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SEA FLOOR TOPOGRAPHY AND BACKSCATTER INTENSITY OF THE HISTORIC AREA REMEDIATION SITE (HARS), OFFSHORE OF NEW YORK, BASED ON MULTIBEAM SURVEYS CONDUCTED IN 1996, 1998, AND 2000

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INTRODUCTION

An area offshore of Sandy Hook, New Jersey, has been used extensively for disposal of dredged and other materials, derived from the New York/New Jersey Harbor and surrounding areas, since the late 1800's (Figure 1). Between 1976 and 1995, the New York Bight Dredged Material Disposal Site, also known as the Mud Dump Site (Figure 2), received on average about 6 million cubic yards of material each year from federal and private maintenance dredging and from harbor deepening activities (Massa and others, 1996). In September 1997 the Mud Dump Site (MDS) was closed as an official ocean disposal site by the U.S. Environmental Protection Agency, and the MDS and surrounding areas were designated as the Historic Area Remediation Site (HARS). The HARS is subdivided into a Primary Remediation Area (PRA, subdivided into 9 cells), a Buffer Zone, and a No-Discharge Zone (Figure 2). The sea floor of the HARS, approximately 9 square nautical miles in area, is being remediated by placing at least a one-meter cap of clean (Category I) dredged material on top of the existing surface sediments that exhibit varying degrees of degradation. About 1.1 million cubic yards of dredged material for remediation was placed in the HARS in 1999, and 2.5 million cubic yards in 2000.

Three multibeam echosounder surveys were carried out to map the topography and surficial geology of the HARS. The surveys were conducted November 23 - December 3, 1996, October 26 - November 11, 1998, and April 6 - 30, 2000. The surveys were carried out as part of a larger survey of the Hudson Shelf Valley and adjacent shelf (Butman and others, 1998). This report presents maps showing topography, shaded relief, and backscatter intensity (a measure of sea floor texture and roughness) at a scale of 1:25,000. Comparison of the topography and backscatter intensity from the three surveys show changes in topography and surficial sediment properties resulting from placement of dredged material in 1996 and 1997 prior to closure of the Mud Dump Site, as well as placement of capping material for remediation of the HARS.

The surficial geology and sediments of the HARS and the surrounding region are described in Butman and others (1998), Schwab and others (1997, 2000). A history of waste disposal in the New York Bight region is presented in Massa and others (1996).

DISPOSAL ACTIVITY IN THE HARS BETWEEN NOVEMBER 1996 AND APRIL 2000

Between November 1996 and April 2000 dredge and capping material consisting of a heterogeneous mix of sediment types were placed in the MDS and within the Primary Remediation Area of the HARS. Based on records from the U.S. Army Corps of Engineers, disposal was clustered in eight areas (Figure 2, Table 1). For material placed in areas 1-6, the plotted locations are the position of the tug towing the scow when disposal began, not the position of the scow carrying the material; thus the actual location of the material on the sea floor may differ from this position by several hundred meters. For the material placed in Areas 6, 7 and 8 between November 1998 and April 2000, the placement location was determined by an automated tracking system installed on the scow (SAIC, 1998). The plotted locations indicate the position of the scow when placement began. Areas 1- 4, located within the MDS, received dredged material from various projects prior to closing of the MDS and designation of the HARS (Table 1). Area 5, located in the southeastern corner of the MDS, received approximately 660,000 cubic yards of Category II fine-grained material dredged from three berthing areas within the Harbor (Category II sediments have no significant toxicity but a potential for bioaccumulation; they are suitable for restricted ocean disposal with appropriate management practices such as capping (EPA, 1996)). This material was covered with a minimum of one meter of sand (approximately 2.4 million cubic yards or 1.83 million cubic meters) dredged from the Ambrose entrance channel to New York harbor. This sand was slowly released from scows and/or hopper dredges along ship tracks oriented north to south (see Figure 2). Capping was completed in February 1998. As of November 1998, when the second multibeam survey was carried out, Category I capping material (silt and clay with a high water content) from dredging of the Passenger Ship Terminal, located on the Hudson River on the west side of Manhattan, had been placed within PRA#1 (Area 6). Between November 1998 and April 2000, additional material was placed in PRA#1 (Area 6), PRA#2 (Area 7), and PRA#3 (Area 8).

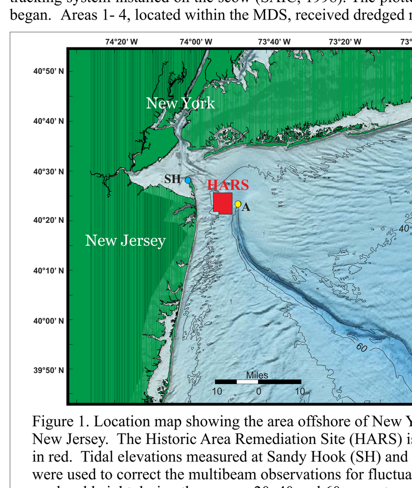

Figure 1. Location map showing the area offshore of New York and New Jersey. The Historic Area Remediation Site (HARS) is shown in red. Tidal elevations measured at Sandy Hook (SH) and Station A were used to correct the multibeam observations for fluctuations in sea level height during the survey. 20, 40 and 60 m contours shown on color-coded shaded relief.

DATA COLLECTION AND PROCESSING

Multibeam surveys

The surveys were conducted using a Simrad EM 1000 multibeam echo sounder mounted aboard the Canadian Hydrographic Service vessel *Frederick G. Creed*, a 60 foot SWATH (Small WAterplane Twin Hull) ship. This multibeam system, mounted on the starboard pontoon of the Creed, utilizes 60 electronically aimed beams spaced at intervals of 2.5° that insonify a strip of sea floor up to 7.5 times the water depth (swath width of 100 to 200 m within the survey area). The horizontal resolution of the beam on the sea floor is approximately 10% of the water depth (3-5 meters in the survey region). Vertical resolution is approximately 1 percent of the water depth, or 0.3 m. The data presented were gridded at 3 m grid cell size.

Software developed by the Ocean Mapping Group, University of New Brunswick, was used to process and edit the topographic, backscatter, and navigation data (see World Wide Web URL http//www.omg.unb.ca/~jhc/SwathEd.html). The Mercator maps use a latitude of true scale at 40° N. and central meridian of -75° W., and are projected on the WGS84 ellipsoid. The vertical datum is mean lower low water and depths in this report are presented as positive numbers.

The measured elevations were adjusted for fluctuations in sea level during the survey by subtracting tidal elevations predicted by a tidal model and low-frequency sea level observed at the National Oceanic and Atmospheric Administration Sandy Hook tide station located at 40°28' N., 74°0.6' W. (Figure 1). The tidal model utilized 9 constituents (Table 2) derived from a 4-month bottom pressure record obtained at Station A, located at 40°23.4' N., 73°47.1' W. in 38 m water depth about 2.7 km east of the HARS, during the winter of 1999-2000. Analysis of output from the ADCIRC tidal model (Westerink and others 1994; Luettich and Westerink, 1995) of the east coast showed that the tides throughout the HARS are less than 2 degrees of phase and 2 cm of amplitude different from Station A. Thus, a spatially uniform tidal sea level correction is applicable over the HARS. The difference between low-passed elevation at Sandy Hook and at Station A for the 4-month observation period was a few cm; thus the low-frequency sea level at Sandy Hook is a good proxy for the non-tidal changes in sea level that have large spatial scales and that occur at periods of a few days and longer. The difference between observed Station A elevations and simulated Station A elevations (Station A tidal predictions plus Sandy Hook low-frequency elevation) for the period Dec 12, 1999 to April 16, 2000 was normally distributed with a standard deviation of 3 cm. Thus, an estimate of the error due to sea level remaining in the multibeam observations after the sea level correction is about 3 cm. The estimated error in using Sandy Hook elevations alone for adjusting the measured elevations is 14 cm.

Bathymetric data were contoured using ARC/INFO geographic information system software (Environmental Systems Research Institute, Inc., version 7.2.1). The processed data were formatted into a point coverage using the ARC/INFO "generate" routine. The point coverage was transformed to a Mercator projection having the longitude of the central meridian at 75° W. and the latitude of true scale at 40° N. The "pointgrid" routine was used to assign depth values to a grid with a cell size of 12 m. Smoothing of the data was accomplished using a 12-cell by 12-cell (144 m by 144 m) median filter with the "focalmedian" routine. Topographic contours at a 1-meter interval were generated from the grid using the "latticecontour" routine.

Bottom sediment texture

Samples of the bottom sediments were obtained in the HARS by means of a modified Van Veen grab sampler or a hydrostatically damped gravity corer on USGS cruises DLW93009, SEAX95007, SEAX96004, and ALPH98020, carried out in May 1993, May 1995, May 1996, and Sept. 1998, respectively. Sediment was obtained from the upper 2 cm of grab samples and analyzed using the methods described in Poppe and others (1985). Percentages of gravel, sand, silt and clay are presented in Table 3. Samples obtained in 1993-1996 are shown on the 1996 map (Figure 5b); samples obtained in 1998 are shown on the 1998 map (Figure 6b).

MAPS

The topographic and backscatter intensity data are presented for the 1996, 1998, and 2000 surveys in Figures 5-7 at a scale of 1:25,000. Each figure contains three maps: (a) shaded relief image overlain with 1 meter topographic contours, (b) gray-scale backscatter intensity overlain with 5 meter topographic contours and sediment texture properties, and (c) pseudo-colored backscatter intensity over a shaded relief image overlain with 1 meter topographic contours. Differences in topography and backscatter intensity are shown in Figures 8 and 9.

Topography - shaded relief image (Figures 5a, 6a, 7a): The shaded relief image was created by vertically exaggerating the topography four times and then artificially illuminating the relief by a light source positioned 45 degrees above the horizon from the north. In the resulting image, topographic features are enhanced by strong illumination on the northward-facing slopes and by shadows cast on southern slopes. The image also accentuates small features (relief of a few meters) that could not be effectively shown as contours alone at this scale. Unnatural-looking features or patterns oriented parallel or perpendicular to survey tracklines (tracklines run north-south) are artifacts of data collection and environmental conditions.

Backscatter intensity (Figures 5b, 6b, 7b): The intensity of the acoustic return from the sea floor is a measure of the properties of the surficial sediments and of the bottom roughness. Generally, a strong return (light gray tones) is associated with rock or coarse-grained sediment, and a weak return (dark gray tones) with fine-grained sediments. However, the micro-topography, such as ripples, burrows, and benthic populations also affect the reflectivity of the sea floor. Direct observations, using bottom photography or video, and surface samples, are needed to verify interpretations of the backscatter intensity data. The backscatter data have a weak striping that runs parallel to the ship's track. Some of the striping is the result of poor data return at nadir that appears as evenly-spaced thin speckled lines. Some striping is also due to critical angle effects, where the intensity of return varies as a function of the angle of incidence of the incoming sound on the seafloor (Hughes-Clark and others, 1997).

Pseudo-colored backscatter intensity superimposed on shaded relief (Figures 5c, 6c, 7c): The acoustic backscatter intensity is combined with the topography to display the distribution of intensity in relation to the topography. In the images shown here, the backscatter intensity is represented by a suite of eight colors ranging from blue, which represents low intensity (fine-grained sediments), to red, which represents high intensity (rock outcrops and coarse-grained sediments). These data are draped over a shaded relief image created by vertically exaggerating the topography four times and then artificially illuminating the relief by a light source positioned 45 degrees above the horizon from an azimuth of 350 degrees. The resulting image displays light and dark intensities within each color band that result from a feature's position with respect to the light source. For example, north-facing slopes, receiving strong illumination, show as a light intensity within a color band, whereas south-facing slopes, being in shadow, show as a dark intensity within a color band.

Difference in topography and backscatter intensity (Figures 8 and 9): The difference in topography between 1996 and 1998 was computed by subtracting the water depths as measured in 1998 from the depths measured in 1996 (positive values indicate shallower water in 1998 compared to 1996) (Figure 8a). The differences in topography between 1998 and 2000 (Figure 8b) and between 1996 and 2000 (Figure 8c) were computed similarly. The change in backscatter intensity between the 1996 and 1998 survey was computed by subtracting the backscatter intensity in 1998 from the intensity in 1996 (negative values indicate increased backscatter in 1998 compared to 1996). The change in backscatter intensity between 2000 and 1998 (Figure 9b) and between 2000 and 1996 (Figure 9c) was computed similarly (negative values indicate increased backscatter intensity in the later year).

RESULTS

One of the most striking aspects of the sea floor shown within the HARS is the variability in backscatter intensity and bottom morphology over scales of a few kilometers or less caused by both natural and anthropogenic processes (Figure 4). The topography, surface features, and the surficial sediments have been heavily influenced by the disposal of dredged and other material in this region over the last century (Williams, 1979; Butman and others, 1998; Massa and others, 1996).

1996 Survey

There are two relatively smooth topographic rises in the northern part of the HARS, each approximately 2 km in diameter (Figures 4 and 5). The two rises are composed of material dumped from the late 1800's to the 1990's (Williams, 1979). The northern rise (shallowest point at 40° 25.5' N. and 73°51.6' W.), referred to as Castle Hill, is material dumped prior to the 1930's. The southern rise (shallowest point at 40°24' N. and 73°51.75' W.) is composed of material dumped between 1930 and 1975. The crests of these rises are about 16 m below the sea surface, approximately 8 m shallower than the adjacent sea floor to the west. The material on the crest of the northern rise is shaped into a series of sand waves with crests running approximately northwest-southeast. The amplitude of these sand waves is less that 2 m. Patches of strong backscatter intensity are superimposed on a background of weak backscatter (Figure 5b). Along the crests of the mounds the background backscatter intensity is weak (dark); it grades to a stronger return (lighter) on the flanks at a water depth of about 20 m (Figures 5c, see also figures 6c and 7c). This transition is clearest on the western side.

The MDS is marked by several mounds of material that extend to within about 15 m of the surface; the shallowest mounds (at 40°22.7' N., 73°50.98' W. and 40°22.97' N., 73° 50.01' W.) are about 12 m below the sea surface. Elongate paired features, on the order of 50 to 75 m long and 40 m wide, are scattered throughout the site. Their relief typically is about 1 m and some of the features are separated by depressions about 1 m deep. It is hypothesized that these are signatures of individual dumps of material from barges. Linear features, on the order of 100 m long and aligned northwest-southeast, are observed on the saddle (40°23.25' N. and 73°51.4' W.) between the southern disposal mound and the present disposal site at water depths between 16 and 18 m. These linear features have about 0.5 m of relief. A few features with similar characteristics are observed to the north of the southern disposal mound. These features may result from placement of material from pocket scows that released material sequentially from multiple compartments.

Throughout the survey area, individual features ranging from a few meters (the resolution of the system) to about 50 m in diameter are apparent in the shaded-relief and backscatter intensity images. Some of the features are topographic highs and some are depressions with a small high in the center. These features are hypothesized to result from disposal of individual scow loads of dredged material. The features are characterized by their relief and high backscatter Intensity. In the area shown in Figures 5-7, the depression features are primarily located in the region north of 40°24.5' N. between 73°49' W. and 73°51' W. where the substrate is fine sand and mud. However, these features are ubiquitous in other areas of the New York Bight (see Butman and others, 1998). The depressions are typically 0.5 to 1 m deep and some have a central mound 0.25 to 0.5 m high. Many of the features occur in linear groupings of 5 or more and are often aligned in a northwest-southeast direction. This pattern is consistent with disposal from ships steaming to, or from, New York Harbor. The depressions may have formed during disposal as material impacted the sea floor, or may be a result of scour by currents and/or animals around the dumped material. In contrast to these depressions, the targets in the area south of 40°24' N. and between 73°49' W. and 73°49.5' W. appear as topographic highs where the substrate is gravel and boulders (see Butman and others, 1998). Some of the features may be derrick stones, large rocks that required a derrick to unload from barges (Williams, 1979), or other rock rubble. Since the early 1900's, the disposal region for derrick stones was 4 to 6.25 nautical miles southeast of Scotland Light (located at approximately 40°27' N., 73°55.7' W.), roughly the location of the MDS. Although most of the individual targets now visible are to the east of the MDS, disposal was probably not confined to the designated sites. The linear alignment of the features suggests an anthropogenic origin, and the distribution suggests that large areas of the sea floor outside of the designated disposal sites have been affected by past ocean disposal.

An area of uniformly smooth topography and low backscatter intensity extends to the northeast, east, and southeast of the MDS for about 1-2 km (see region between 40°22.5' N. and 40°24' N. along 73°50' W.) in the 1996 survey (Figure 6b). The absence of the backscatter and topographic signatures of individual dumps in this area, which are ubiquitous throughout much of the adjacent area, suggests that this area may be floored with fine material winnowed form the MDS and transported eastward and downslope. The composition of the two surface sediment samples (stations 38 and 48, Table 3) obtained in this region, are both clayey silt. Another region of relatively smooth topography and low backscatter (between 40°22' N. and 40°23' N. and centered at 73°52.5' W.) is found to the west of the MDS. All of these broad areas characterized by low-backscatter intensity are within the area of the HARS to be remediated by capping.

The western edge of outcropping beds of coastal plain strata (Schwab and others, 2000), probably of Cretaceous age, is visible at 40°23' N. and 73°49' W. Individual mounds, hypothesized to be disposed material, lie on this hard substrate, which is located within the old Cellar Dirt Dump Site (Figure 2). To the west of the outcropping strata is a shallow northwest-southeast trending channel, 2-4 m deep, and about 400 m wide that is floored by fine-grained sediments. The channel is cut into Cretaceous strata and is Pleistocene or early Holocene in age. The channel may be a pathway for movement of sediments from the shelf to the western side of the Hudson Shelf Valley. The presence of small targets in this channel, interpreted as individual piles of rock or gravel, implies scouring around these features, or non-burial as a result of relatively slow accumulation.

In the 1996 survey, a circular region approximately 1 km in diameter in the southern part of the MDS (centered at 40°22' N. and 73°51' W.) is characterized by relatively low backscatter intensity. Within the circular region, there are at least 10 individual mounds less than 2 m in height. This feature and associated subfeatures is located in the experimental quadrant of the MDS, known as Ex. MDS, where sediments contaminated with dioxin were disposed in this area and capped with sand in the early 1980's. The site was subsequently used during the Dioxin Capping Projects of 1993 and 1997 (see below).

Changes between 1996 and 1998

The surveys clearly identify regions where the depth of the sea floor decreased between 1996 and 1998 (Figure 8a). All of the areas of shallower water are areas where dredged material was placed between the 1996 and 1998 surveys (Areas 1, 2, 4, 5 and 6). The highest mound, located in Area 1 and centered at about 40°23.55' N., 73°50.08' W., is approximately 400 m in diameter. New accumulation in the center of this feature exceeds 7 m. Smaller mounds in Area 1, on the order of 150 m in diameter, are located to the west and south; new accumulation exceeds 3 m and in some places 4 m in these areas.

The largest area of accumulation is in a circular feature about 1 km in diameter, centered at about 40°22.25' N. and 73°50.45' W. (Area 5). Contaminated sediment was placed in this location and capped with sand from Ambrose Channel in 1997. The increase in sediment thickness ranges from about 1 m at the outer edge of the cap, to about 3 meters near the center (see transect E-F in Figure 3). The western side of this accumulation overlies the site of an earlier disposal and capping project involving dioxin-contaminated sediments. The backscatter difference map (Figure 9a) shows decreased backscatter intensity on the eastern side of the cap between 1996 and 1998.

A circular feature about 900 m across and centered at about 40°24.75' N., 73°52.8' W., reflects remediation activities in the northwest part of the HARS (Area 6). The change in surficial sediment reflectivity of the capping material is clearly seen in the backscatter intensity map (6b) and in the pseudo-colored backscatter map (Figure 6c), and in the backscatter intensity difference map (Figure 9a). The feature is approximately 0.5 m thick (see transect A-B in Figure 3). Within the overall feature, there are small mounds of material about 1 m in height and of order 100 m horizontally which are thought to be formed from the remedial capping.

Some of the areas of sediment accumulation associated with newly placed material show increased backscatter intensity (Figure 9a, Areas 1 and 4) from 1996 to 1998, while some show a decrease in backscatter intensity (Areas 2, 3, eastern portion of Area 5, and Area 6). These changes in backscatter intensity may reflect changes in sediment properties and/or microtopography such as texture, dewatering, compaction, ripple formation, and benthic reworking. Two areas that received dredged material (Areas 2 and 3) show only a minimal change in water depth but a decrease in backscatter intensity. The areas showing least change in backscatter intensity between the 1996 and 1998 surveys are broad areas of low backscatter intensity (dark blue areas in the southwest part of the map centered at 40°22.5' N., 73°52.5 W'.; eastern part of the map centered at 40°24.0' N., 73°50.0' W., and along the crest of the ridge centered at 73°51.5' W., see figure 4, and 5-7c). These are interpreted to be areas of long-term fine-sediment accumulation where the addition of fine sediment from distant sources would not alter the backscatter intensity characteristics.

Across the entire survey area, the average difference in depth between 1996 and 1998 was 24 cm (1998 shallower than 1996) and the standard deviation was 36 cm (Figure 8a); the difference is within the 30 cm accuracy of the Simrad Em1000 mapping system. The north-south striping of the topographic difference is most likely caused by refraction error at the outer edge of the survey swaths.

The 'noisy' or speckled pattern in the backscatter intensity difference map that occurs throughout the survey area (Figure 9a) (especially noticeable away from the areas of consistent or no change) are hypothesized to partially result from critical angle effects, where the intensity of the reflected sound varies as a function of the angle of incidence. Since the angle of incidence for a particular location is not the same during each survey, this effect will produce noise in the backscatter intensity difference, most prominently displayed in lines parallel to the ship track.

Changes between 1998 and 2000

Placement of new capping material in the western two-thirds of PRA#2 between November 1998 and April 2000 (see Figure 2) resulted in features that appear as craters 30 to 70 m long and of order 20 m wide, with the major axis oriented roughly north-south (Figure 7a and 7c). The craters have elevated rims and depressions in the center and were apparently formed as the placed material impacted the soft sea floor. Most of the craters are in rows oriented east-west and spaced north-south by about 250 m and are characterized by increased backscatter intensity (Figure 6c, 7c, and 9b). Placement of capping material in the northeastern portion of PRA#2 (Figure 2) resulted in decreased backscatter intensity (Figures 7b and 9b).

Some of the area characterized by low backscatter intensity in PRA#1 in the 1998 survey appears as higher backscatter intensity in the 2000 survey (Figure 7b, 9b). Some of the higher backscatter intensity is the result of the placement of new capping material (Figure 2). The changes in backscatter intensity may also reflect changes in sediment properties and/or microtopography such as texture, dewatering, compaction, ripple formation, and benthic reworking. Increased backscatter intensity on local topographic features formed during the placement of material prior to the 2000 survey may be the result of winnowing of material between 1998 and 2000. For example, see the increased backscatter intensity centered near 40°24.85' N. and 73° 52.62' W., 40°24.87' N. and 73°53.09' W., and 40°24.64 'N. and 73°52.6' W.

Across the entire survey area, the average difference in depth between 1998 and 2000 survey was -14 cm and the standard deviation was 33 cm (Figure 8b); the difference is within the 30 cm accuracy of the Simrad Em1000 mapping system. The western 1 km of the survey area, all surveyed on April 6th, 2000 shows a systematic decrease in depth (blue area in Figure 8b); the cause of this apparent survey artifact is not understood.

Mass Balance

Changes in depth and backscatter intensity associated with newly placed material are clearly identifiable in the topographic and backscatter intensity maps of the HARS. However, the resolution of the multibeam system precludes utilizing differences in depth measured between repeated surveys to estimate the amount of material placed in the HARS, because modest amounts of material were placed over a large area. For example, the resolution limits of the Simrad EM1000 of 30 cm amounts to an uncertainty of about 300,000 m^3 of material over a 1 km^2 area, equivalent in magnitude to the volume of material placed in each of the Areas (Figure 2, Table 1). In addition, more information on the amount of material contained within each scow is needed to determine the volume placed at each site (the volume of the scow was used to develop the volume estimates in Table 1 with no correction for water content), and compaction rates of the material on the sea floor are needed in order to estimate the amount of placed material on the sea floor from the measured topographic differences. However, despite these uncertainties, the data suggests little net accumulation in Area 3, compared to the other Areas that received similar amounts of material (Figure 8a, Table 1). The material placed in Area 3 was mud and silt which is easily eroded, and some spreading and transport of material is expected at this shallow site. The repeated multibeam surveys are most useful in identifying the location of new material placed on the sea floor and changes in surficial characteristics through time based on changes in backscatter intensity.

SUMMARY

Surveys of the HARS conducted in 1996, 1998, and 2000 using a multibeam seafloor mapping system provide a detailed view of the geology, topography and sedimentary features of the sea floor. One of the most striking aspects of the sea floor shown within the HARS is the variability in backscatter intensity and bottom morphology over scales of a few kilometers or less caused by both natural and anthropogenic processes. The topography, surface features, and the surficial sediments have been heavily influenced by the disposal of dredged and other material in this region over the last century. Major changes in the sea floor between the 1996 and 1998 include the appearance of mounds of material, some as high as 5 m, resulting from placement of dredged material prior to closing of the Mud Dump Site, a circular feature approximately 1 km in diameter and 3 m thick resulting from a 1997 disposal and capping project, and a circular feature also approximately 1 km in diameter and about 0.5 m thick resulting from remedial capping within PRA #1. Major changes in the sea floor between 1998 and 2000 include the formation of numerous craters caused by placement of capping material in the soft sediments in PRA#2, and an increase in backscatter intensity in PRA#1 resulting from new placement of capping material and modification of previously placed sediments. The difference in backscatter intensity shows decreased as well as increased backscatter in areas where dredged material has been placed on the sea floor. The resolution of the multibeam system precludes utilizing differences in depth between repeated surveys to estimate the amount of material placed in the HARS, because modest amounts of material were placed over a large area. In addition, more accurate data defining the amounts of placed material and the compaction of material on the sea floor are needed to develop an accurate mass balance. The principal use of the multibeam data is to reveal the regional surficial geology, and to document the location of placed material and changes in sediment characteristics over time through comparison of backscatter intensity.

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Any use of trade or product names is for descriptive purposes only, and does not imply endorsement by the U.S. Government. This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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Table 1. Volume of material placed in Areas 1-6 between December 1996 and November 1998, and in Areas 6*, 7, and 8 between November 1998 and April 2000 (see figure 2). The volume of material placed in each area was calculated as the sum of the barge volumes, an upper-bound because the barge contains some water. Data from U.S. Army Corps of Engineers dredged material disposal records. Sand for capping is an estimate provided by USACE. One cubic meter is 1.308 cubic yards.

Area	Number of Trips	Volume (thousands of cubic meters)	Major Project(s)	Predominate Material
1	492	1,282	Port Authority CDF, Earle NWS	Clay, red clay
2	292	570	Earle NWS, Port Authority CDF	Silt, mud
3	187	660	ITO Passenger Ship Terminal, South Brothers Island Channel	Mud-silt
4	147	465	Wards Point Bend, Flushing Bay and Creek, South Brothers Island Channel	Mud, silt
5	249	663	Port Authority CDF	Mud and clay
5	613	1,835	Capping	Sand from Ambrose Channel
6	124	341	ITO Passenger Ship Terminal	Silt
6*	110	272	ITO Passenger Ship Terminal	Muddy silt
7	298	680	1999 Kill Van Kull Phase II, Brooklyn Marine Terminal	Sand, clay, gravel, mud and silt
8	14	35	Jack Frost Refined Sugar	Silt

Table 2. Tidal constituents, based on analysis of bottom pressure at Station A (40° 23.4' N., 73°47.1' W., 38 m water depth, see Figure 1) for the period December 1999 April 2000.

Constituent	Frequency ($hours^{-1}$)	Amplitude (cm)	Phase (degrees)
O_1	0.03873065	6.8	167.1
P_1	0.04155259	3.0	174.6
K_1	0.04178075	9.8	174.6
MU_2	0.07768947	3.8	339.0
$2N_2$	0.07748710	2.4	310.9
N_2	0.07899925	16.8	327.6
M_2	0.07899925	64.0	351.8
S_2	0.08333334	13.9	16.3
K_2	0.08356149	3.7	16.3

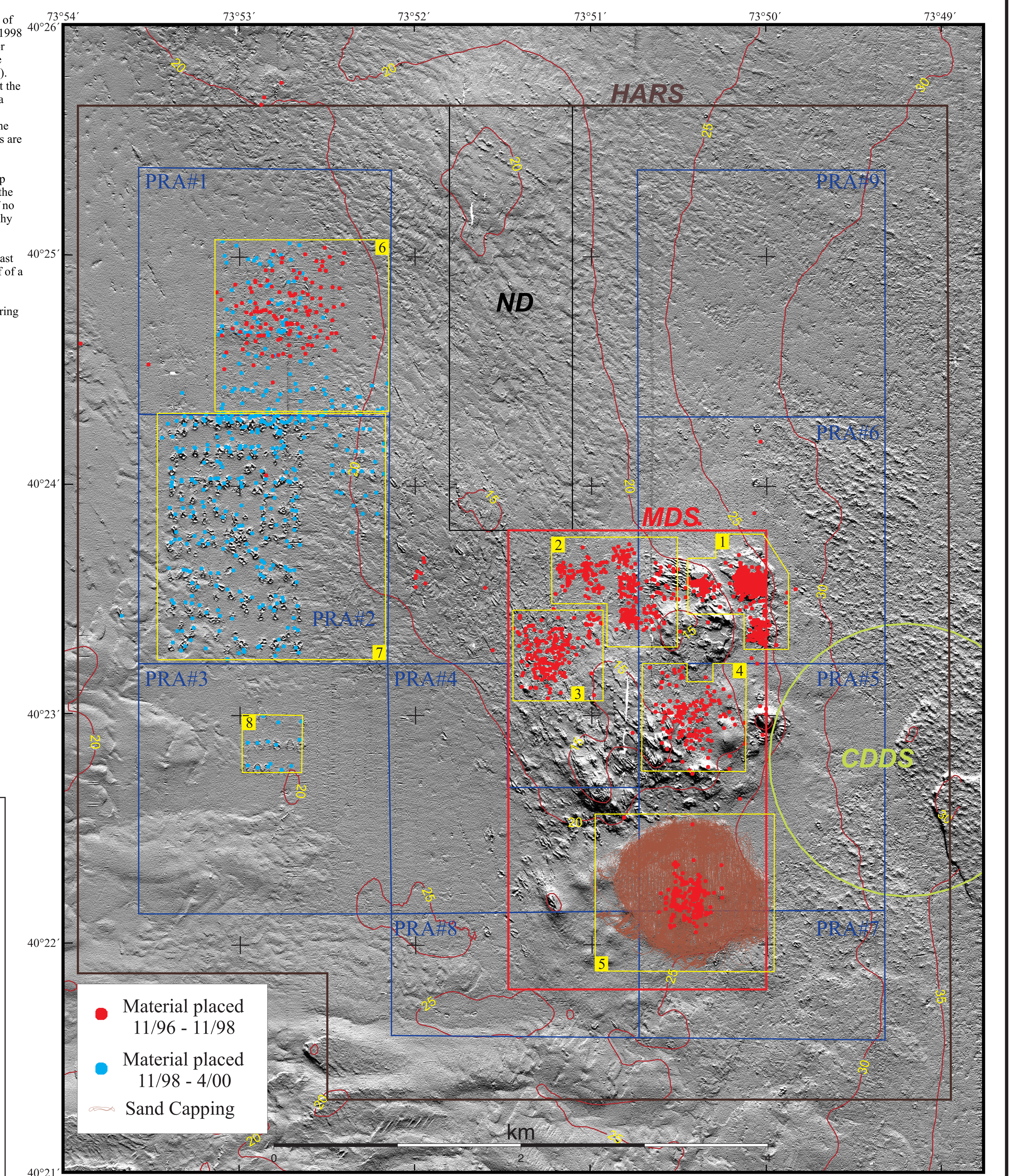

Figure 2. Shaded relief image of the HARS (collected in 2000) showing locations of dredged material placed on the sea floor between November 1996 and November 1998 (red dots), between November 1998 and April 2000 (light blue dots), and tracks for sand capping (brown), based on records of the U.S. Army Corps of Engineers (See Table 1). The placements are grouped in eight areas (Areas 1-8 outlined in yellow). For the 1996-1998 placements, the plotted locations are the position of the tug (not the towed scow) when placement began. The actual location of the material on the sea floor may differ by several hundred meters from this position. For the 1998-2000 placements, the plotted locations are the position of the scow at the beginning of the placement event, essentially the location of release. For the sand capping, the lines are the track of the tug as material was released from the scow. The boundaries of the Historic Area Remediation Site (HARS) (brown), the Primary Remediation Area (PRA) (divided into 9 cells outlined in blue and labeled PRA #1-9), the Mud Dump Site (MDS) (red), the no-discharge zone (ND) (black), and the western portion of the Cellar Dirt Disposal Site (CDDS) (green) are also shown. White areas are areas of no data. The shaded relief image was created by vertically exaggerating the topography four times and then artificially illuminating the relief by a light source 45 degrees above the horizon from the north. In the resulting image, topographic features are enhanced by strong illumination on the northward-facing slopes and by shadows cast on southern slopes. The shaded relief image also accentuates small features (relief of a few meters) that could not be effectively shown as contours alone at this scale. Unnatural-looking features or patterns oriented parallel or perpendicular to survey tracklines (tracklines run north-south) are artifacts of environmental conditions during data collection. Topographic contour interval is 5 m.

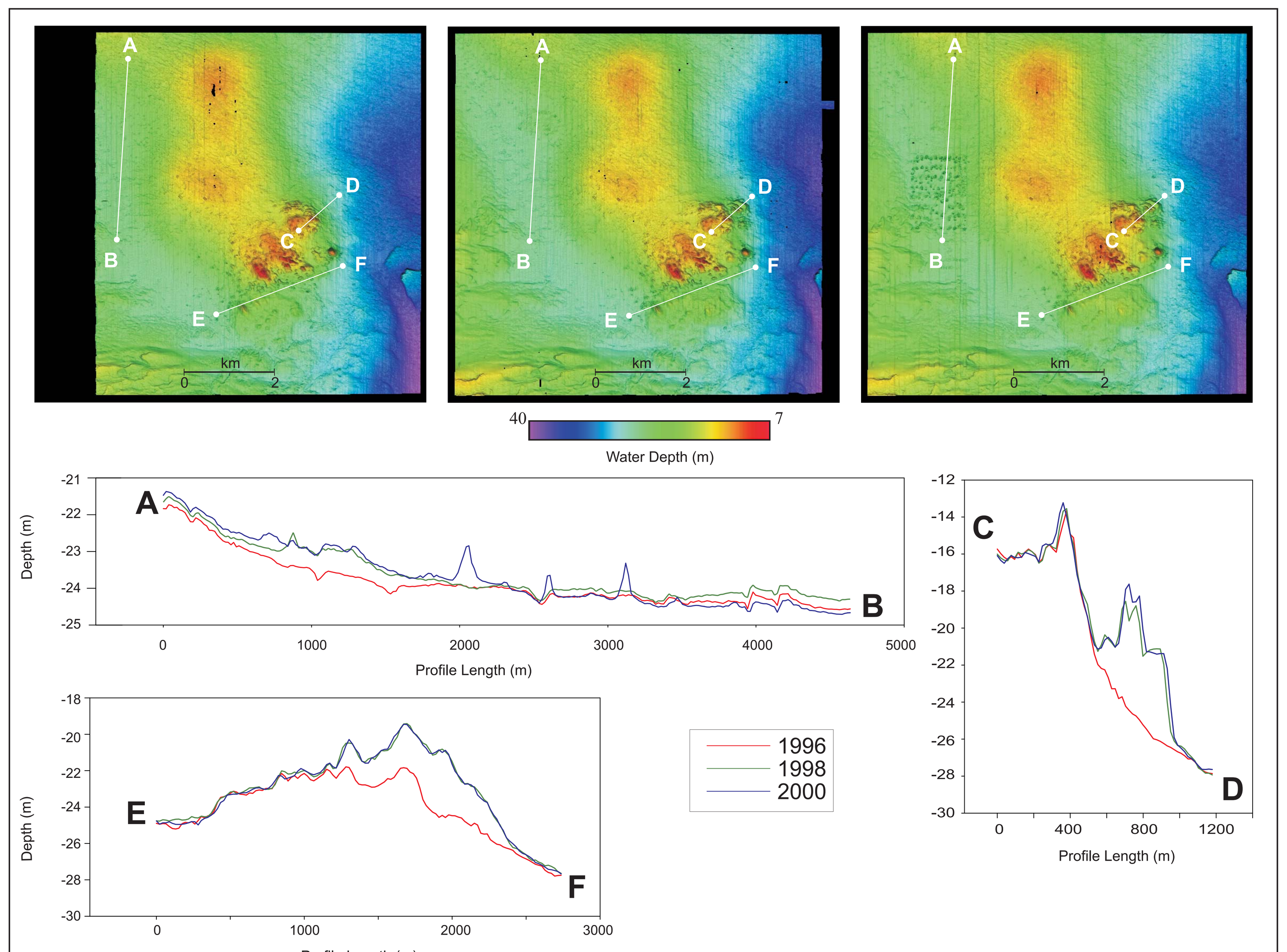

Figure 3. **Top:** Plan view of the color-coded topography in 1996, 1998, and 2000. **Bottom:** Topography along three transects in the Historic Area Remediation Site showing differences between the 1996, 1998, and 2000 surveys. Transect A-B shows the changes in topography in Area 6 and Area 7 (see Figure 2) where remediation has provided a cover of about 0.5 m. Transect C-D shows the accumulation of material caused by placement of material in Area 1 (see Figure 2) on the eastern edge of the Mud Dump Site between 1996 and 1998. Transect E-F shows the changes in topography across the two capping projects in the southern part of the Mud Dump Site (Area 5). Black indicates areas of no data.

Table 3. Texture of sediment samples obtained in the HARS area. Cruises DLW93009, SEAX95007, SEAX96004 and ALPH98020 were carried out in May 1993, May 1995, May 1996 and Sept. 1998 respectively.

Station #	Cruise ID	Latitude	Longitude	Depth(m)	%Gravel	%Sand	%Silt	%Clay	Classification
5G	DLW93009	40 22.64	73 50.72	23	0	34.9	50.8	14.3	SANDY SILT
5S	DLW93009	40 22.60	73 50.72	23	0	19.2	66.2	14.6	SANDY SILT
36	SEAX95007	40 25.43	73 50.27	14	45.0	54.9	0.1	0	GRAVELLY SEDIMENT
38	SEAX95007	40 23.17	73 49.75	27	0	13.6	55.2	31.2	CLAYEY SILT
48	SEAX95007	40 23.49	73 50.01	30	0	12.8	59.6	27.6	CLAYEY SILT
150	SEAX96004	40 22.67	73 50.72	20	0.4	98.7	0.7	0.2	SAND
93	SEAX96004	40 21.06	73 51.46	20	0.2	99.7	0.1	0	SAND
54	ALPH98020	40 25.61	73 53.84	23	2.2	78.0	18.1	1.7	SAND
55	ALPH98020	40 23.42	73 52.94	24	2.8	58.4	32.3	6.6	SILTY SAND
69	ALPH98020	40 24.60	73 49.76	30	0.3	11.8	62.3	25.7	CLAYEY SILT
70	ALPH98020	40 24.02	73 51.56	16	0	99.6	0.3	0.1	SAND
71	ALPH98020	40 25.24	73 51.56	15	3.7	95.7	0.4	0.2	SAND
135	ALPH98020	40 22.53	73 49.26	34	0.1	36.5	59.6	3.9	SANDY SILT
136	ALPH98020	40 23.29	73 50.04	24	0	3.9	66.3	29.9	CLAYEY SILT
138	ALPH98020	40 23.31	73 51.37	17	0.2	82.2	14.0	3.5	SAND
139	ALPH98020	40 23.97	73 51.44	15	0	99.6	0.3	0.1	SAND
140	ALPH98020	40 24.60	73 52.28	22	2.9	76.3	16.7	4.1	SAND
141	ALPH98020	40 23.60	73 50.47	20	0.2	47.5	46.3	6.0	SILTY SAND
142	ALPH98020	40 24.39	73 50.48	28	3.3	47.9	40.4	8.4	SILTY SAND

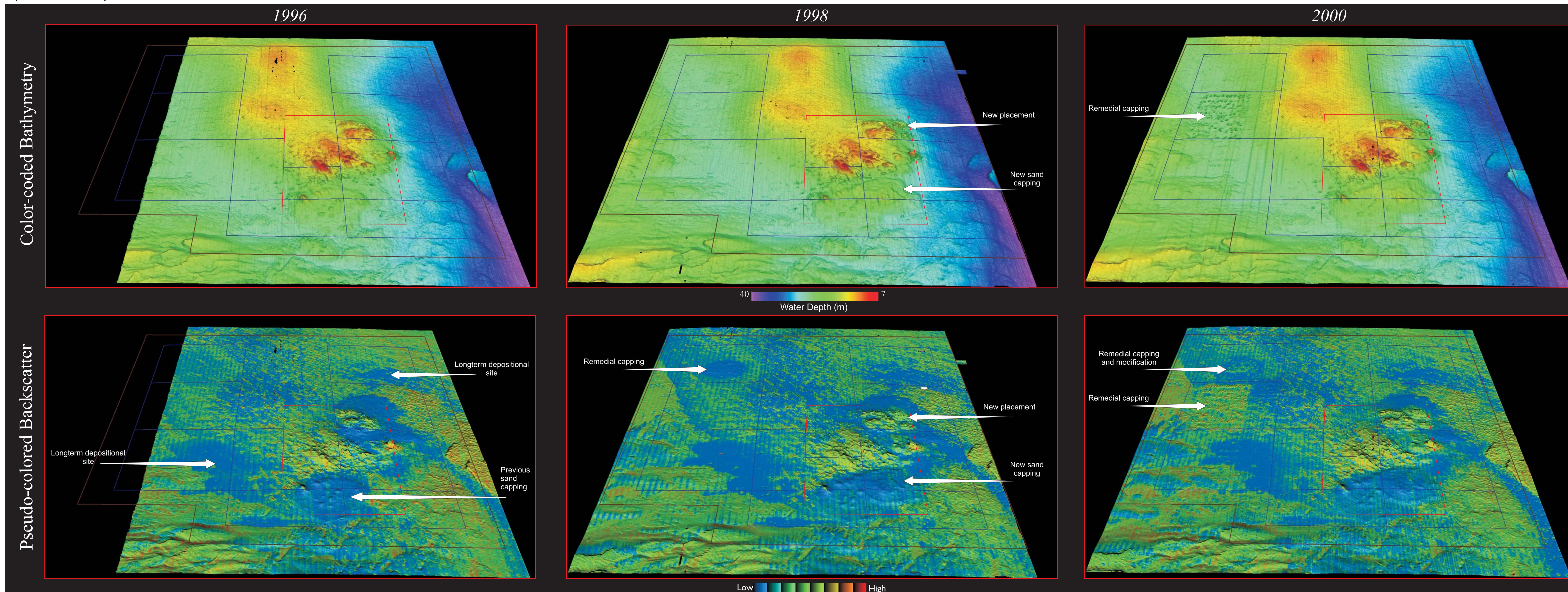

Figure 4. Perspective views of the Historic Area Remediation Site, looking from the south toward the north, for 1996 (left), 1998 (center) and 2000 (right). **Top:** Shaded relief and color coded bathymetry. The shaded relief image was created by vertically exaggerating the topography four times and then artificially illuminating the relief by a light source positioned 45 degrees above the horizon from an azimuth of 350 degrees. The water depth, using a color scale from red (shallow) to purple (deep), is superimposed. **Bottom:** Pseudo-colored backscatter intensity draped over shaded relief. In this image, the backscatter intensity is represented by a suite of eight colors ranging from blue, representing low backscatter intensity, to red, representing high backscatter intensity (see description of backscatter intensity in map section of text). These data are draped over the shaded relief image. The resulting image displays light and dark intensities within each color band resulting from a feature's position with respect to the light source. For example, north-facing slopes, receiving strong illumination, show as a light intensity within a color band, whereas south-facing slopes, being in shadow, show as a dark intensity within a color band.

Principal changes between 1996 and 1998 are the placement of new dredged material in the eastern part of the Mud Dump Site (MDS), capping in the southern part of the MDS, and placement in Primary Remediation Area (PRA#1) in the northwestern part of the HARS. The placement in PRA#1 appears as a circular area of low backscatter intensity material. Principal changes between 1998 and 2000 are increased backscatter intensity in PRA#1 due to additional placement of material and changes in the previous cover, and placement of new material in the western two-thirds of PRA#2. These new placements resulted in features that appear as craters 30 to 70 m long and on the order of 20 m wide, with the major axis oriented roughly north-south. The craters have elevated rims and depressions in the center and were apparently formed as the placed material impacted the soft sediments on the sea floor. Backscatter intensity is generally increased throughout the area surrounding the individual craters. The north-south stripes, running parallel to the survey tracklines, are artifacts of data collection and environmental conditions.