Monitoring Cruise at the
Massachusetts Bay Disposal Site,
August 1994

Disposal Area Monitoring System DAMOS

D A M O S

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13. ABSTRACT

Sediment-profile and plan view photographs were collected at the Massachusetts Bay Disposal Site (MBDS) for three separate objectives. The first objective was to assess the recolonization status of the recently disposed dredged material. The remaining two objectives were in response to results from the MBDS baseline survey of 1993. The second objective was to determine the areal limits of historical dredged material using acoustical data from the 1993 survey as a reference. The final objective was to investigate the successional status and general benthic conditions at the area around historical Station 12-3 that has shown evidence of historical contamination.

Results from sampling at the active disposal buoy indicated that the disposal of dredged material at MBDS is not impeding benthic recolonization. The results were compared with reference area data and showed that the area near the disposal buoy contained a relatively advanced benthic community, despite the recent disposal of sediments.

The areal extent of both recent and historical dredged material that had been defined using acoustical data in the 1993 baseline survey was confirmed with the photographic data. Both the acoustic and the photographic data, however, were not apt to detect highly reworked dredged material around the flanks of the current and historical dredged material deposits at MBDS.

Although sediments at the 12-3 Grid did show signs of organic eutrophication (reduced sediments with high sediment oxygen demand and locally thin apparent redox potential discontinuity intervals), most of the stations still contained a highly developed Stage III community. While any chemical contaminants that may be present are not apparently toxic to the local benthic assemblage, the potential for bioaccumulation in their tissues still persists. Because Station 12-3 represents a small area (less than 400 m in diameter) there is little risk of significant transfer of contaminants to benthic predators. Station 12-3 may provide a field test bed for evaluation of the sensitivity of REMOTS® technology in assessing the impact of sublethal contaminant levels on the benthic community.

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EXECUTIVE SUMMARY

Sediment-profile and plan view photographs were collected at the Massachusetts Bay Disposal Site (MBDS) for three separate objectives. The first objective was to assess the recolonization status of the recently disposed dredged material. The remaining two objectives were in response to results from the MBDS baseline survey of 1993. The second objective was to determine the areal limits of historical dredged material using acoustical data from the 1993 survey as a reference. The final objective was to investigate the successional status and general benthic conditions at the area around historical Station 12-3 that has shown evidence of historical contamination.

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The areal extent of both recent and historical dredged material that had been defined using acoustical data in the 1993 baseline survey was confirmed with the photographic data. Both the acoustic and the photographic data, however, were not apt to detect highly reworked dredged material around the flanks of the current and historical dredged material deposits at MBDS.

Although sediments at the 12-3 Grid did show signs of organic eutrophication (reduced sediments with high sediment oxygen demand and locally thin apparent redox potential discontinuity intervals), most of the stations still contained a highly developed Stage III community. While any chemical contaminants that may be present are not apparently toxic to the local benthic assemblage, the potential for bioaccumulation in their tissues still persists. Because Station 12-3 represents a small area (less than 400 m in diameter) there is little risk of significant transfer of contaminants to benthic predators. Station 12-3 may provide a field test bed for evaluation of the sensitivity of REMOTS® technology in assessing the impact of sublethal contaminant levels on the benthic community.

1.0 INTRODUCTION

1.1 The Massachusetts Bay Disposal Site

A monitoring survey of the Massachusetts Bay Disposal Site (MBDS) was conducted from 8 to 9 August 1994; the primary task was to document several characteristics of the disposal site using a sediment-profile camera system (Remote Ecological Monitoring Of The Seafloor [REMOTS®]; Rhoads and Germano 1986). The disposal site, a 3.7 km diameter circular area centered at 42°25.100' N, 70°35.000' W, is located 22.23 km southeast of Gales Point (Figure 1-1). Three reference areas, designated to serve as control points for field efforts, were also sampled (SE, MBD-REF, and FG-23; Figure 1-1).

The MBDS was officially designated a dredged material disposal site by the US Environmental Protection Agency in 1993 (USEPA 1992). The site was relocated from the interim disposal site (Figure 1-1), used for the disposal of dredged material from 1977 to 1993, and previously known as the Foul Area Disposal Site (FADS) and the Boston Foul Ground (BFG). Relocation of the MBDS boundary provided several advantages. First, the relatively pristine eastern portion of the interim MBDS, including the edge that overlaps with the Stellwagen Bank National Marine Sanctuary, was excluded from the relocated area. Second, the new boundary encompassed the area west of the interim MBDS where contaminated sediments, present as a result of past disposal practices, have been identified. Finally, disposal activities will be avoided in the northern part of the Industrial Waste Site (IWS, closed by the EPA in 1977), where historical disposal of waste barrels and other types of debris has occurred (Figure 1-2).

Disposal of dredged material to MBDS is managed by the New England Division (NED) of the US Army Corps of Engineers (USACE). Monitoring of the disposal of dredged material has been conducted at MBDS through the Disposal Area Monitoring System (DAMOS) Program since 1978 (NUSC 1979, Supplement D) because of intensive use of this disposal site. Approximately 100,000 m^3 of dredged material was disposed at the MDA buoy (Figure 1-2) between August 1993 and August 1994 (Table 1-1). An additional 100,000 m^3 was disposed at an alternate "rock site" east of MBDS along the edge of Stellwagen Bank. Materials disposed here consisted primarily of fresh blasted rock from the Third Harbor Tunnel (THT) project in Boston Harbor and were disposed to create an artificial reef. Finer grained materials from the THT project, including the distinctive Boston Blue Clay, were disposed at the MDA buoy. Approximately 1/3 of the material disposed at the buoy originated from the THT project (Table 1-1).

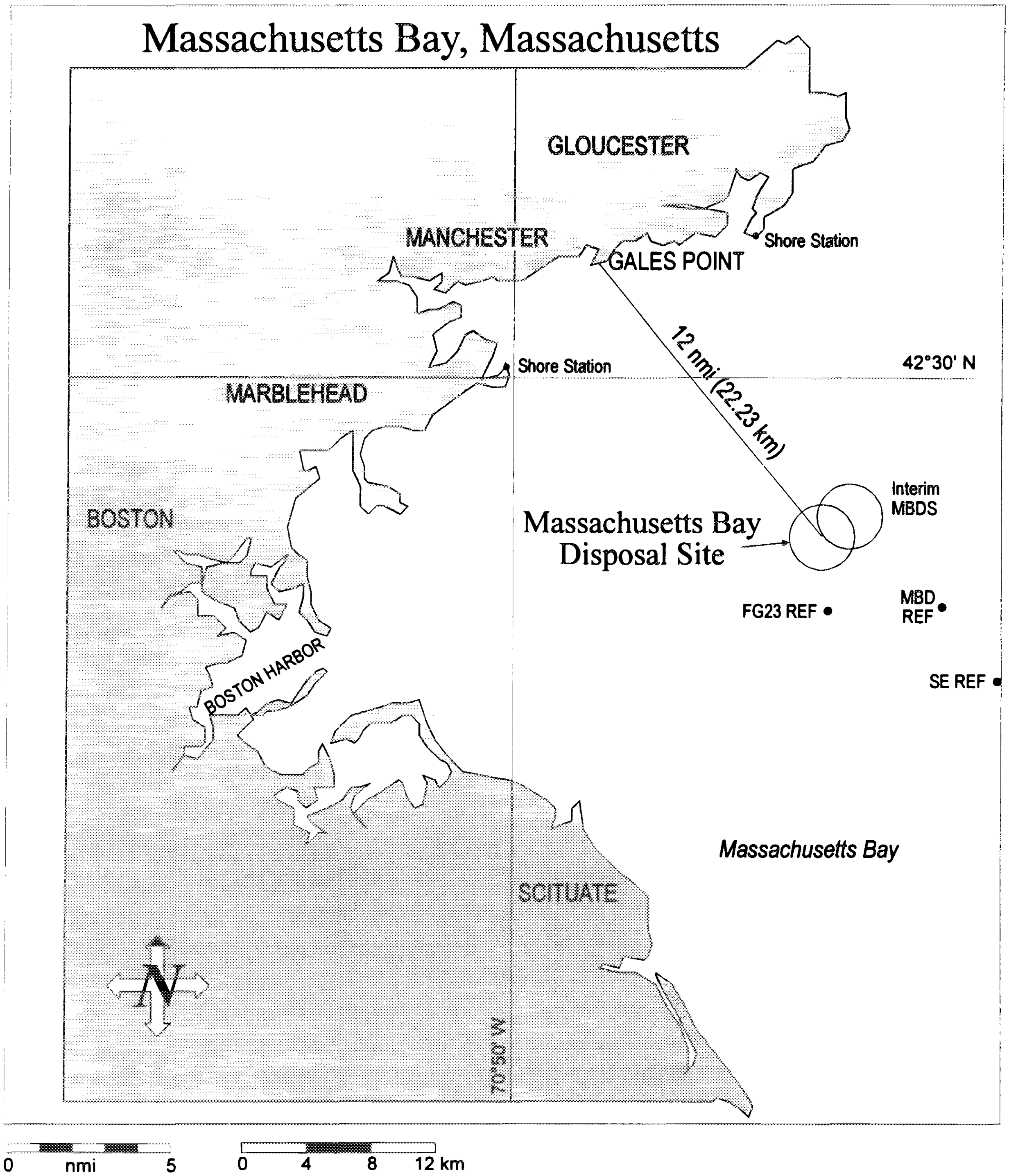

Figure 1-1. Location of the Massachusetts Bay Disposal Site (MBDS), the interim site, and the three MBDS reference areas

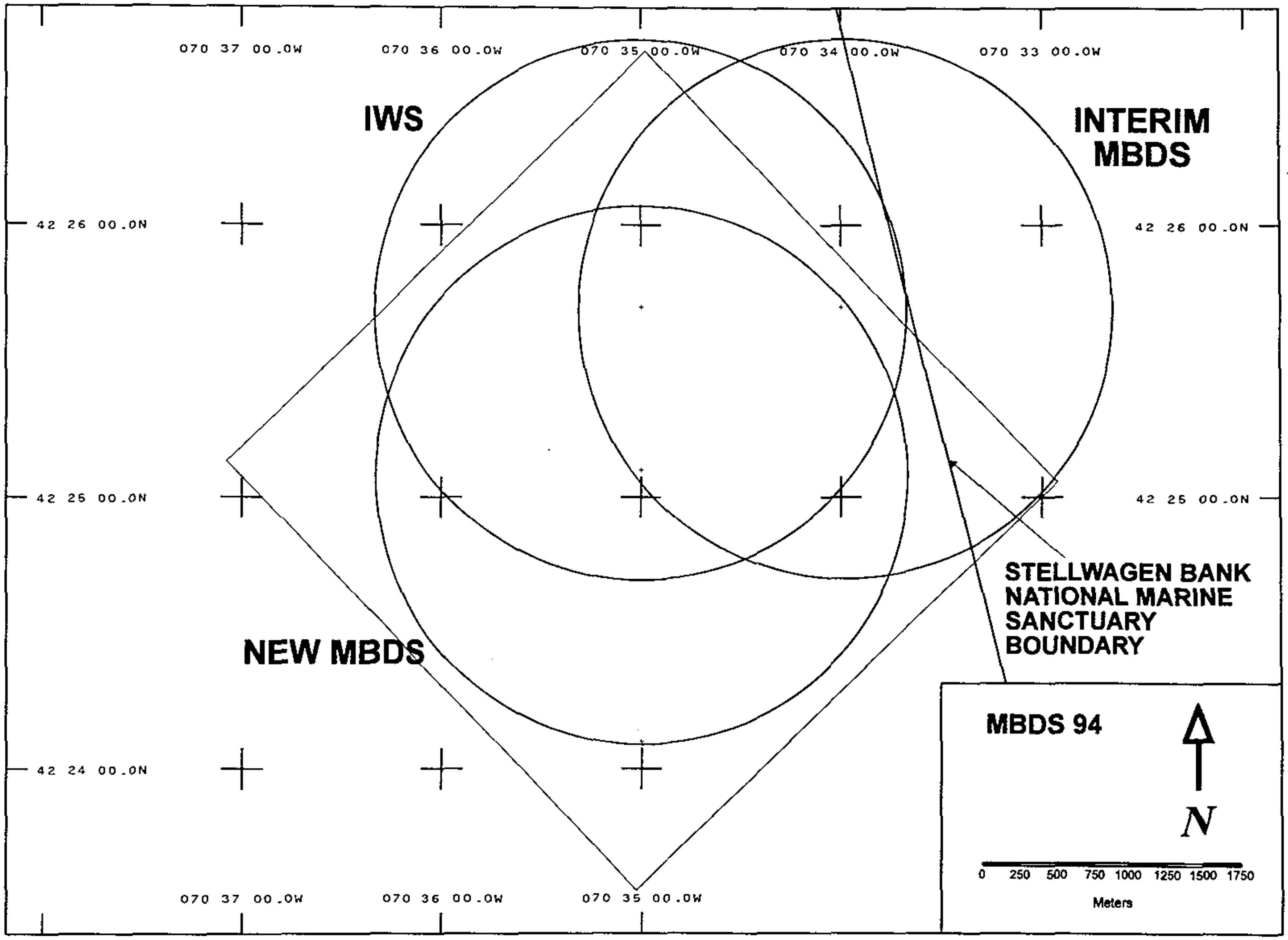

Figure 1-2. Location of MBDS in relation to the interim MBDS, the IWS, and the Stellwagen Bank National Marine Sanctuary boundary

Table 1-1

Dredged Material Volume Disposed at MBDS 1993-1994

Project	Disposal Site	Disposal Date First	Disposal Date Last	Total Volume (cy)	Total Volume (cm)
DION BASIN, SALEM HARBOR, MA	MDA Buoy	02-Mar-94	31-Mar-94	9150	6954
ESSEX RIVER	MDA Buoy	24-Oct-93	07-Feb-94	27805	21132
NEPONSET LANDING	MDA Buoy	24-Sep-93	15-Oct-93	21400	16264
PORT NORFOLK	MDA Buoy	12-Jan-94	01-Feb-94	17600	13376
SALEM HARBOR HISTORIC SITE	MDA Buoy	15-May-94	03-Aug-94	9075	6897
THIRD HARBOR TUNNEL	MDA Buoy	01-Aug-93	02-Nov-93	40630	30879
THIRD HARBOR TUNNEL	Rock Site	01-Aug-93	24-Oct-93	126930	96467
Total Volume Disposed:				252590	191968
Total Volume Disposed at MDA Buoy:				125660	95502
Total Volume Disposed at Rock Site:				126930	96467

Volumes are summed from disposal logs beginning 1 August 1993 through 8 August 1994 (the survey date).

1.2 Objectives of the Survey

The MBDS 1994 REMOTS® survey had three primary objectives:

- Assess the recolonization status of the recently disposed dredged material around the MDA disposal buoy (**MDA Buoy Grid**).
- Determine the areal limits of historical dredged material documented in the baseline acoustical surveys of 1993 (**SACS Grid**).
- Investigate the successional status and general benthic conditions at the area around historical Station 12-3 that has shown evidence of polycyclic aromatic hydrocarbon (PAH) contamination (**12-3 Grid**).

The sample plan for the second and third objectives was designed in response to the results of the 1993 baseline survey (DeAngelo and Murray 1994). Design of the station locations is discussed further in Section 2.2.

1.2.1 The MDA Buoy Grid

The 1993 bathymetric results showed a prominent mound at the current location of the MDA buoy (Figure 1-3). Disposal volume records indicate that approximately 2 million m^3 of dredged material have been disposed in the area of the MDA buoy since the 1985-1986 disposal season. Prior to this, material was disposed at the approximate

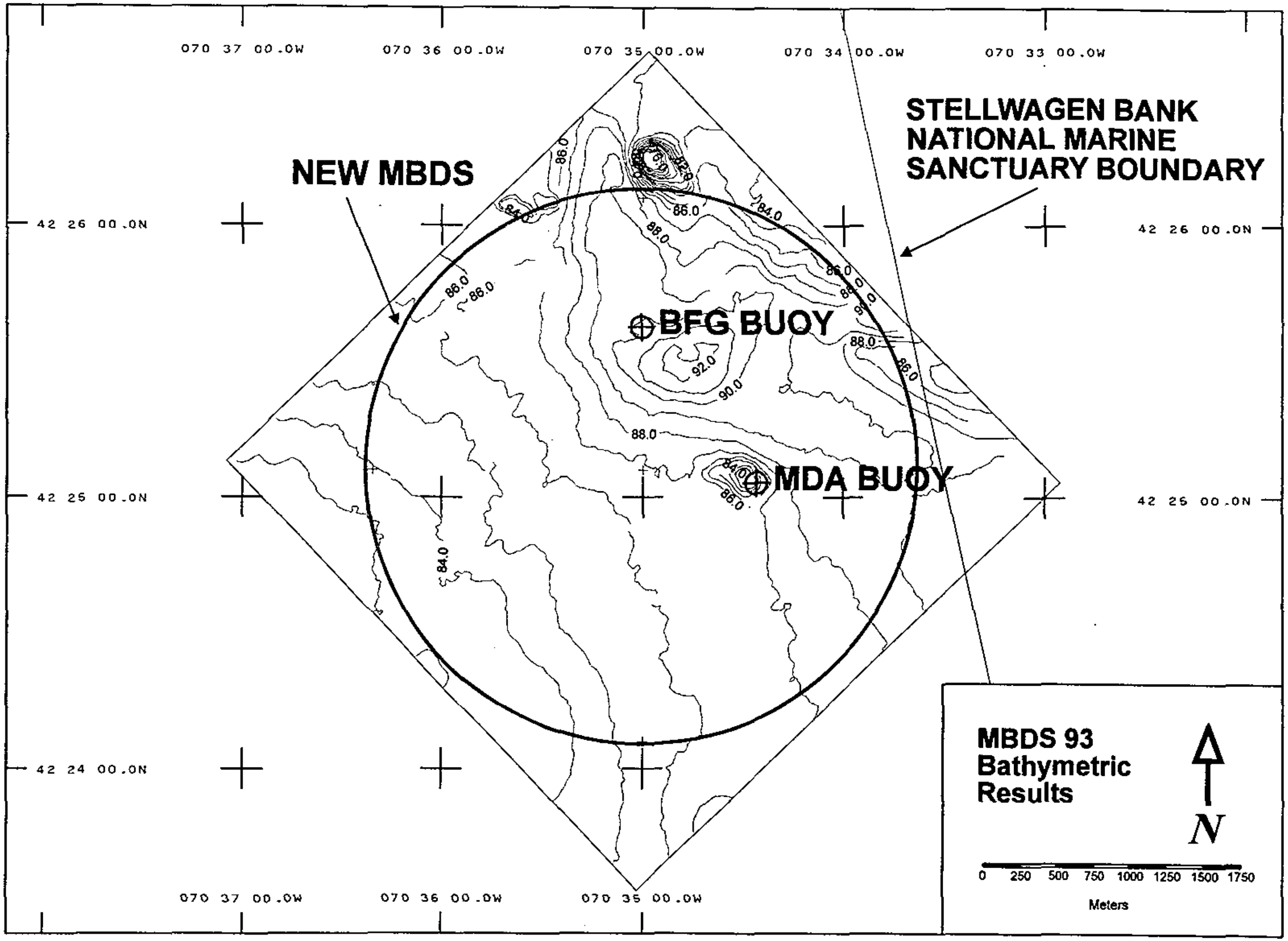

Figure 1-3. Bathymetric results from the 1993 MBDS baseline survey (depth in meters)

location of the BFG buoy on Figure 1-3; the actual location of this buoy was varied from year to year. The BFG was placed specifically due to the bathymetric depression present at this location.

Approximately 100,000 m^3 of dredged material was placed between August 1993 and the 1994 survey at the MDA buoy (Table 1-1). The first objective of the 1994 survey was to assess the preliminary recolonization around the disposal buoy. Research in Long Island Sound (McCall 1977, Rhoads et al. 1978) and prior DAMOS experience (e.g., SAIC 1994, Germano et al. 1994) have shown that benthic production on areas of disturbed seafloor consists of the rapid evolution of a Stage I sere community (primarily spionid, capitellid, or oweniid polychaetes). Disposal at the MBDS, unlike NED disposal sites in Long Island Sound, takes place all year, so the 1994 monitoring cruise took place while disposal was still being conducted (Table 1-1). Consequently, the hypothesis for this segment of the cruise was that a Stage I community would be dominant at the MDA Buoy Grid stations. Later deposit-feeding successional stages, including Stage II (tubicolous amphipods) and Stage III (head-down deposit-feeding polychaetes) seres, would not be expected to colonize the area for several months to a year following disposal.

Results from the 1994 REMOTS® survey at the MDA Buoy Grid showed, however, that Stage II were very common, and evidence for Stage III (e.g., feeding voids) was found at most stations, even in the freshest dredged material. These results indicate that the disposal of dredged material at the MDA buoy is 1) having no impact on the established benthic assemblages; 2) not impeding the successful recolonization of the sediments near the MDA buoy; or 3) reflecting a combination of the two factors.

1.2.2 The SACS Grid

REMOTS® photographs were collected in a grid defined by contours of high-reflectance sediments mapped from 1993 acoustic data, and interpreted as new or historical dredged material (DeAngelo and Murray 1994). The 1993 baseline acoustic survey included a high-resolution bathymetric survey conducted in tandem with a side-scan sonar and a bottom characterization survey using the Sediment Acoustic Characterization System (SACS). The SACS utilizes the high-frequency transducer to define the depth of the sediment-water interface, and a low-frequency (24 kHz) transducer for subbottom information.

Both the side-scan and SACS acoustic data sets from the 1993 baseline surveys indicated that the MDA mound and the area immediately surrounding the mound were distinctively more reflective than ambient sediments. Fresh dredged material has a rough, irregular surface topography prior to reworking by bioturbating organisms and bottom currents. In addition, much of the more recently disposed material (since the beginning of 1992) originated from the THT project. The THT material contains both rock fragments from tunnel blasting and large consolidated blocks of Boston Blue Clay (Wiley 1993). The acoustic reflection from both of these materials was stronger than the ambient silts and clays, as supported by both the side-scan and SACS results (DeAngelo and Murray 1994).

Boston Blue Clay is also optically reflective, and therefore is a good tracer for dredged material from Boston Harbor. It is a light greenish-gray to medium gray clay that originated from glacial meltwater runoff about 18,000 years ago (MDPW 1991). The lithology is almost pure clay with lenses of coarser material; the clay has a high bulk density with low porosity and has a strong capacity to retain water without loss of internal cohesion. Because of these properties, Boston Blue Clay was identified as material suitable for a cap for a landfill (MDPW 1991).

The key difference between the SACS and side-scan results from the 1993 survey (Figures 1-4 and 1-5) was the area surrounding historical dredged material disposed at the BFG buoy (Figure 1-3). The BFG buoy was moved from year to year, but remained in the same general area as depicted on Figure 1-3. The area around the BFG buoy was more reflective than ambient sediments in the SACS data but was indistinguishable from ambient in the side-scan mosaic. The SACS data outlined a "plateau" of strong acoustic returns both around the MDA buoy and to the north covering the bathymetric depression. The brightest side-scan reflectivity was limited to the area around the MDA buoy and distinct targets throughout the mosaic.

The difference in the acoustic reflection data from the high frequency side-scan sonar and the SACS data was attributed to a difference in the sediment-depth interval over which the instruments are measuring. The hypothesis was that, with time, in the depositional regime of Stellwagen Basin, the dredged material will be biologically reworked and covered with ambient silts and clays, resulting in a surficial layer that resembles ambient sediment as detected by side-scan. By contrast, the underlying layer detectable by SACS presumably will still contain somewhat coarser grained, more chaotic dredged material that has a harder acoustic return than the surface.

From these acoustic data, the objectives of the 1994 REMOTS® survey at the SACS Grid were twofold: 1) use a combination of the SACS and REMOTS® data to define the areal extent of both recent and historical dredged material; and 2) test the hypothesis that SACS data are sensitive to the presence of reworked historical dredged material, while side-scan is not. Plan view photographs were also taken; the textural surface was described and incorporated with the REMOTS® results in order to gain a three-dimensional perspective of the sediment that was sonified during the 1993 acoustical surveys.

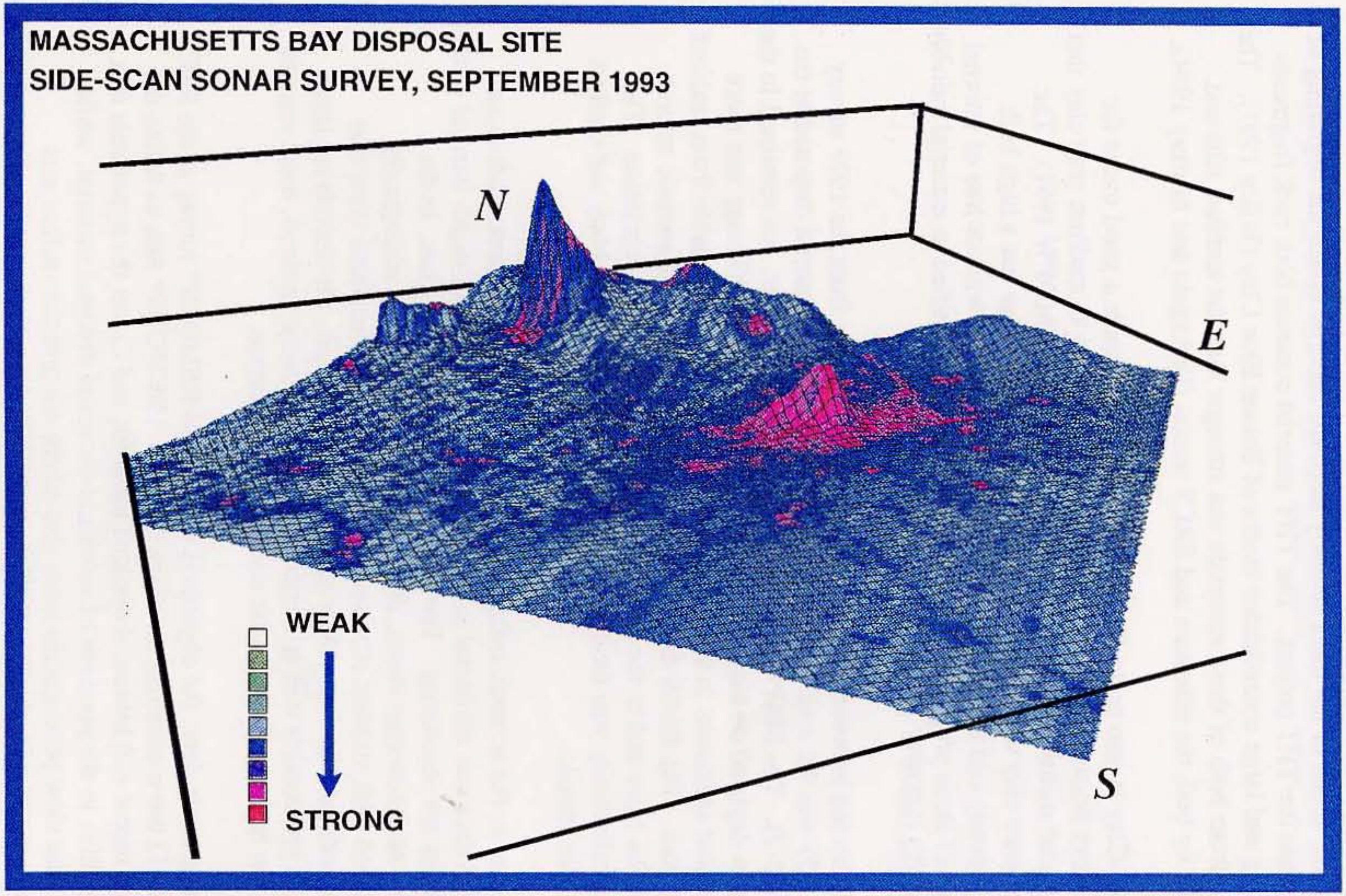

Figure 1-4. Side-scan mosaic draped over a 3-D bathymetric plot (DeAngelo and Murray 1994)

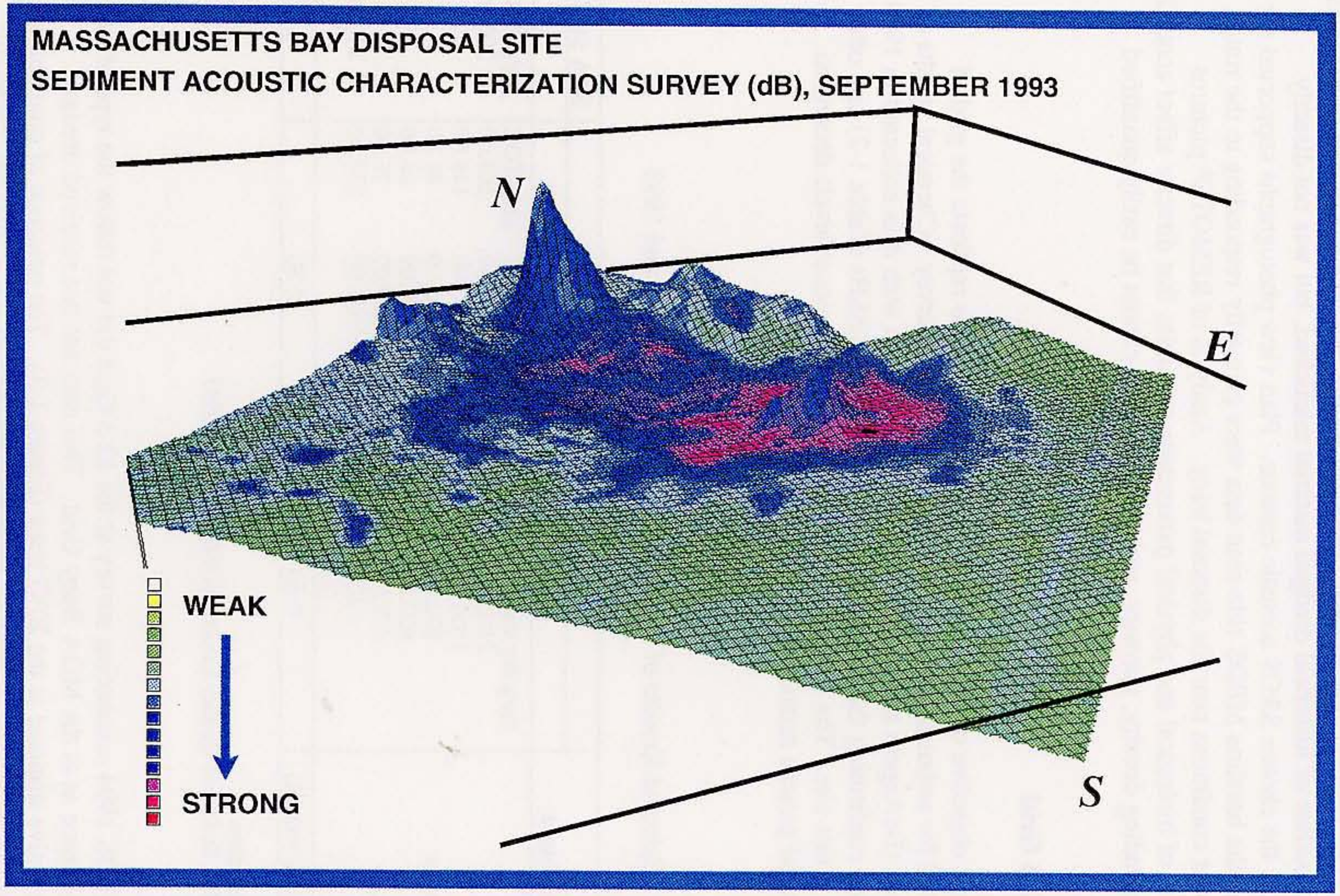

Figure 1-5. SACS contours draped over a 3-D bathymetric plot (DeAngelo and Murray 1994)

REMOTS® results were primarily analyzed for the presence or absence of dredged material. The outline of historical dredged material mimicked, but was not directly correlated with, the chosen SACS acoustic contour. Plan view photographs supported the hypothesis that the baseline MBDS side-scan data were primarily responding to the rough surface sediment conditions near the disposal buoy. Analysis of REMOTS® pictures includes a suite of biological and physical parameters; variables that directly affect acoustic impedance, including density, porosity, and water content, cannot be easily quantified visually.

1.2.3 The 12-3 Grid

The final objective of the 1994 REMOTS® survey was to replicate the grid of stations sampled for sediment chemistry in the 1993 baseline survey. Chemical results of the 1993 survey (DeAngelo and Murray 1994) were consistent with data collected in 1989 (Murray 1994), confirming the presence of elevated levels of PAHs (Table 1-2) and other contaminants at this site. The 1993 results revealed that contaminant levels decreased rapidly in a radial pattern surrounding Station 12-3.

Table 1-2

Selected Results of PAH and TOC Analyses, 1989 and 1993

PAH Compound	**Results from Station 12-3**				**EPA SQC**
	1989		1993		
	ng/g dry weight	μg/g TOC	ng/g dry weight	μg/g TOC	μg/g TOC
fluoranthene	1100.00	138.00	4700.00	168.00	300.00
pyrene	1800.00	225.00	4100.00	146.00	
benzo(a)anthracene	870.00	109.00	2300.00	82.00	
chrysene	920.00	115.00	1900.00	68.00	
benzo(a)pyrene	470.00	59.00	2100.00	75.00	
phenanthrene	<400	50.00	6500.00	232.00	240.00
TOC (percent dry weight)	0.80		2.80		

< = Below Detection
EPA SQC = EPA Sediment Quality Criteria (USEPA 1993, 1994)

The MBDS 1994 monitoring survey at the 12-3 Grid did not follow the typical field monitoring sequence as at the MDA Buoy Grid. This area has not received dredged material since active disposal at the BFG buoy (Figure 1-3). The presence of contaminants at this site was not surprising because of historical practices of waste disposal, especially since the 12-3 Grid is within the boundaries of the IWS (Figure 1-2). The presence of the contaminated sediments, however, offered an opportunity to test monitoring protocols as defined in the Tiered Monitoring approach used for DAMOS (Germano et al. 1994).

The Tiered Monitoring approach defines protocols for monitoring disposed dredged material at both unconfined and confined (capped) disposal mounds. The underlying assumption for this approach is that there is an organism-sediment successional paradigm for disturbed bottom sediments. Benthic invertebrates that colonize dredged material are used as a surrogate indicator of the effects of dredged material, and the results are extrapolated to demersal fish and crustaceans, which feed on the benthic fauna, and so on up the food chain (Germano et al. 1994). The standard approach for unconfined disposal (more appropriate for the exposed contaminated sediments at the 12-3 Grid) is to collect REMOTS® data 4-12 weeks following disposal; if a healthy Stage I community is present, then no action is recommended until the following year. The following year, a Stage II or III assemblage is expected to be present. If these hypotheses are proved incorrect, evidence for physical disturbance (generally by comparing with the reference areas) is considered to explain the lack of these assemblages. If there is no evidence for physical disturbance, a bioassay is conducted to check for sediment toxicity.

The results from the 1994 REMOTS® survey at the 12-3 Grid indicated that there is evidence for a healthy Stage III community. Two conclusions can be drawn: 1) the contaminants are not bioavailable; or 2) the contaminants are not toxic to the particular assemblage. For the former case, the contaminants will not be concentrated in the tissues of the benthic organisms, and therefore have no or little risk associated with them. In the latter case, however, if contaminants are being stored in infaunal tissues, then a potential pathway to the food chain exists. It is not possible to determine if contaminants are bioavailable and are accumulating in infaunal tissues from sediment-profile images.

The Tiered Monitoring approach relies on the ability to discern benthic community responses to habitat disturbance from REMOTS® sediment-profile images. At issue here is a question of sensitivity. Is the information that may be derived from sediment-profile images sensitive enough to detect sediment contaminants at levels that might trigger response in a laboratory bioassay? Station 12-3 results suggest that, as laboratory bioeffects testing and detection limits for sediment contaminants continue to be refined, the sensitivity for *in situ* benthic response as detected by REMOTS® may not equate to laboratory results.

2.0 METHODS

2.1 Navigation

Science Applications International Corporation (SAIC) conducted survey operations at MBDS from 8 to 9 August 1994. The SAIC Portable Integrated Navigation and Survey System (PINSS) provided the precision navigation required for all field operations. This system uses an IBM-compatible PC computer to collect position, depth, and time data for subsequent analysis and to provide real-time navigation; positions are calculated using a Kalman filter. PINSS was interfaced with a Magnavox MX4200 GPS with a MX50R DGPS (Differential Global Positioning System) receiver. Vessel positioning accuracy with DGPS is ±5 m.

During all field operations, PINSS provided the operator and the helmsman with range and bearing to selected targets (i.e., REMOTS® stations), signal quality, time of day, and current position. The positions of the stations were fixed at the point the camera reached the bottom. A Hewlett-Packard 7475A plotter recorded the station locations during survey operations, allowing the navigator to assess the ship's location relative to other targets in the area. A printer generated a hard copy of all position fixes incorporating date and time of day, and the ship's position in latitude/longitude.

2.2 Sample Design

The **MDA Buoy Grid** was a 13-station grid, with the center station located at the buoy, and three stations spaced 200 meters apart north, south, east, and west of the center station (Figure 2-1). The **SACS Grid** was designed around the 110 dB contour; this contour was used to define the outer limits of the acoustic "plateau" seen in the contoured SACS data. Thirty-four stations were placed along eight arms radiating from the MDA buoy. The stations were placed so that some fell inside and some fell outside of the 110 dB contour line (Figure 2-1). The **12-3 Grid** replicated the 13-station grid sampled in the 1993 baseline survey (Figure 2-1).

A total of 16 stations were sampled over the three MBDS reference areas to serve as a comparison for the MDA Buoy Grid stations. The reference stations were occupied randomly within a 300 meter radius of the center of each reference area. Reference data are used to compare the recolonization status at an area that has recently received dredged material so that regional effects can be monitored (e.g., a large storm removing the upper sediment surface). Thirteen stations were planned so that the number of stations would be the same as that collected at the MDA buoy; three extra stations (one per reference area) were sampled.

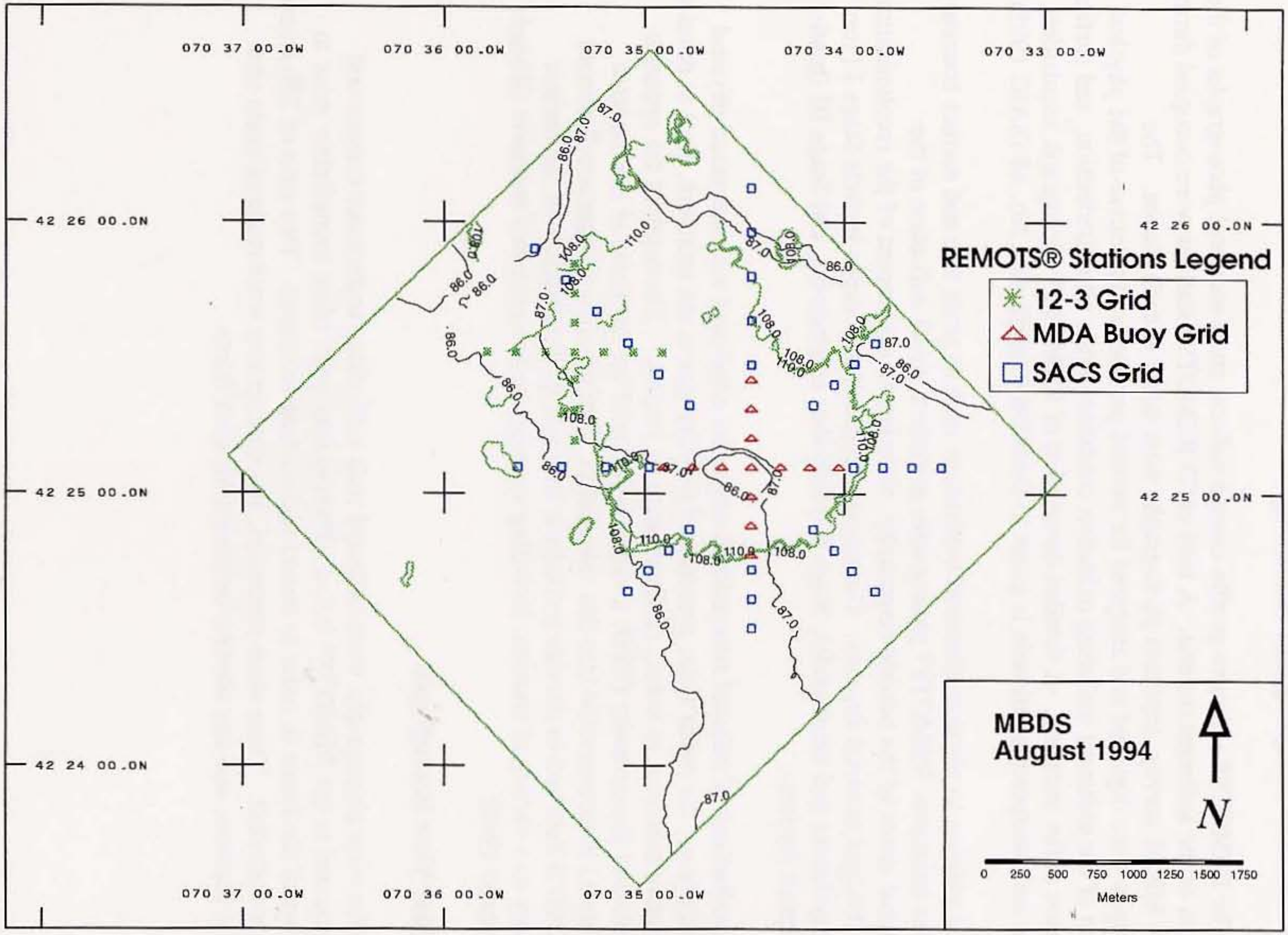

Figure 2-1. Location of the three REMOTS® grids sampled in the 1994 survey relative to the 108-110 dB contours (green) and the 86-87 m bathymetric contours (black)

2.3 REMOTS® Sampling and Processing

The REMOTS® sediment-profile camera collects cross-sectional photographs of the top 20 cm of the sediment column. A total of 73 REMOTS® stations were occupied during the 1994 MBDS survey; triplicate photographs were taken at each station. The photographs were digitized and analyzed for several parameters indicative of the physical condition of the sediment including oxidation condition, grain size distribution, and surface disturbance at the interface. A detailed description of REMOTS® photograph acquisition, analysis, and interpretive rationale is given in DAMOS Contribution No. 48 (SAIC 1985).

In addition to physical-chemical evaluations such as grain size and surface boundary roughness estimates, REMOTS® photographs provide a visual indication of the successional status of the benthic community, allowing an assessment of the recolonization rates of dredged material deposits. Documented successional stages include Stage I (very small polychaetes and amphipods), Stage II (tubicolous amphipods), and Stage III (head-down deposit feeders).

Evaluations of infaunal successional stages are combined with measured physical parameters (e.g., the redox state, presence of methane gas in the sediment, etc.) to develop a quantitative measure, or index, of disturbance or "stress." The depth of the apparent redox potential discontinuity (RPD; a visual estimate of the thickness of the oxidized surface layer) is incorporated into this calculation. The calculated Organism-Sediment Index (OSI) is believed to provide a sensitive indicator of the response of the benthic community to a variety of stresses, including exposure to contaminated sediment (Rhoads and Germano 1986).

2.4 Plan View Photographs

Plan view photographs were collected with a Photosea underwater camera and strobe mounted to the REMOTS® frame. Photographs were taken immediately prior to touchdown of the frame in order to record undisturbed sediments. Two rolls of 250 frames each were collected. These were processed, and descriptions were made of grain size, biological features, and any obvious bedforms for each frame.

3.0 RESULTS

3.1 The MDA Buoy Grid

Dredged material was detected at every replicate photograph taken from the MDA Buoy Grid (Table 3-1). The thickness of dredged material was greater than the camera penetration in 9 of the 13 stations, and in at least one replicate of every station. The material appeared to be fresh (recently disposed) at many of the replicates within 200 m of the center of the grid (Figure 3-1). Boundary roughness values averaged for each station were all less than 2 cm except for 200N, 600E, and CTR. The higher boundary roughness values at 200N and CTR were caused by physical disturbance of the surface (recent dredged material), whereas biological disturbance was the source of boundary roughness at almost all of the other replicates.

The overall modal grain size was fine material (silt and clay); variation in grain size was primarily due to the presence of small rock and shell fragments at replicates from 200N, 200W, and CTR. The average thickness of the apparent redox potential discontinuity (RPD) interval ranged from 1.0 (200N) to 3.9 cm (600S; Table 3-1).

Regardless of the obvious presence of dredged material, there was no sign of methane, reduced mud clasts, or restricted oxygen conditions, and the successional stages were relatively well developed for recently disposed dredged material. The most commonly described assemblage was Stage I organisms at the surface living over burrowing Stage III organisms (60% of all replicates). This assemblage was the mode for 7 of the 13 stations. The other six stations were mixed among the replicates and had no mode. No replicates were azoic. Only three replicates had Stage I only (one replicate each at 200W, 200N, and CTR). Several replicates contained evidence of Stage II organisms: 400N, 400S, 600E, 600S, and 600N. Four replicates had indeterminate successional stages (low penetration, camera disturbance).

More significantly, of the stations showing evidence of fresh dredged material, two of the four replicates at 200N and one replicate at 600W showed evidence of Stage III organisms. The relatively high Organism-Sediment Indices (OSIs) reflected this advanced successional stage (Table 3-1). Replicate OSIs ranged from 2 to 11; median OSI values at individual stations ranged from 6 to 11. Station 600S had the highest median OSI (11), and stations CTR (6) and 200N (6.5) had the lowest.

Table 3-1

REMOTS® Results at the MDA Buoy Grid

Station	Replicate	DM Present	Boundary Roughness (cm)	Boundary Roughness Type	Grain Size Mode	Grain Size Range	RPD (cm)	Successional Stage	OSI
200E	a	Yes	0.6	Biological	>4	1 to >4	1.11	Stage I ON Stage III	7
200E	b	Yes	1.06	Biological	>4	2 to >4	2.53	Stage I ON Stage III	9
200E	c	Yes	0.82	Biological	>4	2 to >4	3.39	Stage I ON Stage III	10
200N	a	Yes	3.21	Physical	3 to 4	-1 to >4	1.78	Stage I	4
200N	b	Yes	3.43	Physical	>4	2 to >4	0.52	IND	NA
200N	d	Yes	1.44	Physical	>4	0 to >4	1.3	Stage III	7
200N	e	Yes	0.4	Biological	3 to 4	0 to >4	0.25	Stage I ON Stage III	6
200S	a	Yes	2.59	Biological	>4	2 to >4	1.55	Stage I ON Stage III	8
200S	b	Yes	2.18	Physical	>4	3 to >4	2.14	Stage III	8
200S	c	Yes	0.17	Biological	>4	2 to >4	2.4	Stage I ON Stage III	9
200W	a	Yes	0.86	Biological	3 to 4	-1 to >4	1.32	IND	NA
200W	b	Yes	1.19	Physical	>4	2 to >4	0.47	Stage I	2
200W	c	Yes	1.09	Biological	3 to 4	1 to >4	2.5	Stage I ON Stage III	9
200W	d	Yes	2.05	Biological	3 to 4	2 to >4	0.68	Stage III	6
400E	a	Yes	0.89	Biological	>4	2 to >4	1.45	Stage I ON Stage III	7
400E	b	Yes	0.72	Biological	>4	3 to >4	2.91	Stage I ON Stage III	9
400E	c	Yes	0.6	Biological	>4	2 to >4	1.11	Stage I ON Stage III	7
400N	a	Yes	1.95	Physical	>4	3 to >4	IND	IND	NA
400N	b	Yes	1.09	Biological	>4	3 to >4	0.89	Stage I -> II	4
400N	c	Yes	0.78	Biological	>4	3 to >4	1.19	Stage I ON Stage III	7
400S	a	Yes	1.15	Biological	>4	3 to >4	1.36	Stage I ON Stage III	7
400S	b	No	1.83	Biological	>4	3 to >4	2.32	Stage II	7
400S	c	No	1.02	Biological	>4	2 to >4	2.63	Stage II ON Stage III	9
400W	a	Yes	0.43	Biological	>4	2 to >4	2.63	Stage I ON Stage III	9
400W	b	Yes	0.98	Biological	>4	2 to >4	2.25	Stage I ON Stage III	9
400W	c	Yes	1.66	Biological	>4	2 to >4	1.76	Stage I ON Stage III	8
600E	a	Yes	2.68	Biological	>4	1 to >4	2.3	Stage I ON Stage III	9
600E	b	Yes	2.12	Biological	>4	2 to >4	2.91	Stage I ON Stage III	9
600E	c	No	1.91	Biological	>4	2 to >4	1.3	Stage II ON Stage III	7
600N	a	No	1	Biological	>4	3 to >4	1.3	Stage I ON Stage III	7
600N	b	No	1.3	Biological	>4	3 to >4	3	Stage II ON Stage III	9
600N	c	Yes	0	Biological	>4	2 to >4	3.59	Stage I ON Stage III	10
600S	a	Yes	0.81	Biological	>4	3 to >4	4.4	Stage II ON Stage III	11
600S	b	No	1.7	Biological	>4	2 to >4	3.32	Stage I -> II	7
600S	c	No	0.76	Biological	>4	3 to >4	3.93	Stage I ON Stage III	11
600W	a	Yes	1.15	Biological	>4	2 to >4	2.97	Stage I ON Stage III	9
600W	b	Yes	1.82	Physical	>4	2 to >4	1.63	Stage I ON Stage III	8
600W	c	Yes	1.95	Biological	>4	2 to >4	1.24	Stage I ON Stage III	7
CTR	a	Yes	2.85	Physical	>4	1 to >4	1.7	Stage I	4
CTR	b	Yes	2.32	Physical	>4	0 to >4	0.7	Stage I ON Stage III	6
CTR	c	Yes	1.7	IND	2 to 3	1 to 4	IND	IND	NA

Figure 3-1. REMOTS® photograph at Station 200W, Replicate C, of fresh dredged material disposal at the MDA Buoy Grid

3.1.1 Reference Area Results

Sixteen reference stations were sampled over three MBDS reference areas to serve as a baseline for comparing the MDA Buoy Grid results. Results from the reference areas were pooled for comparison with the MDA Buoy Grid stations (Table 3-2). The overall modal grain size was fine material (>4 phi) at all replicates of the reference areas. The apparent RPD thickness averaged over the three replicates at each station ranged from 1.7 (MBD-REF) to 8.25 cm (SE).

Stage III was present in almost all of the replicate photographs, except for two replicates at MBD-REF and one replicate at SE. One of the replicates at MBD-REF only showed evidence of Stage I, but the penetration was low, so Stage III could have been missed. Eleven replicates (most from MBD-REF) had Stage I on Stage III indicating some recent disturbance of the sediment. Stage II was also common in the photographs (Table 3-2).

The most common median OSI was 11; 11 of the 16 stations had a median OSI of 11. The lowest OSI was 7 at one of the MBD-REF stations. This was due to low RPD (1-3 cm) and one replicate having low penetration. Two stations had an OSI of 9, and one had an OSI of 10; these stations were all at MBD-REF. Finally, one station at FG-23 had an OSI of 10.5. The relatively high Organism-Sediment Indices (OSIs) reflected the advanced successional stage, and the well-oxygenated ambient sediments.

3.2 The SACS Grid

Dredged material was detected in all of the replicates of 12 of the 34 SACS stations (Table 3-3). Fourteen stations were designated as "ambient" stations because no dredged material was detected in any of the replicates of OSI stations. Ambient (no sign of dredged material) was mapped as a zero (0) on Figure 3-2, and dredged material was mapped as a one (1). In six of the stations, the replicates were inconsistent; either not all of the replicates showed evidence of dredged material, or the presence of dredged material was questionable. This is the two (2) category in Figure 3-2. In this latter group, the presence of high-reflectance Boston Blue Clay was considered evidence of dredged material, even if the clay was a minor constituent in an otherwise healthy, well-colonized, reworked, and oxidized sediment (e.g., Figure 3-3).

Stations that showed no evidence of dredged material were concentrated in the southern and eastern transects (Figure 3-2). The northern and western transects indicated that historical dredged material extended throughout much of the northwestern half of

Table 3-2

REMOTS® Results at the Reference Areas

Reference Area	Station	Replicate	DM Present	Boundary Roughness (cm)	Boundary Roughness Type	Grain Size Mode	Grain Size Range	RPD (cm)	Successional Stage	OSI
MBD-REF	1	a	No	0.74	IND	>4	3 to >4	IND	Stage III	NA
MBD-REF	1	b	No	1.3	Biological	>4	2 to >4	4.71	Stage III	11
MBD-REF	1	c	No	1.17	Biological	>4	2 to >4	4.87	Stage III	11
MBD-REF	2	a	No	0.87	Biological	>4	3 to >4	2.98	Stage I ON Stage III	9
MBD-REF	2	b	No	1.48	Physical	>4	3 to >4	2.8	Stage I	5
MBD-REF	2	c	No	0.74	Biological	>4	3 to >4	5	Stage I ON Stage III	11
MBD-REF	3	a	No	1.48	Biological	>4	3 to >4	3.65	Stage I ON Stage III	10
MBD-REF	3	b	No	0.91	Biological	>4	3 to >4	5.78	Stage I ON Stage III	11
MBD-REF	3	c	No	0.65	Biological	>4	to >4	2.26	Stage I ON Stage III	9
MBD-REF	4	a	No	0.52	IND	>4	to >4	2.41	Stage I	5
MBD-REF	4	b	No	1.13	Biological	>4	2 to >4	1.35	Stage I ON Stage III	7
MBD-REF	4	c	No	1.3	Biological	>4	2 to >4	1.35	Stage I ON Stage III	7
MBD-REF	5	a	No	1.48	Biological	>4	4 to >4	IND	IND	NA
MBD-REF	5	b	No	1.22	IND	>4	to	IND	IND	NA
MBD-REF	CTR	a	No	1.17	Biological	>4	3 to >4	2.71	Stage II ON Stage III	9
MBD-REF	CTR	b	No	1.69	Biological	>4	3 to >4	2.45	Stage II ON Stage III	9
FG-REF	1	a	No	0.17	IND	>4	4 to >4	7.24	IND	NA
FG-REF	1	b	No	2.43	Biological	>4	3 to >4	7.5	Stage II ON Stage III	11
FG-REF	1	c	No	1.3	Physical	>4	3 to >4	7.52	Stage III	11
FG-REF	2	b	No	1.22	IND	>4	3 to >4	7.8	Stage III	11
FG-REF	2	c	No	1.3	Biological	>4	3 to >4	7.52	Stage II ON Stage III	11
FG-REF	2	d	No	1.74	IND	>4	3 to >4	8.22	Stage III	11
FG-REF	3	b	No	0.65	Biological	>4	2 to >4	9.13	Stage III	11
FG-REF	3	c	No	1.83	Biological	>4	3 to >4	6.89	Stage II ON Stage III	11
FG-REF	4	b	No	2.65	Biological	>4	3 to >4	7.26	Stage III	11
FG-REF	4	c	No	0.52	IND	>4	2 to >4	6.09	Stage III	11
FG-REF	4	d	No	2.83	Physical	>4	2 to >4	5.43	Stage III	11
FG-REF	CTR	a	No	0.77	Biological	>4	2 to >4	3.53	Stage I ON Stage III	10
FG-REF	CTR	d	No	1.96	IND	>4	3 to >4	IND	IND	NA
FG-REF	CTR	e	No	4.09	Biological	>4	3 to >4	7.37	Stage III	11
SE-REF	1	b	No	0	IND	>4	to	IND	Stage III	NA
SE-REF	1	d	No	0.83	Biological	>4	2 to >4	8.25	Stage III	11
SE-REF	2	a	No	1.78	Biological	>4	2 to >4	6.62	Stage II ON Stage III	11
SE-REF	2	b	No	4.04	Biological	>4	2 to >4	4.17	Stage I -> II	8
SE-REF	2	c	No	1	Biological	>4	2 to >4	8.38	Stage II ON Stage III	11
SE-REF	3	b	No	2.65	Biological	>4	3 to >4	7.62	Stage I ON Stage III	11
SE-REF	3	c	No	0.43	Biological	>4	3 to >4	6.06	Stage III	11
SE-REF	3	d	No	1.09	Biological	>4	3 to >4	8.77	Stage II ON Stage III	11
SE-REF	4	a	No	1.3	Biological	>4	3 to >4	6.8	Stage III	11
SE-REF	4	b	No	0.96	Biological	>4	3 to >4	2.98	Stage II ON Stage III	9
SE-REF	4	c	No	0.74	Biological	>4	2 to >4	6.82	Stage II ON Stage III	11
SE-REF	5	a	No	0.78	Biological	>4	3 to >4	6.62	Stage I ON Stage III	11
SE-REF	5	b	No	1.56	Physical	>4	2 to >4	10.45	Stage I ON Stage III	11
SE-REF	5	c	No	1.95	Biological	>4	2 to >4	5.91	Stage II ON Stage III	11

Table 3-3

REMOTS® Results at the SACS Grid

Station	Replicate	DM Present	Grain Size Mode	RPD Range (cm)
700N	A	Yes	>4	4-5
700N	B	Yes	4-3	>6
1000N	A	Yes	>4	3
1000N	B	Yes	>4	3
1000N	C	Yes	>4	3
1300N	A	Yes	>4	IND
1300N	B	Yes	>4	2.5
1300N	C	Yes	>4	IND
1600N	A	Yes	>4	2-3
1600N	B	Yes	>4	3
1600N	C	Yes	>4	2-3
1900N	B	No	>4	4
1900N	C	No	>4	OVERPEN
1900N	D	No	>4	4
600NE	A	No	>4	4
600NE	B	No	>4	4-5
600NE	C	No	>4	4-5
800NE	A	No	>4	4-5
800NE	B	No	>4	4-5
800NE	C	No	>4	4-5
1000NE	A	No	>4	4-5
1000NE	B	No	>4	4-5
1000NE	C	No	>4	4-5
1200NE	A	No	>4	4-5
1200NE	B	No	>4	4-5
1200NE	C	No	>4	4-5
700E	A	No	>4	IND
700E	B	No	>4	>6
700E	C	No	>4	3-4
900E	A	Yes	>4	4-5
900E	B	Yes	>4	2-3
900E	C	Yes	>4	2
1100E	B	No	>4	4-5
1100E	C	No	>4	3-4
1300E	A	No	>4	4-5
1300E	B	No	>4	4-5
1300E	C	No	>4	>4-5
600NW	A	Yes	>4	PULL AWAY
600NW	B	Yes	>4	2-3
600NW	C	Yes	>4	2-3
900NW	A	Yes	>4	3-4
900NW	B	Yes	>4	3-4
900NW	C	Yes	>4	3-4
1200NW	A	Yes	>4	3-4
1200NW	B	Yes	>4	3-4
1200NW	C	Yes	>4	3-4
1500NW	C	Yes	>4	3-4
1500NW	B	Yes	>4	3-4
1800NW	A	Yes	>4	4-5
1800NW	B	Yes	>4	4-5
1800NW	C	Yes	>4	4-5
2100NW	A	Possibly	>4	4-5
2100NW	B	Possibly	>4	4-5
2100NW	C	Possibly	>4	4-5
600SE	A	No	>4	2-3
600SE	B	No	>4	>6
600SE	C	No	>4	4-5
800SE	A	Yes	>4	2-3
800SE	B	Yes	>4	1-2
800SE	C	Yes	>4	2-3
1000SE	A	No	>4	4-5
1000SE	B	No	>4	4-5
1000SE	C	No	>4	4-5
1200SE	D	No	>4	4-5
1200SE	E	No	>4	4-5
1200SE	G	No	>4	4-5
700W	A	Yes	>4	3-4
700W	B	Yes	>4	3-4
700W	C	Yes	>4	3-4
1000W	A	Possibly	>4	4-5
1000W	B	No	>4	4-5
1000W	C	No	>4	4-5
1300W	A	No	>4	>6
1300W	B	No	>4	2-3
1300W	D	No	>4	4-5
1600W	A	Yes	>4	1-2
1600W	B	Yes	>4	>3
1600W	C	Yes	>4	3
2100NW	D	Possibly	>4	4-5
2100NW	E	Possibly	>4	2-3
1800NW	D	Yes	>4	IND
1800NW	F	Yes	>4	IND
1800NW	G	Yes	>4	4-5
1100E	D	No	>4	4-5
1100E	E	No	>4	4-5
1300E	D	No	>4	4-5
1300E	E	No	>4	4-5
1300E	F	No	>4	4-5
1200SW	A	No	>4	2-13
1200SW	B	No	>4	1-2
1200SW	C	No	>4	2-3
1000SW	A	Possibly	>4	1-2
1000SW	B	Possibly	>4	1-3
1000SW	C	Yes	>4	2-3
800SW	D	No	>4	2-4
800SW	E	No	>4	2-3
800SW	F	No	>4	2-3
600SW	D	No	>4	2-4
600SW	E	No	>4	1-2
600SW	F	No	>4	2-3
700S	A	No	>4	2-3
700S	B	No	>4	2-3
700S	C	Yes	>4	2-3
900S	A	Yes	>4	1-3
900S	B	Yes	>4	2-3
900S	C	No	>4	1-2
1100S	A	No	>4	2-3
1100S	B	No	>4	2-3
1100S	C	No	>4	1-2

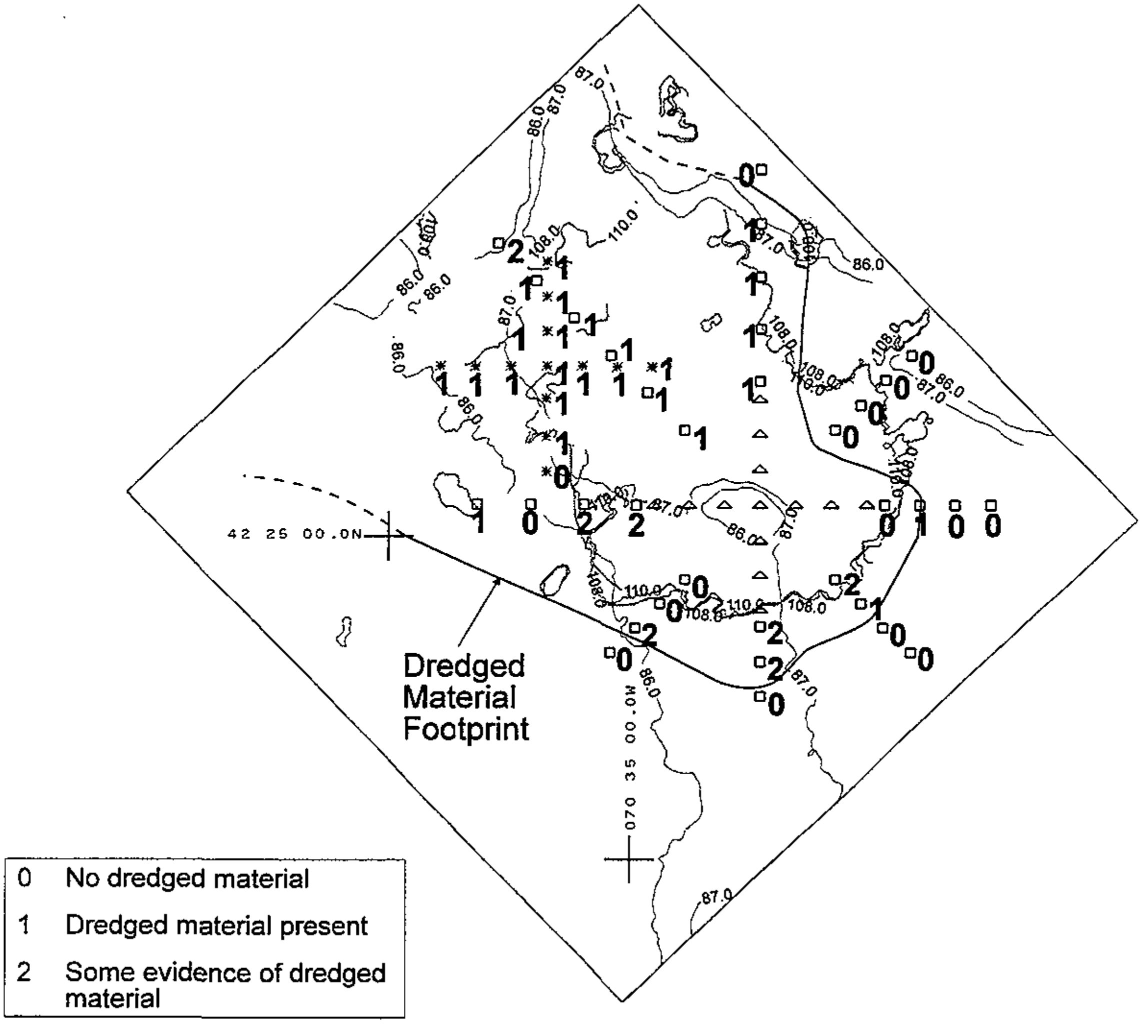

Figure 3-2. SACS REMOTS® stations showing the areal extent of historical dredged material, relative to the 110 dB SACS contour

Figure 3-3. REMOTS® photograph at SACS Grid Station 700W, Replicate B, showing traces of Boston Blue Clay

MBDS. All three replicates of the farthest northern station contained no dredged material, suggesting the limit of dredged material to the north.

3.3 The 12-3 Grid

Dredged material was present in almost all of the replicate photographs and present at every station except 600S (Table 3-4). The thickness of the apparent RPD was variable between the 12-3 Grid stations. The replicate-averaged RPD ranged from 1.46 to 5.86 (Table 3-4). The shallower RPDs were reflective of a thin oxidized layer overlying black, anoxic sediments, typically with high sediment oxygen demand (SOD; Figure 3-4). Although there was no visual sign of methane (usually obvious in photographs because of its high reflectivity), several stations showed signs of reduced mud clasts.

Despite the presence of high SOD sediments, Stage III organisms were present in all but 7 of the 34 replicate photographs taken at the 12-3 Grid, and in at least one replicate of every station (Table 3-4). Of the 7 replicates lacking Stage III, 6 contained Stage II, and one was indeterminate. Stage I or II living over Stage III was the most common successional stage mode (Table 3-4).

Because of the relatively consistent successional status of the REMOTS® photographs, the thicknesses of the apparent RPDs were the primary factor influencing the final set of calculated OSIs. Median OSIs varied from 6 to 11 at the 12-3 Grid stations (Table 3-4).

Table 3-4

REMOTS® Results at the 12-3 Grid

Station	Replicate	DM Present	Boundary Roughness (cm)	Boundary Roughness Type	Grain Size Mode	Grain Size Range	RPD (cm)	Successional Stage	OSI
200N	a	No	0.7	Biological	>4	3 to >4	4.11	Stage II ON Stage III	11
200N	b	Yes	0.96	Biological	>4	2 to >4	7.37	Stage II ON Stage III	11
200N	c	Yes	1.3	Biological	>4	2 to >4	6.11	Stage I ON Stage III	11
200S	a	Yes	0.61	Biological	>4	2 to >4	5.8	Stage I ON Stage III	11
200S	b	Yes	0.65	IND	>4	2 to >4	4.76	Stage III	11
200S	c	Yes	2.17	Biological	>4	2 to >4	3.85	Stage II ON Stage III	11
400N	a	Yes	1.16	Biological	>4	2 to >4	4.28	Stage I ON Stage III	11
400N	b	Yes	2.76	Physical	>4	2 to >4	2.4	Stage I ON Stage III	9
400N	c	Yes	1.5	Biological	>4	2 to >4	2.52	Stage II ON Stage III	9
400S	a	Yes	0.91	Biological	>4	2 to >4	4.13	Stage II ON Stage III	11
400S	b	Yes	1.13	Biological	>4	2 to >4	4.52	Stage II ON Stage III	11
400S	c	No	0.7	Biological	>4	2 to >4	3.5	Stage II	8
600S	a	No	1.61	Biological	>4	2 to >4	3.37	Stage II ON Stage III	10
600S	b	No	2.83	Biological	>4	2 to >4	3.43	Stage II	8
600S	c	No	1.43	Biological	>4	2 to >4	4.54	Stage II ON Stage III	11
CTR	a	Yes	0.83	Biological	>4	2 to >4	2.96	Stage I ON Stage III	9
CTR	b	Yes	2.39	Biological	>4	3 to >4	3.37	Stage I ON Stage III	10
CTR	c	Yes	3.7	Biological	>4	2 to >4	5.41	Stage II ON Stage III	11
200E	b	Yes	1.82	Biological	>4	3 to >4	1.85	Stage I ON Stage III	8
200E	c	Yes	2.22	Biological	>4	3 to >4	1.87	Stage I ON Stage III	8
200E	d	Yes	1.61	Biological	>4	3 to >4	1.11	Stage I ON Stage III	7
200W	a	Yes	1.43	Biological	>4	3 to >4	2.63	Stage I ON Stage III	9
200W	b	Yes	0.65	Biological	>4	3 to >4	1.87	Stage II ON Stage III	8
200W	c	Yes	1	Biological	>4	3 to >4	2.13	Stage II ON Stage III	8
400E	a	Yes	1.91	Biological	>4	3 to >4	1.67	Stage II	6
400E	b	Yes	1.13	Physical	>4	3 to >4	2.52	Stage III	9
400E	c	Yes	0.96	Biological	>4	3 to >4	1.61	Stage II	6
400W	a	Yes	2.95	Biological	>4	3 to >4	1.8	Stage II ON Stage III	8
400W	b	Yes	0.65	Biological	>4	3 to >4	1.91	Stage II ON Stage III	8
400W	c	Yes	0.56	Biological	>4	3 to >4	2.32	Stage II ON Stage III	9
600E	a	Yes	0.83	Biological	>4	3 to >4	1.5	Stage II ON Stage III	7
600E	b	Yes	2.04	Biological	>4	3 to >4	1.59	Stage II ON Stage III	8
600E	c	Yes	0.52	Biological	>4	3 to >4	1.3	Stage II	5
600N	a	Yes	1.04	Biological	>4	3 to >4	2.06	Stage II	6
600N	b	Yes	2.56	Biological	>4	3 to >4	2.26	Stage III	9
600N	c	Yes	1	Biological	>4	3 to >4	2.09	Stage II ON Stage III	8
600W	a	Yes	0.22	Biological	>4	3 to >4	2.13	Stage II ON Stage III	8
600W	b	Yes	1.39	Biological	>4	3 to >4	3.15	Stage I ON Stage III	10
600W	c	No	3.61	IND	>4	to >4	IND	IND	IND

Figure 3-4. REMOTS® photograph at Station 200W, Replicate B, showing evidence of Stage III living over high SOD sediments

4.0 DISCUSSION

4.1 Benthic Recolonization at the MDA Buoy

The median OSIs of the MDA Buoy Grid stations were lower than those from the pooled reference areas (Figure 4-1). Median OSIs for the MDA Buoy Grid stations were evenly distributed between 5 and 11, with 9 being the most common OSI. Only one station, CTR, had an OSI lower than 6 (considered to be indicative of a stressed environment); because of the recent disposal at this station, this result is not unexpected.

Median MDA Buoy Grid OSIs were also compared with the individual reference areas (Figure 4-2). These results show that all of the OSIs that were 10 or below came from the new MBD-REF reference area. This reference area was just designated last year to replace a historical MBDS reference area (18-17), considered to be not representative of ambient conditions because of its close proximity to the disposal site and because of previous data collected there. The new reference area is located south of the MBDS, and east of FG-23 (Figure 1-1), within the Stellwagen Bank Marine Sanctuary. The low OSIs reflect thinner RPDs than at the other reference areas; the range is 1.7-4.79 (relative to 5.45-8.01 at FG-REF and 5.53-8.25 at SE; Table 3-2).

The results from the MDA Buoy Grid indicate that the active disposal is not impeding benthic recolonization. In fact, some of the assemblages appear to be so advanced that it is possible that the disposal of dredged material has not disrupted the benthic communities at all. The barge release locations as documented by NED disposal logs (Figure 4-3) indicate a concentration of disposal points at the buoy location. Because of the patchy distribution of dredged material, it is possible that most of the MDA Buoy Grid stations were sampled in areas that had not recently received dredged material, except for those stations near the center of the grid.

The results from the new MBDS reference area (MBD-REF) indicate a generally thinner RPD interval than was observed at the other two reference areas. The presence of an apparently healthy late stage benthic assemblage suggests that the RPDs may be a result of a high sediment oxygen demand (SOD). The 1994 survey represents the first time REMOTS® data has been collected at this reference area. With the limited data available it is difficult to ascertain whether the thin RPDs are within the range of natural variability or are due to anthropogenic input of organically enriched material. Results from the August 1994 REMOTS® survey at the Boston Lightship Disposal Site also identified areas with apparently high SODs and thin RPDs, suggesting that high SOD sediments may not be uncommon in Massachusetts Bay.

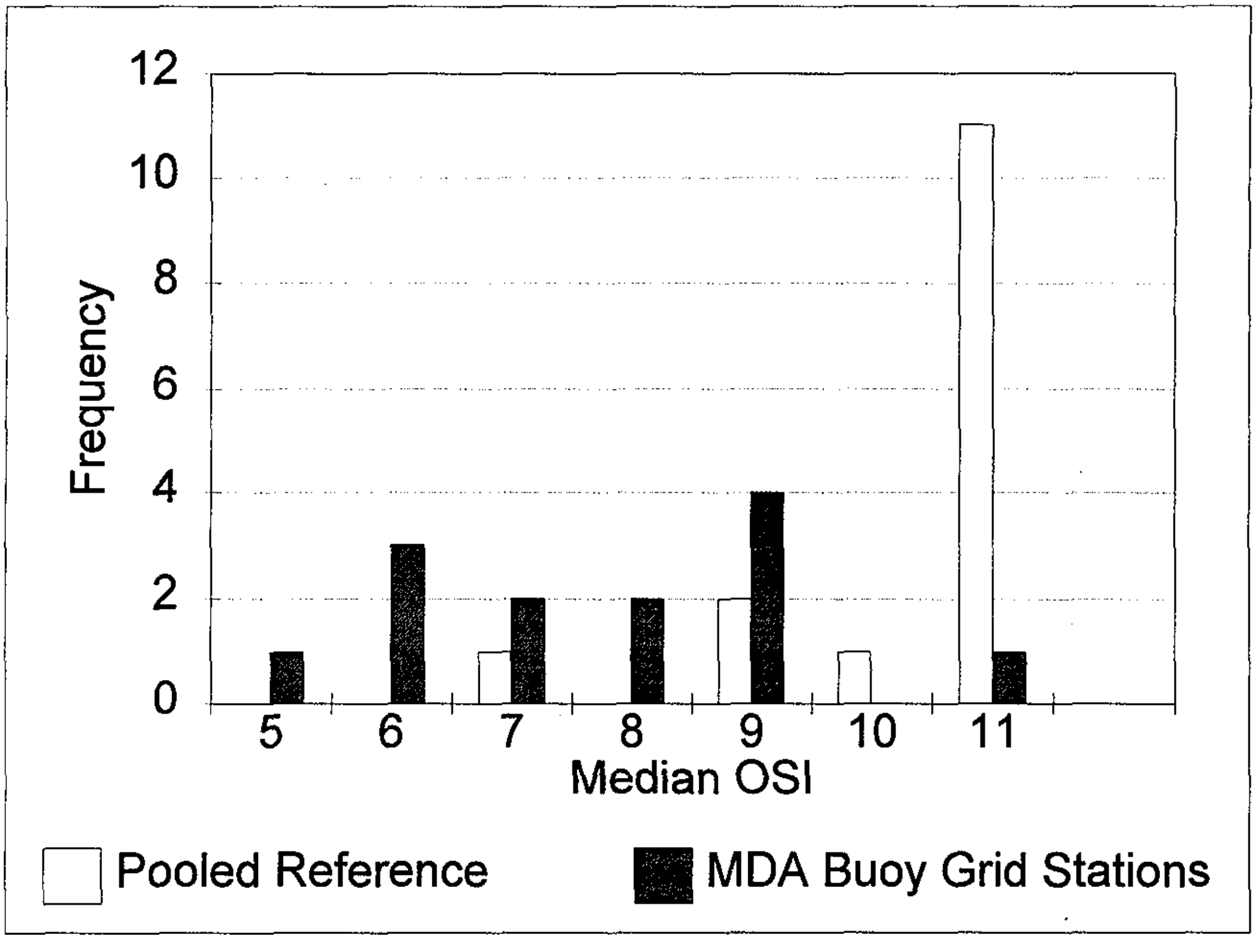

Figure 4-1. OSI at MDA Buoy Grid versus cumulative reference areas

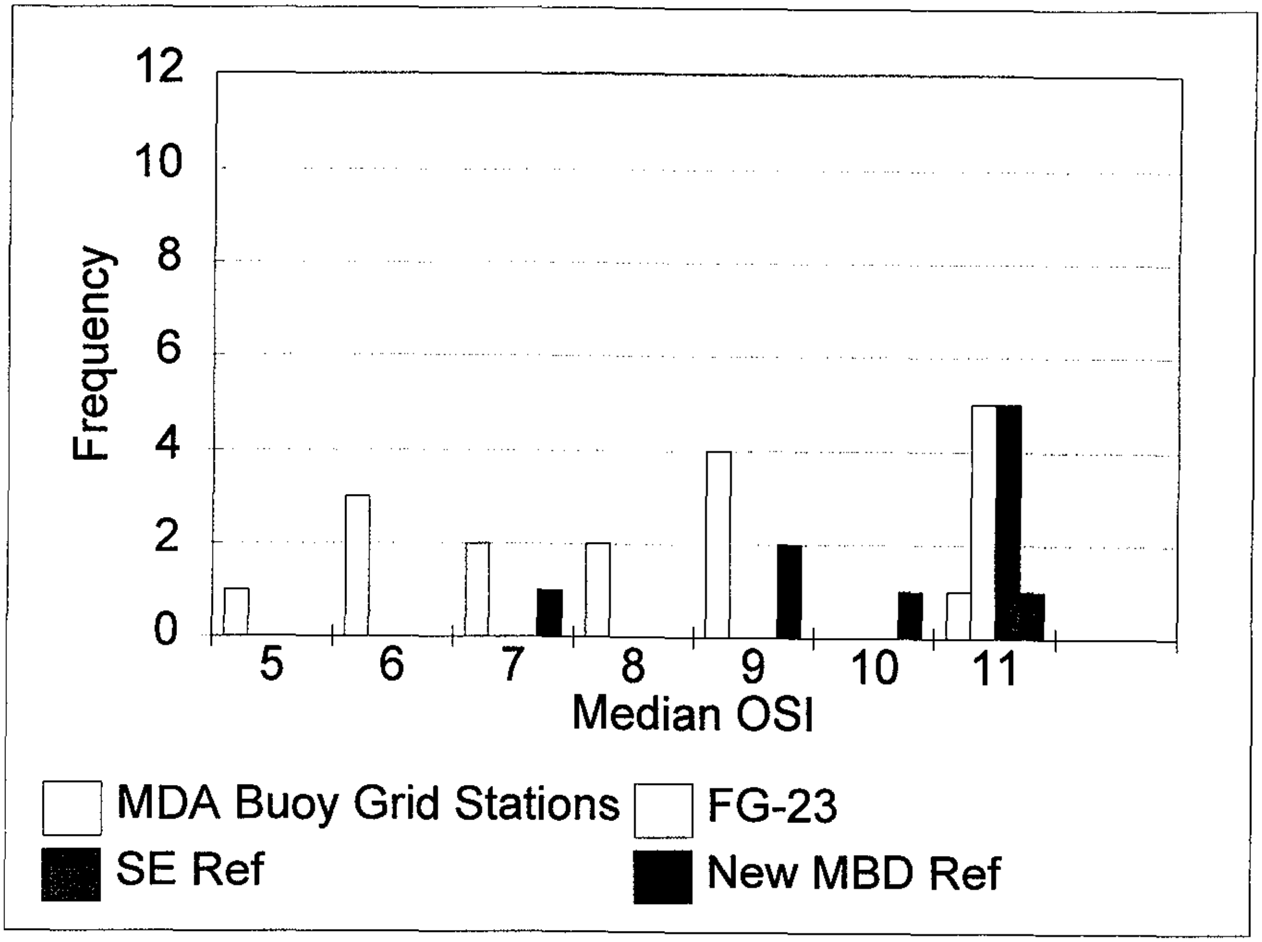

Figure 4-2. OSI at MDA Buoy Grid versus individual reference areas

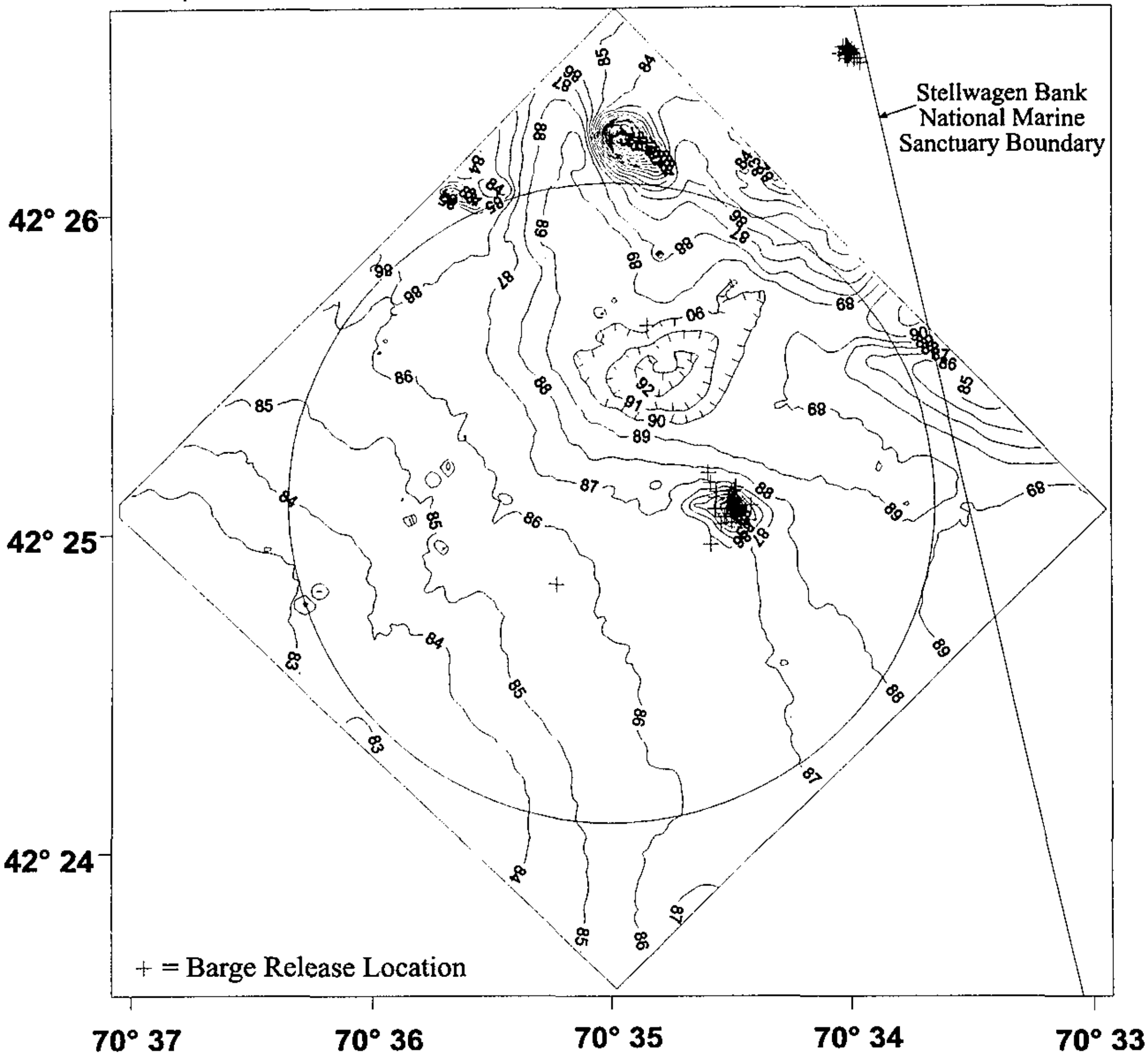

Figure 4-3. Barge release locations from August 1993 to August 1994 (contours in meters)

4.2 REMOTS® Ground-Truthing of Acoustic Data

Comparing the REMOTS® data from the SACS Grid to the acoustic results from 1993 (Figure 4-4) suggests that the SACS data were relatively accurate in detecting both recent and historical dredged material. To the south and east, the acoustic footprint extended farther than indicated by the REMOTS® photographs. The presence of the uncertain stations (triangles in Figure 4-4) suggests that the limits of detection for dredged material that is almost completely reworked are different for the acoustic and visual data. The only evidence of dredged material in some of these photographs is some minor, but very reflective, Boston Blue Clay (Figure 3-3).

Plan view photographs showed fairly consistent sandy silt bottom with variable degrees of bioturbation. The other extreme was a rocky surface, documented at several stations (CTR, 200N, 200W, and 400N), or large clay clumps, both indicative of fresh dredged material. Comparing the plan view (Figure 4-5) and REMOTS® photographs (Figure 3-1) allowed for a three-dimensional view of this highly textured bottom. The brightest side-scan reflections were probably a result of these coarser materials which have been covered or broken down in the older material.

Other indicators measured were not directly correlatable with the acoustic data. Grain size major mode was fairly consistent throughout the photographs. The major mode, however, is determined from the entire photographed section; perhaps an estimate of the major mode of the upper 2 cm would be more appropriate in terms of looking for acoustical variation. The variation of the RPD was looked at as a possible indicator for the amount of reworking, and therefore the homogeneity of the sediment. This variable is less a function of geotechnical parameters such as density and porosity than it is of chemical parameters that do not affect the acoustic impedance. Geotechnical parameters such as density, porosity, and water content presently cannot be measured directly from the REMOTS® photographs.

4.3 Testing Tiered Monitoring Protocols: The 12-3 Grid

Results of sampling at the 12-3 Grid indicated no strong evidence that the PAHs present at this area, especially at the center station, are affecting the benthic community. Although many stations showed the presence of historic dredged material, almost all of the replicates had a healthy, well-developed benthic community.

Several replicate photographs showed minor evidence of chemical oxygen demand (Figure 3-4) in the sediments as evidenced by reduced mud clasts at 200N and 400N. The presence of methane or overall low oxygen conditions, however, was not noted.

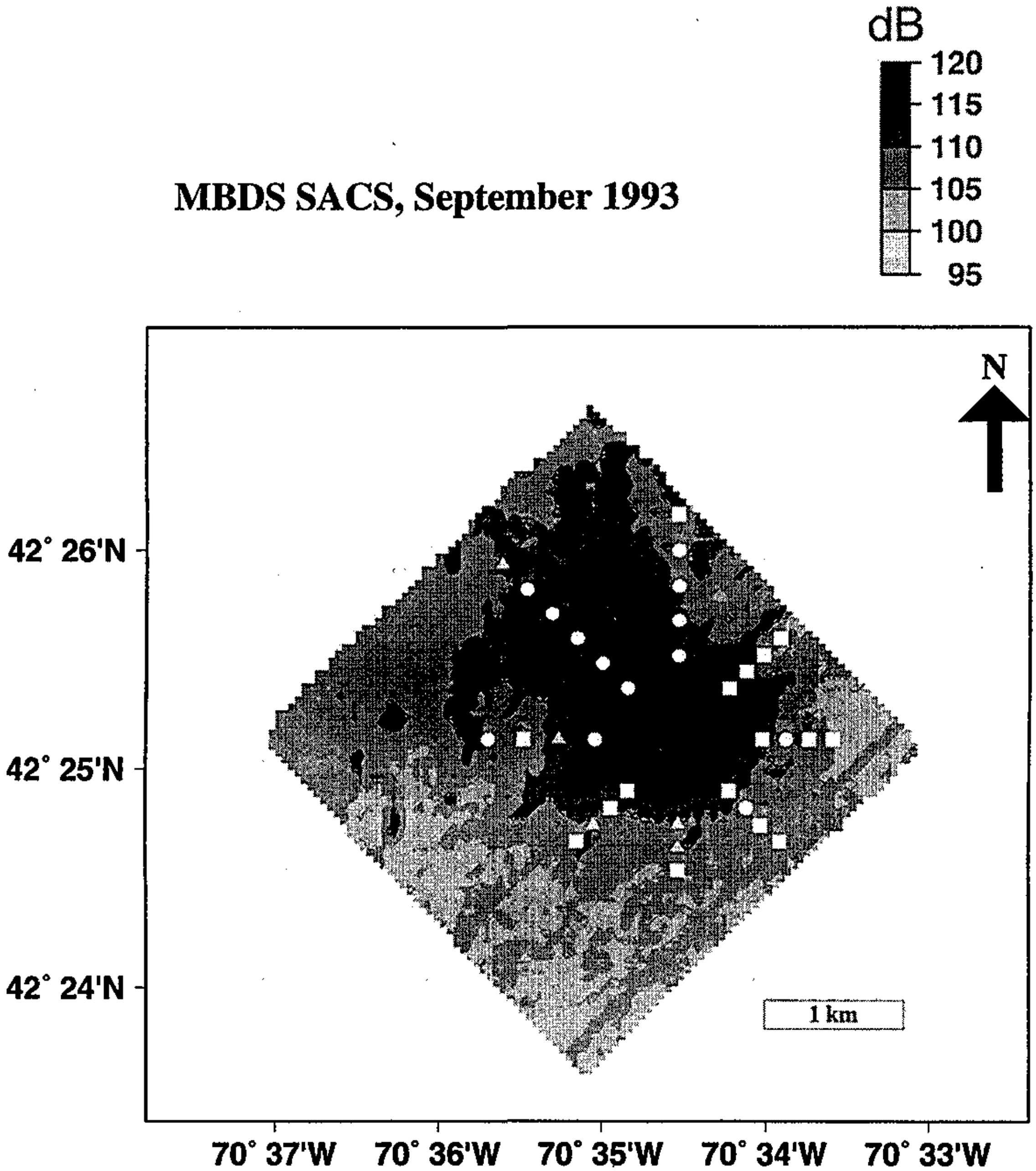

Figure 4-4. SACS data from MBDS baseline survey with locations of SACS Grid stations. Circles indicate dredged material present; squares indicate no dredged material; and triangles indicate mixed results.

Figure 4-5. REMOTS® plan view photograph at MDA Buoy Grid Station 200N showing evidence of fresh dredged material

REMOTS® parameters at Station CTR, equivalent to historical Station 12-3, were not distinctive in any way from other stations in the grid. These results indicate that the presence of the contaminant levels measured in prior surveys has not prevented the development of a normal benthic community at these stations.

Based on the Tiered Monitoring method of dredged material monitoring (Germano et al. 1994) for unconfined disposal, the presence of an apparently healthy infaunal community composed of late successional stage seres at Station 12-3 indicates that no further investigation other than periodic monitoring is required. However, the results from previous chemical analyses (1989 and 1993) of the sediments from this station indicate elevated levels of organic contaminants and heavy metals. For example the concentration of phenanthrene normalized to TOC in 1993 was 232 mg/g organic carbon, a value close to the EPA sediment quality criteria (SQC) limit of 240 mg/g organic carbon (USEPA 1993, 1994). This case presents a situation where the benthic infauna are living in and feeding on low to moderately contaminated sediments and leaves open the question of whether the infauna are accumulating the contaminants in their tissues and passing them on to their predators (demersal fish and shellfish).

Operationally, Station 12-3 poses little risk to the ecology of Massachusetts Bay. The observed contaminant "hot spot" represents a small patch of the seafloor, less than 400 m in diameter based on the 1993 radial sampling grid. Further small scale patchiness within the station was also indicated by the variability in TOC content of the sediments between sediment sampling surveys (0.8% in 1989 and 2.8% in 1993). Finally, the measured analytes were only considered marginally contaminated, and the high instrument detection limits make it difficult to draw definite conclusions concerning potential contamination from the 1989 and 1993 results. Because demersal fish and shellfish generally feed over large areas, and the primary contaminants in question, PAHs, do not biomagnify, there is little chance that significant contaminant levels will enter the food chain via the benthic infauna living in the sediments of Station 12-3.

Station 12-3 may provide an opportunity for DAMOS managers to evaluate the sensitivity of REMOTS® and the assumptions upon which Tiered Monitoring is based. Under Tiered Monitoring, REMOTS® sediment-profile images are used to assess the infaunal successional status and activity following disposal activity. The early Stage I colonizers are presumed to be least sensitive to sediment contamination because they are filter feeders and surface deposit feeders that reside near the sediment-water interface where rapid exchange with oxygenated water may deplete or degrade many contaminants. Conversely, the late Stage III colonizers which are the head-down conveyor belt deposit feeders are presumed to be most sensitive due to their close association with the sediment fabric. If, after a sufficient amount of time has passed to allow benthic recovery, no evidence of a Stage III community is observed in REMOTS® images collected from a disposal mound, then tiered monitoring prescribes further investigation to determine if delayed recovery is due to toxic components of the sediments.

Station 12-3 appears to be a case where, either due to actual concentration or high infaunal tolerance, contaminant levels are not quite high enough to have a toxic effect on the benthic community but are still considered unacceptably contaminated. Here unacceptably contaminated is a definition based on current permitting standards developed from observations of laboratory populations. Studies suggest that, when Stage III species survive in these sediments, they may accumulate contaminants in their fatty tissue, which opens a potential pathway into the food chain through benthic predators.

REMOTS® observations from the other sampling grids suggest that the Stage III community at MBDS is fairly robust. For example, at the MDA mound, there probably had not been enough time between the end of disposal activity and this survey for the benthic community that was observed to establish itself through normal succession. More likely, the Stage III species evident on the mound survived anastrophic burial and repopulated the sediments from the bottom up through escape burrowing.

One can view Station 12-3 as a situation where a robust, highly tolerant Stage III community has established itself in low to moderately contaminated sediments. From the data available it is not possible to determine whether the contaminants are bioavailable and/or whether they are being accumulated in the tissue of the infaunal population. To address this situation further, sampling is required, for which there are several options.

Bulk sediments may be collected from the station and subjected to the same laboratory toxicity and bioaccumulation screening that is conducted during the permitting process (28-day bioaccumulation test, USEPA/USACE 1991). While this would allow the current permitting standards to be used as a reference benchmark, it may not be truly representative of actual field conditions and benthic community response. A second option is to collect and analyze field sediment and tissue samples. This has the advantage of determining actual body burdens. However, given the apparent small-scale patchiness at the station, it would be difficult and expensive to collect enough samples from the contaminated sediments to have statistical confidence. A final option may be to use new technologies such as SAIC's Hyperspectral UV Imaging Spectrometer to find localized "hot spots" for sediment and tissue sampling.

5.0 SUMMARY AND RECOMMENDATIONS

Sampling at the MDA Buoy Grid indicated that dredged material disposal over the 1993-94 disposal season was not a deterrent to healthy benthic recolonization. The widespread presence of Stage III organisms indicated that many of the stations may not even have received dredged material within the last year.

REMOTS® results from the reference areas revealed the newest reference area, MBD-REF, was characterized by high SOD sediments as suggested by thinner RPD values than were measured at the two other reference areas. This is the first time REMOTS® sampling was used at this location, which makes it difficult to determine if the observed thin RPDs are within the natural variability for the area and not due to some anthropogenic disturbance. During future REMOTS® surveys in this area, RPD values should be examined closely to determine if the conditions observed during the present survey are persistent.

Sampling at the SACS Grid indicated that the SACS data were relatively accurate in outlining the footprint of historical dredged material. The results from several stations with questionable signs of historical dredged material indicated that both SACS and REMOTS® are limited in detecting the presence of highly reworked dredged material. The plan view photographs supported the hypothesis that side-scan data are most sensitive to fresh dredged material that still retains a rough, irregular surface.

Station 12-3 may be a useful field test bed for examining the sensitivity of REMOTS® technology in detecting the effects of sublethal contaminant concentrations on the benthic community. The presence of a highly developed Stage III community in high SOD sediments with known contaminants leads to the question of bioavailability. We recommend further investigations including field sediment and tissue sampling.

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