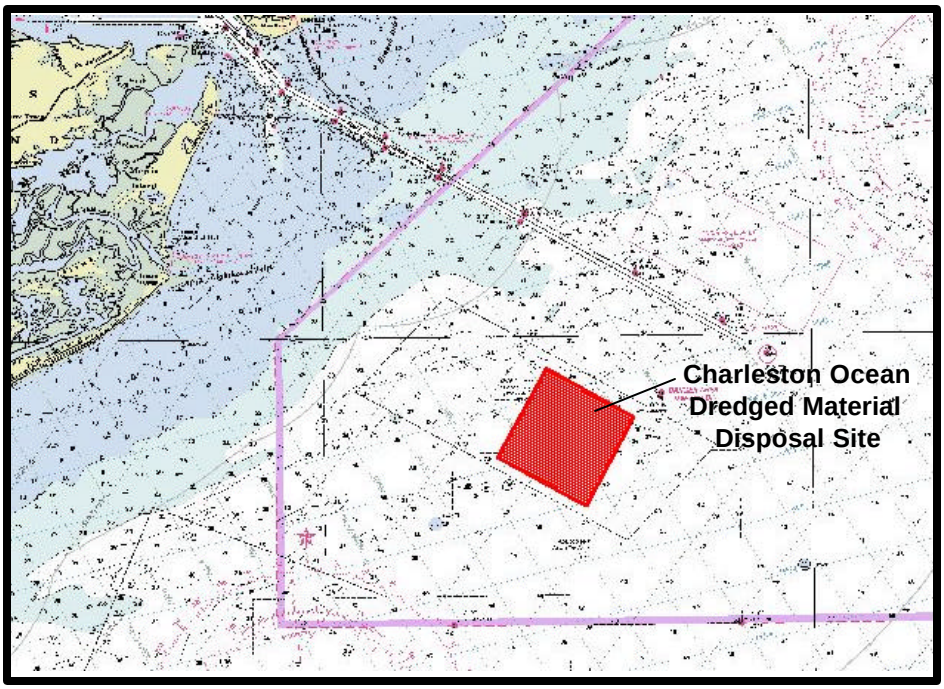
# Analysis of Sediments and Habitat in the Areas Surrounding the Charleston Ocean Dredged Material Disposal Site, Including Unauthorized Disposal Operations




# FINAL REPORT

**Prepared for:**

**Norfolk Dredging Company**
**and**
**U.S. Army Corps of Engineers Charleston District**

**Prepared by:**
**South Carolina Department of Natural Resources**
**Marine Resources Division**

Final Report

# Analysis of Sediments and Habitat in the Areas Surrounding the Charleston Ocean Dredged Material Disposal Site, Including Unauthorized Disposal Operations

by

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## Introduction

This report summarizes the analysis of underwater video surveys and two sets of sediment samples that were collected in boundary areas surrounding the Charleston Ocean Dredged Material Disposal Site (ODMDS). The Charleston ODMDS, located approximately seven miles from shore, was designated by the U.S. Environmental Protection Agency (USEPA) to receive material from both maintenance and deepening dredging operations. The ODMDS that is currently authorized for use is located within a much larger ODMDS that was originally established for the Charleston area and surveyed in 1978 (SCWMRD 1979, Van Dolah *et al.* 1983). The smaller ODMDS was established after sensitive hard bottom reef habitat was discovered within the western portion of the larger ODMDS (Winn *et al.* 1989). Additional hard bottom habitats in the areas surrounding the currently used ODMDS have been reported (SCDNR, unpublished).

The currently used ODMDS and surrounding bottom areas were intensively sampled in 1993 and 1994 to obtain baseline information on bottom communities, sediment characteristics, and contaminant levels (Van Dolah *et al.* 1996, 1997). As part of this previous monitoring program, the Charleston ODMDS was divided into three areas (disposal area, inner surrounding boundary area, and outer surrounding boundary area), which form 20 discrete zones (Figure 1). All of the zones are approximately one square mile in size.

The South Carolina Department of Natural Resources (SCDNR) began receiving reports in early 2000 from local shrimpers about muddy bottom sediments in areas near the Charleston ODMDS. The areas reported were inshore of the ODMDS boundary zones that were previously sampled. Boundary zones closest to the reported area (Zones OG and OH) had little to no muddy sediments in the 1993 and 1994 surveys.

In response to shrimpers' concerns, the SCDNR collected 72 sediment samples in February and March 2000 to assess sediment composition in the inner

and outer boundary zones (Figure 1). During the same time period, SCDNR staff met with U.S. Army Corps of Engineers (USACE) staff to discuss the problem and locate additional data available to identify the source of the problem. After a detailed review of disposal activity logs in March 2000, the USACE reported to the SCDNR that Norfolk Dredging Company, a contractor for the USACE on the Charleston Harbor deepening project, had 53 documented incidents of unauthorized disposal activity outside the designated ODMDS since dredging began in July 1999. The majority of the unauthorized dumps occurred in December 1999 and January 2000 (n = 37).

SCDNR, USEPA, USACE, and Norfolk Dredging Company personnel met on May 31, 2000 to review unauthorized disposal activities and discuss assessment of each unauthorized disposal site. Based on these discussions, a small-scale diver assessment was planned with the goal of determining the type of material disposed at each site and the type of bottom habitat that was impacted. All dumps made by Norfolk Dredging Company between 7/6/99 and 6/4/00 were plotted. A 100 m buffer was created around the disposal area, and any dumps occurring within this buffer were not included in the assessment. The 29 dumps that occurred outside of this buffer were included in the assessment (Figure 2). In addition to these 29 sites, 11 sites were identified by SCDNR for assessment based on features that appeared to be characteristic of disposal activity using side scan sonar records of the area that had recently been completed by USGS and Coastal Carolina University in March 2000 (Figure 3). Eason Diving and Marine Contractors, Inc. completed site assessment and sample collection at all 40 sites (Figure 1). The diver assessment included collection of sediment samples, a videotaped reconnaissance of the immediate bottom area at each site, and a 300 ft videotaped survey away from each site to characterize adjacent bottom habitats.

The specific objectives of this report are to:

1. present sediment composition data and analyses for samples collected by SCDNR staff in February and March 2000 in the boundary areas surrounding the Charleston ODMDS.
2. present sediment composition data and analyses for samples collected by Eason Diving and Marine Contractors, Inc. at unauthorized disposal sites.
3. summarize SCDNR reviews of video surveys collected by Eason Diving and Marine Contractors, Inc. at unauthorized disposal sites.

## Methods

All sediment samples were collected in the inner and outer boundary areas surrounding the Charleston ODMDS (Figure 1). The 72 samples collected by SCDNR staff in February and March 2000 were obtained using a 0.043 $m^2$ Young grab. Station positions were located using a global positioning system (GPS). At least one sample was collected in each zone, but more sampling effort was concentrated in the inner boundary zones. Therefore, the number of samples collected per zone was not consistent, and the zones were generally not sampled as intensively as the 1993 and 1994 baseline assessment. Each sediment core was collected by inserting a plastic tube (3.5 cm diameter) through the top of each grab to the bottom of the sample. Core contents were placed in a plastic bag marked with both an internal and external tag.

Eason Diving and Marine Contractors, Inc. completed a site assessment and collected sediment samples at 40 sites in the boundary areas surrounding the Charleston ODMDS, based on a scope of work provided by SCDNR. All divers involved with the assessment participated in a briefing with the SCDNR to ensure familiarity with typical hard bottom fauna and dredge material. After each site was marked with a subsurface float, divers conducted a circular sweep of the immediate bottom area, approximately 50-100 ft radius. Divers videotaped this reconnaissance

and noted whether any evidence of disposal material was observed. The divers also conducted a 300 ft videotaped survey away from each site in the direction provided by the SCDNR to characterize the adjacent bottom habitat. Site assessment occurred from August through October 2000.

At each of the 40 sites surveyed by divers, three core samples were collected from different locations within the circular transect radius of the site being surveyed. Each sediment core was collected using a plastic tube (3.5 cm diameter) that was inserted to a depth of 20 cm and placed in a plastic bag, which was pre-labeled with the site number and date of collection. Upon return to the surface, the bags were kept on ice and maintained at 4$^{o}$C in a refrigerator until they were delivered to the SCDNR Marine Resources Research Institute (MRRI).

Upon receipt, the samples were signed for on the date received and stored in a locked freezer until analysis. All samples were processed at the MRRI by personnel from the Institute's Environmental Research Section. Analyses of these sediment samples were limited to describing the percentages of sand/$CaCO_3$ (without additional grain-size data), silt and clay.

Analyses were performed using a modification of the pipette method described in Plumb (1981). All samples for each station were stored at 0$^{o}$C until processing began. After thawing, the two samples collected in closest proximity to the center coordinates of each dump site were composited; the third sample was not analyzed since in most cases this sample was located well away from the original dive coordinates and may not have been taken on the disposal pile. The two samples were thoroughly homogenized, and a subsample was removed for particle size analysis. The subsample consisted of 20 g from the fine-grained samples and 50 g from coarser samples. Each subsample was then wet sieved through a 63-micron stainless steel sieve using distilled water. Filtrate was collected in a 1000 ml graduated cylinder for pipette extraction of the fine component (silts and clays). The material retained on the sieve (sand and $CaCO_3$) was dried at 90$^{o}$C to obtain a total dry weight for the sand and $CaCO_3$ fractions. This fraction was not separated

further since our primary goal was to identify the silt/clay fraction as an "indicator" of inner harbor maintenance and new work material. Distilled water and 20 ml of dispersant (sodium hexametaphosphate solution) were then added to the graduated cylinder containing the silt/clay filtrate to attain 1000 ml. The filtrate mixture was resuspended and a 20 ml sample was withdrawn from a depth of 20 cm at the time and temperature described by Plumb (1981) to determine the amount of silt and clay in suspension. An additional 20 ml was withdrawn at the 10 cm depth after further settlement of the filtrate to estimate the amount of clay in suspension. Extracts were thoroughly dried and weighed to the nearest 0.001 gram.

The total dry weights of the silt and clay fractions were determined after corrections for the dispersant. All percentage estimates are provided to the nearest 0.1%; however, it should be noted that pipette analysis is probably not accurate to this level for the estimates of percent silt versus clay. Therefore, the combined estimates of silt and clay are also provided.

Ten percent of the samples (11) were reanalyzed by the lab manager using the same procedures to provide quality assurance/quality control (QA/QC) information. Criteria for acceptance require that a difference of no greater than 10% may exist in the dominant component, representing either sand/$CaCO_3$ combined or silt/clay combined.

Percent composition of sand/$CaCO_3$ and silt/clay were rank transformed and analyzed using ANOVA followed by post-hoc comparisons using the Tukey Test. Sand and $CaCO_3$ fractions were measured individually during the 1993 and 1994 studies (Van Dolah *et al*. 1996, 1997); these fractions were combined for the current analysis to allow for valid statistical comparisons of sediment composition among years. SigmaStat for Windows Version 2.0 (SPSS 1997) was used for all statistical tests.

## Results and Discussion

The results of sediment analyses completed on the 72 samples collected by SCDNR staff in February/March 2000 in the areas surrounding the Charleston ODMDS are presented in Table 1. Table 2 summarizes the results of sediment samples analyzed from the 40 sites surveyed by divers in the zones surrounding the Charleston ODMDS. QA/QC results indicated that all sediment samples that were reevaluated had less than 4.0% difference in the dominant component (Table 3). A summary of sand/$CaCO_3$ and silt/clay contents found in the areas surrounding the Charleston ODMDS during the 1993 and 1994 monitoring periods are presented in Table 4, as well as a summary of February/March 2000 samples and unauthorized dump samples. All tables are available in digital form on the attached computer disk in Excel® format.

### *February and March 2000 Samples*

Sediment samples collected in February/March 2000 (not including unauthorized dump samples collected in August-October 2000) indicate that the zones to the west of the ODMDS were higher in silt/clay content than sediments collected in areas to the east of the disposal area (Figure 4). Samples collected in the inner boundary area in zones IA-IE, and in the outer boundary area in zones OA-OE (see Figure 1), were generally high in sand/$CaCO_3$ content (mean = 98.7%) and low in silt/clay content (mean = 1.3%). Samples collected in Zones IF, IG, and IH, located adjacent to disposal activities on the western berm, had higher silt/clay content (mean = 4.7%) and lower sand/$CaCO_3$ content (mean = 95.3%) than the other inner boundary zones. The same trend was observed in samples collected in 1993 and 1994 (Van Dolah *et al.* 1996, 1997).

A statistical comparison of the sediment composition among the samples collected in February/March 2000 indicates that the sediment composition in the western zones of the inner and outer boundary areas was significantly different from the other zones. Sand/$CaCO_3$ content in Zone OD (mean = 99.9%) was significantly

higher than that found in Zone OG (mean = 89.5%), Zone IG (mean = 95.0%), and Zone IH (mean = 95.8%). During this same period, silt/clay content in Zone OD (mean = 0.1%) was significantly lower than the content at Zone OG (mean = 10.5%).

Temporal changes in sediment composition were also observed. Figure 5 compares the mean silt/clay content found in 1993, 1994, and 2000 samples; the yellow bars showing the 2000 data include samples collected by SCDNR in February/March 2000 and samples collected by Eason Diving and Marine Contractors, Inc. in August- October 2000. Red horizontal lines on the bars represent the mean silt/clay values from SCDNR samples. A red line is not shown for Zone OA because the mean silt/clay values for sediments collected by SCDNR in February/March 2000 were similar to values collected by Eason Diving and Marine Contractors, Inc. in August-October 2000. No unauthorized dumps were sampled in Zone OG.

Higher silt/clay values were collected in Zones IF, IG, OF, OH, and OG in February/March 2000 than in 1993 or 1994. Statistical comparisons among years indicated that the sand/$CaCO_3$ content in Zone IF in February/March 2000 (95.3%) was significantly lower than 1993 samples (96.6%), and silt/clay content was higher. Statistical comparisons also indicate that sediment composition in Zone IG showed a significant increase in silt/clay content compared to 1994 data, but were comparable to the silt/clay content observed in 1993. Although these differences were statistically significant ($P<0.001$), the percent change was relatively small.

Temporal changes in sediment composition were also observed in the outer boundary zones. Zone OF exhibited decreases in sand/$CaCO_3$ content, and increases in silt/clay content when compared to 1993 samples. The sand/$CaCO_3$ content in Zone OG was lower than 1994 values, and silt/clay content was higher than 1994 samples. These percent changes were relatively small, but statistically significant ($P<0.001$).

*Unauthorized Dump Samples*

Underwater video recorded during site reconnaissance (see details below), indicated that no disposal material was observed at three of the sites (1173, SCDNR-7, and SCDNR-9). For consistency, results of sediment analyses from these three sites were included during statistical comparisons of sediment type among zones. Three of the unauthorized disposal sites investigated were outside the boundary areas (102, 956, and 1173). The results of sediment analyses for these three sites were included with the boundary zone located closest to these sites: OA, OH, and OA, respectively.

Sediment composition in the samples collected at the unauthorized dump sites in the inner boundary zones indicates that disposal activity did occur outside the designated disposal area, and that the sediments were high in silt/clay content and low in sand/$CaCO_3$ content. Figure 5 compares the mean silt/clay content found in 1993, 1994, and 2000 samples; the bars showing the 2000 data include samples collected by SCDNR in February/March 2000 and samples collected by Eason Diving and Marine Contractors, Inc. in August- October 2000.

Zones IF, IG, IH, OF, and OG had higher mean silt/clay content than 1993 and 1994 samples, and correspondingly lower sand/$CaCO_3$ values (Figure 5). Statistical tests were completed to compare the amount of silt/clay found in unauthorized dump samples (not including SCDNR samples) and 1993 and 1994 samples. These tests indicated that the lower sand/$CaCO_3$ content and higher silt/clay content found in the unauthorized dumps in Zone IF were significantly different ($P < 0.001$) when compared to 1993 and 1994 samples. The unauthorized dump sediments collected in Zone IA, IG, and IH had statistically significantly lower sand/$CaCO_3$ content and statistically significantly higher silt/clay content than samples collected in 1994 ($P<0.001$). In the outer boundary area, Zones OA, OF, and OH had statistically significantly lower sand/$CaCO_3$ and higher silt/clay content than both 1993 and 1994 samples ($P<0.001$).

*Video Surveys at Unauthorized Disposal Sites*

The review of the video surveys collected at all 40 unauthorized disposal sites clearly indicated the presence of disposal material at the majority of the sites. No disposal material was observed at three sites (1173, SCDNR-7, and SCDNR-9). This may have been due to difficulty in locating the exact coordinates due to slumping of the original disposal pile, or dipsoal may not have occurred at the suspected sites (SCDNR-7 and SCDNR-9). At the sites where disposal material was observed, clay, silt, and marl had spread onto the surrounding bottom, and in many cases evidence of the material was observed throughout the 300 ft diver survey. Therefore, the goal of identifying the type of habitat impacted by the disposal activity was difficult to achieve. Hard bottom reef habitat was observed during the reconnaissance of one site (484). Organisms typically associated with hard bottom reef habitat (e.g. octocorals, sponges) were observed on the sediment surface, unattached to any substrate, at several of the other sites.

## Summary

The results of sediment analyses conducted on samples collected in the boundary areas surrounding the Charleston ODMDS indicate that disposal activities associated with the deepening project are resulting in changes in sediment composition outside the ODMDS. The sediment composition in the boundary areas to the west of the disposal site displayed, in most cases, higher silt/clay content than samples collected in 1993 and 1994.

This study documents what appears to be a trend of fine materials migrating from the ODMDS in a predominately southwest direction, compounded by unauthorized disposal activities in the west/southwest region of the boundary areas.

Due to the reconnaissance nature of this assessment, it was not possible to collect a large number of samples in all of the zones surrounding the ODMDS, and the sample size ranged from one to ten samples per zone. A more intense sampling

regime was used during the 1993 and 1994 baseline assessment (10 samples per zone) and would be expected to more accurately depict sediment composition in these large areas (one square mile per zone). Findings from the interim assessment completed in October 2000 will provide further insight into the sediment conditions in these boundary areas.

The sediment composition found at the unauthorized disposal sites was generally higher in silt/clay content than the original bottom sediments present in the areas surrounding the disposal site. The higher silt/clay content found at other locations in the boundary area, particularly to the west of the disposal site, is probably the result of the movement of fines from the ODMDS, combined with the disposal of fine grained material from the unauthorized dumps. Diver observations clearly indicated that most of the dumps investigated had spread, with spoil material extending to the end of the 300 ft transect surveyed away from the dump. Hard bottom reef habitat was clearly impacted at one of the disposal sites. Further monitoring of the fate and effects of this change in bottom sediment composition are required to ensure that adverse biological effects are not occurring. These studies are currently in progress.

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Table 1. Results of sediment analyses conducted on samples collected within the inner and outer boundary areas surrounding the Charleston ODMDS in February and March 2000.

| SCDNR Station Code | Zone | SCDNR Collection Number | Sample Weight | Sand/ $CaCO_3$ Weight | Silt/Clay Weight | Sand/ $CaCO_3$ % | Silt/Clay % | Silt % | Clay % |
|---|---|---|---|---|---|---|---|---|---|
| IA09 | IA | 000012 | 50.1 | 39.1 | 0.6 | 98.4 | 1.6 | 0.3 | 1.3 |
| IA27 | IA | 000013 | 50.2 | 39.3 | 0.6 | 98.5 | 1.5 | 0.1 | 1.4 |
| IA03 | IA | 000024 | 50.0 | 39.4 | 0.3 | 99.1 | 0.9 | 0.4 | 0.5 |
| IA17 | IA | 000026 | 50.0 | 39.5 | 0.4 | 99.0 | 1.0 | 0.1 | 1.0 |
| IA20 | IA | 000025 | 50.0 | 39.2 | 0.8 | 98.1 | 1.9 | 0.8 | 1.1 |
| IB21 | IB | 000014 | 50.2 | 38.5 | 0.8 | 98.1 | 1.9 | 0.2 | 1.8 |
| IB05 | IB | 000028 | 50.0 | 39.4 | 0.7 | 98.4 | 1.6 | 0.1 | 1.5 |
| IB07 | IB | 000030 | 50.0 | 39.4 | 0.7 | 98.3 | 1.7 | 1.4 | 0.4 |
| IB17 | IB | 000029 | 50.1 | 39.8 | 0.0 | 99.9 | 0.1 | 0.1 | 0.0 |
| IB30 | IB | 000027 | 50.0 | 36.5 | 0.1 | 99.8 | 0.2 | 0.1 | 0.1 |
| IC05 | IC | 000015 | 50.2 | 39.4 | 1.1 | 97.2 | 2.8 | 1.1 | 1.7 |
| IC16 | IC | 000016 | 50.1 | 39.5 | 1.0 | 97.5 | 2.5 | 0.0 | 2.5 |
| IC19 | IC | 000032 | 50.2 | 39.6 | 0.6 | 98.6 | 1.4 | 1.1 | 0.3 |
| IC25 | IC | 000031 | 50.1 | 38.8 | 0.4 | 99.0 | 1.0 | 0.2 | 0.8 |
| IC32 | IC | 000033 | 50.2 | 37.8 | 0.6 | 98.5 | 1.5 | 0.4 | 1.1 |
| ID18 | ID | 000017 | 50.1 | 39.3 | 0.8 | 98.1 | 1.9 | 0.3 | 1.6 |
| ID04 | ID | 000034 | 50.1 | 39.1 | 0.3 | 99.2 | 0.8 | 0.2 | 0.6 |
| ID16 | ID | 000037 | 50.0 | 39.5 | 0.4 | 99.0 | 1.0 | 0.6 | 0.4 |
| ID19 | ID | 000035 | 50.1 | 39.4 | 0.5 | 98.7 | 1.3 | 0.1 | 1.2 |
| ID31 | ID | 000036 | 50.1 | 42.3 | 0.3 | 99.4 | 0.6 | 0.5 | 0.1 |
| IE27 | IE | 000018 | 50.0 | 39.7 | 0.7 | 98.2 | 1.8 | 0.5 | 1.3 |
| IE04 | IE | 000040 | 50.1 | 39.6 | 0.5 | 98.8 | 1.2 | 0.7 | 0.5 |
| IE18 | IE | 000041 | 50.1 | 39.3 | 0.6 | 98.4 | 1.6 | 1.5 | 0.1 |
| IE30 | IE | 000039 | 50.1 | 39.0 | 0.1 | 99.7 | 0.3 | 0.2 | 0.1 |
| IE33 | IE | 000038 | 50.0 | 39.3 | 0.1 | 99.8 | 0.2 | 0.1 | 0.1 |
| IF05 | IF | 000019 | 50.1 | 38.7 | 1.0 | 97.5 | 2.5 | 1.5 | 1.0 |
| IF22 | IF | 000020 | 50.1 | 39.9 | 0.2 | 99.6 | 0.4 | 0.3 | 0.1 |
| IF03 | IF | 000044 | 50.1 | 38.6 | 0.6 | 98.6 | 1.4 | 0.8 | 0.7 |
| IF25 | IF | 000043 | 50.0 | 38.5 | 0.5 | 98.7 | 1.3 | 0.5 | 0.8 |
| IF32 | IF | 000042 | 31.0 | 16.4 | 3.6 | 82.0 | 18.0 | 5.3 | 12.7 |
| IG08 | IG | 000021 | 50.0 | 37.4 | 1.2 | 96.8 | 3.2 | 1.3 | 1.9 |
| IG30 | IG | 000022 | 50.0 | 38.4 | 1.1 | 97.2 | 2.8 | 0.1 | 2.7 |
| IG03 | IG | 000045 | 50.1 | 35.2 | 2.6 | 93.1 | 6.9 | 3.2 | 3.7 |
| IG11 | IG | 000050 | 50.1 | 36.9 | 1.9 | 95.0 | 5.0 | 2.7 | 2.3 |
| IG12 | IG | 000051 | 50.0 | 36.5 | 1.3 | 96.6 | 3.4 | 1.0 | 2.4 |
| IG19 | IG | 000049 | 50.1 | 38.1 | 1.0 | 97.4 | 2.6 | 1.0 | 1.5 |
| IG23 | IG | 000052 | 50.1 | 34.9 | 2.4 | 93.5 | 6.5 | 3.1 | 3.3 |
| IG25 | IG | 000046 | 50.1 | 28.0 | 5.2 | 84.3 | 15.7 | 5.7 | 10.0 |
| IG29 | IG | 000048 | 50.1 | 39.5 | 0.7 | 98.3 | 1.7 | 0.3 | 1.4 |
| IG32 | IG | 000047 | 50.2 | 38.9 | 0.8 | 97.9 | 2.1 | 0.8 | 1.3 |
| IH09 | IH | 000023 | 50.0 | 38.3 | 1.2 | 97.0 | 3.0 | 1.4 | 1.5 |
| IH02 | IH | 000053 | 50.1 | 38.9 | 0.8 | 98.0 | 2.0 | 0.4 | 1.6 |
| IH19 | IH | 000055 | 50.3 | 30.1 | 3.9 | 88.5 | 11.5 | 4.6 | 6.9 |
| IH21 | IH | 000056 | 50.1 | 37.2 | 1.2 | 96.9 | 3.1 | 1.4 | 1.8 |
| IH26 | IH | 000054 | 50.1 | 37.9 | 0.5 | 98.6 | 1.4 | 0.4 | 1.0 |

Table 1. Results of sediment analyses conducted on samples collected within the inner and outer boundary areas surrounding the Charleston ODMDS in February and March 2000.

| SCDNR Station Code | Zone | SCDNR Collection Number | Sample Weight | Sand/ $CaCO_3$ Weight | Silt/Clay Weight | Sand/ $CaCO_3$ % | Silt/Clay % | Silt % | Clay % |
|---|---|---|---|---|---|---|---|---|---|
| OA05 | OA | 000000 | 50.2 | 39.7 | 0.6 | 98.4 | 1.6 | 0.1 | 1.4 |
| OB10 | OB | 000001 | 50.0 | 38.9 | 0.6 | 98.4 | 1.6 | 0.1 | 1.6 |
| OB36 | OB | 000002 | 50.1 | 39.4 | 1.2 | 97.1 | 2.9 | 0.6 | 2.3 |
| OC10 | OC | 000003 | 50.1 | 40.2 | 0.3 | 99.1 | 0.9 | 0.4 | 0.5 |
| OD13 | OD | 000004 | 50.1 | 38.4 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| OD33 | OD | 000005 | 50.1 | 39.0 | 0.1 | 99.7 | 0.3 | 0.0 | 0.3 |
| OE12 | OE | 000006 | 50.0 | 38.9 | 0.5 | 98.7 | 1.3 | 1.1 | 0.2 |
| OF05 | OF | 000007 | 50.0 | 38.8 | 1.7 | 95.7 | 4.3 | 1.0 | 3.2 |
| OF35 | OF | 000008 | 50.1 | 40.3 | 0.4 | 99.1 | 0.9 | 0.0 | 0.9 |
| OF03 | OF | 000058 | 50.0 | 38.5 | 0.7 | 98.3 | 1.7 | 0.0 | 1.7 |
| OF10 | OF | 000057 | 50.1 | 39.1 | 1.6 | 96.1 | 3.9 | 0.9 | 3.0 |
| OF26 | OF | 000059 | 50.0 | 38.9 | 0.5 | 98.7 | 1.3 | 0.2 | 1.1 |
| OG10 | OG | 000009 | 50.0 | 30.5 | 4.7 | 86.5 | 13.5 | 7.0 | 6.4 |
| OG23 | OG | 000010 | 50.0 | 37.4 | 1.2 | 96.9 | 3.1 | 0.4 | 2.8 |
| OG03 | OG | 000062 | 50.0 | 30.4 | 4.7 | 86.7 | 13.3 | 6.9 | 6.5 |
| OG09 | OG | 000067 | 50.2 | 38.6 | 0.8 | 97.9 | 2.1 | 1.0 | 1.1 |
| OG14 | OG | 000061 | 50.2 | 22.7 | 9.3 | 70.9 | 29.1 | 16.2 | 12.8 |
| OG15 | OG | 000066 | 50.1 | 26.6 | 6.6 | 80.1 | 19.9 | 12.7 | 7.2 |
| OG22 | OG | 000065 | 50.1 | 35.8 | 1.3 | 96.5 | 3.5 | 2.0 | 1.6 |
| OG27 | OG | 000064 | 45.8 | 24.8 | 5.0 | 83.3 | 16.7 | 9.8 | 6.9 |
| OG29 | OG | 000063 | 50.1 | 38.5 | 0.7 | 98.3 | 1.7 | 0.5 | 1.2 |
| OG33 | OG | 000060 | 50.0 | 38.7 | 0.8 | 97.9 | 2.1 | 0.9 | 1.2 |
| OH10 | OH | 000011 | 50.0 | 39.3 | 0.5 | 98.7 | 1.3 | 0.7 | 0.6 |
| OH01 | OH | 000069 | 50.3 | 38.5 | 1.1 | 97.2 | 2.8 | 0.4 | 2.4 |
| OH02 | OH | 000071 | 50.2 | 39.9 | 0.7 | 98.3 | 1.7 | 0.8 | 0.8 |
| OH15 | OH | 000070 | 50.2 | 38.5 | 0.4 | 98.8 | 1.2 | 0.2 | 1.0 |
| OH30 | OH | 000068 | 50.2 | 39.0 | 1.5 | 96.2 | 3.8 | 2.3 | 1.4 |

Table 2. Results of sediment analyses conducted at unauthorized dump locations outside the Charleston ODMDS.

| Norfolk Load Number | SCDNR Station Code | Zone | SCDNR Collection Number | Sample Weight | Sand/ $CaCO_3$ Weight | Silt/Clay Weight | Sand/ $CaCO_3$ % | Silt/Clay % | Silt % | Clay % |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | MD13 | IH | 009513 | 20.2 | 6.0 | 5.5 | 52.0 | 48.0 | 17.4 | 30.6 |
| 102 | MD26 | N of OA | 009526 | 20.3 | 15.2 | 0.8 | 95.1 | 4.9 | 0.9 | 4.0 |
| 167 | MD30 | IG | 009530 | 20.3 | 8.6 | 3.6 | 70.7 | 29.3 | 8.2 | 21.2 |
| 317 | MD11 | IF | 009511 | 20.2 | 8.9 | 3.2 | 73.6 | 26.4 | 9.9 | 16.5 |
| 433 | MD16 | IH | 009516 | 20.4 | 13.8 | 1.6 | 89.5 | 10.5 | 1.8 | 8.7 |
| 435 | MD20 | IH | 009520 | 20.7 | 7.9 | 5.6 | 58.7 | 41.3 | 12.3 | 29.0 |
| 437 | MD17 | IH | 009517 | 20.3 | 11.4 | 2.5 | 82.3 | 17.7 | 4.1 | 13.6 |
| 444 | MD02 | IH | 009502 | 20.8 | 4.6 | 4.2 | 52.2 | 47.8 | 17.6 | 30.2 |
| 467 | MD01 | IH | 009501 | 20.1 | 12.5 | 1.5 | 89.3 | 10.7 | 3.3 | 7.4 |
| 474 | MD19 | IH | 009519 | 20.3 | 10.7 | 2.4 | 81.7 | 18.3 | 4.1 | 14.2 |
| 476 | MD04 | IH | 009504 | 20.4 | 6.2 | 5.4 | 53.3 | 46.7 | 9.6 | 37.0 |
| 479 | MD28 | IG | 009528 | 20.6 | 14.5 | 1.0 | 93.7 | 6.3 | 1.9 | 4.4 |
| 484 | MD24 | IH | 009524 | 20.4 | 408.4 | 3.7 | 99.1 | 0.9 | 0.4 | 0.5 |
| 492 | MD27 | IG | 009527 | 20.2 | 10.7 | 3.4 | 75.8 | 24.2 | 6.0 | 18.2 |
| 522 | MD33 | IG | 009533 | 20.4 | 14.8 | 0.9 | 94.2 | 5.8 | 2.7 | 3.2 |
| 525 | MD32 | IG | 009532 | 20.4 | 9.9 | 2.8 | 78.0 | 22.0 | 5.6 | 16.4 |
| 625 | MD34 | IH | 009534 | 20.4 | 8.0 | 4.0 | 66.5 | 33.5 | 9.3 | 24.3 |
| 631 | MD35 | IH | 009535 | 20.4 | 4.7 | 6.0 | 43.6 | 56.4 | 8.3 | 48.1 |
| 636 | MD39 | IG | 009539 | 20.7 | 7.2 | 3.1 | 70.3 | 29.7 | 5.3 | 24.4 |
| 694 | MD14 | IH | 009514 | 20.2 | 10.9 | 2.9 | 78.8 | 21.2 | 6.2 | 15.0 |
| 710 | MD18 | IH | 009518 | 20.6 | 3.2 | 8.1 | 28.5 | 71.5 | 18.9 | 52.5 |
| 743 | MD40 | IF | 009540 | 20.3 | 11.2 | 2.7 | 80.6 | 19.4 | 2.4 | 17.0 |
| 779 | MD12 | IF | 009512 | 20.2 | 6.9 | 5.9 | 54.1 | 45.9 | 17.6 | 28.3 |
| 817 | MD06 | IH | 009506 | 20.7 | 15.2 | 0.6 | 95.9 | 4.1 | 0.8 | 3.3 |
| 820 | MD21 | IH | 009521 | 20.6 | 9.7 | 3.9 | 71.4 | 28.6 | 10.1 | 18.5 |
| 956 | MD07 | NW of OH | 009507 | 20.2 | 11.7 | 3.1 | 79.3 | 20.7 | 6.5 | 14.2 |
| 1028 | MD22 | IH | 009522 | 20.5 | 6.1 | 4.5 | 57.6 | 42.4 | 9.5 | 32.9 |
| 1163 | MD23 | IG | 009523 | 20.5 | 14.6 | 1.6 | 90.2 | 9.8 | 3.0 | 6.9 |
| 1173 | MD08 | N of OA | 009508 | 20.5 | 15.5 | 0.5 | 97.1 | 2.9 | 2.6 | 0.2 |
| SCDNR 1 | MD10 | IA | 009510 | 20.6 | 15.4 | 0.4 | 97.3 | 2.7 | 0.3 | 2.4 |
| SCDNR 2 | MD31 | IH | 009531 | 20.0 | 12.2 | 2.2 | 84.7 | 15.3 | 4.8 | 10.5 |
| SCDNR 3 | MD03 | IH | 009503 | 20.6 | 7.7 | 4.8 | 61.6 | 38.4 | 5.5 | 32.9 |
| SCDNR 4 | MD37 | IG | 009537 | 20.8 | 15.5 | 0.7 | 95.9 | 4.1 | 2.2 | 1.9 |
| SCDNR 5 | MD05 | IF | 009505 | 20.1 | 9.5 | 3.3 | 74.1 | 25.9 | 6.8 | 19.1 |
| SCDNR 6 | MD38 | OF | 009538 | 20.8 | 13.4 | 2.0 | 87.2 | 12.8 | 3.1 | 9.6 |
| SCDNR 7 | MD09 | IA | 009509 | 20.2 | 15.3 | 0.4 | 97.2 | 2.8 | 0.3 | 2.5 |
| SCDNR 8 | MD25 | IA | 009525 | 20.3 | 13.5 | 2.3 | 85.6 | 14.4 | 7.8 | 6.6 |
| SCDNR 9 | MD15 | OH | 009515 | 21.3 | 16.1 | 0.4 | 97.5 | 2.5 | 0.2 | 2.3 |
| SCDNR 10 | MD29 | IG | 009529 | 20.7 | 14.2 | 1.4 | 91.3 | 8.7 | 3.7 | 5.0 |
| SCDNR 11 | MD36 | IG | 009536 | 20.2 | 15.0 | 0.6 | 96.0 | 4.0 | 2.0 | 2.0 |

Table 3. Results from quality assurance/quality control analyses on 10% of sediment samples.

| SCDNR Station Code | Zone | SCDNR Collection Number | Norfolk Load Number | Sample Weight | Sand/ $CaCO_3$ Weight | Silt/Clay Weight | Sand/ $CaCO_3$ % | Silt/Clay % | Silt % | Clay % |
|---|---|---|---|---|---|---|---|---|---|---|
| IA17 | IA | 000026 | | 52.6 | 42.1 | 0.8 | 98.1 | 1.9 | 0.1 | 1.9 |
| IE18 | IE | 000041 | | 42.2 | 33.6 | 0.8 | 97.5 | 2.5 | 0.1 | 2.3 |
| IE27 | IE | 000018 | | 50.4 | 39.5 | 0.9 | 97.7 | 2.3 | 0.3 | 1.9 |
| IG19 | IG | 000049 | | 50.6 | 36.4 | 1.1 | 97.1 | 2.9 | 0.7 | 2.2 |
| OB36 | OB | 000002 | | 50.9 | 39.8 | 0.7 | 98.2 | 1.8 | 0.2 | 1.6 |
| OG09 | OG | 000067 | | 50.5 | 38.8 | 1.0 | 97.4 | 2.6 | 0.3 | 2.3 |
| OH01 | OH | 000069 | | 50.6 | 39.0 | 1.1 | 97.3 | 2.7 | 0.3 | 2.4 |
| MD01 | IH | 009501 | 467 | 20.5 | 13.9 | 1.2 | 92.2 | 7.8 | 2.6 | 5.2 |
| MD15 | OH | 009515 | SCDNR 9 | 20.2 | 15.5 | 0.2 | 98.5 | 1.5 | 1.1 | 0.4 |
| MD26 | N of OA | 009526 | 102 | 20.3 | 15.5 | 0.3 | 98.1 | 1.9 | 1.9 | 0.0 |
| MD29 | IG | 009529 | SCDNR 10 | 20.1 | 14.6 | 0.8 | 94.6 | 5.4 | 1.9 | 3.5 |

Table 4. Comparison of sand/$CaCO_3$ and silt/clay content in samples collected in 1993, 1994, and 2000 in the boundary zones surrounding the Charleston ODMDS. Sand/$CaCO_3$ and silt/clay content collected at unauthorized dump sites in these areas is also reported.

| | Sample location | Sand/$CaCO_3$ % | Silt/Clay % |
|---|---|---|---|
| **Zone IA** | mean 1993 | 94.4 | 5.6 |
| | mean 1994 | 99.4 | 0.6 |
| | mean 2000 | 98.6 | 1.4 |
| | SCDNR 1 | 97.3 | 2.7 |
| | SCDNR 7 | 97.2 | 2.8 |
| | SCDNR 8 | 85.6 | 14.4 |
| **Zone IF** | mean 1993 | 96.6 | 3.4 |
| | mean 1994 | 98.0 | 2.0 |
| | mean 2000 | 95.3 | 4.7 |
| | 317 | 73.6 | 26.4 |
| | 743 | 80.6 | 19.4 |
| | 779 | 54.1 | 45.9 |
| | SCDNR 5 | 74.1 | 25.9 |
| **Zone IG** | mean 1993 | 95.1 | 4.9 |
| | mean 1994 | 97.6 | 2.4 |
| | mean 2000 | 95.0 | 5.0 |
| | 167 | 70.7 | 29.3 |
| | 479 | 93.7 | 6.3 |
| | 492 | 75.8 | 24.2 |
| | 522 | 94.2 | 5.8 |
| | 525 | 78.0 | 22.0 |
| | 636 | 70.3 | 29.7 |
| | 1163 | 90.2 | 9.8 |
| | SCDNR 4 | 95.9 | 4.1 |
| | SCDNR 10 | 91.3 | 8.7 |
| | SCDNR 11 | 96.0 | 4.0 |
| **Zone OG** | mean 1993 | 90.6 | 9.4 |
| | mean 1994 | 95.2 | 4.8 |
| | mean 2000 | 89.5 | 10.5 |

| | Sample location | Sand/$CaCO_3$ % | Silt/Clay % |
|---|---|---|---|
| **Zone IH** | mean 1993 | 90.1 | 9.9 |
| | mean 1994 | 88.6 | 11.4 |
| | mean 2000 | 95.8 | 4.2 |
| | 20 | 52.0 | 48.0 |
| | 433 | 89.5 | 10.5 |
| | 435 | 58.7 | 41.3 |
| | 437 | 82.3 | 17.7 |
| | 444 | 52.2 | 47.8 |
| | 467 | 89.3 | 10.7 |
| | 474 | 81.7 | 18.3 |
| | 476 | 53.3 | 46.7 |
| | 484 | 99.1 | 0.9 |
| | 625 | 66.5 | 33.5 |
| | 631 | 43.6 | 56.4 |
| | 694 | 78.8 | 21.2 |
| | 710 | 28.5 | 71.5 |
| | 817 | 95.9 | 4.1 |
| | 820 | 71.4 | 28.6 |
| | 1028 | 57.6 | 42.4 |
| | SCDNR 2 | 84.7 | 15.3 |
| | SCDNR 3 | 61.6 | 38.4 |
| **Zone OA** | mean 1993 | 98.5 | 1.5 |
| | mean 1994 | 99.1 | 0.9 |
| | mean 2000 | 98.4 | 1.6 |
| | 102 | 95.1 | 4.9 |
| | 1173 | 97.1 | 2.9 |
| **Zone OF** | mean 1993 | 98.8 | 1.2 |
| | mean 1994 | 98.1 | 1.9 |
| | mean 2000 | 97.6 | 2.4 |
| | SCDNR 6 | 87.2 | 12.8 |
| **Zone OH** | mean 1993 | 98.3 | 1.7 |
| | mean 1994 | 98.8 | 1.2 |
| | mean 2000 | 97.9 | 2.1 |
| | 956 | 79.3 | 20.7 |
| | SCDNR 9 | 97.5 | 2.5 |

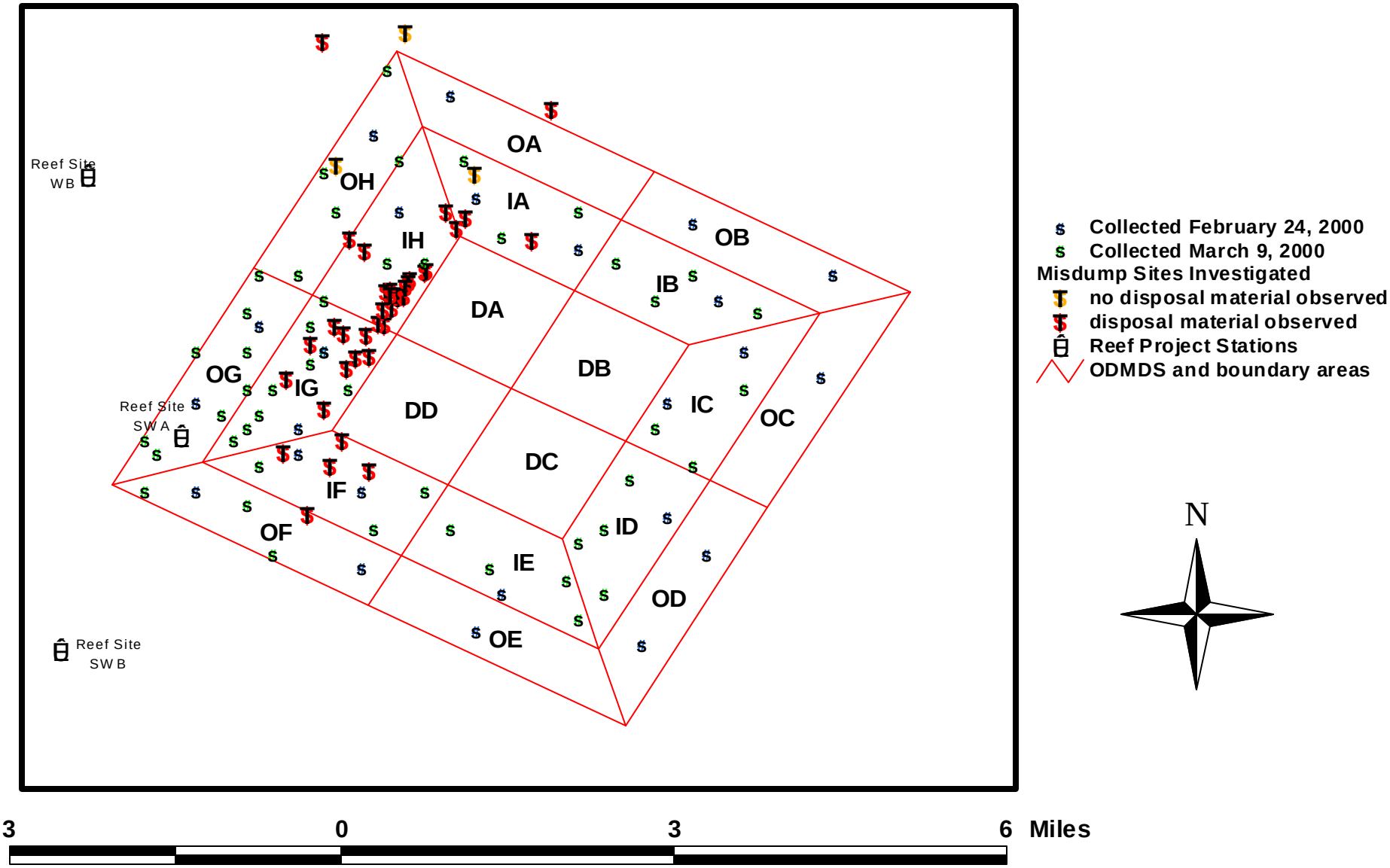



Figure 1. Location of sediment samples collected by SCNDR in February/March 2000, and the location of unauthorized disposal sites investigated by Eason Diving and Marine Contractors, Inc.

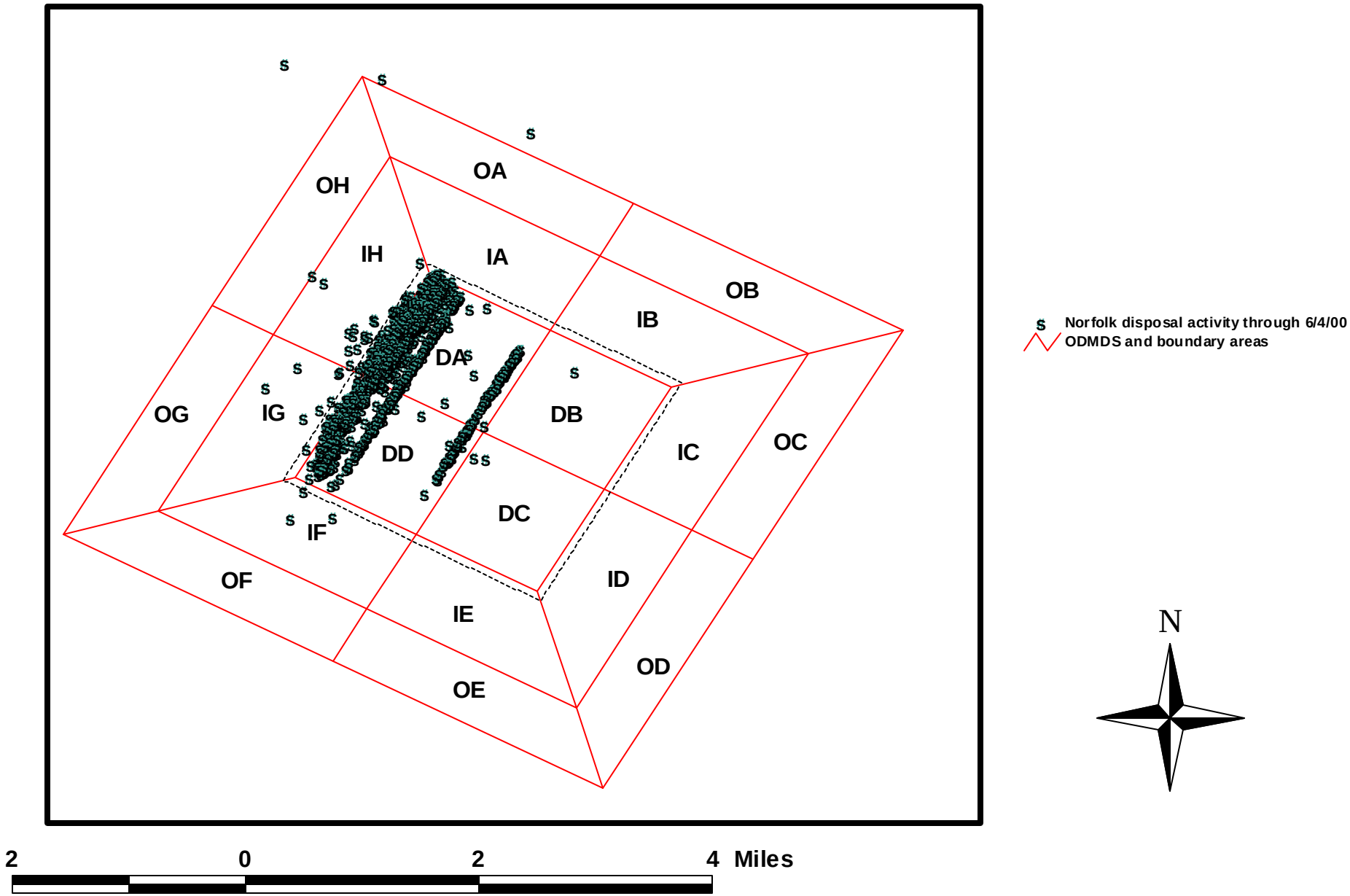



Figure 2. Norfolk Dredging Company disposal activity through June 4, 2000. Black dashed lines indicate the 100-m buffer created to the west and south of the disposal area (see text for details).

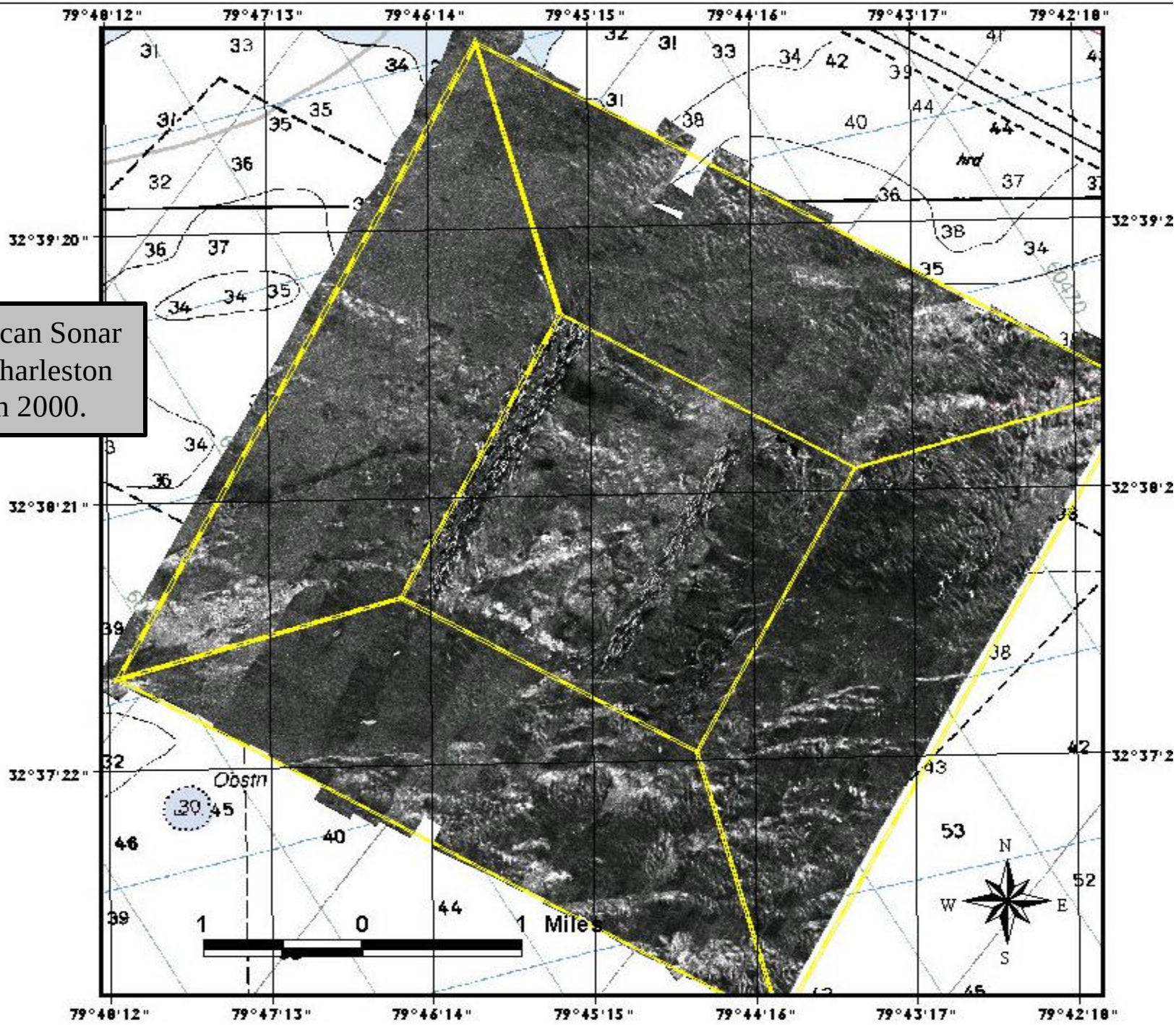



Figure 3. Side Scan Sonar Mosaic of the Charleston ODMDS- March 2000.

| Zone | 1993 | 1994 |
|---|---|---|
| IA | 5.6 | 0.6 |
| IB | 7.1 | 1.7 |
| IC | 1.0 | 1.4 |
| ID | 3.9 | 2.8 |
| IE | 2.8 | 1.2 |
| IF | 3.4 | 2.0 |
| IG | 4.9 | 2.4 |
| IH | 9.9 | 11.4 |
| OA | 1.4 | 0.9 |
| OB | 2.1 | 2.0 |
| OC | 3.4 | 2.2 |
| OD | 3.3 | 2.4 |
| OE | 1.3 | 2.0 |
| OF | 1.3 | 1.9 |
| OG | 9.3 | 4.8 |
| OH | 1.7 | 1.2 |

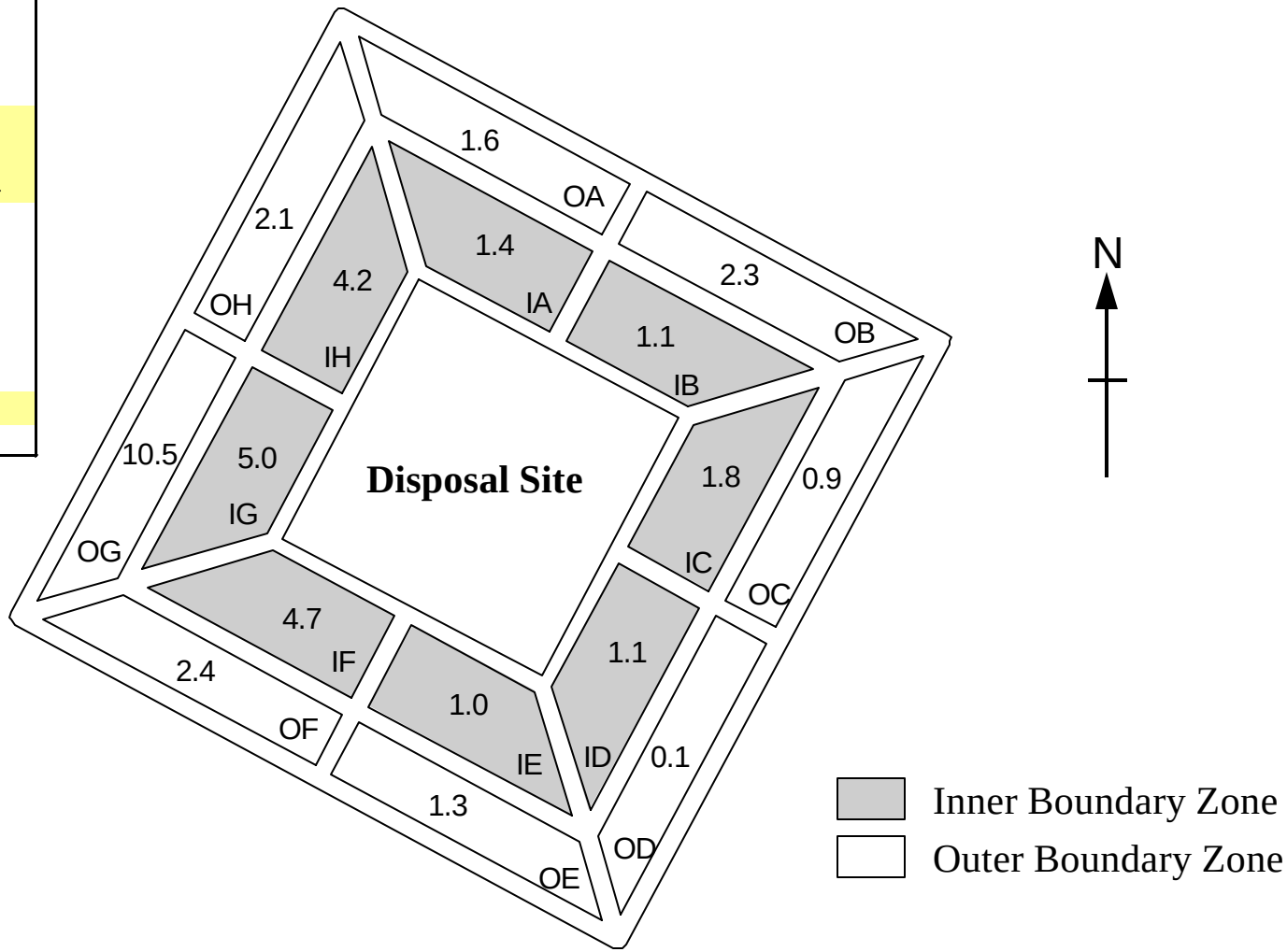
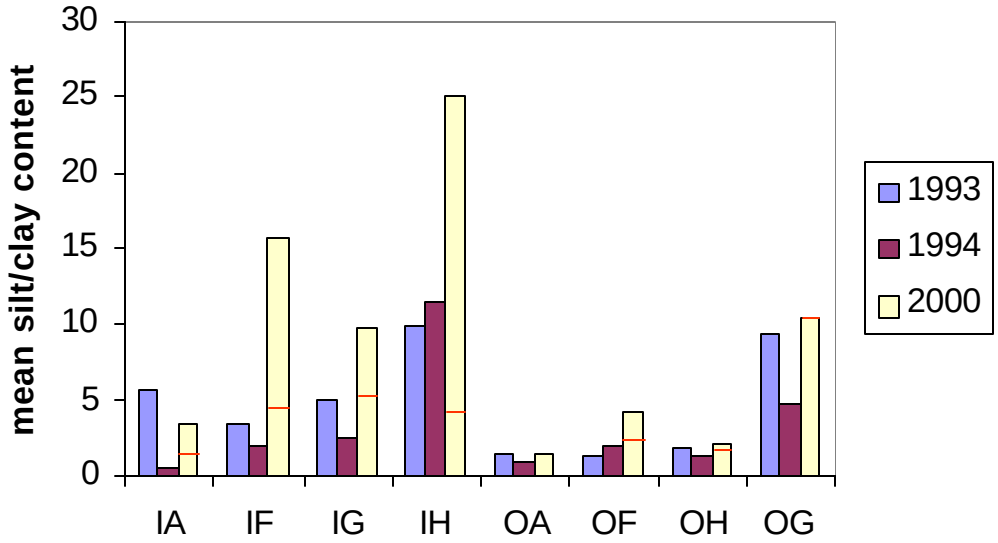



Figure 4. Mean percent silt/clay content in samples collected in the inner and outer boundary zones by SCDNR in February and March 2000. The number of samples collected per zone ranged from one to ten. Sample site locations were selected from sites previously sampled during the 1993 or 1994 assessment. The table lists mean percent silt/clay content for 1993 and 1994 samples (n = 10 samples per zone). The zones highlighted in yellow correspond to zones with elevated silt/clay content in the 2000 samples.



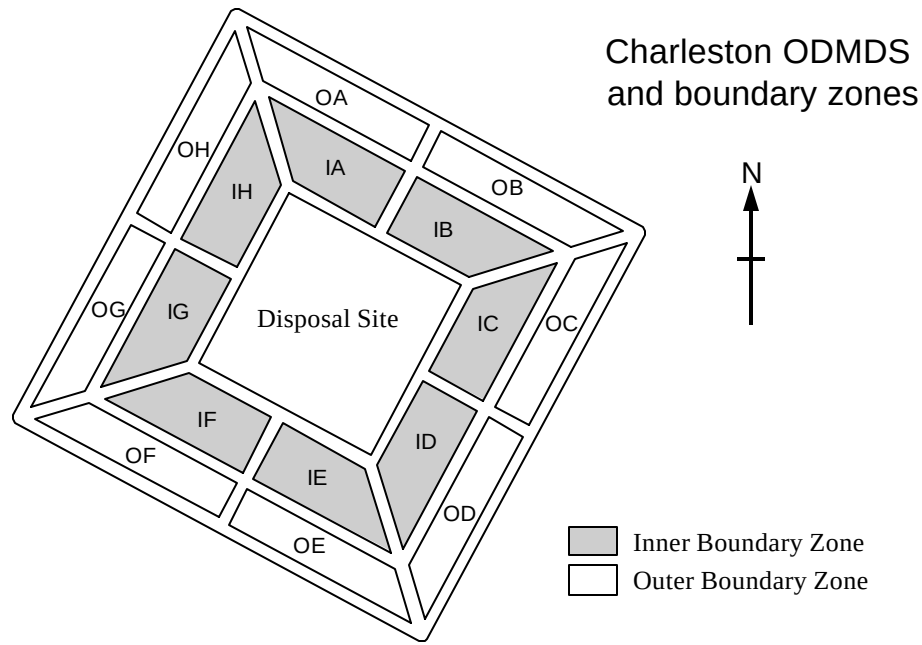




Figure 5. The mean percent silt/clay content collected in selected areas of the inner and outer boundary zones in 1993, 1994, and 2000. The mean silt/clay content for 2000 includes both samples collected by SCDNR and Eason Diving and Marine Contractors, Inc. The red horizontal line on the 2000 data represents the mean percent silt/clay content in samples collected by SCDNR in February/March 2000. See text for details. The location of sampling zones is shown in the figure in the bottom right.