay	clayey silt	clayey silt	clayey silt
Water content (%)	49.3 ±2.2	52.6 ±2.3	47.8 ±2.1	53.9 ±2.4
Bulk density (g/cm ³)	1.46 ±0.03	1.42 ±0.03	1.48 ±0.03	1.40 ±0.03
Porosity	0.720 ±0.018	0.746 ±0.018	0.708 ±0.018	0.756 ±0.018
Void ratio	2.6 ±0.2	2.9 ±0.3	2.4 ±0.2	3.1 ±0.3
Core location	92-24	92-24A	92-B	92-B1
Sediment thickness in core (ft.)	1.6	0.7	1.6	1.6
Sand/silt/clay fraction (%)	4/54/42	4/56/40	6/53/41	4/57/39
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	52.2 ±2.3	51.7 ±2.3	57.8 ±2.6	56.8 ±2.5
Bulk density (g/cm ³)	1.42 ±0.03	1.43 ±0.03	1.39 ±0.03	1.37 ±0.03
Porosity	0.743 ±0.018	0.739 ±0.018	0.780 ±0.018	0.777 ±0.018
Void ratio	2.9 ±0.3	2.8 ±0.3	3.5 ±0.4	3.5 ±0.4

Table 12. Physical properties of placed sediments at completion of placement (February 20, 2008).				
Core location	92-4	92-8	92-9	92-12
Sediment thickness in core (ft.)	1.0	0.3	0.7	1.0
Sand/silt/clay fraction (%)	4/56/40	6/60/34	4/55/41	3/56/41
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	52.2 ±2.3	58.3 ±2.6	58.7 ±2.6	53.4 ±2.4
Bulk density (g/cm ³)	1.42 ±0.03	1.35 ±0.03	1.35 ±0.03	1.41 ±0.03
Porosity	0.744 ±0.018	0.788 ±0.018	0.790 ±0.018	0.752 ±0.018
Void ratio	2.9 ±0.3	3.7 ±0.4	3.8 ±0.4	3.0 ±0.3
Core location	92-13	92-13A	92-15	92-16
Sediment thickness in core (ft.)	0.3	1.0	3.0	0.6
Sand/silt/clay fraction (%)	3/54/43	3/54/43	3/55/42	3/52/45
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	64.1 ±2.9	58.5 ±2.6	55.6 ±2.5	60.5 ±2.7
Bulk density (g/cm ³)	1.29 ±0.03	1.35 ±0.03	1.38 ±0.03	1.33 ±0.03
Porosity	0.826 ±0.018	0.789 ±0.018	0.769 ±0.018	0.802 ±0.018
Void ratio	4.7 ±0.6	3.7 ±0.4	3.3 ±0.4	4.1 ±0.4
Core location	92-18	92-18A	92-24	92-24A
Sediment thickness in core (ft.)	0.7	1.7	0.9	1.4
Sand/silt/clay fraction (%)	3/55/42	0/51/49	3/55/42	4/55/41
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	55.3 ±2.5	66.0 ±2.9	54.5 ±2.4	55.0 ±2.5
Bulk density (g/cm ³)	1.39 ±0.03	1.27 ±0.03	1.40 ±0.03	1.39 ±0.03
Porosity	0.766 ±0.018	0.838 ±0.018	0.760 ±0.018	0.764 ±0.018
Void ratio	3.3 ±0.3	5.2 ±0.7	3.2 ±0.3	3.2 ±0.3

Table 13. Physical properties of placed sediments at ten months (December 3, 2008).

Core location	92-4	92-8	92-8A	92-9
Sediment thickness in core (ft.)	1.0	0.9	0.9	0.7
Sand/silt/clay fraction (%)	4/56/40	4/55/41	6/59/35	5/55/40
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	53.7 ±2.4	51.3 ±2.3	57.8 ±2.6	55.2 ±2.5
Bulk density (g/cm ³)	1.41 ±0.03	1.43 ±0.03	1.36 ±0.03	1.39 ±0.03
Porosity	0.755 ±0.018	0.737 ±0.018	0.784 ±0.018	0.766 ±0.018
Void ratio	3.1 ±0.3	2.8 ±0.3	3.6 ±0.4	3.3±0.3
Core location	92-12	92-13A	92-15	92-16
Sediment thickness in core (ft.)	1.3	0.8	1.2	0.3
Sand/silt/clay fraction (%)	5/55/40	3/53/44	3/54/43	3/52/45
Shepard's (1954) classification	clayey silt	clayey silt	clayey silt	clayey silt
Water content (%)	51.3 ±2.3	55.6 ±2.5	50.7 ±2.3	61.1 ±2.7
Bulk density (g/cm ³)	1.44 ±0.03	1.38 ±0.03	1.44 ±0.03	1.32 ±0.03
Porosity	0.736 ±0.018	0.768 ±0.018	0.732 ±0.018	0.807 ±0.018
Void ratio	2.8 ±0.3	3.3 ±0.4	2.7 ±0.3	4.2 ±0.5
Core location	92-18			
Sediment thickness in core (ft.)	0.9			
Sand/silt/clay fraction (%)	6/55/39			
Shepard's (1954) classification	clayey silt			
Water content (%)	55.8 ±2.5			
Bulk density (g/cm ³)	1.38 ±0.03			
Porosity	0.770 ±0.018			
Void ratio	3.4 ±0.4			