SCIENCE APPLICATIONS, INC.

DRAFT

DREDGED MATERIAL DISPOSAL OPERATIONS AT THE BOSTON FOUL GROUND JUNE 1982 - FEBRUARY 1983

CONTRIBUTION #41

April 18, 1984

Contract #DACW-33-82-D-0001
Work Order #1

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Work Order #1, #3, #15

DRAFT

Submitted to:

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ERRATA
DAMOS CONTRIBUTION #41

Page 3, Line 17.

Following disposal of Boston Harbor sediments during . . .

should read

Following disposal of 374,000 cubic meters of Boston Harbor sediments during . . .

Page 9, Line 14.

Add the following sentence to the end of the paragraph

Assuming an even distribution of dredged material over this area we would expect a deposit approximately 25 cm thick.

Page 9, Line 15.

Replace the sentence with

Based on these data, it is hardly surprising that the mound was not detectable with bathymetry, which when used at these depths has a resolution of approximately $\pm$ 50 cm.

Page 9, Line 17.

Change "control" to "positioning"

Page 23, Line 16.

during 1983 presented . . .

should read

during 1982 and 1983 presented . . .

Page 23, line 23.

Delete

such provisions were unsuccessful in controlling disposal. No mound was formed and there is evidence that disposal occurred as much as 500 meters NW of the buoy.

and insert

scow disposal occurred up to a few hundred meters from the buoy, producing a mound that was not within the detection range of the bathymetry instrumentation.

Page 28, Line 18.

. . . there was better control of the operation.

should read

. . . there was better positional control of the operation.

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1.0 INTRODUCTION

During the fall and winter of 1982-83, a major dredging project was conducted over a large portion of Boston Harbor, and the material created from this project was dumped at the Boston Foul Ground (Fig. 1-1). The material from the inner harbor was dredged using a clamshell bucket and transported to the disposal site using large scows. Upon completion of the inner harbor work, a second project in President Roads was dredged using the hopper dredge SUGAR ISLAND. The material from this project was deposited using a Loran-C control system as described in DAMOS Contribution #26.

In order to obtain a consensus as to the suitability of dredging and disposing of silt with a hopper dredge in the New England region, a study comparing the results of hopper versus scow disposal operations was funded by Great Lakes Dredge and Dock Co. and reviewed by the New England Division of the U.S. Army Corps of Engineers. Studies of the scow disposal operations were conducted during the summer and fall of 1982. Observations of the hopper dredge disposal took place during January of 1983. Plans for repetitive measurements on a number of dumping events were not fully executed because the SUGAR ISLAND was ordered to a different location for an emergency operation. Sufficient data were obtained, however, to provide a meaningful comparison between the two techniques and this report presents the results of that study.

2.0 CLAMSHELL/SCOW DISPOSAL OPERATION

Disposal of dredged material from the clamshell scow

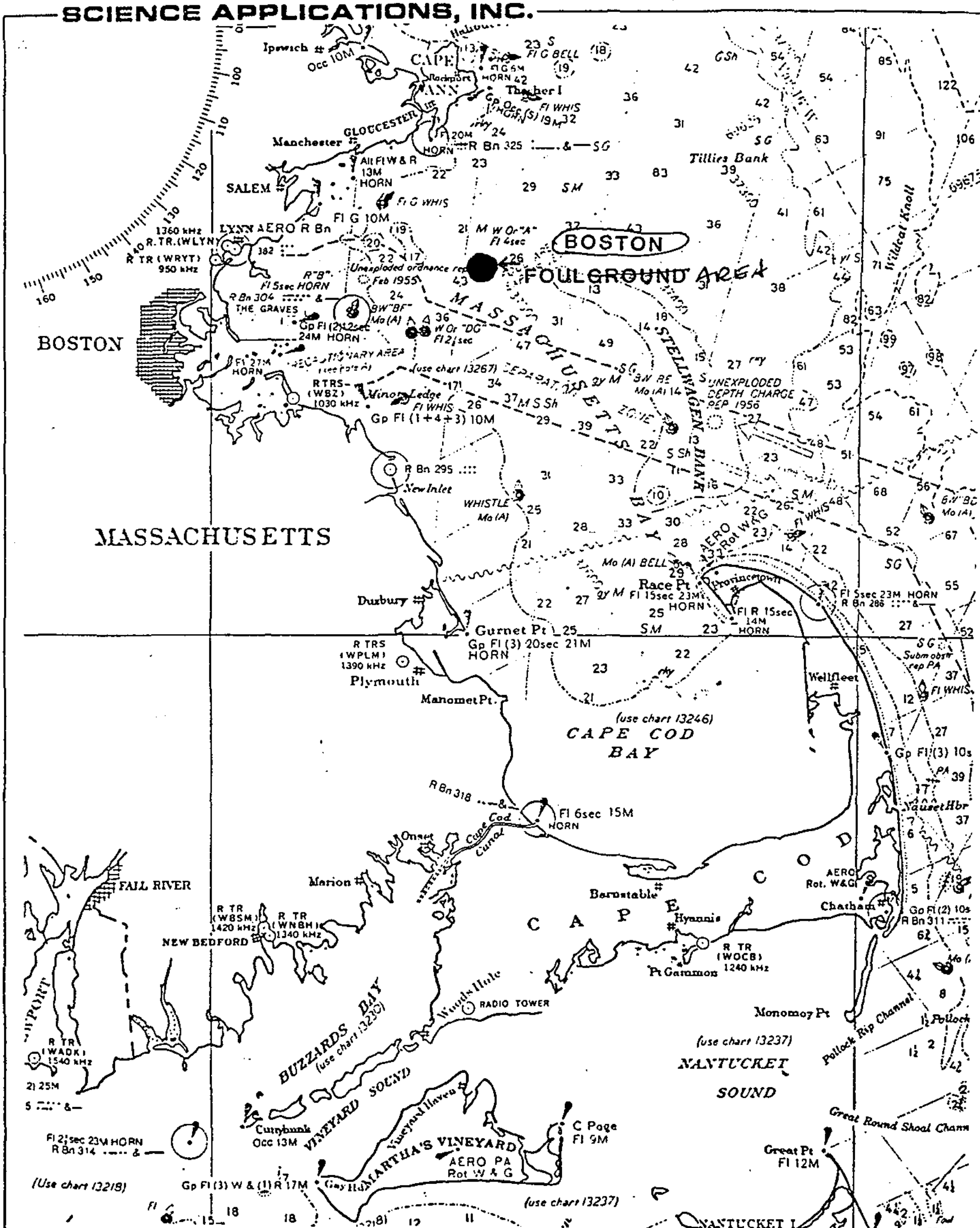

Figure 1 - 1. Boston Foul ~~Ground~~ AREA, Disposal Site

operation took place at a taut-wire moored buoy located approximately 700m east of the Coast Guard buoy marking the center of the disposal site. Bathymetric and sediment surveys were made over the area surrounding this location to obtain baseline information for assessing changes resulting from the disposal operation.

Depth measurements of an $800m^2$ area surrounding the disposal point indicated a gently sloping bottom from approximately 90m on the northern margin into a circular depression with a maximum depth of 93.5m in the southern portion of the survey area. Sediments from the area consisted of oxidized silts supporting a diverse and mature infaunal community. Analysis of heavy metal content of sediments (Table 2-1) indicates a fairly homogeneous distribution of metals with slightly higher values of Pb, Zn, Hg and Cu in the vicinity of the disposal buoy.

Following disposal of Boston Harbor sediments during the summer of 1982, replicate surveys of the disposal site were conducted during September and October to assess the results of disposal operations. The resulting contour charts (Figs. 2-1 and 2-2) show no indication of formation of a disposal mound. However, side scan surveys of the area (Fig. 2-3 and 2-4) showed a series of dark, high reflectance areas in a pattern extending from NW to SE across the site. These high reflectance zones have been seen in other disposal sites and are generally indicative of recently deposited dredged material and samples taken from the locations of these zones support such a conclusion.

Bulk sediment chemistry data from these samples

TABLE 2-1

Results of Chemical Analysis - Boston Foul Ground
Arranged From West to East
July, 1982

Location	% Volatile Solids NED	ppm Hg	ppm As	ppm Pb	ppm Zn	ppm Cr	ppm Cu
BF18 (350W)	4.8	0.13	14	100	240	42	38
BF17(350W/200S)	3.9	0.14	12	150	270	45	55
BF21(200W/100N)	4.5	0.07	12	30	150	38	21
BF19 (200W)	5.5	0.20	19	31	260	39	39
BF7 (100W)	4.7	0.24	12	190	210	60	65
BF16	3.8	0.12	10	100	190	38	36
BF20 (CTR)	3.2	0.07	13	57	140	45	31
	4.34	0.14	13.14	94.00	208.57	43.86	40.71
	0.76	0.06	2.85	60.36	51.46	7.73	14.77
BF9(REF)	4.7	*	19	51	170	64	21
REF-#1	4.7	-	17	59	200	75	25
REF-#2	4.6	-	22	23	99	72	21
REF-#3	4.2	-	18	*	190	61	17
REF-#4	3.8	-	18	24	150	67	19
REF-#5	4.5	-	17	28	150	72	20
$\bar{X}$	4.41		18.50	37.00	159.83	18.50	20.50
σ	0.35		1.87	16.78	36.11	5.39	2.66

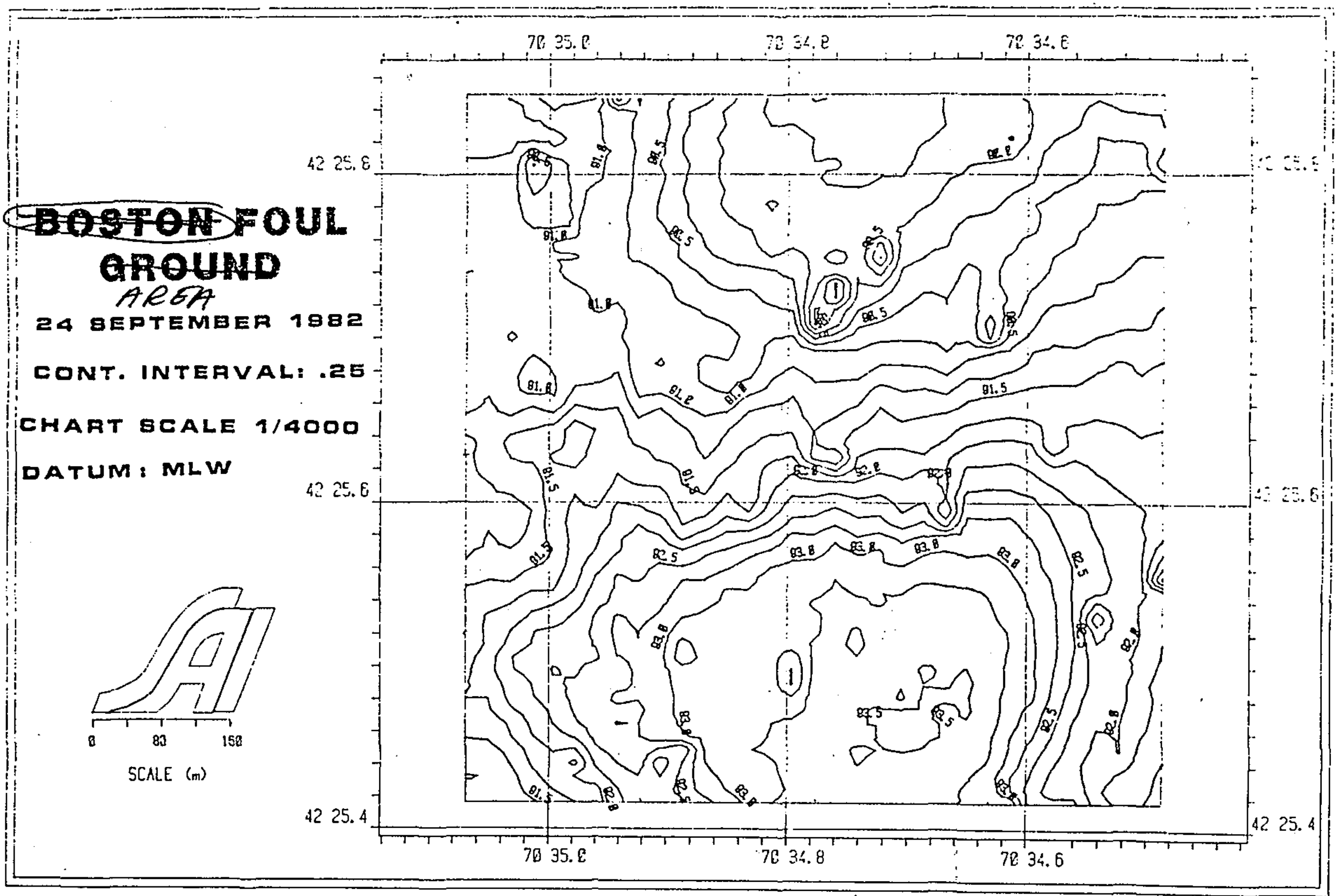
BOSTON FOUL GROUND
AREA
24 SEPTEMBER 1982
CONT. INTERVAL: .25
CHART SCALE 1/4000
DATUM: MLW
0 80 150
SCALE (m)
70 35.0
70 34.8
70 34.6
42 25.8
42 25.6
42 25.4

Figure 2 - 1

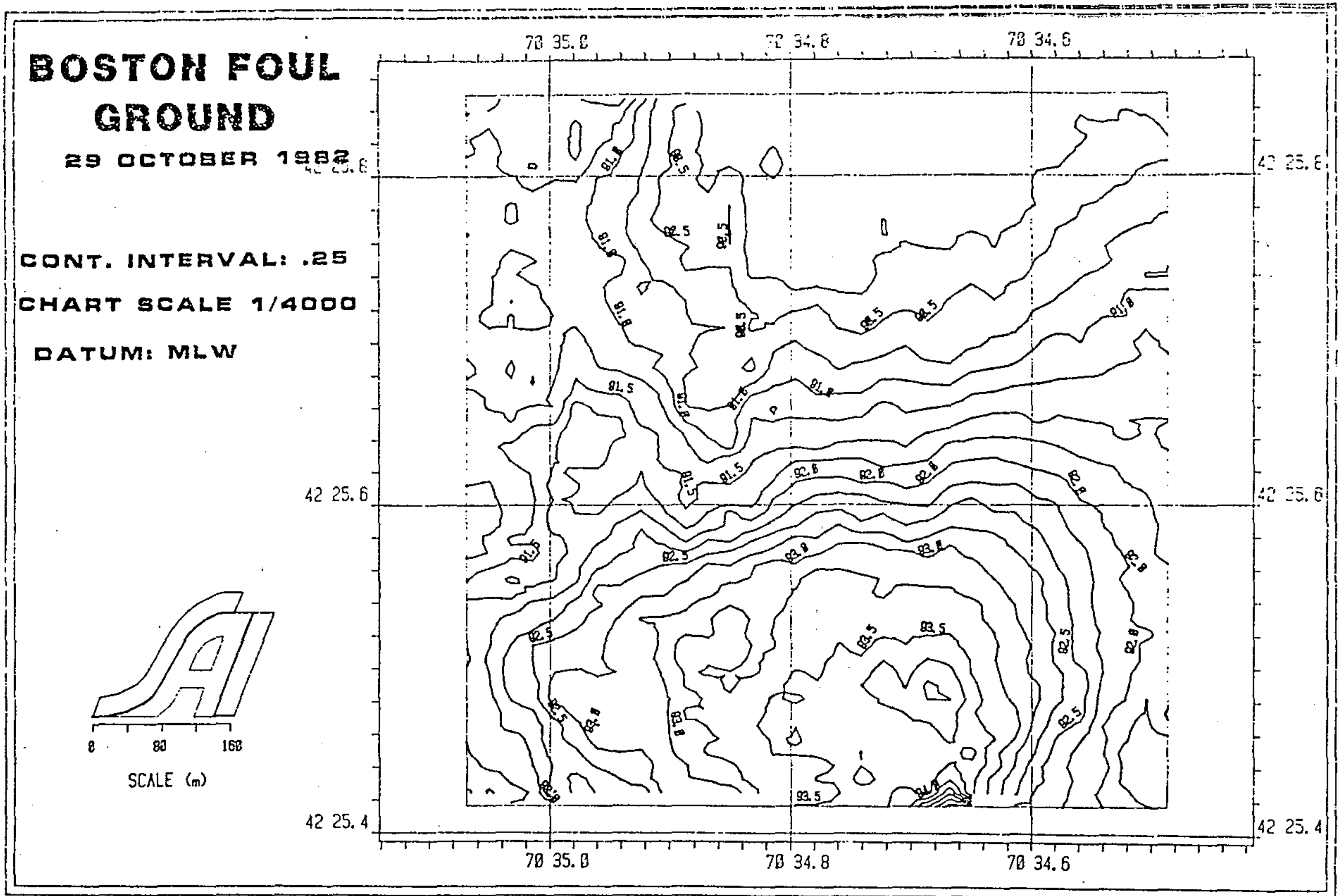
BOSTON FOUL GROUND
29 OCTOBER 1982
CONT. INTERVAL: .25
CHART SCALE 1/4000
DATUM: MLW
0
80
160
SCALE (m)
70 35.0
70 34.8
70 34.6
42 25.8
42 25.6
42 25.4

Figure 2 - 2

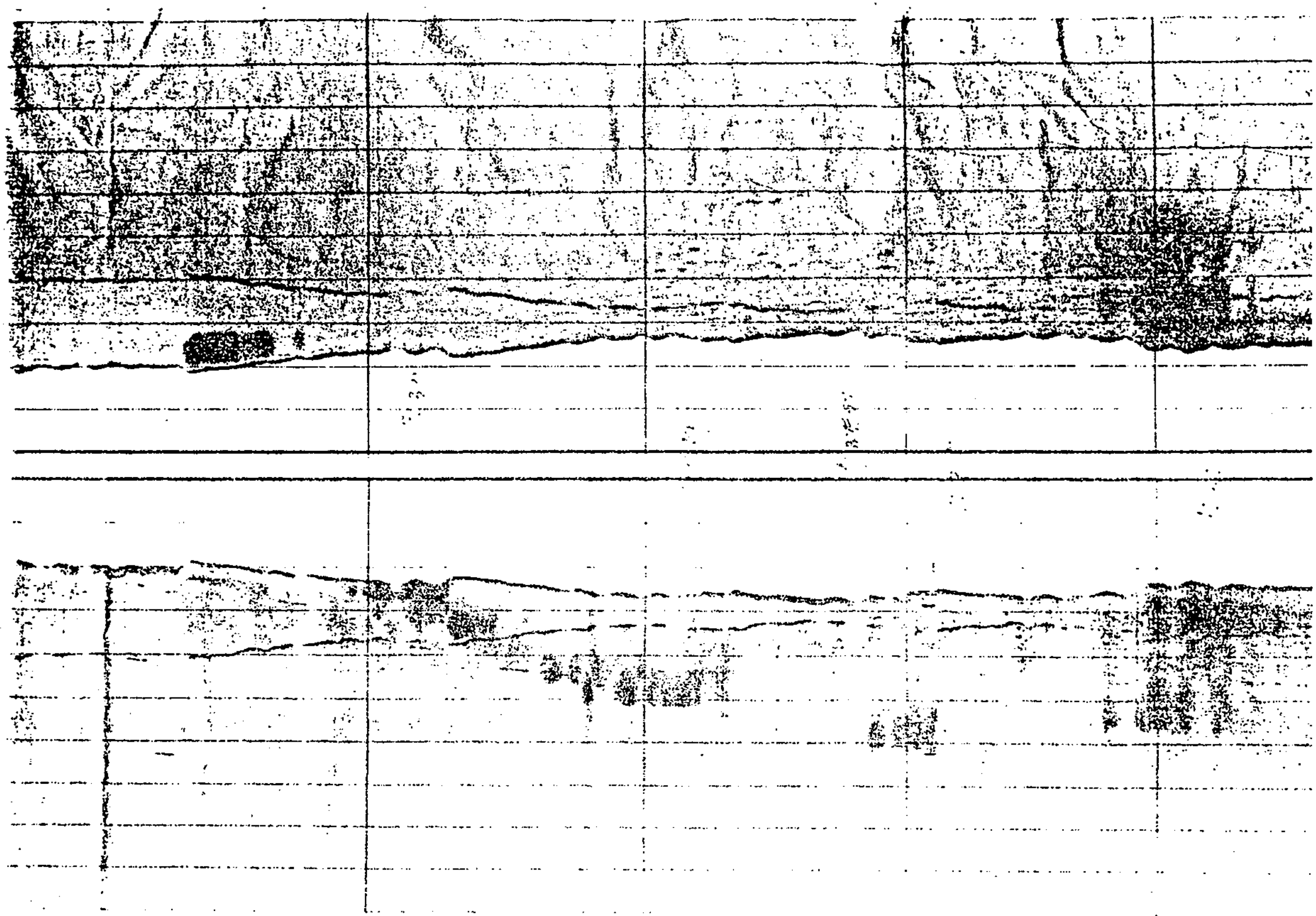

Figure 2 - 3. Representative Side Scan Sonar Records, Boston Foul Grounds, October, 1982.

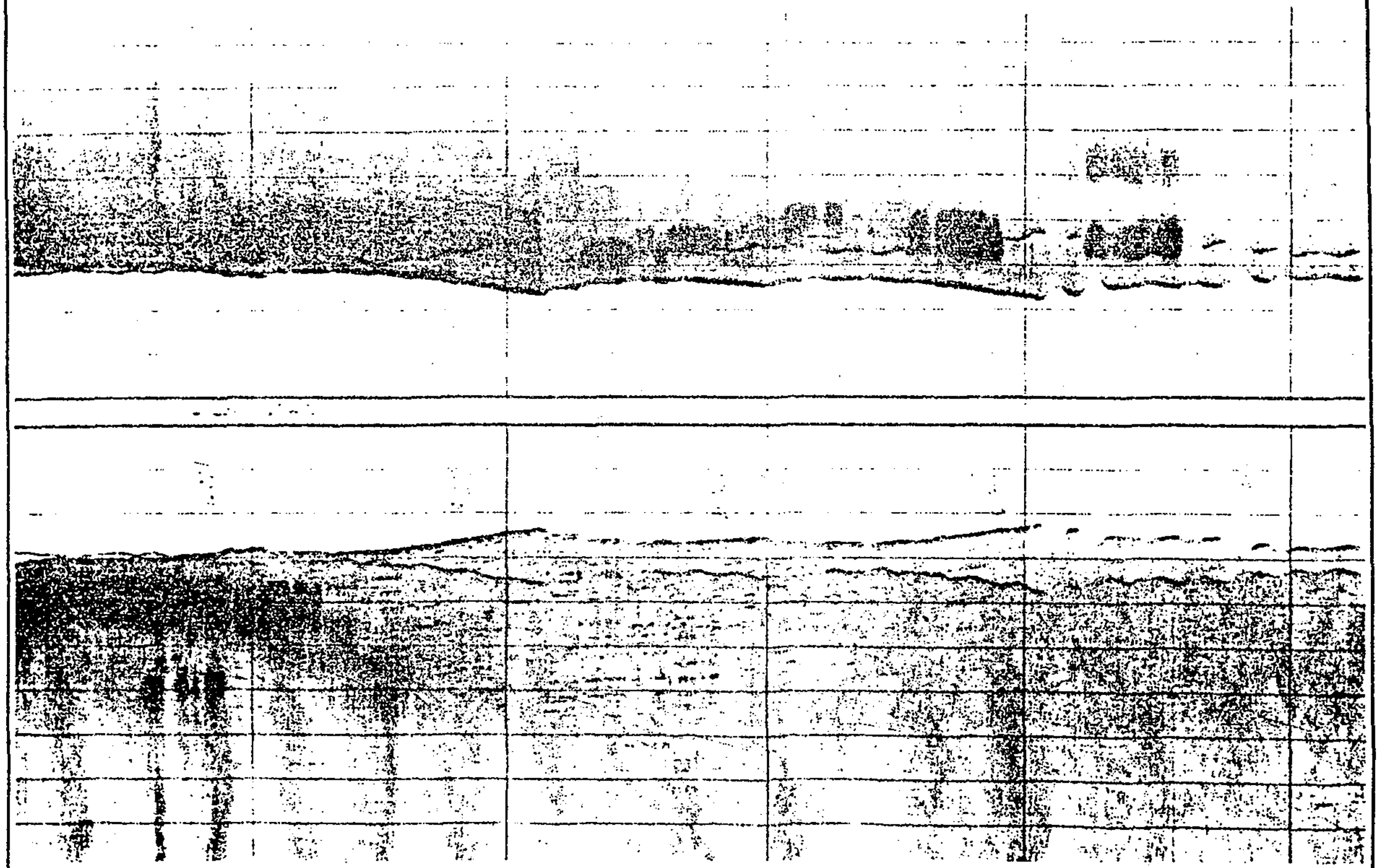

Figure 2 - 4. Representative Side Scan Sonar Record, Boston Foul Ground, October, 1982.

obtained in October 1982 are presented in Table 2-2 as locations NW #1, 2 and 3. It is readily apparent that these sediments have some of the highest values of heavy metals sampled during that period. Since these samples were obtained from locations more than 400 meters from the designated disposal point, it is apparent that point dumping of material was not accomplished on this project.

A description of samples obtained from the disposal site, presented in Table 2-3, shows a distribution of dredged material extending to distances of 500 meters to the south and east and more than 700 meters to the north and west. Furthermore, gravel and cohesive clay modules indicative of scow disposal locations were found at distances of 500 meters north and northwest of the disposal point.

Based on these data, it is hardly surprising that no mound was created. Particularly in depths as great as 90m, it is essential that accurate control of the scow be maintained to reduce the initial radius of dispersal. Disposal of similar material at Portland, Maine in depths of 60m has resulted in a definite mound formation. In the future, greater care should be exercised to control disposal by shortening the hawser, slowing the tug and opening the scow only when close aboard the disposal buoy.

3.0 HOPPER DREDGE OPERATIONS

Observations of the disposal of dredged material by the hopper dredge SUGAR ISLAND were conducted on February 1, 1983, on the last operation prior to departure for emergency service in

Table 2-2a

Results of Chemical Analysis-Boston Foul Ground
October Cruise - 1982
North-South

Location	% Volatile NED	ppm O&G	ppm Hg	ppm As	ppm Pb	ppm Cr	ppm Cu	ppm Zn
700N	5.58	3,610	0.14	10.0	184	159	105	380
500N	3.70	4,140	0.32	11.0	227	126	137	604
300N	1.76	1,840	0.30	5.2	124	209	72	271
CTR	2.77	2,800	0.20	4.0	84	157	60	212
300S	4.60	3,430	0.53	14.0	210	139	135	608
500S	4.48	1,040	0.12	8.9	90	74	58	190
BL4	3.25	3,900	0.61	11.9	179	186	117	287
NW#1	5.84	5,200	0.64	6.4	233	201	157	402
NW#2	5.23	5,800	0.56	*	246	161	155	409
NW#3	4.53	5,000	0.69	14.8	212	176	137	367
$\overline{X}$	4.17	3676.00	0.41	9.58	178.90	158.80	113.30	373.00
σ	1.30	1490.86	0.22	3.80	59.40	39.45	37.90	144.54
REF	4.49	171	*	89	48	54	18	143

Table 2-2 b

Results of Chemical Analysis-Boston Foul Ground
October Cruise - 1982
East-West

Location	% Volatile Solids	ppm O&G	ppm Hg	ppm As	ppm Pb	ppm Cr	ppm Cu	ppm Zn
500E	3.75	2,630	*	13.5	167	108	96	367
300E	5.89	6,500	0.57	19.7	227	153	156	699
100E	3.16	3,920	0.18	6.2	123	202	74	352
CTR	2.77	2,800	0.20	4.0	84	157	60	212
500W	3.27	2,830	0.50	18.9	239	157	129	565
700W	5.93	2,650	0.44	16.9	242	216	142	789
800E	5.80	373	*	10.1	69	75	35	162
$\overline{X}$	4.37	3100.43	0.38	12.76	164.43	152.57	98.86	449.43
σ	1.44	1837.85	0.18	6.20	73.93	49.18	45.18	240.22
REF	4.49	171	*	8.9	48	54	18	143

SEDIMENT SAMPLE DESCRIPTIONS

BOSTON FOUL GROUND

OCTOBER, 1982

BFG - CTR	Dredged Material, black sandy silt with some gravel, oil present
BFG - 100E	Dredged Material, Homogeneous black fine sandy silt, some gray clay nodules
BFG - 300E	9 cm Dredged Material, Homogeneous silt, similar to 100E, over natural oxidized bottom several large rocks on surface
BFG - 500E	Thin veneer of Dredged Material over oxidized natural bottom, worms present
BFG - REFERENCE (approx 1800E)	Natural Bottom, no dredged material, lot of worm tubes & starfish
BFG - 300S	5 cm Dredged Material, Homogeneous black silt over natural oxidized bottom
BFG - 500S	Thin veneer of Dredged Material over oxidized natural bottom, worms & other infauna present
BFG - 500W	Dredged Material, Homogeneous black silt, trace of natural sediment in bottom of grab
BFG - 700W	Thin veneer of Dredged Material, very fluid and mixed with natural sediment
BFG - 300N	Dredged Material, Black silt matrix around gravel, rocks and clay nodules
BFG - 500N	Dredged Material, Black silt matrix around gravel and clay nodules
BFG - 700N	Veneer of Dredged Material, Black silt over oxidized natural bottom

Table 2-3a

SEDIMENT SAMPLE DESCRIPTIONS

BOSTON FOUL GROUND

JULY - OCT, 1982

BFG - BASELINE #4 (approx. 500mNW)	July - Soft oxidized silty clay over gray clay with some sand, worm tubes, Nepthys present
	Oct - Dredged Material, black matrix around large cohesive gray clumps, some gravel oil present
BFG - BASELINE #18 (approx. 700mE)	July - Veneer of black, oily silt over oxidized brown mud
	Oct - Some indication of black silt, mostly natural bottom with worm tubes & starfish
BFG - NW#1	10 cm Dredged Material, black silt with oil, gray clay nodules, over brown oxidized natural sediment
BFG - NW#2	8 cm Dredged Material, black silt with oil & gray clay nodules over oxidized silt
BFG - NW#3	Dredged Material, coarser sediment than NW #1&2 No natual oxidized sediment present

Table 2-3b

Florida. As a result, multiple samples could not be obtained, however, a great deal was learned from that single operation.

The major questions raised relative to the use of a hopper dredge for projects in the New England area centered around the behavior of silt material during disposal. Previous experience had shown that, in general, silts dredged by a clamshell/scow operation were immediately transported to the bottom in a turbidity like flow that produced a relatively small plume. A concern existed that the hopper dredge technique would add water to the silt and break down any cohesiveness in the sediment so that disposal would generate a large plume that might be transported for substantial distances.

Consequently, the emphasis of this program was placed on examination of plume behavior through a combination of acoustic tracking and in-situ sampling. The R/V EDGERTON was configured for tracking the plume with a dual channel (50 and 200 KHz) Acoustic Remote Sensing System manufactured by Datasonics Inc. and a precision navigation system provided by Science Applications, Inc. utilizing a Del Norte Trisponder positioning system for ± 2 meter accuracy.

The Datasonics Model DFS-2100 system provides simultaneous dual channel operation with high power output, low receiver noise levels and calibrated control of signal level which permits monitoring of extremely low concentrations of material in the water column, and acquisition of quantitative concentration levels when correlated with ground truth sampling. On this study, ground truth data were obtained from the M/V HUDSON RIVER, a support vessel supplied by Great Lake Dredge &

Dock Co. Samples of the water column were obtained during the plume tracking operation using Niskin bottles. The HUDSON RIVER was located in the plume by the EDGERTON as a messenger was dropped to trip the bottles. The salinity of each water sample was measured with a Beckman RS-7B induction salinometer and the concentration of material was determined by filtering an aliquot through a pre-weighed 0.4 μ nucleopore filter, and then weighing the filter and deposited material on a Mettler H-51 analytical balance.

In order to relate acoustic backscatter measurements in a plume of suspended particulate matter to quantitative concentration levels, it is necessary to measure the reflection, or backscattering characteristics of the material in the scattering volume of interest. The echo or reverberation level received back at the towed vehicle transducer from particulate scatterers in the dredge material plume may be expressed as part of a standard sonar equation as follows:

$$RL = SL - 40 \text{ Log } R - 2\alpha R + S_v + 10 \text{ Log } V \qquad (1)$$

where:

RL	=	reverberation level
SL	=	source level
$40 \text{ Log } R + 2\alpha R$	=	Two way transmission loss, where 40 Log R is spreading loss and 2 R is absorbtion
$S_v + 10 \text{ Log } V$	=	backscattering strength due to volume reverberation

The S_v term is the correlation factor that determines the concentration of scatterers, or in this case the concentration of suspended material.

Equation 1 summarizes acoustic losses within the water column, however, this must be transferred to a receiver voltage output to quantify the measurements made during a survey. For a receiver:

$$\sqrt{OV\ (rms)} = RL + RS + GAIN \qquad (2)$$

where:

OV	=	Output voltage (root mean square)
RS	=	Receiver sensitivity
GAIN	=	Overall receiver gain including a Time Variable Gain (TVG)

Since equation (2) can be rewritten as:

$$RL = \sqrt{OV\ (rms)} - RS - GAIN \qquad (3)$$

equations (1) and (3) can be equated and solved for output voltage such that:

$$\sqrt{OV\ (rms)} = SL - 40 \log R - 2\alpha R + Sv + 10 \log V + RS + GAIN \qquad (4)$$

Evaluating this equation in terms of this study, the TVG accounts for transmission loss, thus eliminating 40 log R + 2 αR from the equation; the Receiver Sensitivity is a constant and can be ignored when making relative measurements, and the source level is also constant which can also be ignored. Removing these quantities from Equation (4), the Output Voltage is proportinal to Sv + 10 log V and the receiver GAIN. Since 10 log V accounts for signal spreading as a function of beamwidth and range, this is only a correction factor for depth and, since the gain is a known factor, the output voltage will be directly proportional to the concentration of suspended matrial. This output is recorded on tape and presented as a graphic display on a dry paper recorder.

Observations of the disposal plume created by the SUGAR ISLAND were conducted on Februay 1 at 1600 under relatively calm conditions. The EDGERTON positioned herself immediately astern of the dredge and moved over the disposal point as soon as dumping occurred. Figure 3-1 indicates the track of the EDGERTON during the next hour and a half as she tracked the plume. The striped section of the chart indicates the spatial distribution of plume 15 minutes after disposal while the cross-hatched section shows the spatial distribution one hour later. During the 75 minute survey period, the maximum extent of dispersion was approximately 750 meters in a southeasterly direction. This represents a dispersal rate of 16 cm/sec or .3 knots.

Although this spatial distribution provides an indication of net transport, the acoustic records provide a much more detailed view of the plume disipation.

Figure 3-2 presents the acoustic record immediately after disposal which displays some important phenomena. First, the 50 KHz channel has substantially stronger reflections than the 200 KHz channel, indicating that relatively coarse material was in suspension. Second, a narrow column of material through the water column and a greatly increased turbidity cloud near the bottom both suggest rapid, convective descent to the bottom. Much of the turbidity near the bottom may in fact be resuspension of previously dumped material.

Based on the calibration provided by the water samples, a concentration of 750 mg/l of sediment was observed in the upper layer of the plume immediately after disposal. As shown in Figure 3-3, this decreased rapidly to 39 mg/l within 20 minutes after disposal. The column of sediment observed in Figure 3-2 had dissipated by this time, and a vertical distribution with a

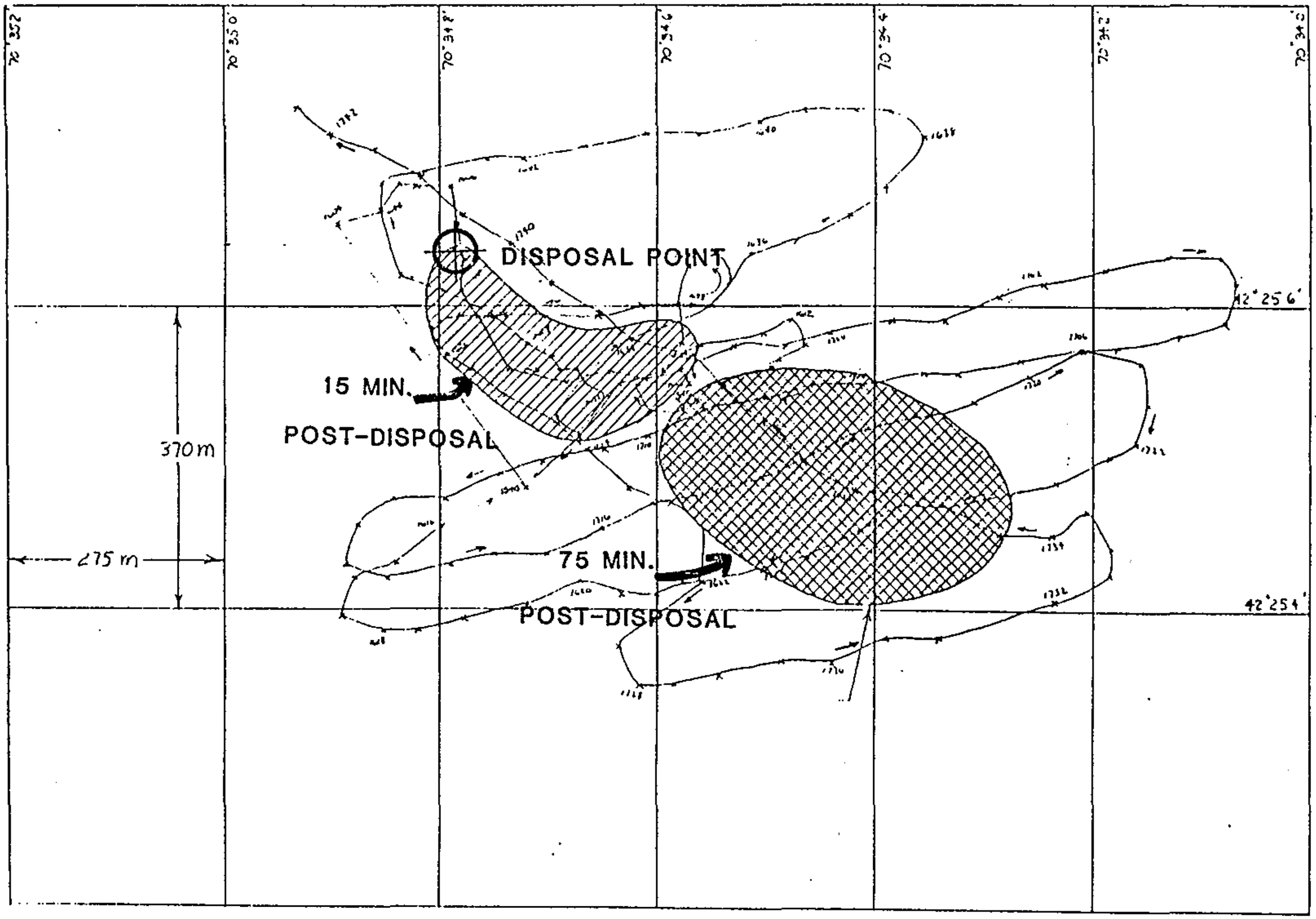

Fig. 3-1. Ships Track and Plume Dispersion following Disposal Operations Hopper Dredge SUGAR ISLAND February 1, 1983

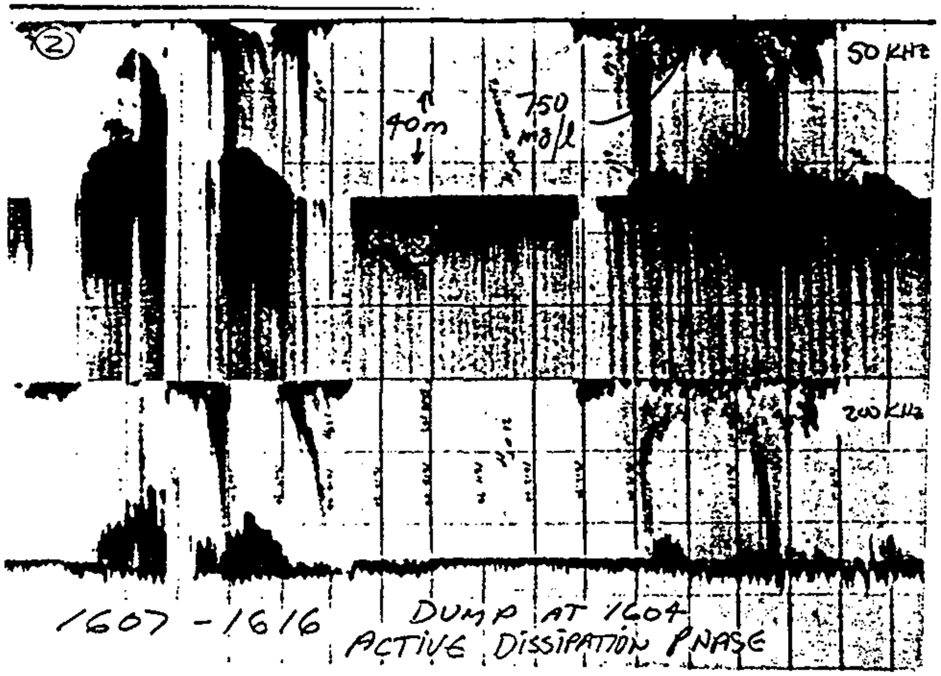

Figure 3-2 Acoustic Signature of Disposal Plume Immediately after Disposal

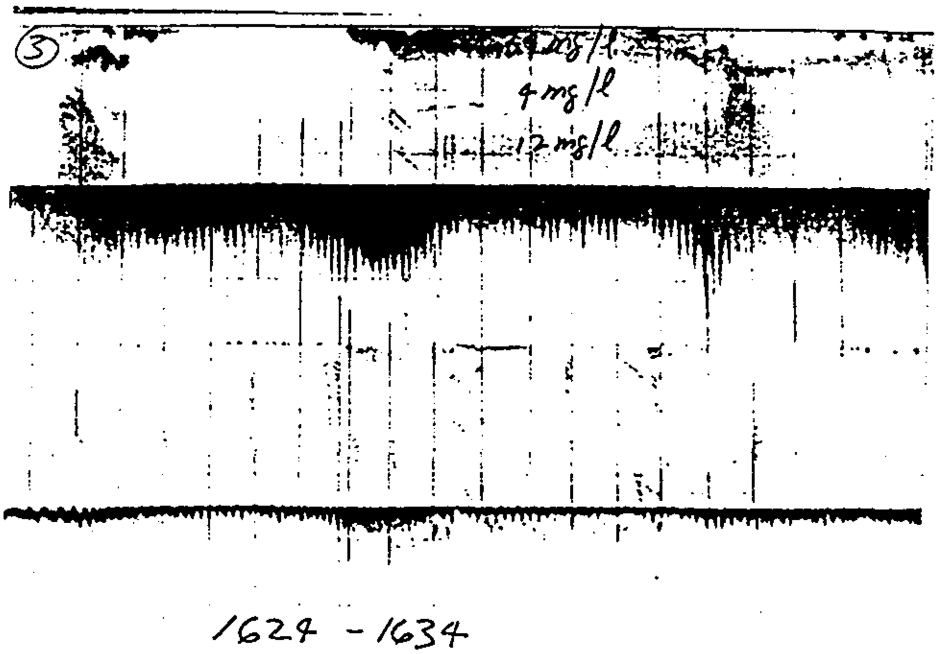

Figure 3-3 Acoustic Signature of Disposal Plume 20 min. after disposal

minimum concentration at mid-depth was observed.

Approximately 20 minutes later (40 minutes after disposal) the 50 KHz signal was essentially gone, indicating a loss of larger particles from the water column. On the high frequency channel, concentrations on the order of 5 mg/l were observed near the surface and bottom (Fig. 3-4). Since the ambient concentration of suspended material averaged approximately 1 mg/l, this plume does represent a detectable increase above background levels.

From this time on, the concentration and distribution of the suspended material in the plume varied only slightly from 5 to 12 mg/l. The plume was evident throughout the water column, as shown in Figures 3-5 through 3-7, with some indications of increased concentrations at a depth of approximately 30-35 meters on what may be the thermocline layer.

Based on an average concentration of 9 mg/l, a mean depth of 90 meters and a spatial distribution described by a circle with a 400 meter diameter, the total mass of material within the plume equals:

$$\pi r^2 H \times \text{conc} = \text{TOTAL MASS}$$
$$\pi (200\text{m})^2 \times 90\text{m} \times 9 \times 10^{-3}\text{kg/m}^3 = 101{,}736\text{kg} \quad (5)$$

At an average density of 1.1gm/cm^3 for dredged material in the hopper, this represents a volume of 92m^3 or approximately 3% of the total load of the SUGAR ISLAND. Such a percentage of material remaining in suspension is comparable to that remaining after scow disposal, indicating that similar processes are occurring and that the material left in suspension may be more a function of the sediment itself than the dredging and disposal

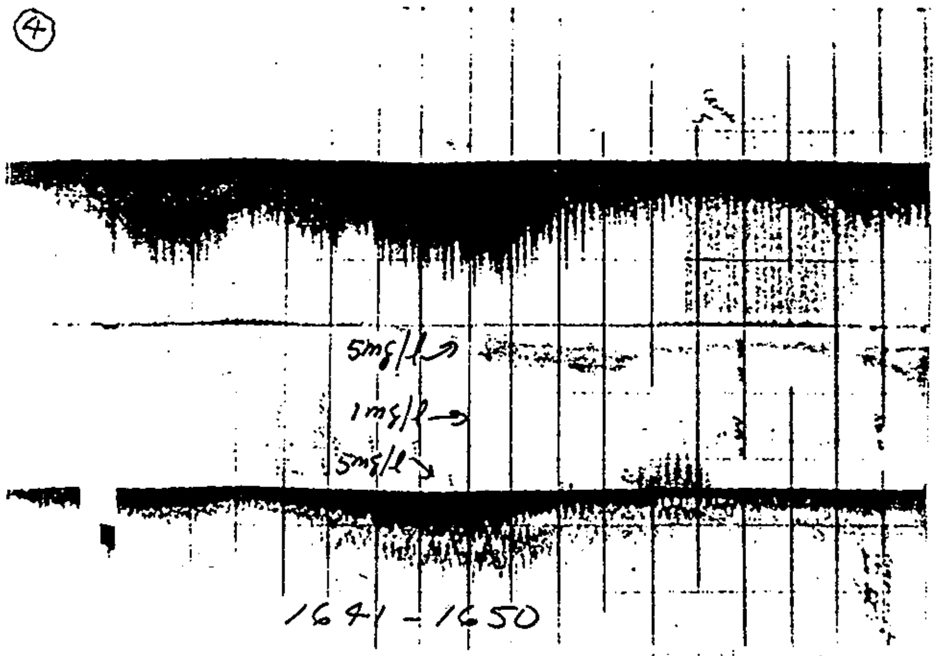

Figure 3-4 Acoustic Signature of Disposal Plume 40 min. after disposal

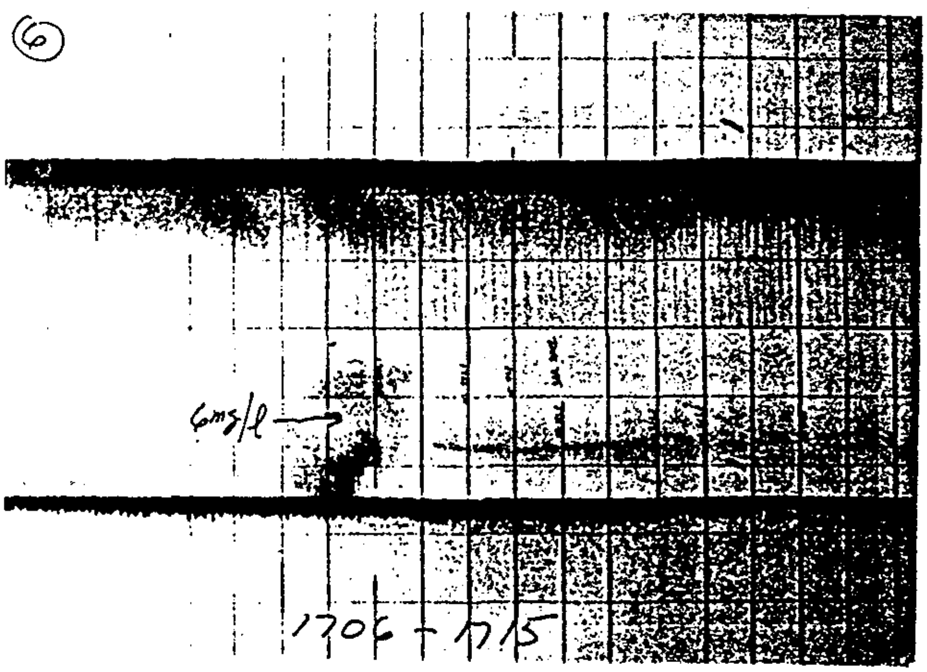

Figure 3-5 Acoustic Signature of Disposal Plume 1 hr. after disposal

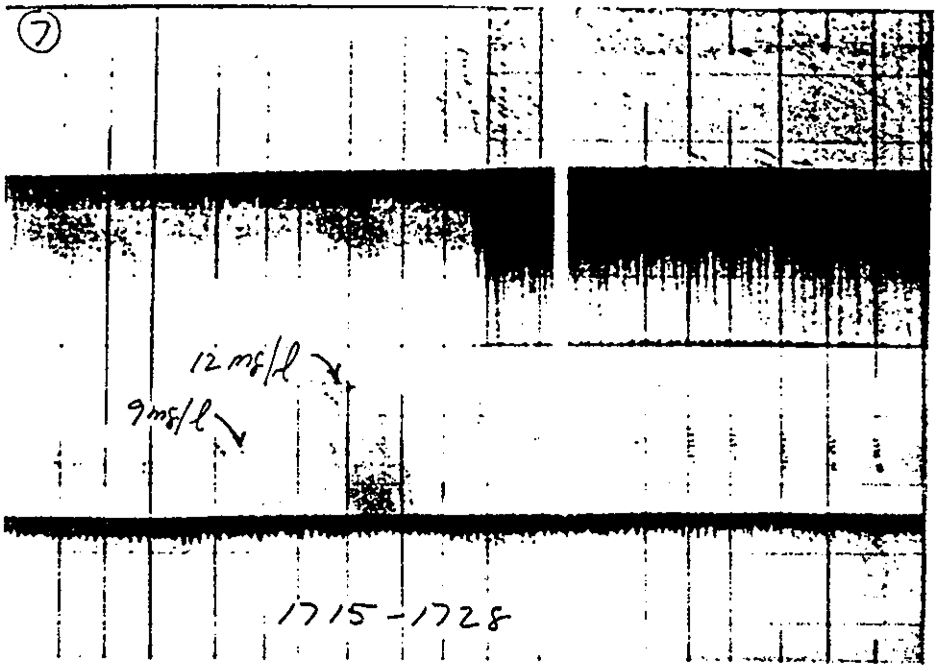

Figure 3-6 Acoustic Signature of Disposal Plume
1 hr. 20 min. after disposal

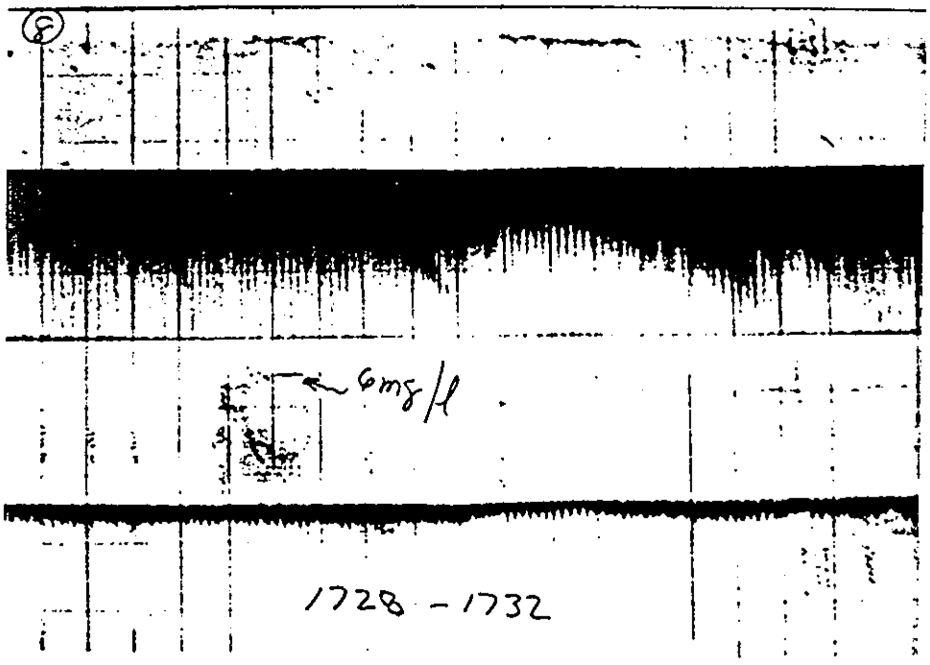

Figure 3-7 Acoustic Signature of Disposal Plume
1 hr. 40 min. after disposal

procedure.

Samples taken in April 1983, following completion of the disposal operation, showed a pattern consistent with observations made during October, 1982. Descriptions of the samples as presented in Table 3-1 indicated the presence of dredged material in approximately the same locations as found in October; however, chemical tests in these areas, presented in Table 3-2, show reduced levels of metals in many cases, particularly in the vicinity of the disposal point. These reduced levels would be expected in material deposited by the SUGAR ISLAND, since sediment from the outer harbor was substantially less contaminated than that dredged by clamshell/scow operations in the inner harbor.

4.0 CONCLUSIONS

Disposal of dredged material at the Boston Foul Ground during 1983 presented a unique opportunity to observe the effects of two different dredging/disposal operations and compare the results for future use in the area.

The clamshell/scow operation was initially used to dredge and dispose material from the inner reaches of Boston Harbor. Provisions for point-dumping at a taut-wire moored buoy were made on this project, however, the distribution of dredged material following disposal indicates that such provisions were unsuccessful in controlling disposal. No mound was formed and there is evidence that disposal occurred as much as 500 meters NW of the buoy. Future operations at this site must be more strictly controlled if capping procedures are to be successful,

Table 3-1

SEDIMENT SAMPLE DESCRIPTIONS

BOSTON FOUL GROUND

APRIL, 1983

BFG - CTR	Dredged Material with large clumps of gray clay, some shill hack
500N	Dark black Dredged Material with oil and sulfur odor, terrigenous material
100N	Dark black Dredged Material with strong oil & sulfur odor
500E	Thin oxidized layer over black organic silt matrix, well colonized
100W	Dark black Dredged Material with strong oil & sulfur odor
350W	Dark black Dredged Material, silt with oil & sulfur odor
300S	Oxidized layer, 1 cm thick, over dark black organic silt with some sand, oil & sulfur odor
500S	Thin oxidized layer over black organic silt with some gray clay nodules
REF STA:	Natural bottom, well oxidized

Table 3-2b

Results of Chemical Analysis-Boston Foul Ground

North-South Transect Near $70^{\circ}34'$ .00 - April 1983

Location	% Volatiles NED	ppm Oil & Grease	ppm Cr	ppm Zn	ppm Cu	ppm As
1000N-850E	1.71	681	37	179	39	9.0
500N-850E	3.64	761	76	175	43	9.3
850E	4.22	1,210	90	196	43	10.0
500S-850E	4.82	201	74	206	23	8.6
1000S-850E	4.95	282	74	156	23	10.0
North-South Transect at $70^{\circ}33.5$						
1000N-1850E	0.72	-	41	75	12	-
500N-1850E	2.90	170	61	124	20	7.6
500S-1850E	4.60	282	70	152	21	8.6
$\overline{X}$	3.45	512.43	65.38	157.88	28.00	9.01
σ	1.55	386.71	18.16	42.36	11.89	0.85

Table 3-2C

Results of Chemical Analysis Boston Foul Ground

East-West - April 1983

Location	% Volatiles NED	ppm Oil & Grease	ppm Cr	ppm Zn	ppm Cu	ppm As
400W	2.22	6,510	444	469	114	10.2
275W	3.66	1,830	225	266	100	5.4
150W	4.39	2,790	215	285	100	5.8
50W	2.99	1,840	176	168	81	5.2
CTR	1.65	158	38	92	17	5.0
850E	4.22	1,210	90	196	43	10.0
$\bar{X}$	3.19	2389.67	198.00	246.00	75.83	6.93
σ	1.10	2196.58	140.91	129.58	37.92	2.47

particularly in this depth of water.

Conversely, the hopper dredge operation, using the SUGAR ISLAND was quite successful. Control of disposal was much better than 90% of the dumping operations confined to a 50 meter radius about the disposal point. Studies of the plume generated by disposal from the hopper dredge showed results similar to those experienced with scow operations. A convective flow to the bottom removed most of the material from the water column within a few minutes, and the remaining plume with a concentration of 5-12 mg/l represented only a small fraction of the total load carried to the disposal site. Furthermore, the material deposited by the hopper dredge on the bottom was contained in an area comparable to that resulting from scow disposal and appeared stable three months after deposition.

In summary, there were no effects at the disposal site resulting from use of the hopper dredge that were significantly different from those experienced with scow disposal and in fact there was better control of the operation. Consequently, future consideration of hopper dredge operations in New England can be considered as a viable alternative with the usual monitoring procedures enforced.