DAMOS

DISPOSAL AREA MONITORING SYSTEM

Summary of Program Results
1981-1984

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Sections IV, V, VI, & VII

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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 Foul Area (Fig. IV-1-1). The material was dredged using a clamshell bucket from the Chelsea and Mystic Rivers in Boston 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 with the hopper dredge under Loran-C control 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 jointly funded by Great Lakes Dredge and Dock Co. and 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 1983. Plans for repetitive measurements on a number of hopper 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 operation took place at a taut-wire moored buoy located approximately 200m east of the Coast Guard buoy (Fig. IV-2-1) 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 800 x 800m 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 IV-2-1) indicated a fairly homogeneous distribution of metals with slightly higher values of Pb, Zn, Hg and Cu in the vicinity of the disposal buoy (Fig. IV-2-2).

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. IV-2-3 and IV-2-4) show no indication of formation of a disposal mound.

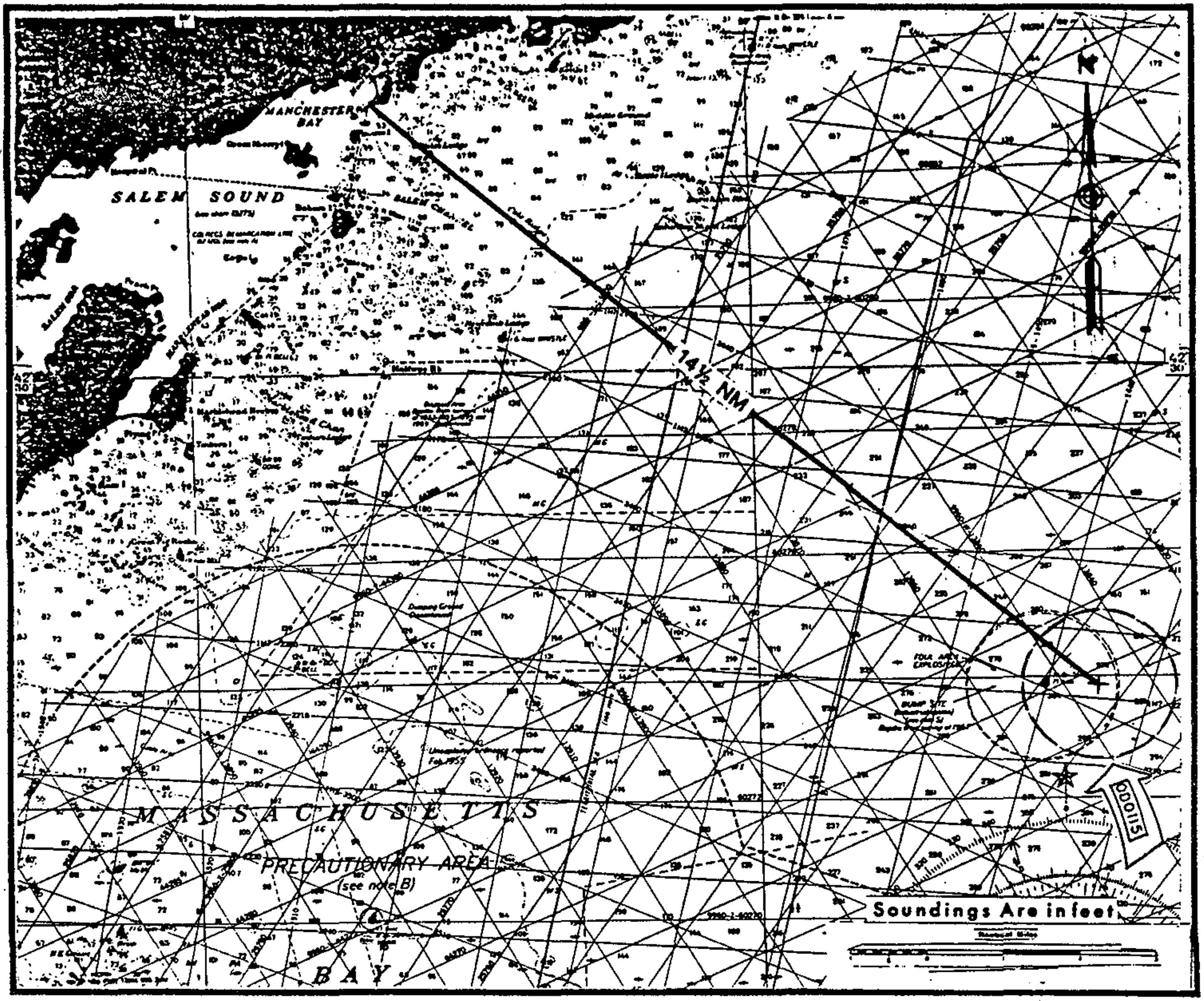

Figure IV-1-1. Foul Area, Massachusetts Bay.

EPA OD0115: FOUL AREA — N.O.S. CHART: 13267
DEPTH RANGE: 159 TO 304 FEET MLW — DATE: 20 DECEMBER 1980
CENTER COORDINATES: 42°-25.7'N, 70°-34.0'W
DESCRIPTION: THIS EPA APPROVED INTERIM SITE IS A CIRCULAR AREA WITH A DIAMETER OF 2 NAUTICAL MILES AND CENTER AT 42°-25.7'N, 70°-34.0'W. FROM THE CENTER, THE MARBLEHEAD TOWER BEARS TRUE 282° AT 24,300 YARDS AND BAKERS ISLAND HORN BEARS TRUE 300° AT 24,300 YARDS.

FOUL AREA DISPOSAL SITE

Figure IV-2-1.

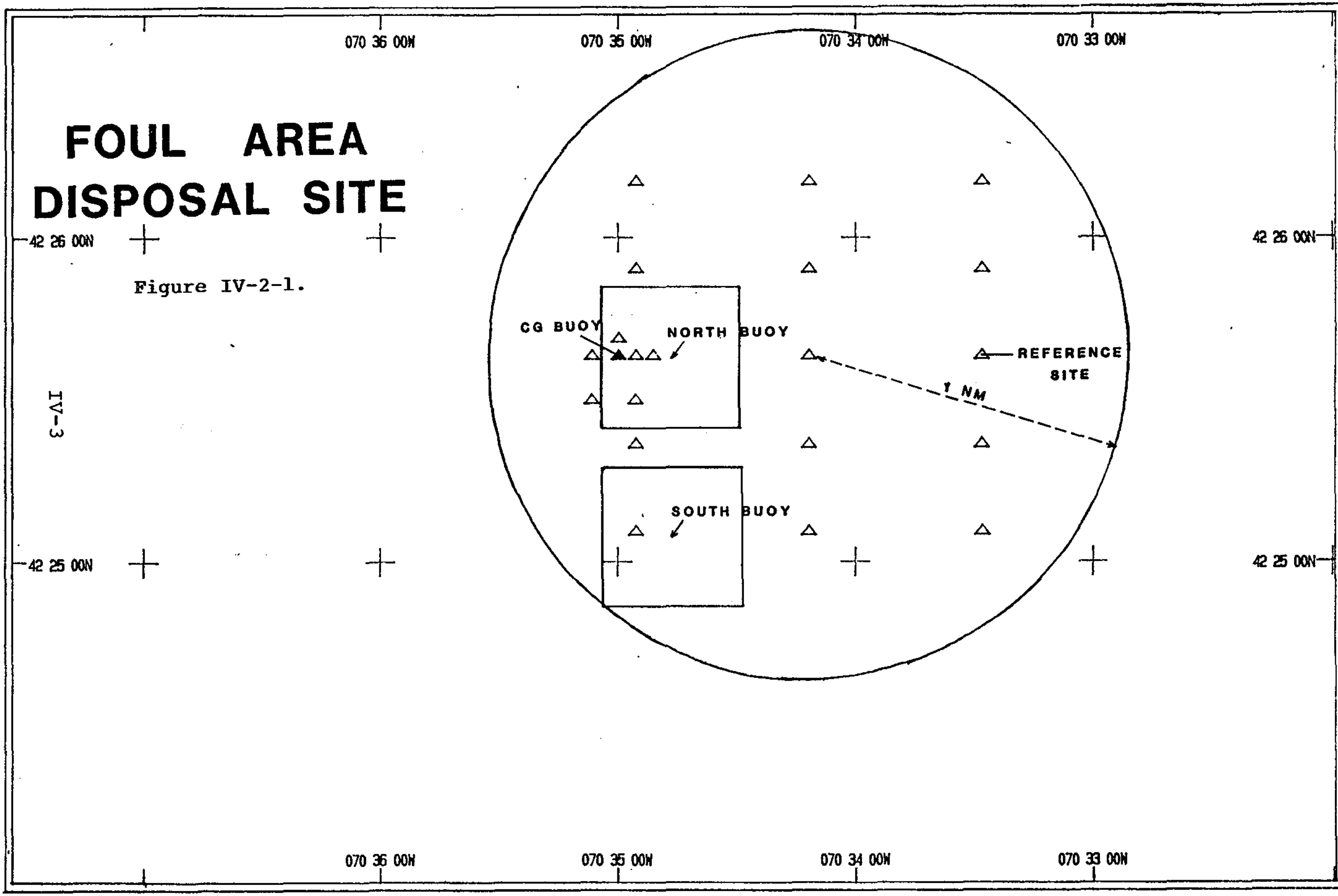

Table IV-2-1

Results of Chemical Analysis - Foul Area
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(100W/250S)	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
$\overline{X}$	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

* = Below Dectection Limit

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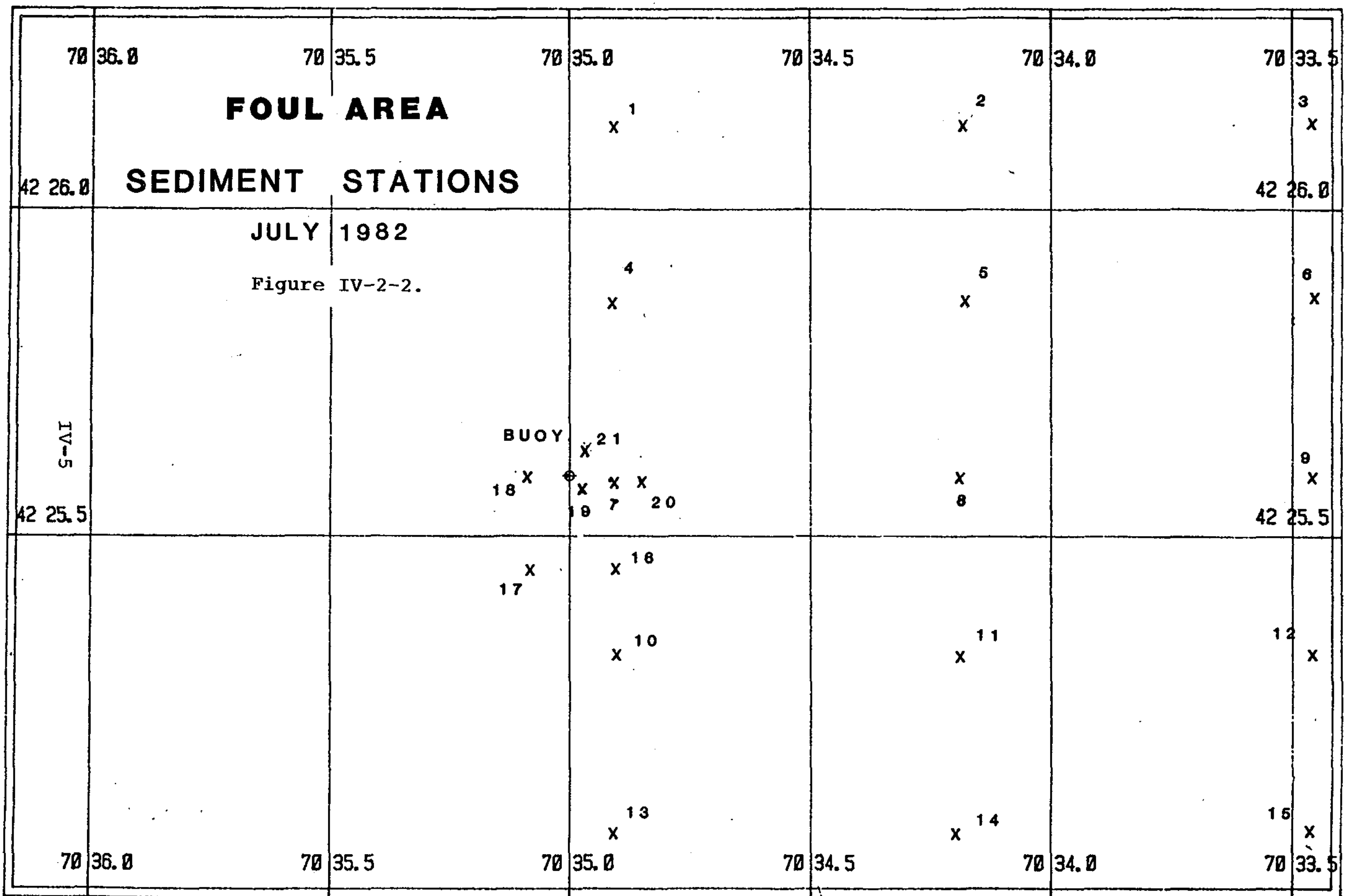

FOUL AREA
SEDIMENT STATIONS
JULY 1982
70 36.0
70 35.5
70 35.0
70 34.5
70 34.0
70 33.5
42 26.0
42 25.5
BUOY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Figure IV-2-2.

Figure IV-2-3.

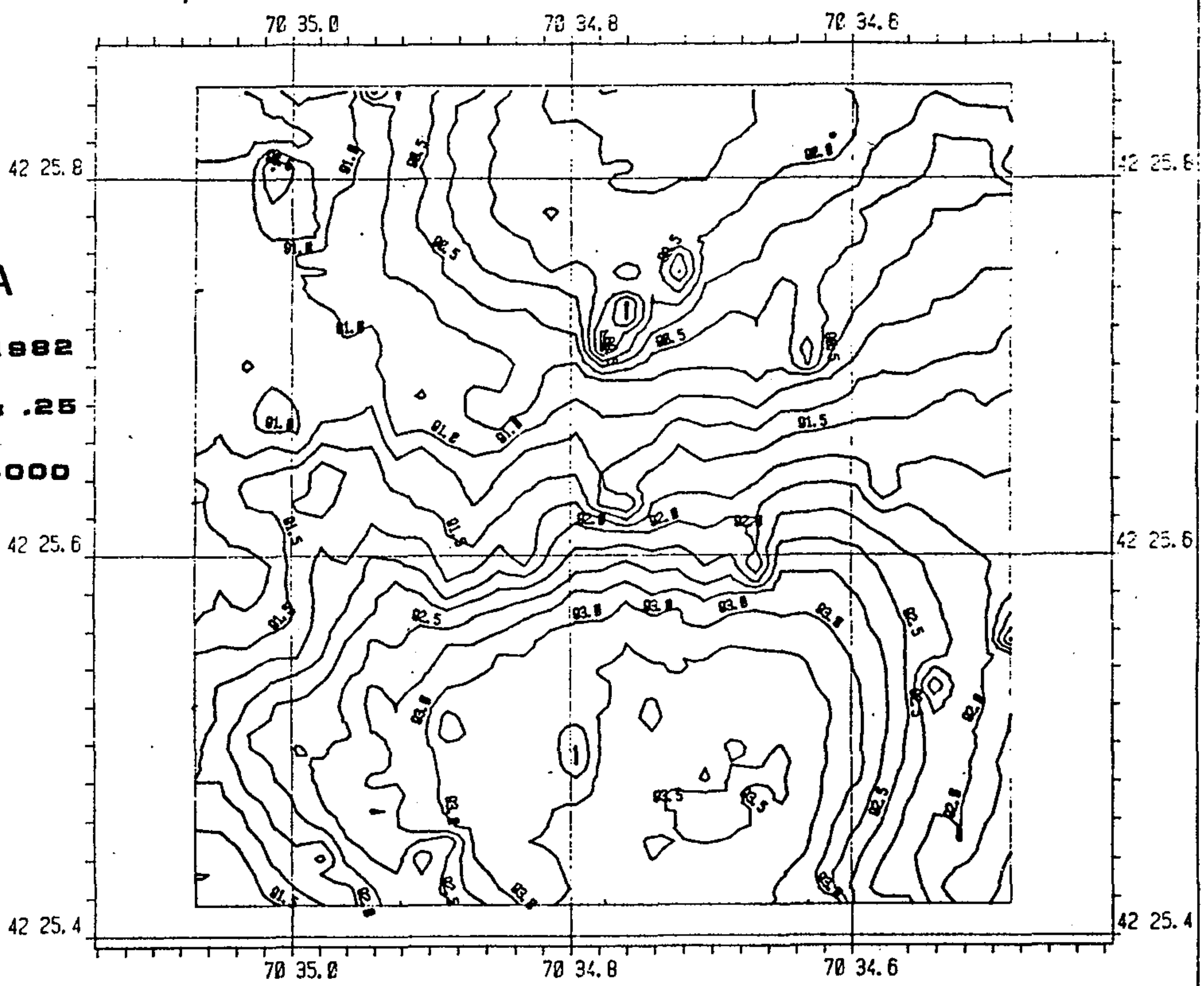
FOUL AREA

24 SEPTEMBER 1982

CONT. INTERVAL: .25

CHART SCALE 1/4000

DATUM: MLW



0 80 160

SCALE (m)

FOUL AREA

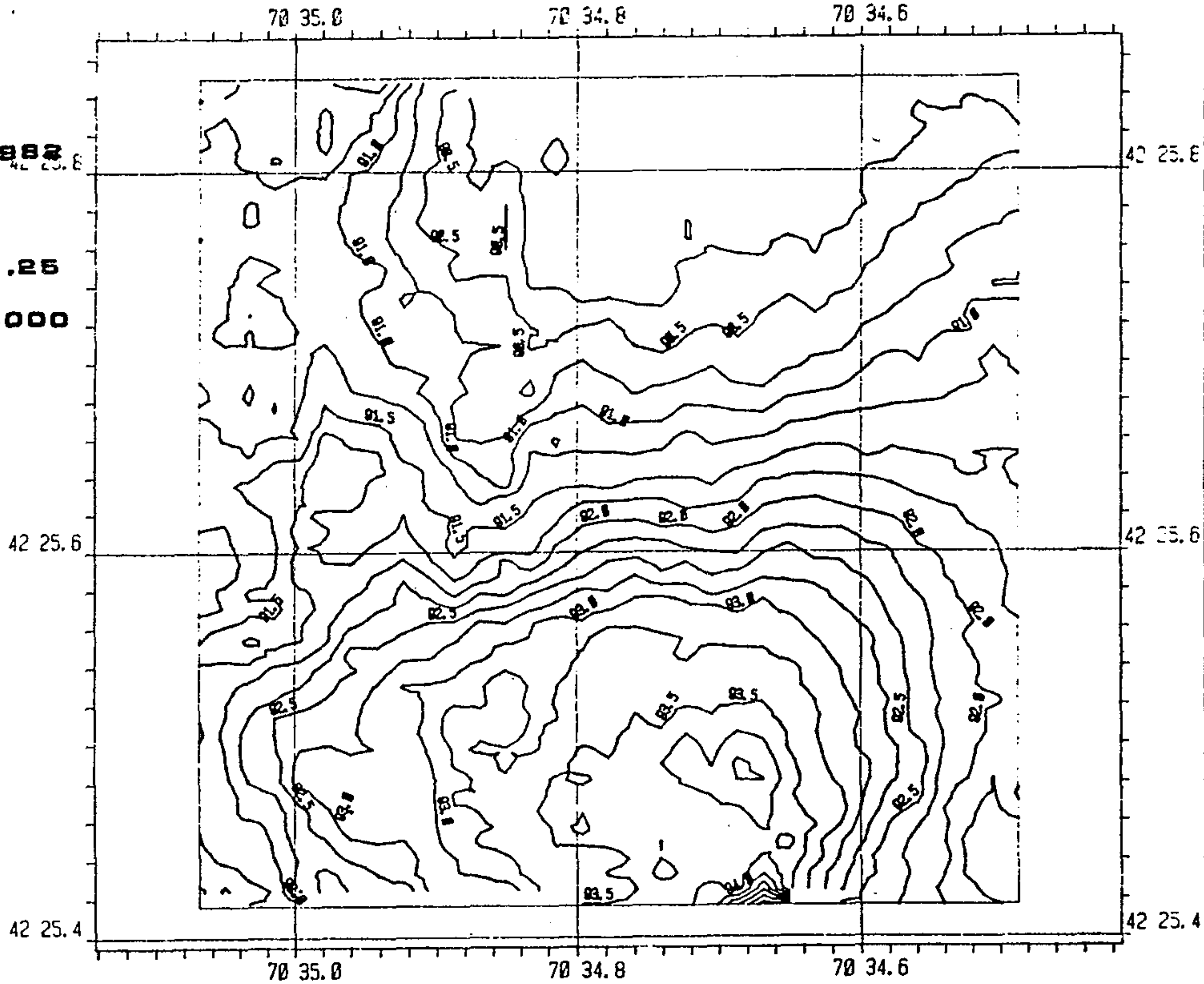
29 OCTOBER 1982

CONT. INTERVAL: .25

CHART SCALE 1/4000

DATUM: MLW

Figure IV-2-4.



0 80 160

SCALE (m)

However, side scan surveys of the area (Figs. IV-2-5 and IV-2-6) 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 obtained in October 1982 are presented in Table IV-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 also apparent that point dumping of material was not accomplished on this project.

A description of samples obtained from the disposal site, presented in Table IV-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 (Fig. IV-2-2).

3.0 HOPPER DREDGE OPERATIONS

Observations of the disposal of dredged material by the hopper dredge SUGAR ISLAND were conducted on 1 February 1983, on the last operation prior to departure for emergency service in 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 convective 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, slowly settling plume that might be transported for substantial distances.

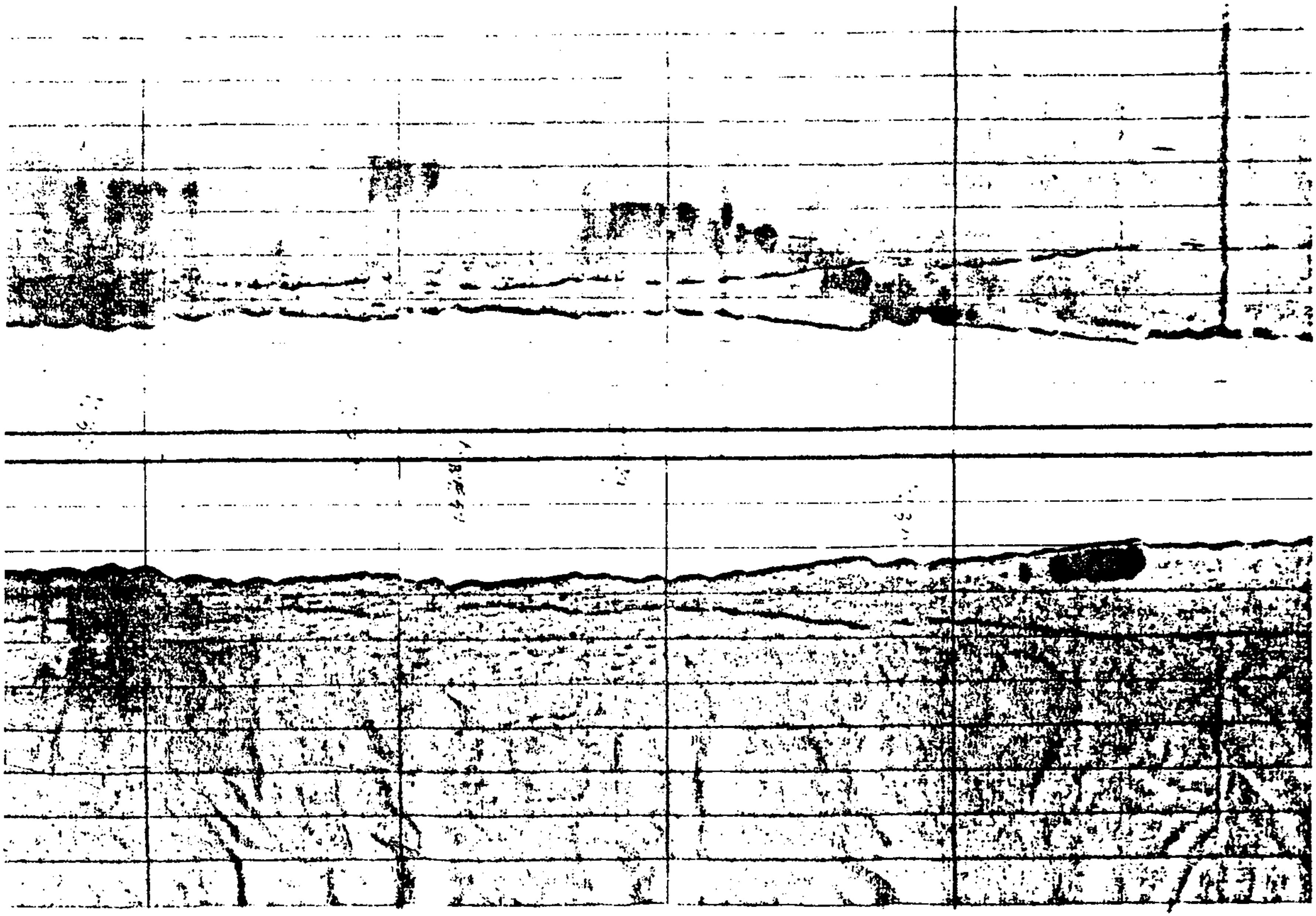


Figure IV-2-5. Side Scan Sonor, October 1982

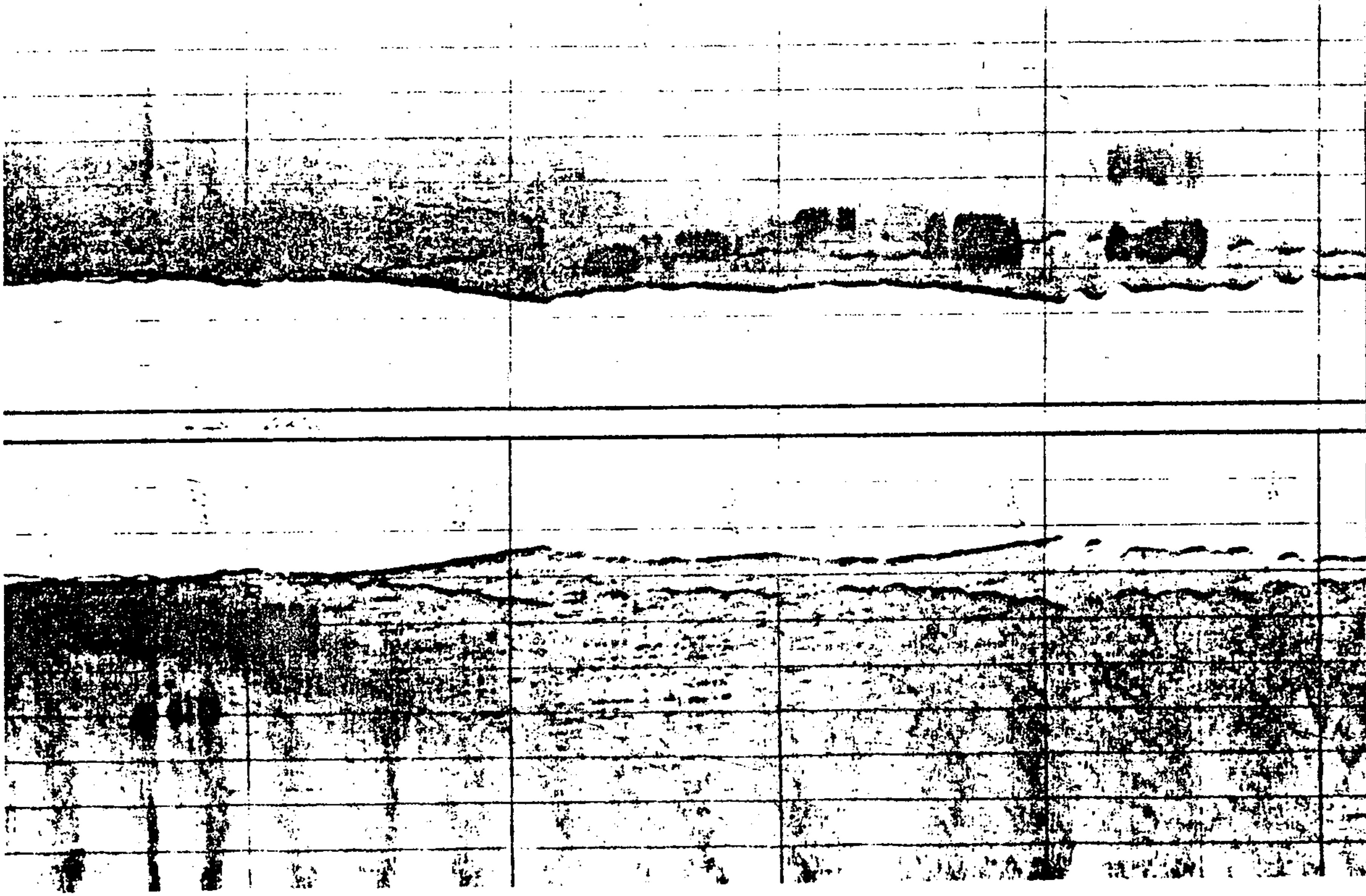


Figure IV-2-6. Side Scan Sonar, October 1982

Table IV-2-2a

Results of Chemical Analysis- Foul Area
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
$\bar{X}$	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	*	8.9	48	54	18	143

* = Below Detection Limit

Table IV-2-2b

Results of Chemical Analysis- Foul Area
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

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Table IV-2-3a

SEDIMENT SAMPLE DESCRIPTIONS

FOUL AREA

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

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Table IV-2-3b

SEDIMENT SAMPLE DESCRIPTIONS

FOUL AREA

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

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 dredged 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 $2\alpha R$ 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 α R 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 S_v + 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 material. 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 1 February 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 IV-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 dissipation.

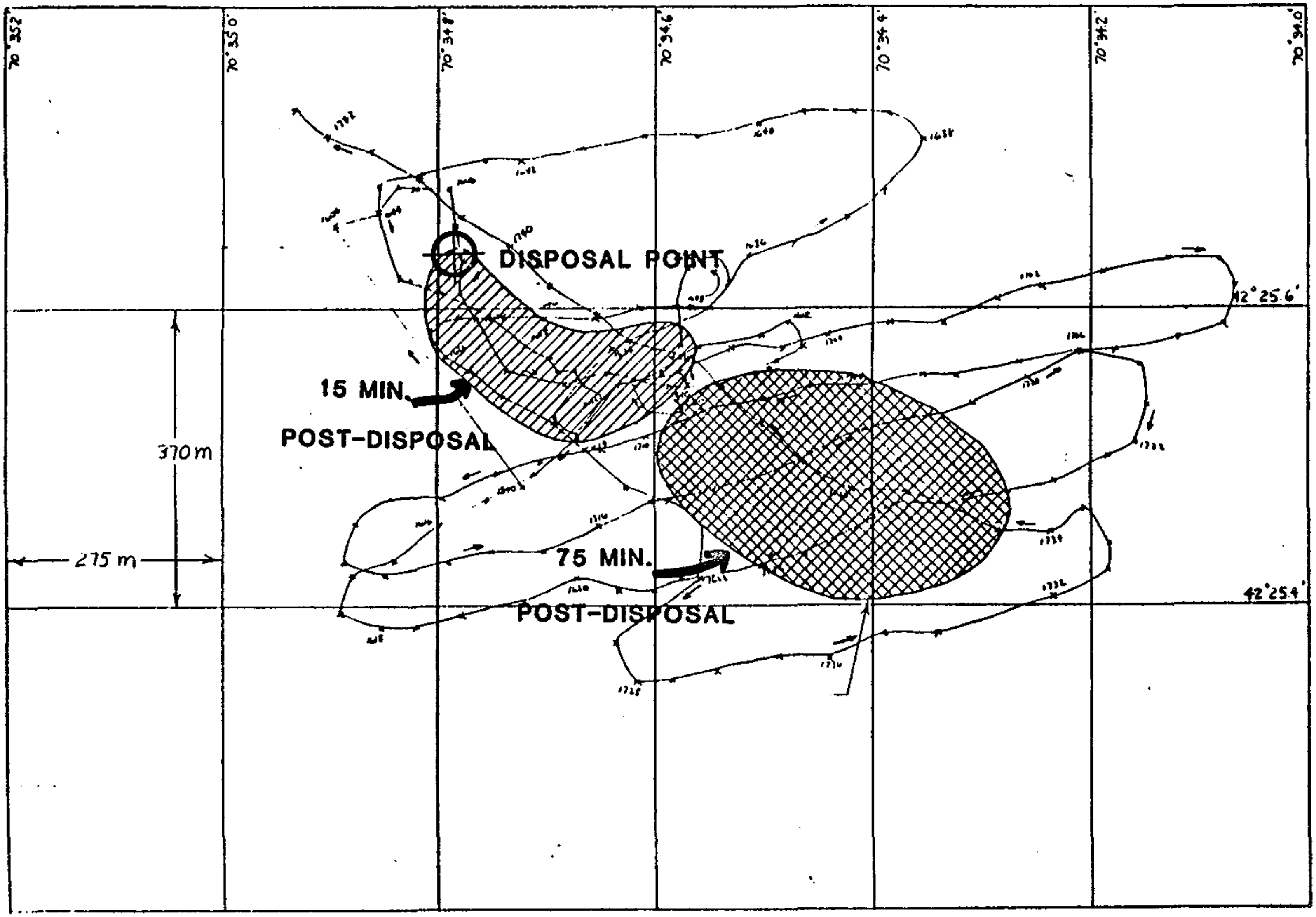

Figure IV-3-1. Ships Track and Plume Dispersion following Disposal Operations Hopper Dredge SUGAR ISLAND February 1, 1983

Figure IV-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 IV-3-3, this decreased rapidly to 39 mg/l within 20 minutes after disposal. The column of sediment observed in Figure IV-3-2 had dissipated by this time and a vertical distribution with a 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. IV-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 IV-3-5 through IV-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:

$$\pi r^2 H \text{ (conc)} = \text{Total Mass}$$

$$\pi (200\text{m})^2 \times 90\text{m} \times 9 \times 10^{-3} \text{kg/m}^3 = 101{,}736 \text{ kg}$$

At an average density of 11 gm/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 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

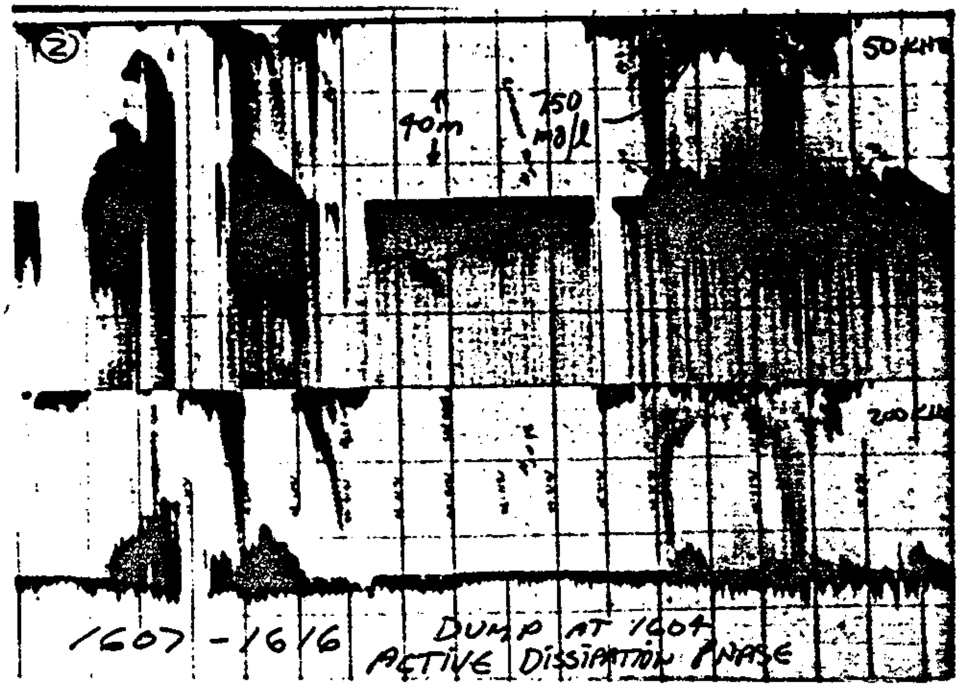

Figure IV-3-2. Acoustic Signature of Disposal Plume Immediately after Disposal

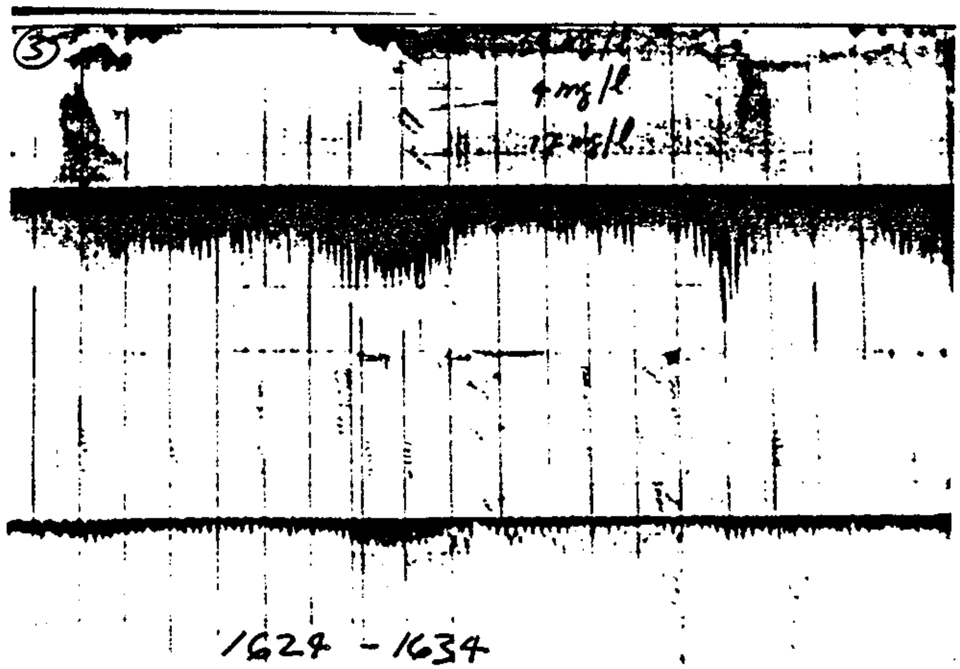

Figure IV-3-3. Acoustic Signature of Disposal Plume 20 min. after disposal

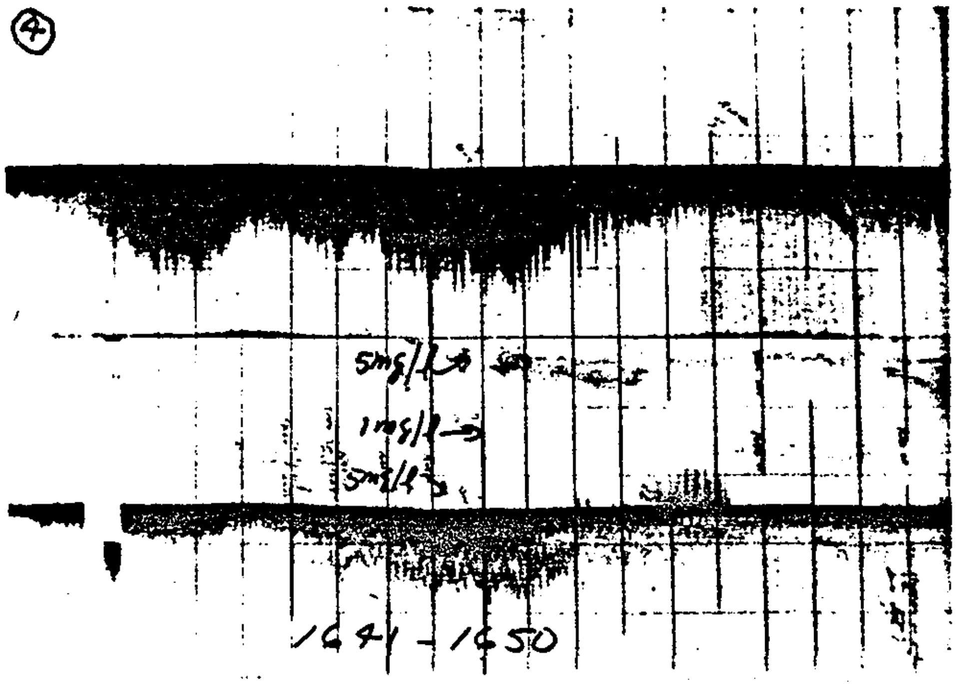

FIGURE IV-3-4. Acoustic Signature of Disposal Plume 40 min. after disposal

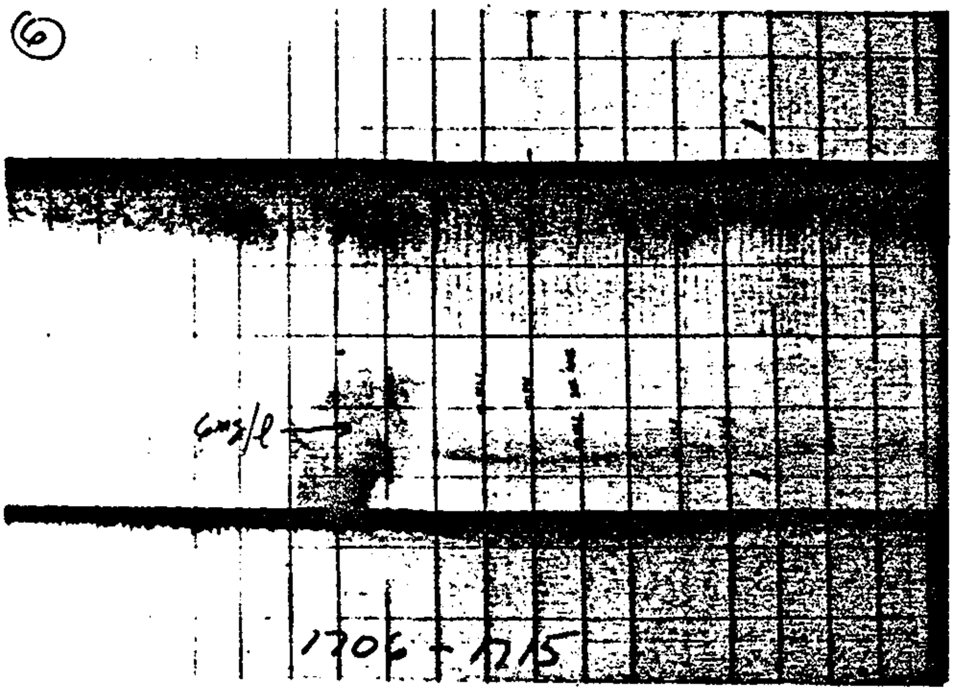

FIGURE IV-3-5. Acoustic Signature of Disposal Plume 1 hr. after disposal

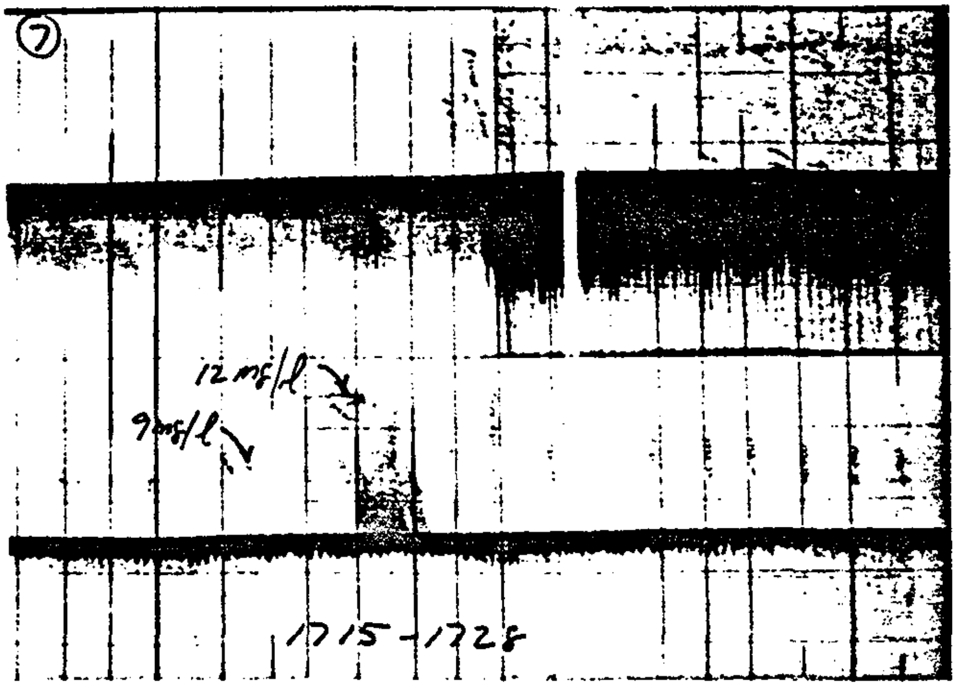

Figure IV-3-6. Acoustic Signature of Disposal Plume
1 hr. 20 min. after disposal

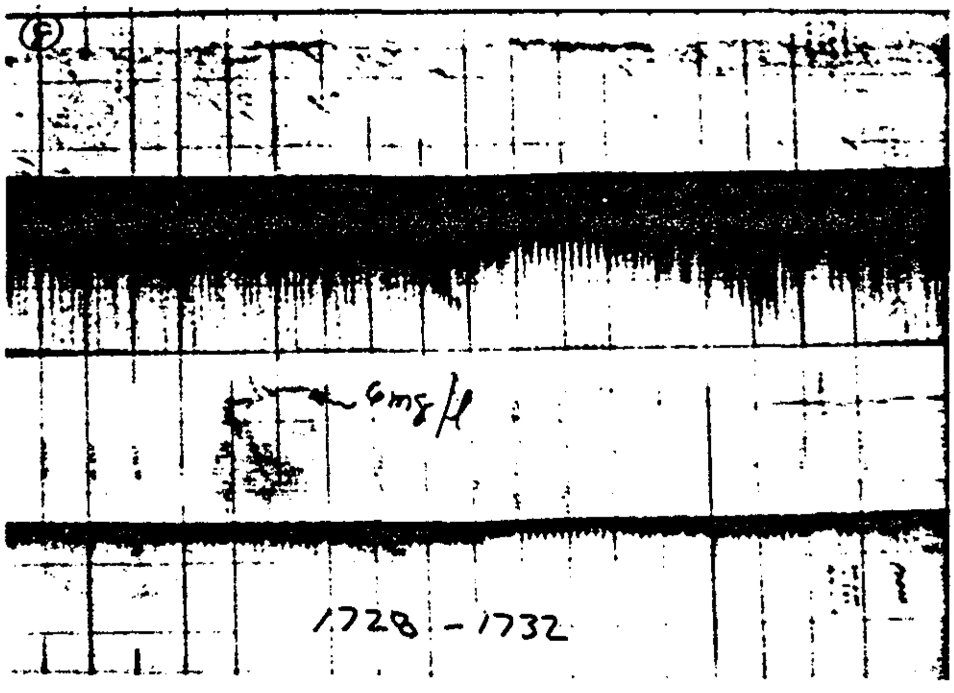

Figure IV-3-7. Acoustic Signature of Disposal Plume
1 hr. 40 min. after disposal

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samples, as presented in Table IV-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 IV-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 FOUL AREA - SOUTH SITE

In order to successfully analyze the effects of dredged material disposal at the Foul Area disposal area, a new site was located on natural bottom south of the original disposal site. This area has similar topography and bottom sediment characteristics and will allow comparison of results with the original site. Pre- and post-disposal surveys were conducted to document the quantity of material disposed of and the success of point dumping with scows at the disposal site.

4.1 Bathymetric Surveys

A bathymetric survey of the new site (FAS) was conducted in January 1983 during which a new disposal buoy was deployed (Fig. IV-2-1). At the conclusion of this survey, the first disposal operations were performed using scows. Figure IV-4-1 illustrates the bathymetry of the FAS site prior to disposal.

The survey was repeated in April 1983 after disposal operations were completed to document the placement of the dredged material at the FAS site (Fig. IV-4-2). The resulting contour difference chart (Fig. IV-4-3) reveals no significant accumulation of dredged material at the disposal site. The irregular topography of this area makes small quantitites of dredged material difficult to detect, except under optimum conditions.

4.2 Sediment Samples

During the January 1983 survey, sediment samples were obtained at the FAS site with a Smith-MacIntyre grab (0.1 m^2) and sent to the NED laboratory for analysis. Table IV-4-1 presents the results of the analyses of these samples. The sediment at the disposal site is similar to the reference area based upon analysis of the physical characteristics of the sediment. The profiles indicate that chemical concentrations generally get progressively lower going from north to south. This indicates a lessening of dredged material influence from the original disposal site, as the concentrations to the south are more like the reference area. Collection of post-disposal sediment samples was attempted in November 1983, but adverse weather conditions made it necessary to cancel the cruise.

Table IV-3-1

SEDIMENT SAMPLE DESCRIPTIONS

FOUL AREA

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

SAIC

Table IV-3-2a

Results of Chemical Analysis- Foul Area
North-South Transect Near 70°35' .00 - April 1983

Location	% Volatiles NED	ppm Oil & Grease	ppm Cr	ppm Zn	ppm Cu	ppm As
1000N-150W	1.51	757	55	233	35	14.5
500N-150W	4.20	2,740	208	327	133	7.6
100N-350W	4.00	1,780	225	260	100	6.5
400W	2.22	6,510	444	469	114	10.2
275W	3.36	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	50
250S-400W	4.10	4,210	241	424	147	14.0
250S-150W	3.28	2,550	216	301	106	6.0
500S-150W	2.69	3,670	188	525	106	25.6
1000S-150W	4.09	610	81	292	46	11.1
$\bar{X}$	3.21	2453.75	192.67	303.50	90.42	13.49
σ	1.01	1757.83	106.39	121.87	39.14	12.90

Table IV-3-2b

Results of Chemical Analysis- Foul Area
North-South Transect Near 70°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°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 IV-3-2c

Results of Chemical Analysis-Foul Area
East-West - April 1983

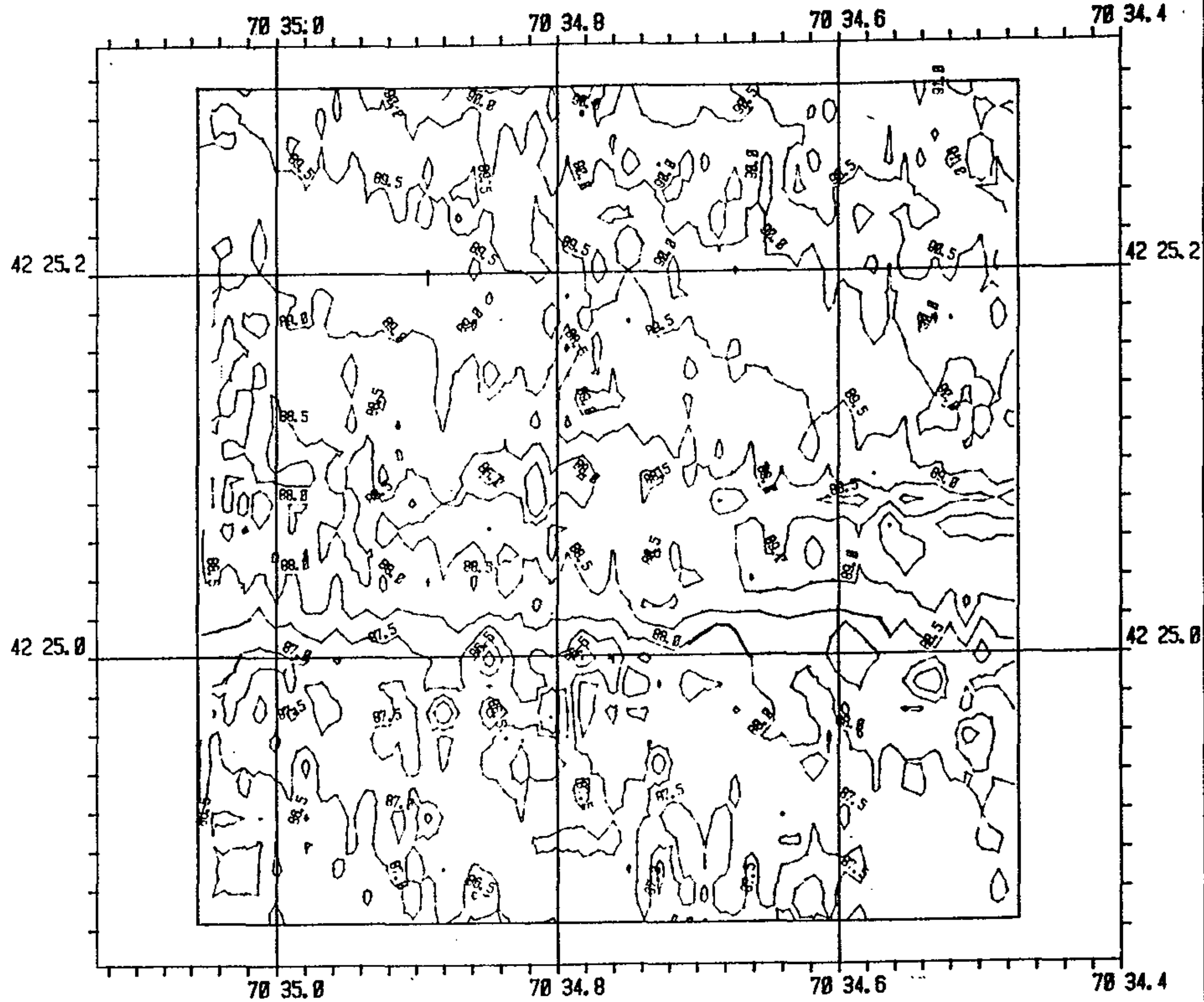
Location	% Volatiles NED	ppm Oil & Grease	ppm Cr	ppm Zn	ppm Cu	ppm As
400W	2.22	6,510	444	469	114	10.2
275W	3.66	1,830	225	266	100	5.4
150W	4.39	2,790	215	285	100	5.8
50W	2.99	1,840	176	168	81	5.2
CTR	1.65	158	38	92	17	5.0
850E	4.22	1,210	90	196	43	10.0
$\bar{X}$	3.19	2389.67	198.00	246.00	75.83	6.93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

SAIC

FOUL AREA SOUTH

JANUARY 1983
SCALE: 1/4000
INTERVAL: .5

Figure IV-4-1.



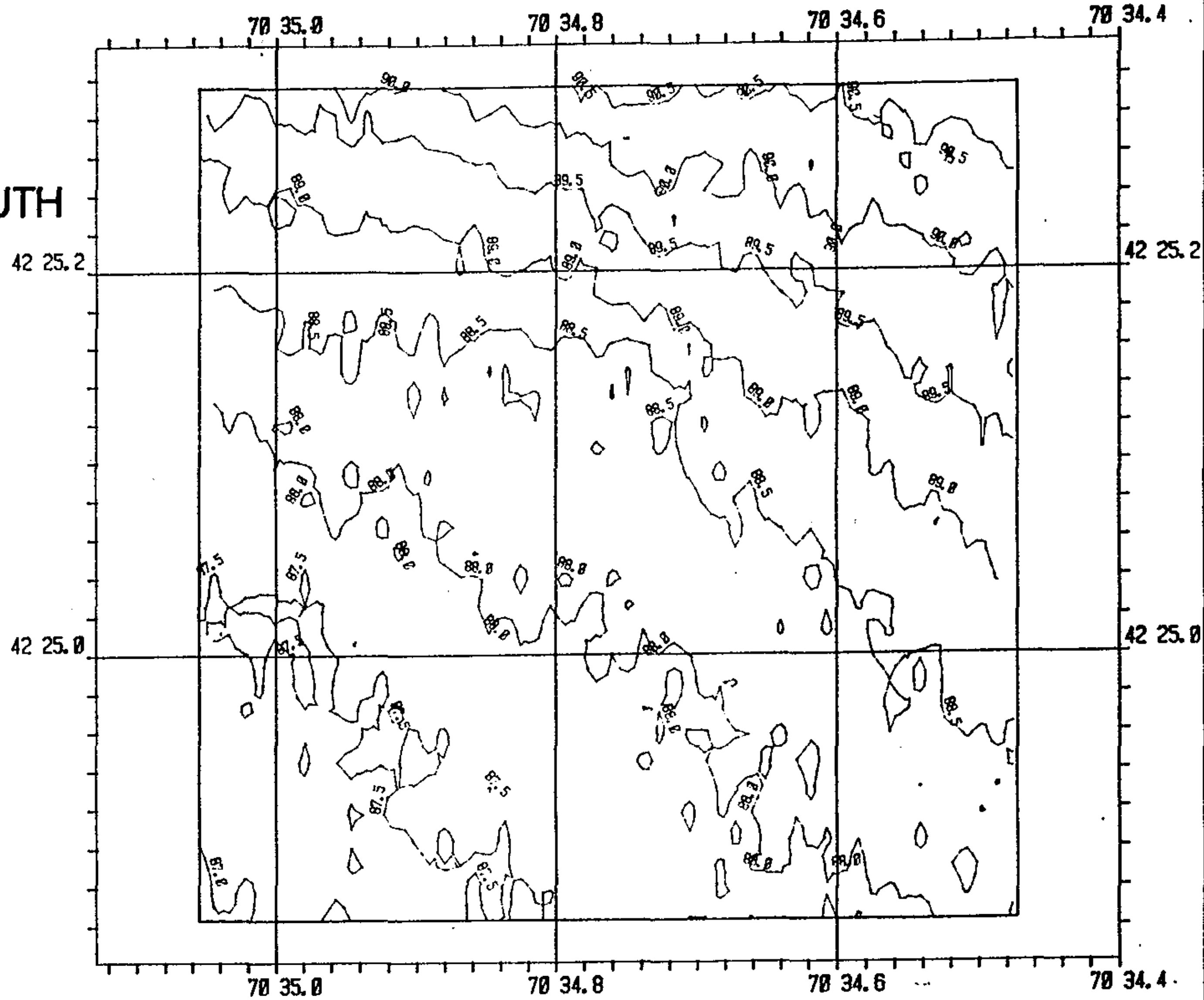
0 80 160

SCALE (m)

FOUL AREA SOUTH

APRIL 1983
SCALE: 1/4000
INTERVAL: .5

Figure IV-4-2.



SCALE (m)
0 80 160

FOUL AREA SOUTH

VOLUME DIFFERENCE

APRIL 1983 - JANUARY 1983

SCALE: 1/4000
INTERVAL: .5

Figure IV-4-3.

0 80 160
SCALE (m)

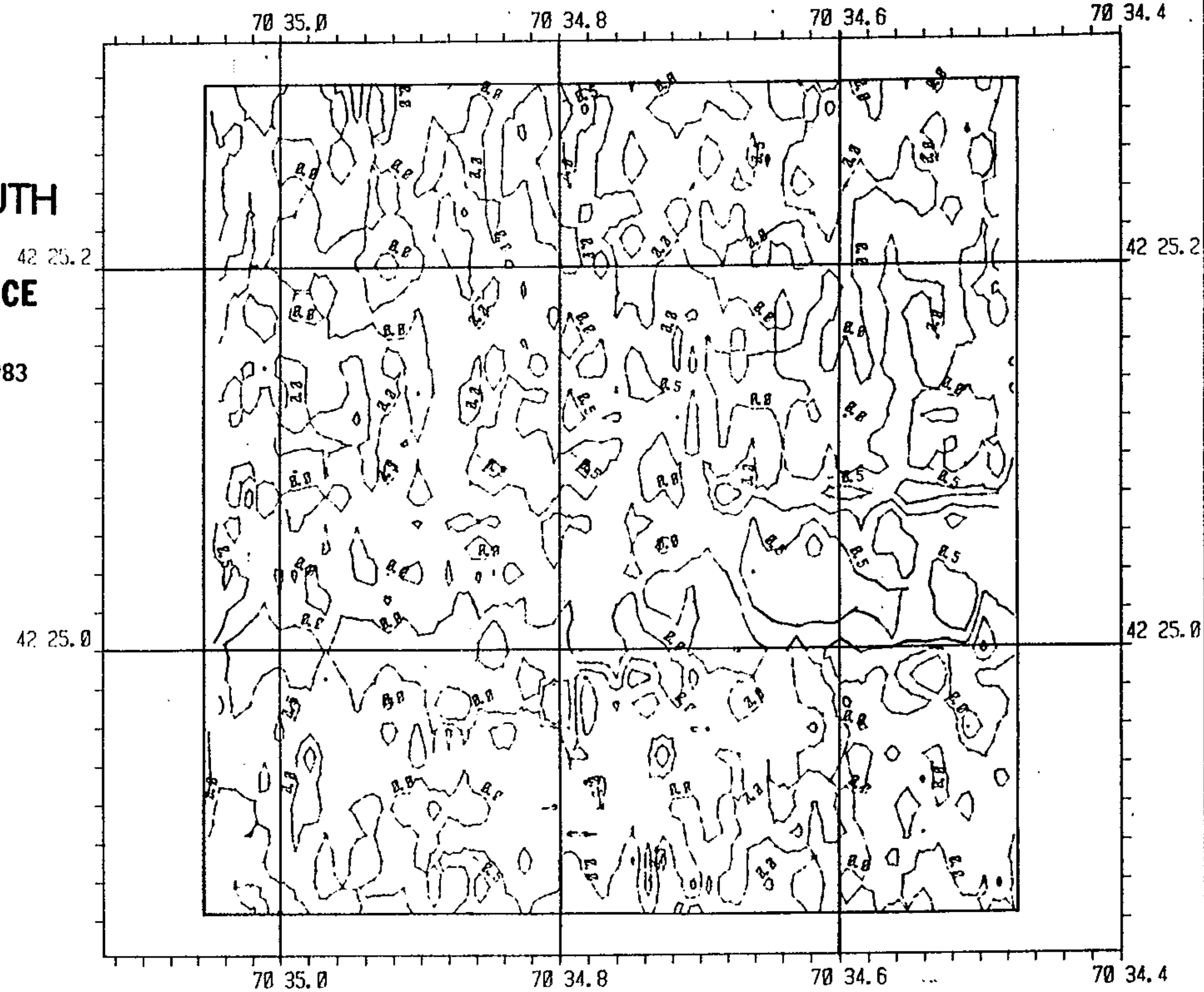


Table IV-4-1

Results of Chemical Analysis- Foul Area-South
January Cruise - 1983

Location	Volatile NED	ppm O&G	ppm Hg	ppm As	ppm Pb	ppm Cr	ppm Cu	ppm Zn
500N	0.95	1200	0.13	8.6	68	111	55	166
250N	4.63	620	0.07	7.1	75	135	61	156
250S	5.31	230	0.07	-	43	101	28	114
500S	5.47	240	-	10.2	37	91	21	91
CTR	5.45	310	0.16	4.7	39	93	35	118
500W	3.95	220	0.10	-	38	86	31	209
250W	5.61	320	0.11	9.3	48	96	31	139
250E	1.29	-	0.16	-	15	54	26	169
500E	5.87	270	0.08	5.1	35	113	27	132
REF-A	4.38	189	0.07	8.3	21	66	15	105
REF-B	4.92	110	0.09	-	23	75	17	91
REF-C	4.41	150	0.06	9.4	33	82	18	90

SAIC

5.0 REMOTS SURVEYS

On 9 October 1984, a REMOTS survey was conducted at the entire Foul Area (FA) disposal site. This is the first REMOTS survey of this area. The two most recent disposal operations took place 3 and 6 weeks before this survey. On 21 September and 31 August, 11,100 yd^3 and 84,800 yd^3 of dredged materials were deposited at the FA, respectively. Prior to these operations, dredged materials were deposited in March 1984 (3800 yd^3) and February through April 1983 (150,000 yd^3). The purpose of this REMOTS survey was to note the extent of observable dredged materials and to characterize the sediments and benthic fauna of this frequently used disposal area. Also, this survey provides a benchmark against which to compare the results of future surveys at the Foul Area.

5.1 Methods

Nineteen stations were occupied at the FA in the configuration shown in Figure IV-5-1. Three replicate images were obtained at stations 2, 4, 6, 7, 10, 11, 13, 15, 16, 17 and 19; two replicates were obtained at stations 3, 8, 9, 12, 14, 18; and one replicate was was obtained at stations 1 and 5. Methods of image interpretation are described in previous sections of this report.

5.2 Results

5.2.1 Extent of Observable Dredged Material

Figure IV-5-1 shows the apparent distribution of dredged material observed at the FA site. Dredged materials were evident throughout the northwestern portion of the survey area. The dredged material layer(s) was relatively thick, ranging from 11.36 to 19.50 cm (exceeding the height of the REMOTS prism window). Isolated patches of dredged material also occurred in single replicates from stations 11 and 14. Evidence of two disposal events was observed at stations 1, 4, 7, 10, 17 and possibly 19 (Fig. IV-5-2).

Station 18 is noteworthy (given its location within a cluster of stations with apparent dredged materials) because no dredged material was apparent in the REMOTS images taken at this location. This observation may represent the real distribution of dredged materials at the FA site. Alternately, the mudclasts and large scale boundary roughness (5.12 cm) present at this station suggest that dredged materials may have been lost due to erosional scouring of the bottom.

5.2.2 Grain Size

A map of apparent grain-size major mode is given in Figure IV-5-3. All stations, except for station 3, consist of

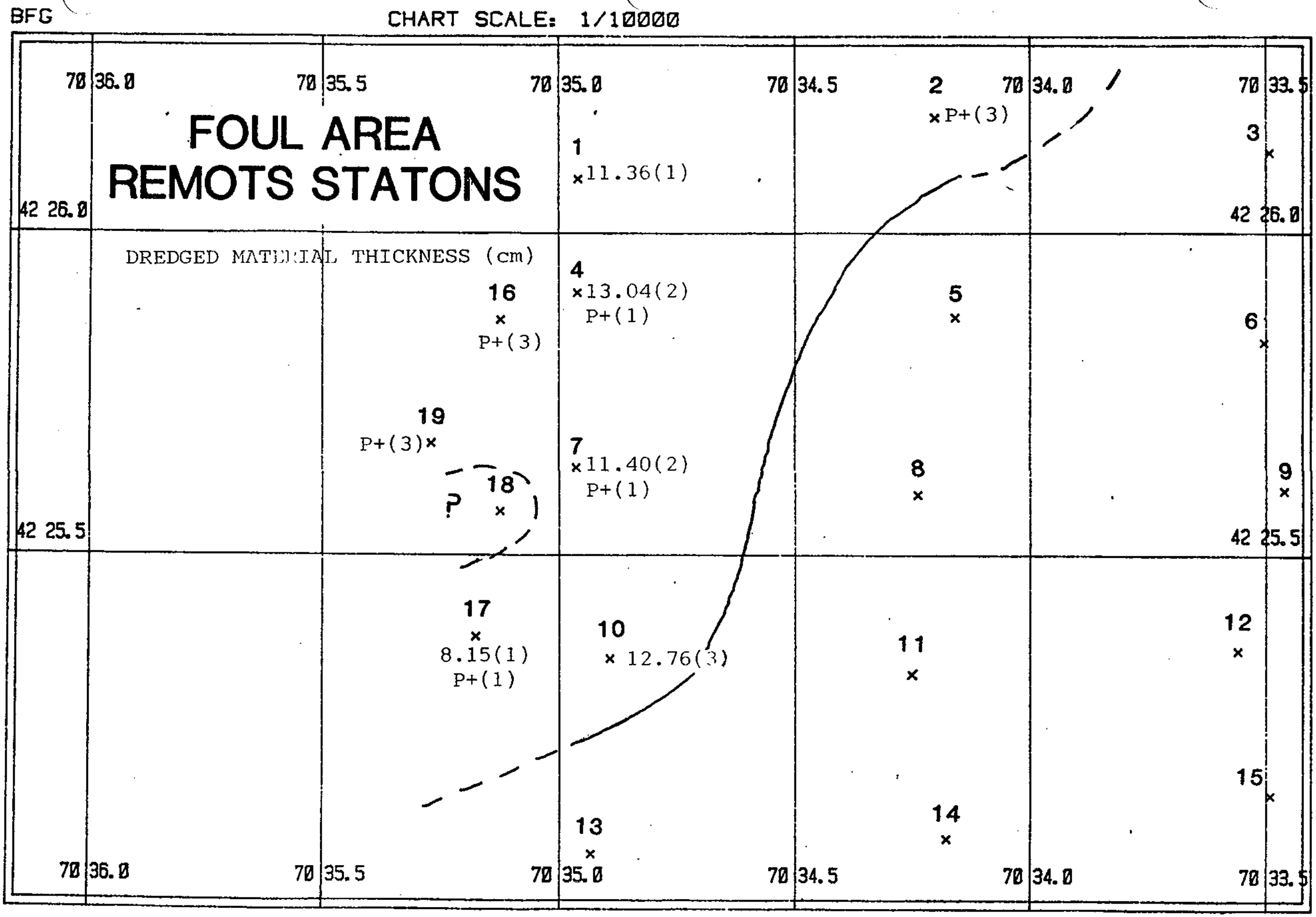


Figure IV-5-1. The distribution of apparent dredged materials (cm) at the Foul Area Ground. () indicates the number of replicate images. The solid line delineates the region where dredged material was apparent.
P+ = Dredged material layer

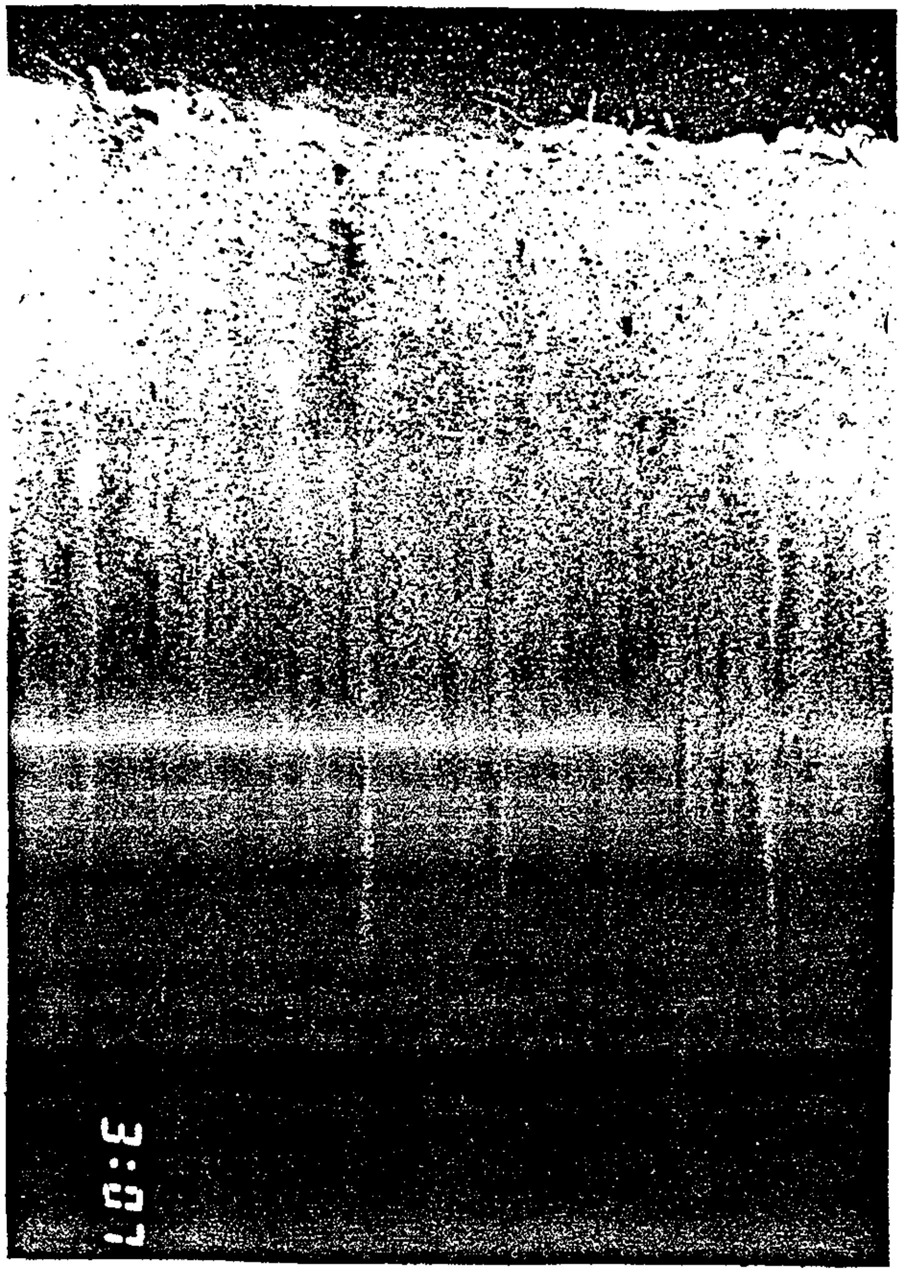


Figure IV-5-2. A REMOTS® image from station 10 revealing evidence of two disposal events. The buried RPD (faint band within the area of lowest reflectance) represents the interface before the last disposal event. Below this relict RPD lies additional dredged material, representative of a previous disposal operation.

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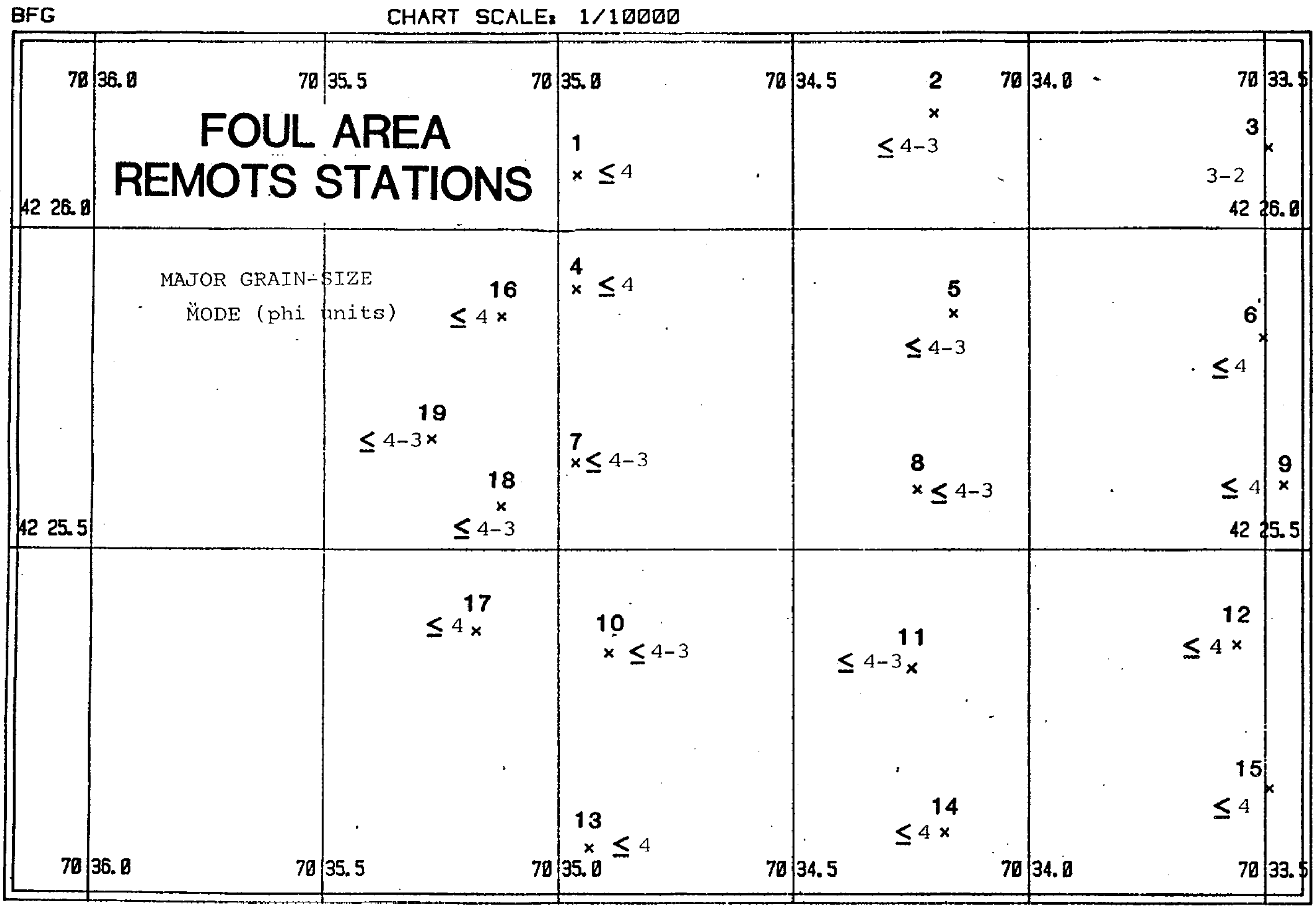

Figure IV-5-3. The mapped distribution of apparent grain-size (phi units) major mode.

silt-clay sediments (> 4 phi) or silt-clay and very fine sand (>4-3 phi) mixtures. The slightly coarser material is found in a wide swath trending northeast to southwest. There is no obvious relationship between the grain-size distribution and the observed distribution of dredged materials (Fig. IV-5-1). Minimal penetration (< 4 cm) was obtained at station 3, where the apparent dominant sediment type was fine sand (3-2 phi). A wide range of grain-sizes, from very coarse to very fine sand (-1 to 3 phi), was noted at this station. The fauna consisted of surface deposit-feeders and/or suspension-feeders. These observations suggest that this area may consist of a coarse sand or gravelly (-1 to 1 phi) substratum upon which a suspension-feeding community has developed. The presence of this community would result in the entrainment of fine-grained material (2-3 phi).

5.2.3 Boundary Roughness

The frequency distribution of small scale topographic relief is shown in Figure IV-5-4. The major mode is at 0.8 cm. Based on surveys in Long Island Sound, this is a characteristic major mode of boundary roughness values for recently used (within 1 year) disposal areas. There is, however, an atypical number of large (> 2.4 cm) boundary roughness values at the FA. These large values represent topographic relief on a scale greater than the width of the prism (Fig. IV-5-5). This large scale relief was observed in images from five stations (5, 6, 13, 15, and 18) without apparent dredged materials; it appears to be the result of both biological and physical disturbance factors.

5.2.4 Redox Potential Discontinuity (RPD) Depths

Figure IV-5-6 shows the mapped distribution of apparent mean RPD depths at the FA. There are no obvious gradients in the distribution of RPD values. However, the combined average RPD depth for stations where dredged material was apparent ($x = 6.29$ cm; stations 1, 2, 4, 7, 10, 17, 19) differs significantly from the average RPD depth for stations without dredged material ($x = 7.69$ cm; Mann-Whitney U-test, $p = .0279$). The frequency distribution of mean RPD values for all stations is shown in Figure IV-5-7. Overall, the RPD's at the FA are well developed; the average RPD for the entire site is 7.06 cm. This is remarkable given the short time interval between this survey and the September and August 1984 disposal operations. To achieve the RPD depths observed at the dredged material stations, recolonization and subsequent bioturbation at these sites had to proceed at a rate which deepened the RPD approximately 1 cm per week.

Rebounding RPD's (Fig. IV-5-8) were evident at five contiguous stations (4, 7, 10, 16, 19), all of which had apparent dredged material. This feature is indicative of retrograde succession. The distribution of rebounding RPD's indicates that stations recently affected by the disposal operation are experiencing second-order stress factors which are not apparent elsewhere.

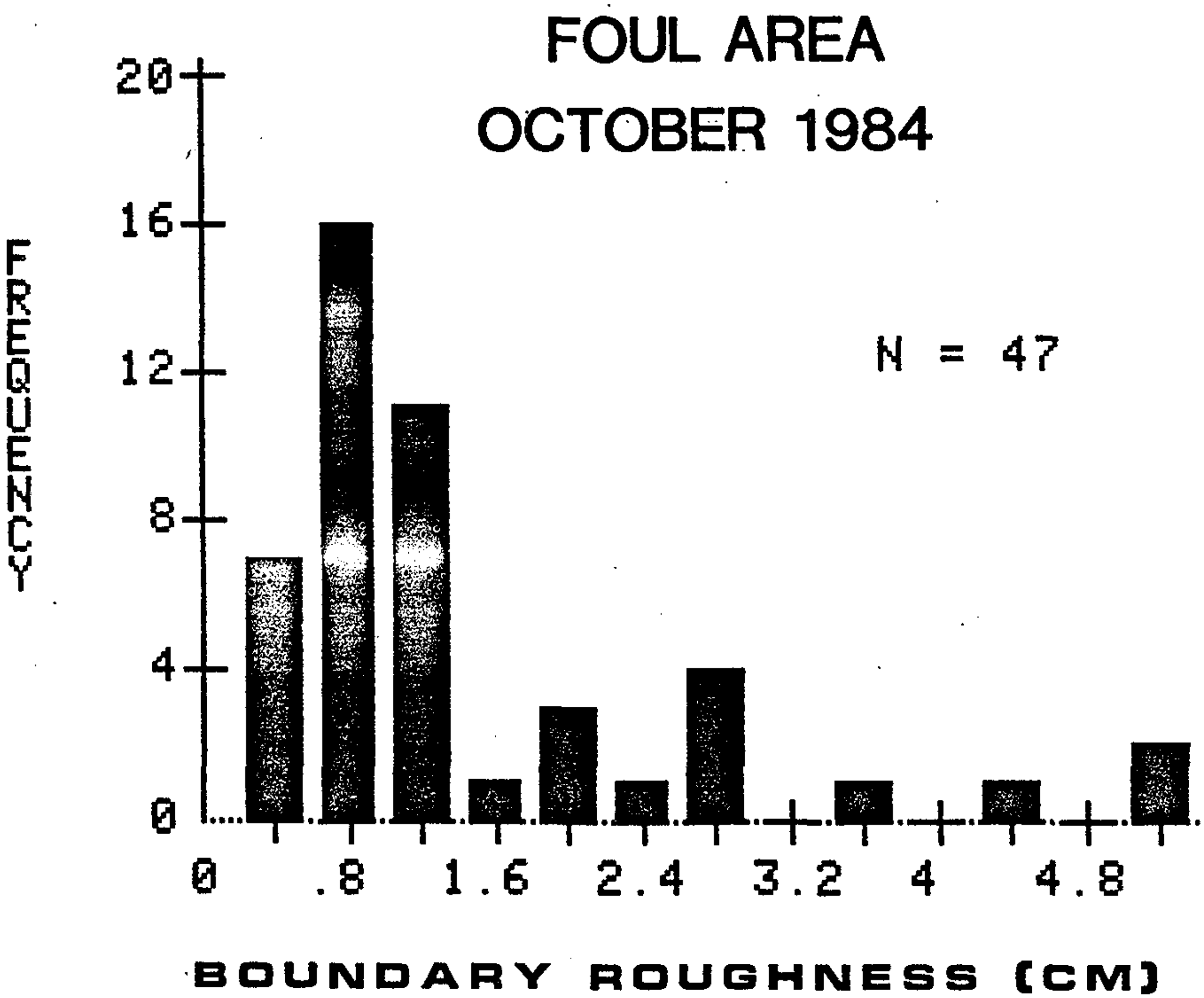

Figure IV-5-4. The frequency distribution of boundary roughness values at the Foul Area.

Figure IV -5-5. A REMOTS® image from station 5 showing unusually large boundary roughness on a scale greater than the width of the photo (1X).

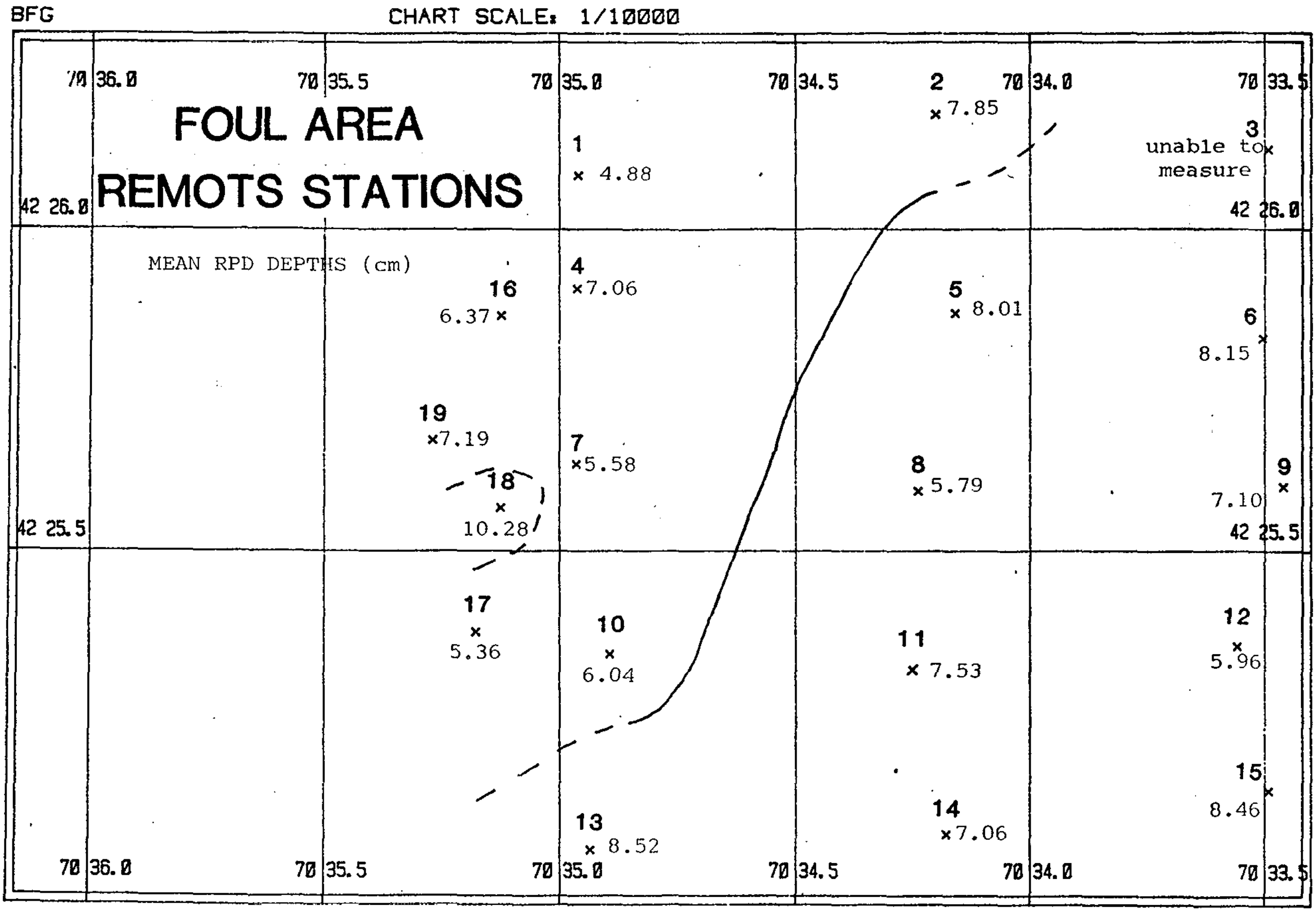

Figure IV-5-6. The mapped distribution of mean RPD depths (cm) (averaged by station) at the survey site. The RPD depth was impossible to measure at station 3 due to inadequate prism penetration. The solid line delineates the region where dredged material was apparent.

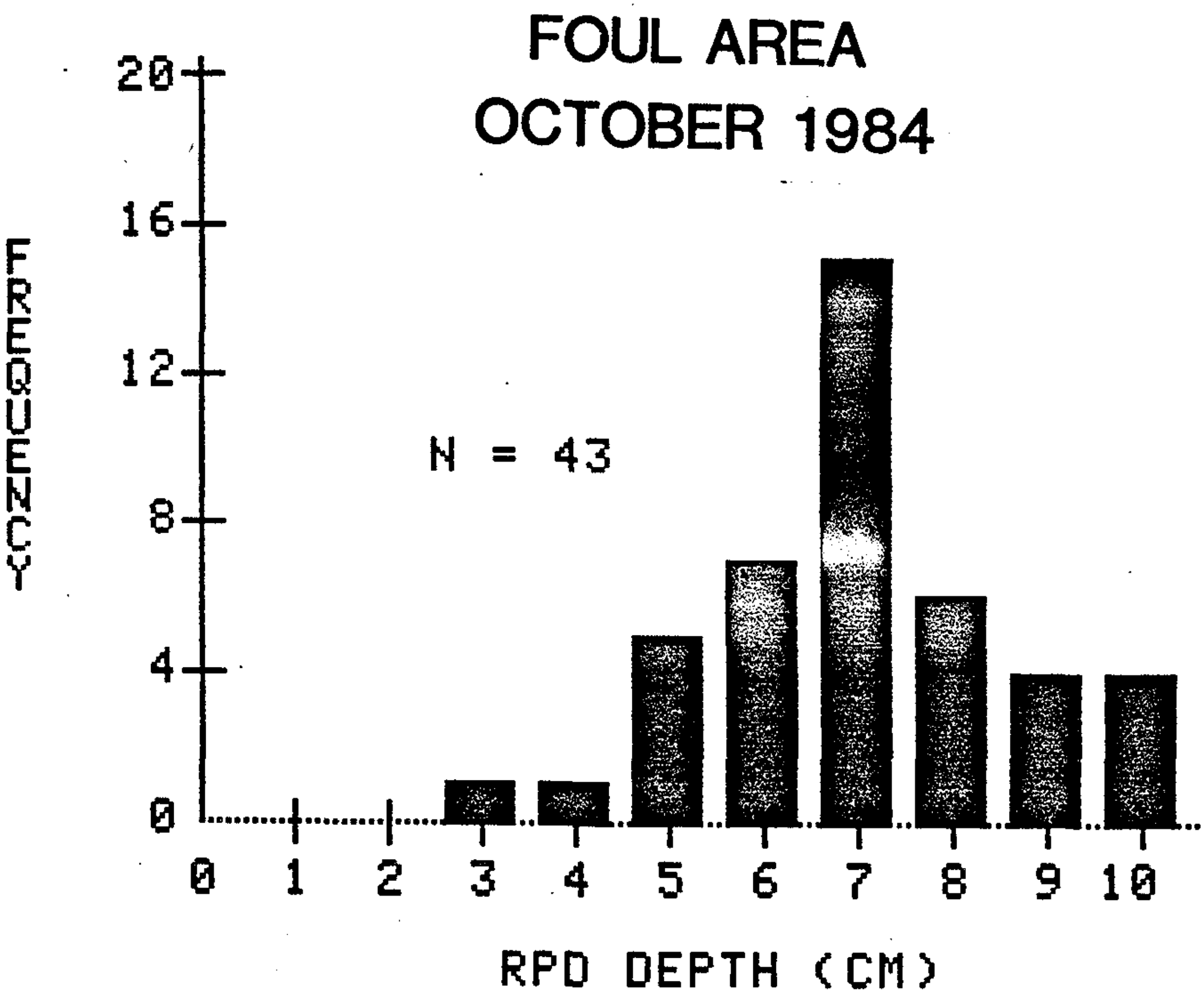

Figure IV-5-7. The frequency distribution of RPD values at the Foul Area.

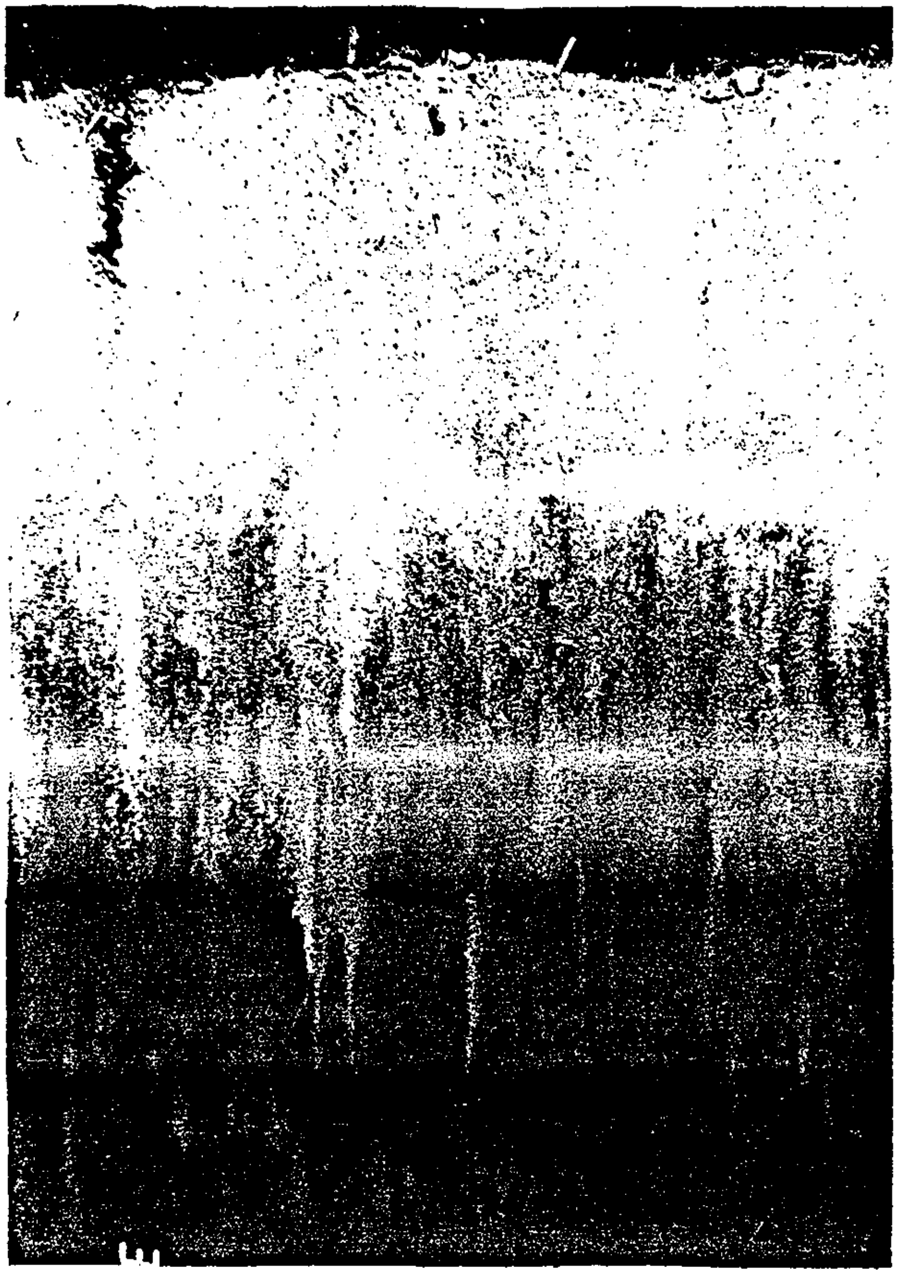

Figure IV-5-8. A REMOTS® image from station 10 showing a rebounded RPD, indicated by the band of intermediate relectance in the center of the photo.

5.2.5 Successional Stages

The mapped distribution of successional stages is given in Figure IV-5-9. Stage I on Stage III (III-I) assemblages dominated the region. A single Stage II assemblage, the tube-dwelling amphipod Ampelisca sp., was observed at station 9. Of all the photographs in which Stage I assemblages were observed, ninety percent were from stations where dredged material was apparent. Forty percent of the REMOTS images from stations with dredged material were in Stage I; this is significantly different from the four percent of Stage I seres in the images from stations without dredged material (Chi-square test; $p = .0116$). This difference illustrates the impact of the disposal operation(s). It remains remarkable, however, that 60% of the replicates in the area very recently affected by a disposal operation(s) exhibit Stage III assemblages (Fig. IV-5-10). If disposal operations did indeed occur at this location 3-6 weeks before the REMOTS survey, the rapid recolonization by late successional taxa (i.e. head-down feeders) precludes the possibility of recolonization by larval settlement. Apparently, these taxa have recolonized the area by burrowing up through the deposited material and re-establishing their life positions, and/or by migrating laterally from adjacent, unaffected areas. It is likely that the latter phenomena was important only in peripheral areas of the deposited materials. This pattern of recolonization suggests that the deposited materials were relatively clean, low BOD sediments.

5.2.6 Benthic Indices

Figure IV-5-11 is the mapped distribution of benthic index values at the FA site. Among the stations without apparent dredged material, only 1 of 22 images did not have the highest possible benthic index value of 11, indicating a relatively pristine, benthic environment (images similar to that shown in Fig. IV-5-5). At stations with dredged material, 60% of the replicates had values of 11. This pattern is a direct result of the distribution of successional stages shown in Figure IV-5-9. The frequency distribution of benthic indices is shown in Figure IV-5-12. The bimodal distribution reflects the disturbed and non-disturbed seafloor, with all but one non-eleven value attributable to the recent disposal operations.

As indicated in previous sections of this report, given that disposal operations took place at the Foul Area 3 and 6 weeks prior to this REMOTS survey, Figure IV-5-11 is noteworthy. In less than two months, 60% of the images form an area which received from 11 to > 19 cm of dredged materials have returned to an apparent pre-disposal state. In addition, the other images from this area have values of 7 (one 6) with relatively deep RPD's, indicating the activity of head-down deposit-feeding organisms. Apparently, the benthic fauna at the FA are highly resilient in response to this type of disturbance. The rate of faunal recovery observed in this survey is much more rapid than any recovery previously monitored with REMOTS technology or reported in the literature for any benthic recolonization

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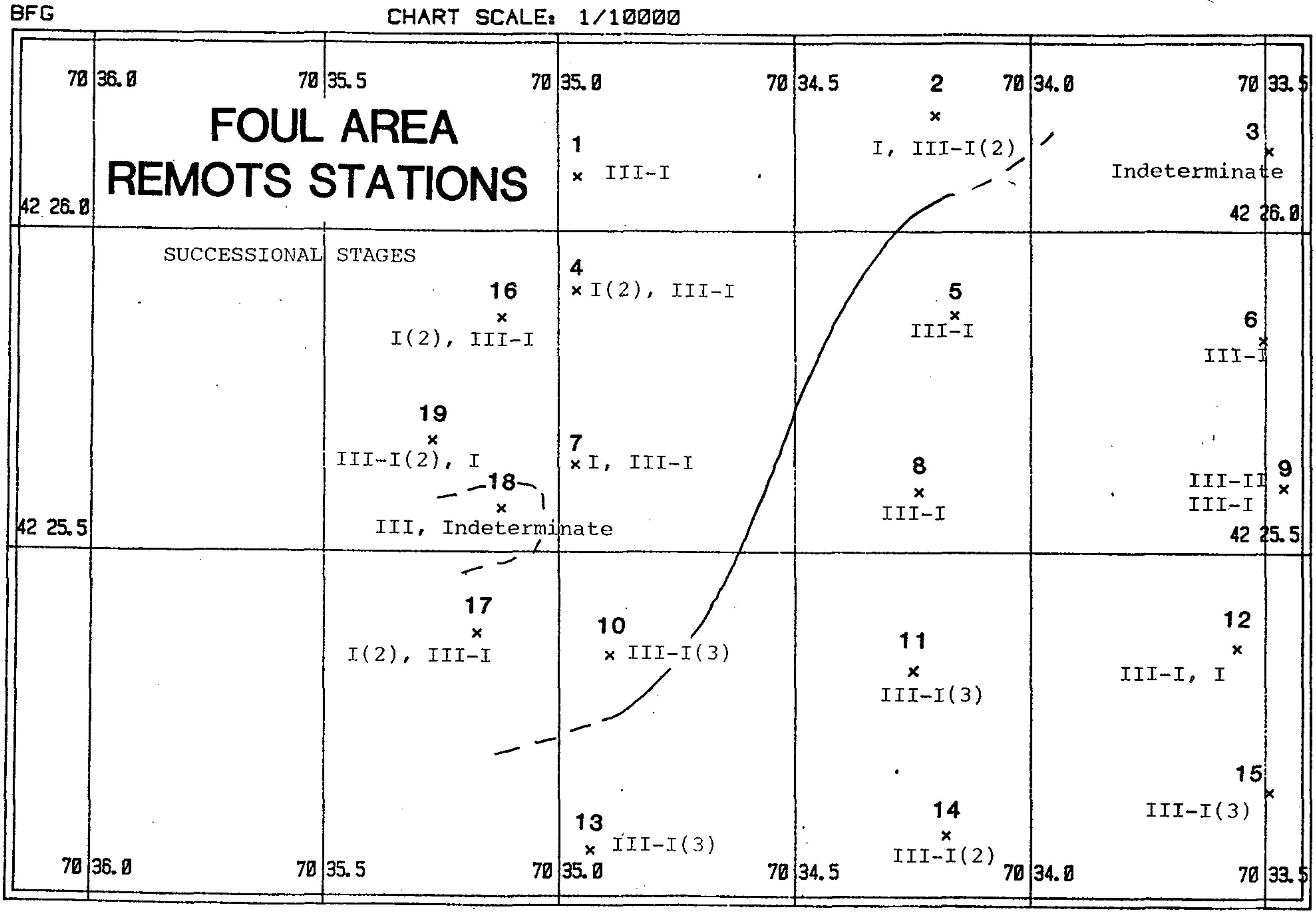


Figure IV-5-9. The mapped distribution of successional stages at the survey site. The solid line delineates the region where dredged material was apparent. () indicates the number of replicate images.

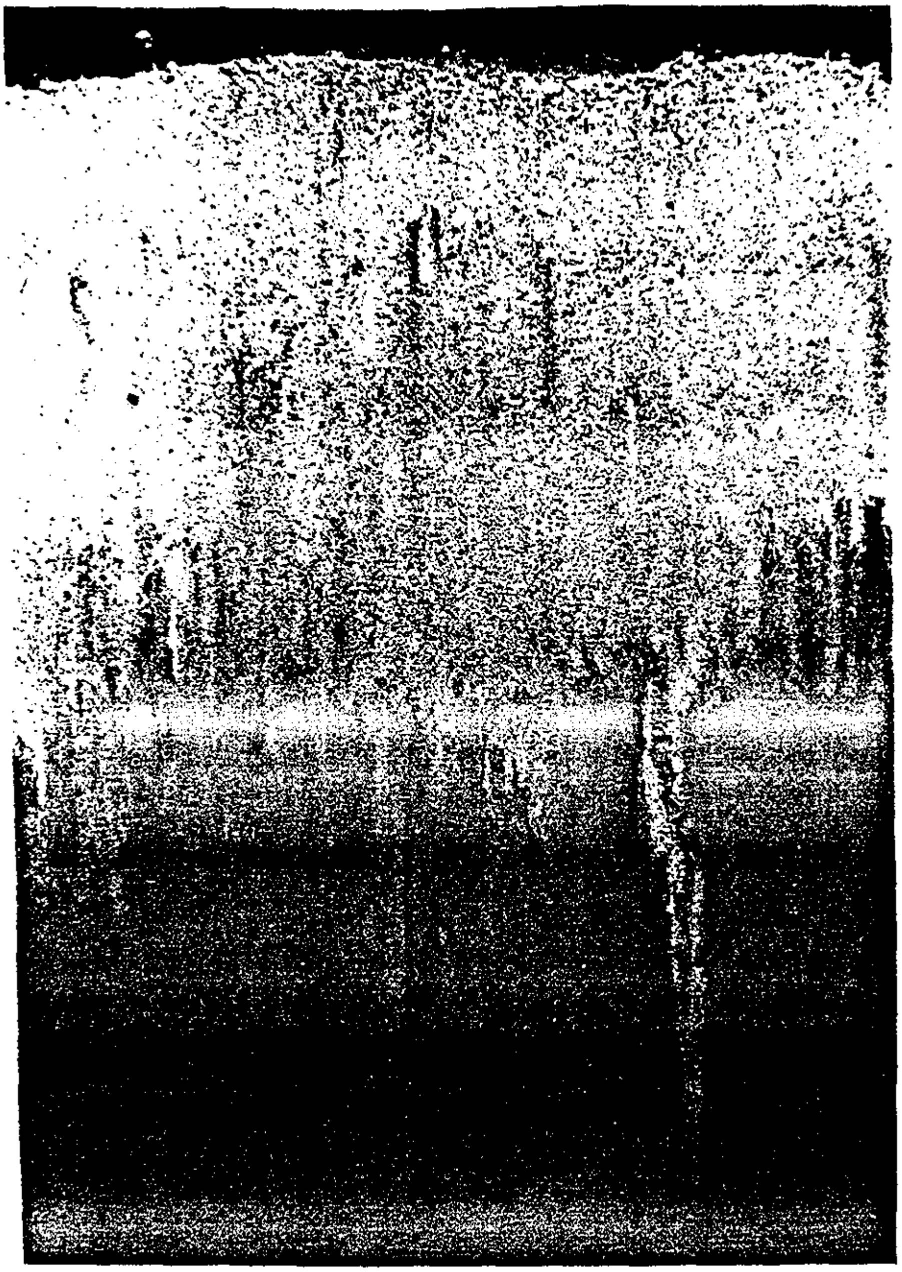


Figure IV-5-10. A REMOTS® image from station 16 showing Stage III taxa inhabiting apparently recently deposited dredged material. A feeding void is evident just below the mean RPD depth and a large worm tube (Maldanid?) can be seen in the background at the interface.

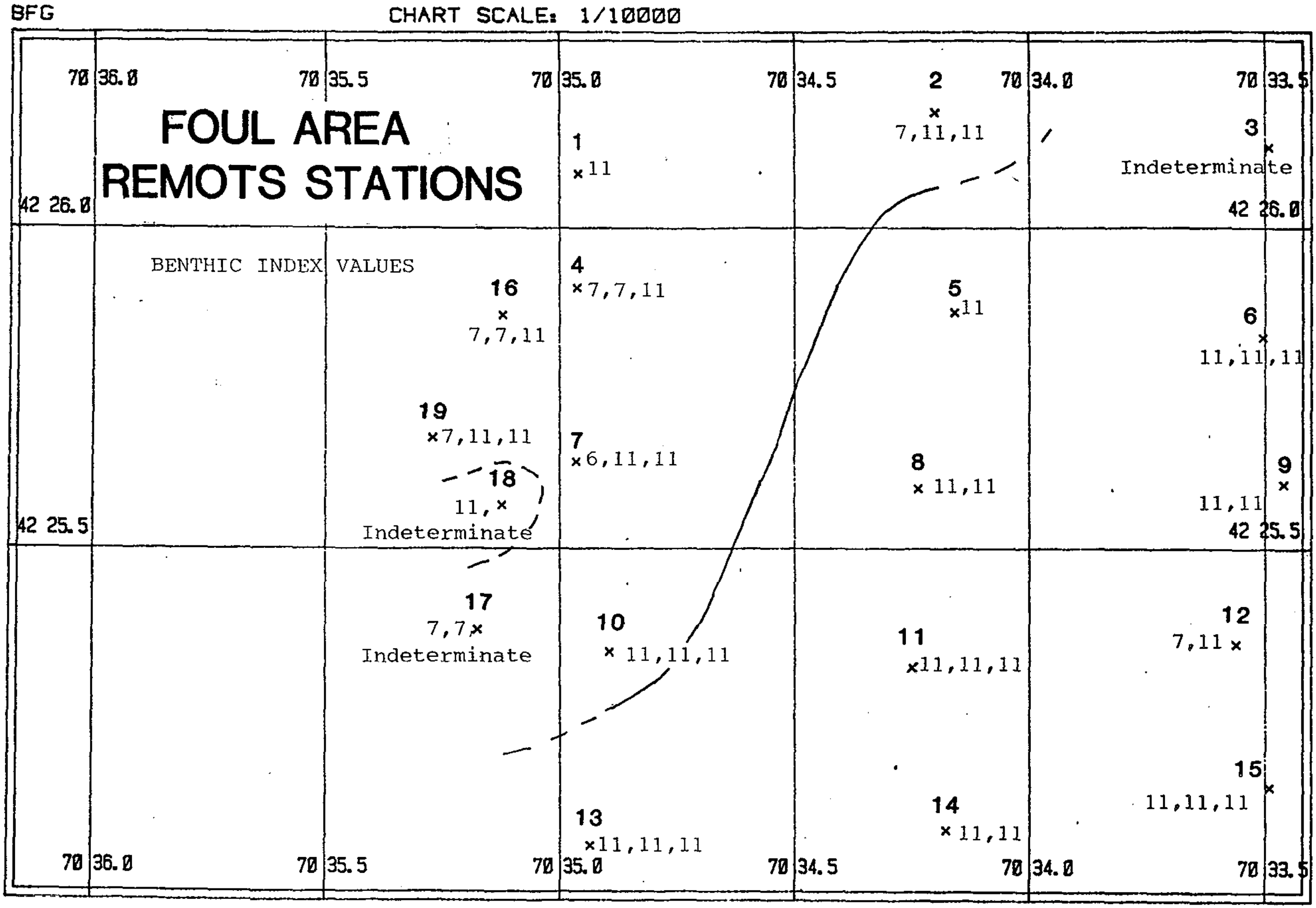


Figure IV-5-11. The mapped distribution of benthic indices at the Foul Area. The solid line delineates the region where dredged material was apparent.

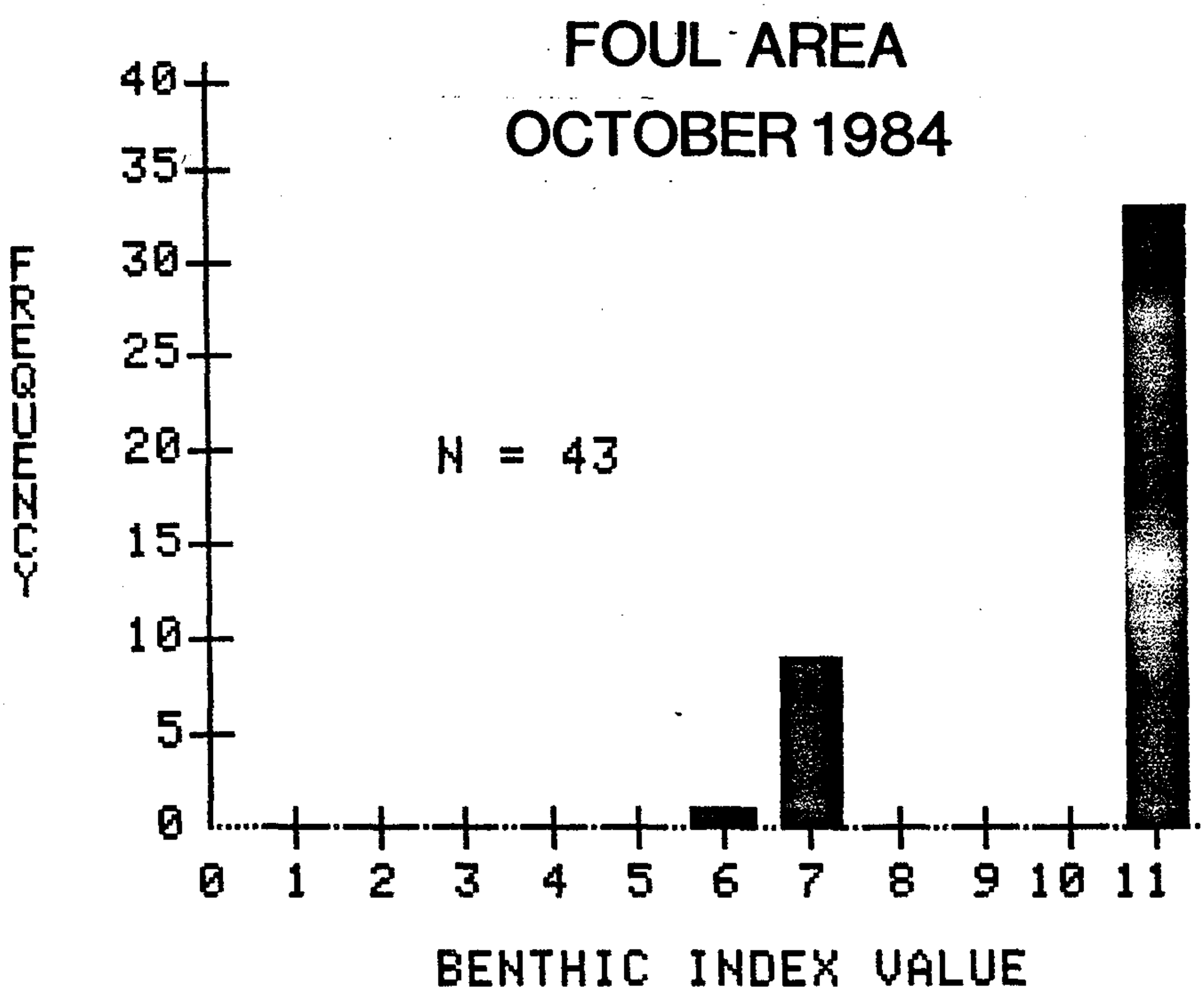


Figure IV-5-12. The frequency distribution of benthic index values for all stations at the survey site. The two modes reflect the disturbed and non-disturbed seafloor.

experiments. Unfortunately, as this was the first REMOTS survey at the FA, direct comparison to pre-disposal REMOTS data cannot be made. It remains possible that the dredged materials noted in this survey do not represent the September and August 1984 disposal operations. Future surveys at this site, however, should reveal whether the present observations accurately describe the resilient nature of the benthic fauna of this region.

5.3 Summary

This first REMOTS survey of the Foul Area was conducted three and six weeks after two disposal operations. A thick (11 to > 19 cm) dredged material layer was detected throughout the northwest half of the site. Aside from isolated patches at two central stations, there was no evidence of dredged materials in the eastern and southern portion of the disposal site.

The sediments at the FA were largely silt-clay (> 4 phi) or silt-clay and very fine sand mixtures (> 4-3 phi). The northeast corner of the area, station 3, exhibited a major mode of fine sand (3-2 phi). A relatively coarse substratum may exist at this site, apparently supporting a surface deposit-feeding or suspension-feeding community.

Mean RPD depths are well-developed throughout the survey area, with an overall average RPD of 7.06 cm. The average RPD for stations with apparent dredged materials is significantly less than the average RPD for stations from the unaffected area (6.29 cm vs 7.69 cm). However, if the disposal data are accurate, the rate at which the RPD has deepened at the stations which recently received dredged materials is extremely rapid (approx. 1 cm per week).

Stations with dredged materials present have significantly more Stage I seres (40%) than stations in the unaffected area (4%). It is remarkable, however, that 60% of the replicate images from an area receiving dredged materials 3 to 6 weeks ago exhibit Stage III seres. This apparent, rapid recolonization by advanced successional taxa indicates that these organisms recolonized the area by burrowing up through the deposited material and/or by migrating laterally from surrounding regions. This pattern of recolonization suggests that the dredged materials were relatively clean, low BOD sediments.

There is a bimodal distribution of benthic index values at the FA. Southern and eastern stations, which apparently did not receive dredged materials, have indices of 11, indicating that this region is a relatively undisturbed benthic environment. The area which recently received dredged materials has index values of 7 and 11. These values are high for an area so recently disturbed. This apparent rapid recovery suggests that either the dredged material deposited at this site was relatively "clean" and had a very low BOD, and that the recolonization of the deposited material primarily occurred by existing Stage III adult organisms which migrated laterally from the edge or upward through the deposit and quickly re-established themselves at the new sediment-water interface, or the dredged material from the disposal operations in August and September 1984 were not deposited at this site.

Unfortunately, comparison to pre-disposal REMOTS data from this location cannot be made; future surveys should determine whether the present observations accurately describe the apparent resilient nature of this benthic environment.

6.0 CONCLUSIONS

Disposal of dredged material at the Foul Area during 1983 presented a unique opportunity to observe the effects of two different dredging/disposal operations and to 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 (Chelsea and Mystic Rivers). Although provisions were made on this project for point-dumping at a taut-wire moored buoy, 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, particularly in this depth of water.

Conversely, the hopper dredge operation, using the SUGAR ISLAND, was quite successful. Control of disposal was much better, and 90% of the dumping operations were confined to a 50 meter radius about the disposal point (Fig. IV-6-1). 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.

Surveys conducted prior to and after disposal operations at the new FAS site revealed no significant accumulation of dredged material. Additional bathymetric surveys and sediment analysis will be needed to document the disposal of dredged material.

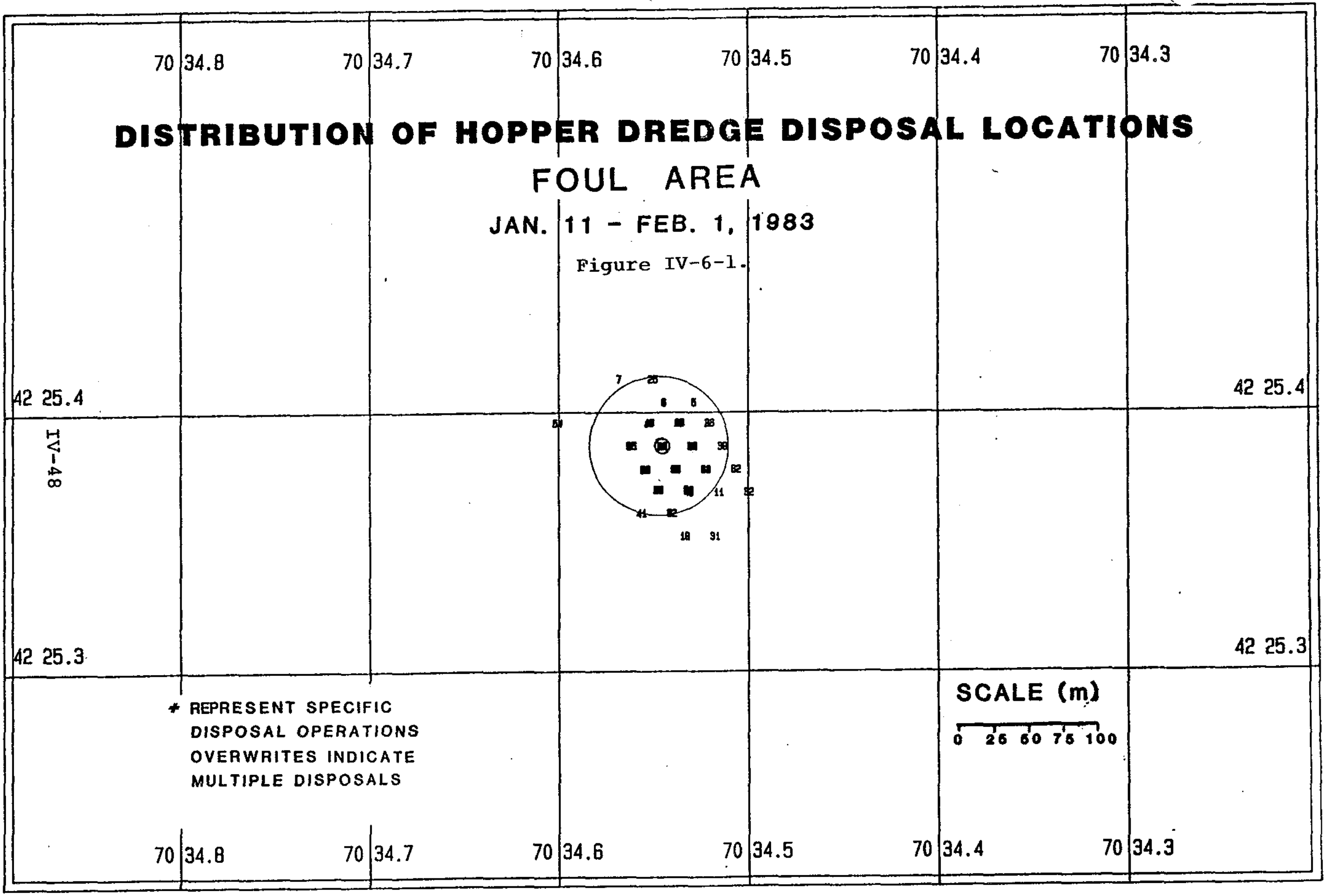

DISTRIBUTION OF HOPPER DREDGE DISPOSAL LOCATIONS
FOUL AREA
JAN. 11 - FEB. 1, 1983
70 34.8
70 34.7
70 34.6
70 34.5
70 34.4
70 34.3
42 25.4
42 25.3
* REPRESENT SPECIFIC DISPOSAL OPERATIONS OVERWRITES INDICATE MULTIPLE DISPOSALS
SCALE (m)
0 25 50 75 100

Figure IV-6-1.

V. CAPE ARUNDEL DISPOSAL SITE

AUTHORS:

Gerald S. Cook - SAIC

Gary D. Paquette - SAIC

Sheldon D. Pratt - URI

V. CAPE ARUNDEL DISPOSAL SITE

1.0 INTRODUCTION

The proposed maintainance dredging of Kennebunk River Federal Navigation Channel in Kennebunkport and Kennebunk, Maine requires the disposal of approximately 20,000 cubic yards of material. Based on a recent draft environmental assessment and finding of no significant impact report prepared by the New England Division (NED), U.S. Army Corps of Engineers, it was recommended that the material be disposed at the EPA interim designated Cape Arundel Disposal Site (CADS) located about 2.75 NM south southeast of the project. This area was previously used for disposal of material from the Kennebunk River in 1975 and from Cape Porpoise Harbor in 1976.

As a consequence of the impending need for the maintenance dredging of the Kennebunk River, the NED's DAMOS program conducted both general and site specific studies of the Cape Arundel Disposal Site. The general environmental conditions discussed below are comprised of a historical review of previous studies conducted in the western Gulf of Maine and cover a variety of subjects pertinent to dredged material disposal management. The site specific studies provide a more detailed picture of conditions at the disposal point and the information necessary to properly manage and monitor the entire disposal operation with minimum impact on the local environment and commercial fishing industry.

The purpose of this report is to present both the general environmental condition and the site specific studies that have been accomplished to date and relate these to the overall management and monitoring of disposal operations at the Cape Arundel Disposal Site. The information developed from his study will be used to support a final site designation effort at CADS.

2.0 GENERAL ENVIRONMENTAL CONDITIONS

This section provides a discussion of previous studies conducted in the western Gulf of Maine which are pertinent to an overall understanding of conditions that can exist at the CADS area. The following topics are discussed in detail below: currents, waves, geology, turbidity and commercial fisheries.

2.1 Currents

Numerous large and small scale studies have been made of the non-tidal circulation in the Gulf of Maine. Many of the studies were conducted for the purpose of deducing the direction and speed of drift as it affects the eventual location of fish larvae when they cease their planktonic existence. Consequently, these studies provide patterns of non-tidal drift on a seasonal basis and ranges of drift velocities at both the surface and bottom as deduced from drift bottle and seabed drifter returns. Such information can be used to estimate seasonal non-tidal circulation in the CADS area. Early studies of the circulation in the Gulf of Maine have been summarized by Colton (1964). Bumpus and Lauzier (1965) provide an excellent summary of non-tidal circulation in the entire Gulf based on drift bottle recoveries. Figure V-2-1, (Bumpus and Lauzier, 1965) shows a southerly drift parallel to the east coast of Maine during all seasons.

Graham (1970a) reviewed historical data and utilized surface and bottom drifters and hydrography to give a comprehensive description of currents along the Maine coast. One station was located about three miles south of the Cape Arundel site (Figure V-2-2). The average drift of all surface bottles was 3 km/day (3.5 cm/sec) in a counterclockwise direction along the coast, a result consistent with earlier studies. Bottom drifters moved shoreward into bays and estuaries at an average rate of 0.09-0.54 km/day. Virtually all recovered bottom drifters released south of Cape Arundel were recovered in Wells Bay. Graham concluded that, while net drift was parallel to the coast, winds and dynamic pressure gradients influenced by Coriolis force and bottom topography directed water shoreward in the study area during spring, summer and autumn.

A bottom drifter study carried out between 1972 and 1977 (Shevenell, 1973) (Figure V-2-3) illustrates very well the expected southerly route parallel to the coast of Maine and New Hampshire. Water properties measured by Shevenell indicated upwelling of cooler, deep water near the coast during periods of offshore winds and intensification of southerly flow and surface water movement toward the coast during northeast storms.

A study of winter circulation in the Western Gulf of Maine was carried out from November 1974 to January 1975 (Brown and Beardsley, 1978; Vermersch, et al., 1978; Brown et al., 1977). The principal goal of the study was to determine the effect of passage of winter storms on the circulation in the area. Data from a moored current, temperature and pressure array and additional records of coastal sea level, meteorology at Portland lightship, and four hydrographic transects perpendicular to the shore were used in the analysis.

Data were collected from one current meter at a depth of 33m at mooring site 3 located about 18 NM south of Cape Porpoise (Figure V-2-2). Time series records of speed, direction, component velocities as a function of time are presented in Figures V-2-4a, b. A progressive vector plot and a central vector diagram of this same time series data is shown in Figure V-2-5.

From the time series records (Fig. V-2-5), it can be seen that maximum tidal currents are of the order of 37 cm/sec and the highest hourly-averaged speeds were about 25 cm/sec. Over the entire 73 day time series record, maximum tidal currents

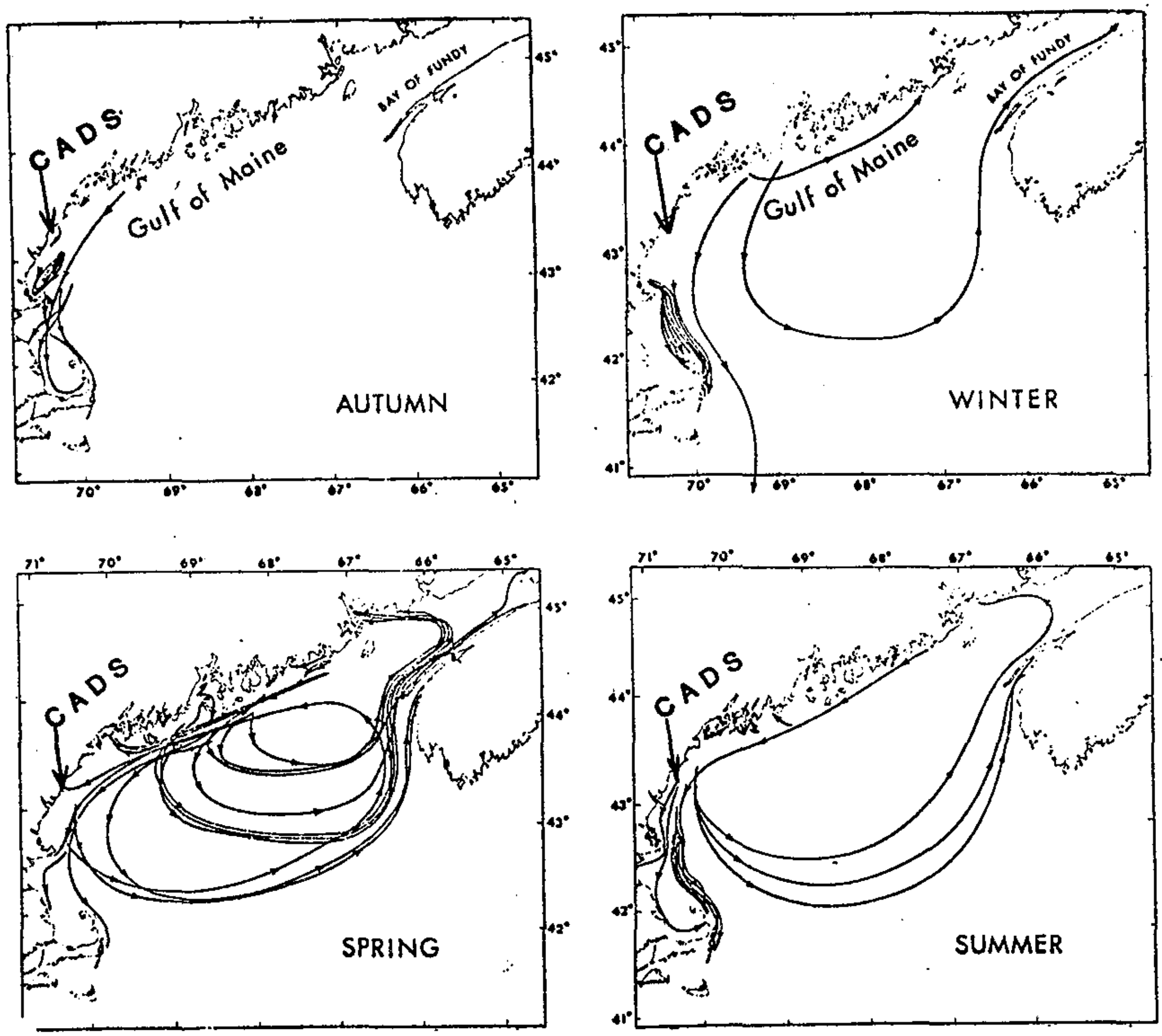


Figure V-2-1. Assumed routes of surface drift bottles released during 1963-64 (routes follow those in Bumpus and Lauzier, 1965). From Graham, 1970. Arrows show location of Cape Arundel site.

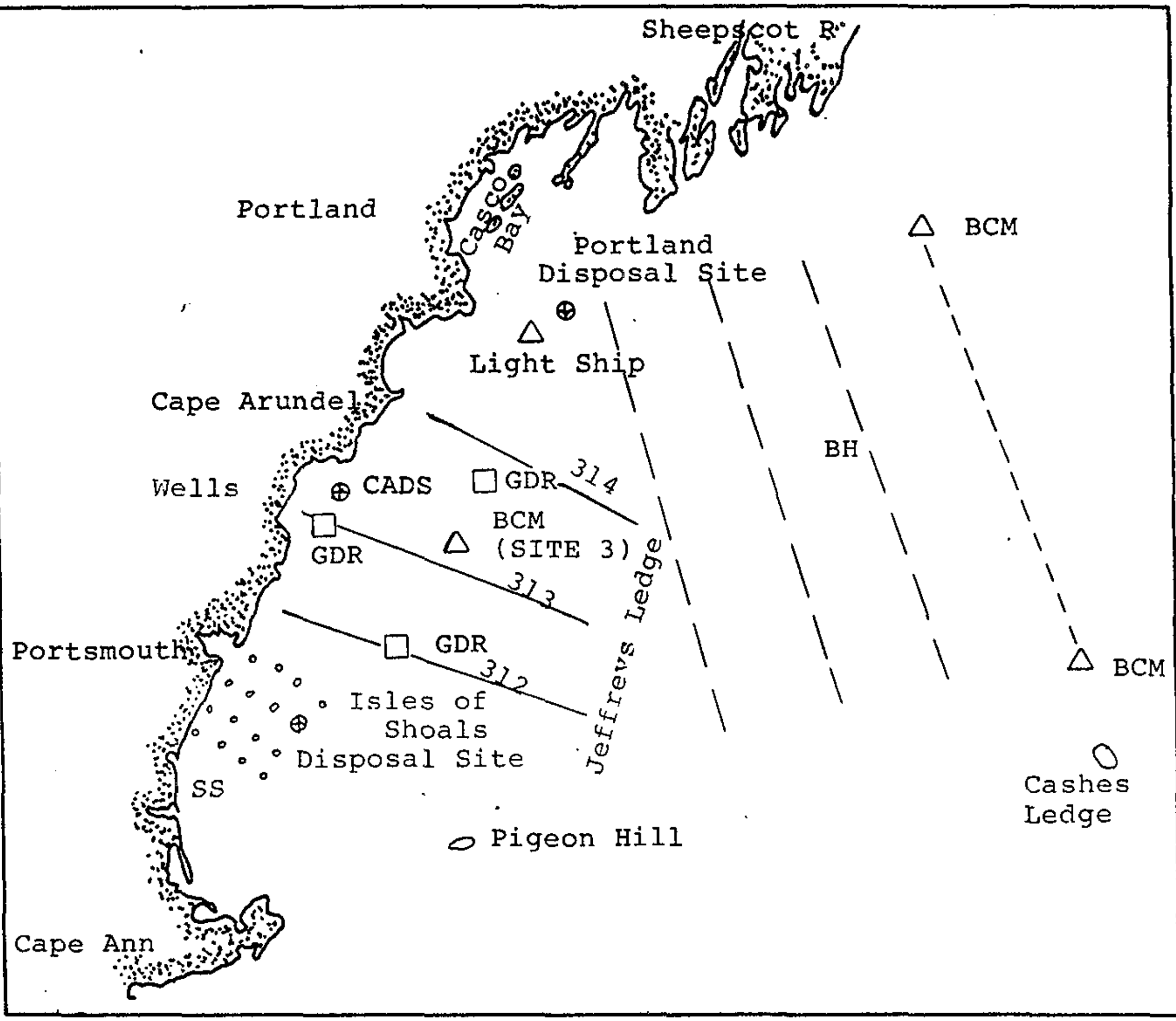


FIGURE V-2-2. Location of studies off the western Maine coast.
BCM, BH - current meter stations and hydrographic tracks. Brown and Beardsley 19278, Vermersch et al 1978.
GDR - drifter releases. Graham, 1970a, 1970b
SS - sampling stations and drifter releases. Shevenell 1974a, 1974b
312-314 - Seismic profiles. Oldale et al. 1973

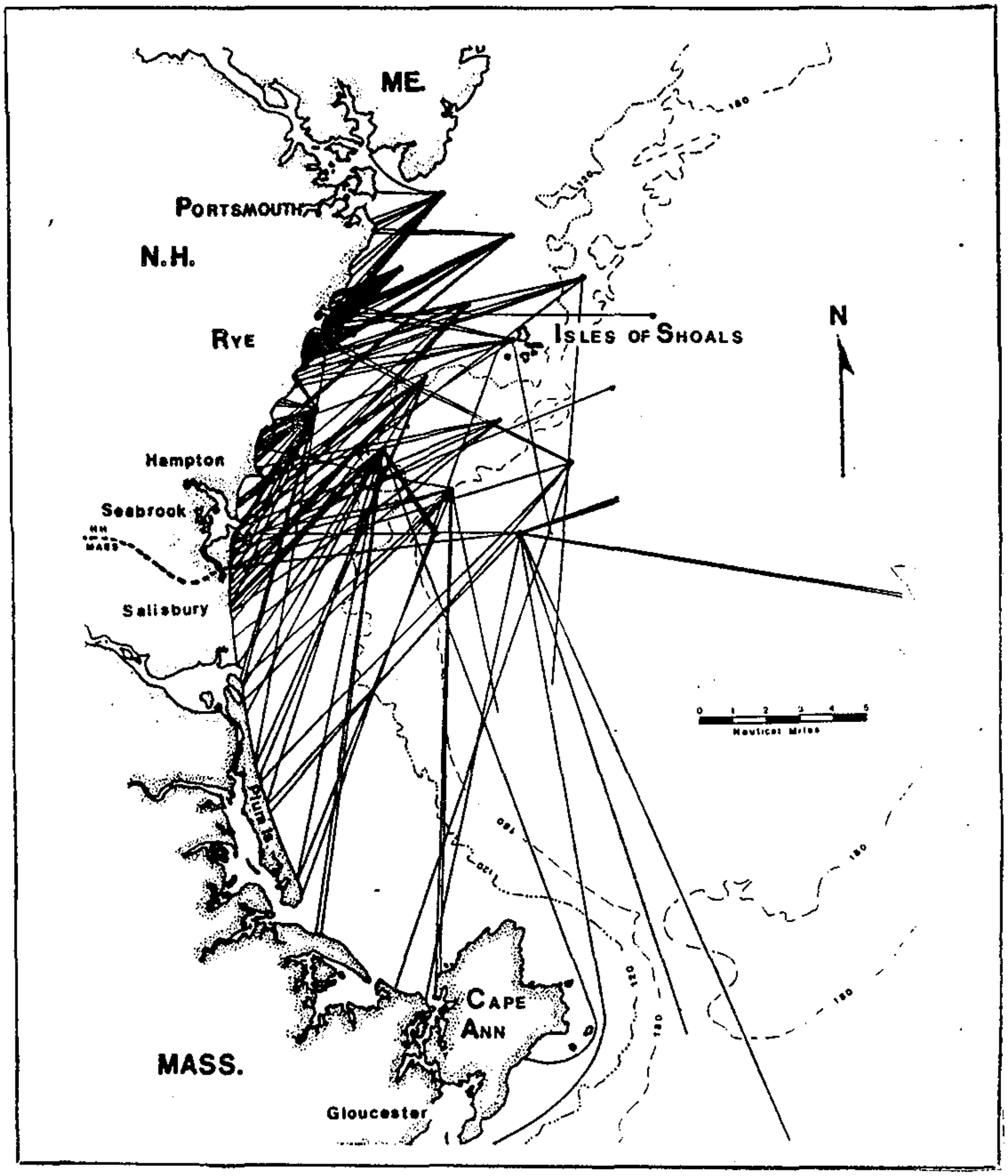


Figure V-2-3. Bottom Drifter Trajectories July 1972 - June 1973 from releases off the New Hampshire coast. Contours in feet. From Shevenell (1973)

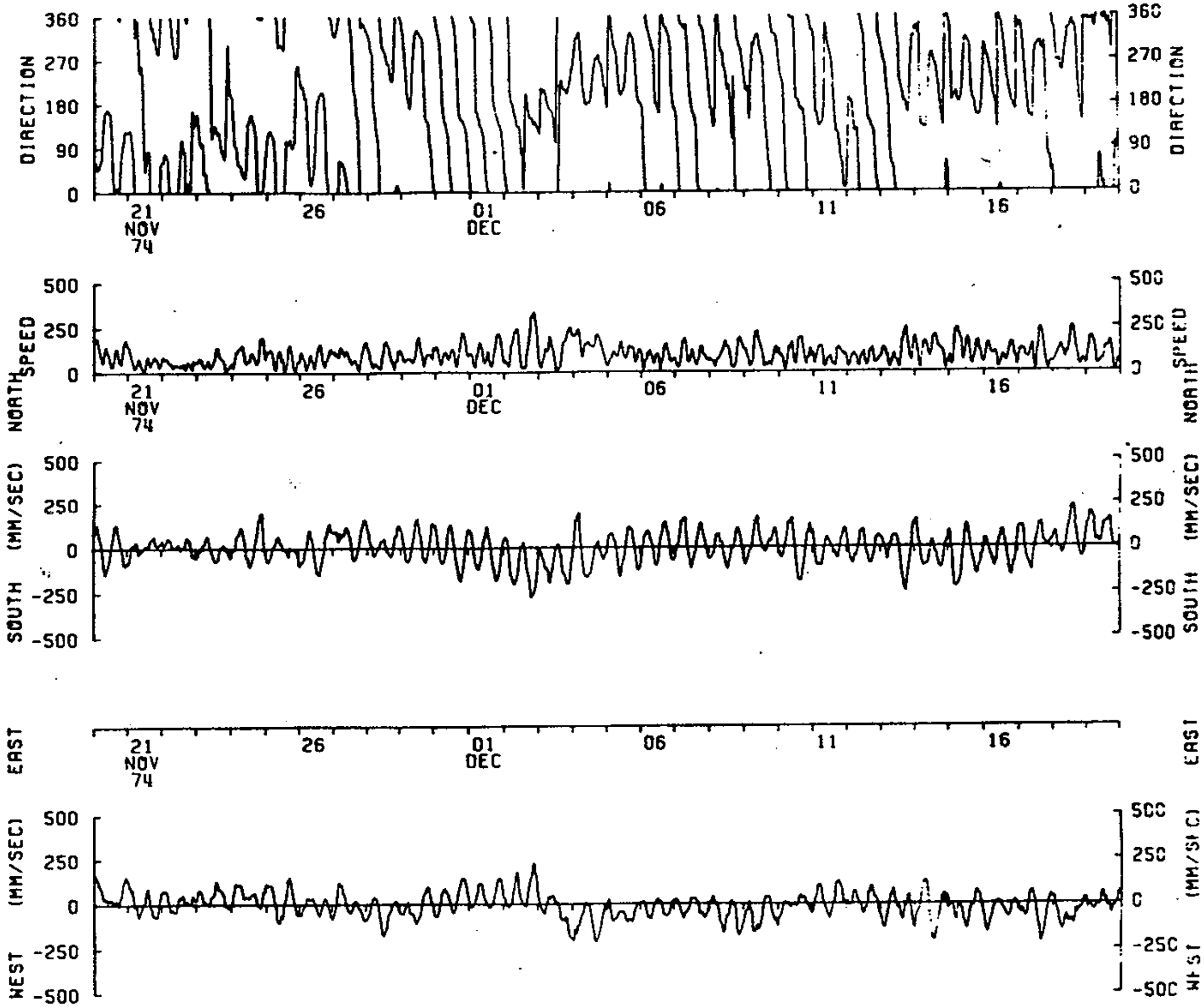


Figure V-2-4a. **Time series of hourly-averaged data for instrument record WGM 23 (first half).** (From Brown et al.)

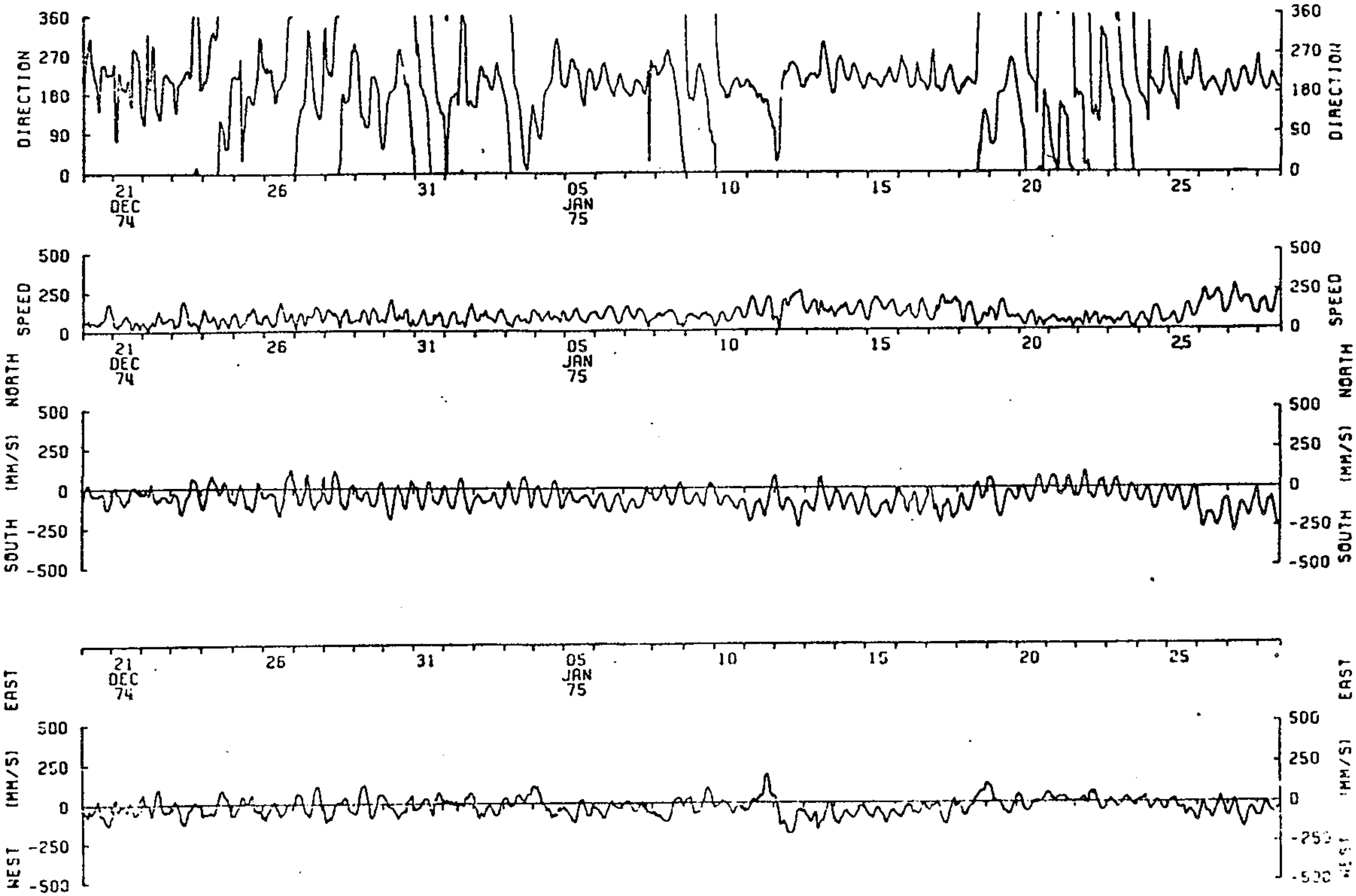


Figure V-2-4 b Time series of hourly-averaged data for instrument record WGM 31 (second half).

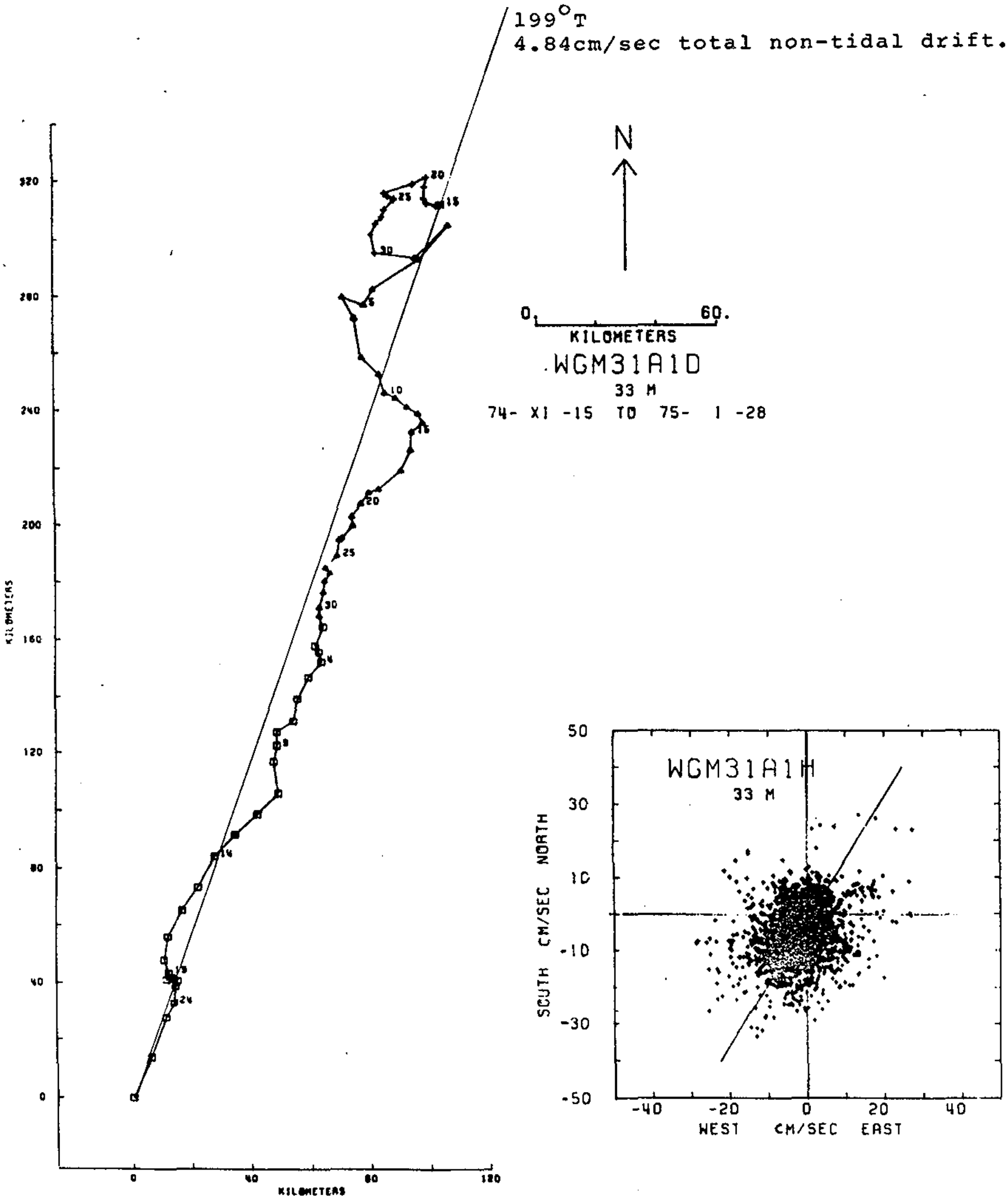


Figure V-2-5. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 31.

averaged about 10-15 cm/sec in a southerly direction and averaged less than 10 cm/sec in other directions.

The net non-tidal flow determined in Figure V-2-5 averaged nearly 5 cm/sec in the direction 199°T, a result consistent with Graham's (1970a) drifter study.

Although longshore pressure gradients were coherent with local winds, currents were not. Currents were also not coherent between sites (about 50 km apart). Vermersch et al. (1978) speculate that this lack of coherence results from the interaction of coastal-parallel flow with rough bottom topography producing baroclinic eddies. Because of the wide variation in the scale of topographic features, the authors were unable to conclude whether these eddies would remain near these features or move downstream with the net flow.

The studies reviewed here describe a general pattern of coastal-parallel tidal and non-tidal flow, inshore and offshore movements caused by winds, and the possible effects of topography in producing eddies. The location of the Cape Arundel site south of Cape Porpoise and within a rough bottom has the potential for production of eddies of a variety of sizes. It is speculated, however, that these eddies would have little significance to the monitoring and management of the disposal site due to the low velocities expected.

2.2 Waves

The presence of fine sediments and benthic fauna requiring a stable substrate at the proposed disposal site indicates that, for long periods of time, waves do not affect the bottom.

Farrell (1972) made detailed studies of sedimentation on the beaches of Saco Bay just north of the study area. He found a rapid decrease in grain size sorting below 22m, the apparent effective wave base within the Bay, and that wave-induced bottom currents were usually below 25-27 cm/sec at depths greater than 22m. He concluded that a wave base of 22m is consistent with northeast swell between 0.75 and 1.0m high with periods of 6.5-8.5 seconds.

Data on fishing gear loss, suspension of very large sediment particles and formation of ripple marks at greater than 22m during intense northeast storms indicate the potential for dispersion of dredged material from the study site. Although engineers from both the University of New Hampshire and the University of Maine have discussed the need for knowing the parameters of these large storm waves in designing coastal structures and sea floor installations, quantitative data on storm waves is virtually non-existent for the coastal region of Maine.

Wave data were measured at a buoy near Cashes Ledge, 70 miles east of the study area between 1978 and 1982 (most data from 1979-1981). Summary tables of data are provided in NCDC, 1983. Mean significant wave heights for each month and maximum heights during each month in the sampling interval are shown in Figure V-2-6. Waves averaged 1m from May to October and 2m from December to March. Waves as high as 4.5m were measured in the summer and waves between 6 and 8m were measured during December through March. These wave heights approach those which Pearce (1981) predicted from information on northeast storms. Data from the Cashes Ledge buoy is available on tape in reduced form (TOF-11, NCC) and with spectral data from NODC. Other variables measured near the buoy include wind speed, wind direction, sea level pressure and wave period.

An alternative method to the deployment of wave recording instrumentation is computer simulation which allows the extrapolation of measured characteristics of deep water incident waves over a wide area. In his study of Saco Bay, Farrel (1972) prepared wave refraction diagrams which predicted considerable refraction as storm waves (7.5 m amplitude, 10 sec period) reached the topographically complex shore. Thrall (1973) developed a refraction program for the New Hampshire coast which included bathymetry, wind speed, and fetch. Simulations were run with different wave periods, wind speeds and wind directions with the result that, for long period waves, the model showed the possibility of energy focusing behind the Isles of Shoals (Savage et al., 1974).

Libby (1975) attempted to describe the deep water waves which formed the measured shallow water waves at the Isles of Shoals after modification by wind and wave effects. He concluded that wave energy struck the Isles of Shoals from the east, although generated by northeast winds. He also discussed the inadaquacy of using deep water wave theory in the Gulf of Maine.

In a research proposal, Ole Madsen (MIT Sea Grant Program, 1984) suggests that attenuation of deep water waves by bottom friction is significant and proposed the development of a finite depth model which would include bottom interactions.

Pearce and Panchang (1983) used a series of models to generate long-term extreme deep water wave statistics for the Gulf of Maine. They used as input historical data on 22 severe "Northeast" storms occurring from 1974 to 1976 (Figure V-2-7). It can be seen that the predicted heights increase significantly from Cape Ann, Massachusetts to off the coast of western Maine. Slightly greater heights are predicted for the area east of CADS.

The study of Pearce and Panchang (1983) provides a valuable worst-case estimate for deep water waves impinging the Cape Arundel site. Deep water waves with a height of nine meters (amplitude 4.5m) induce bottom currents with velocities over 100 cm/sec at depths of 45 meters by classical wave theory. There is no question that sediments at 40m will be eroded by these very large storm waves.

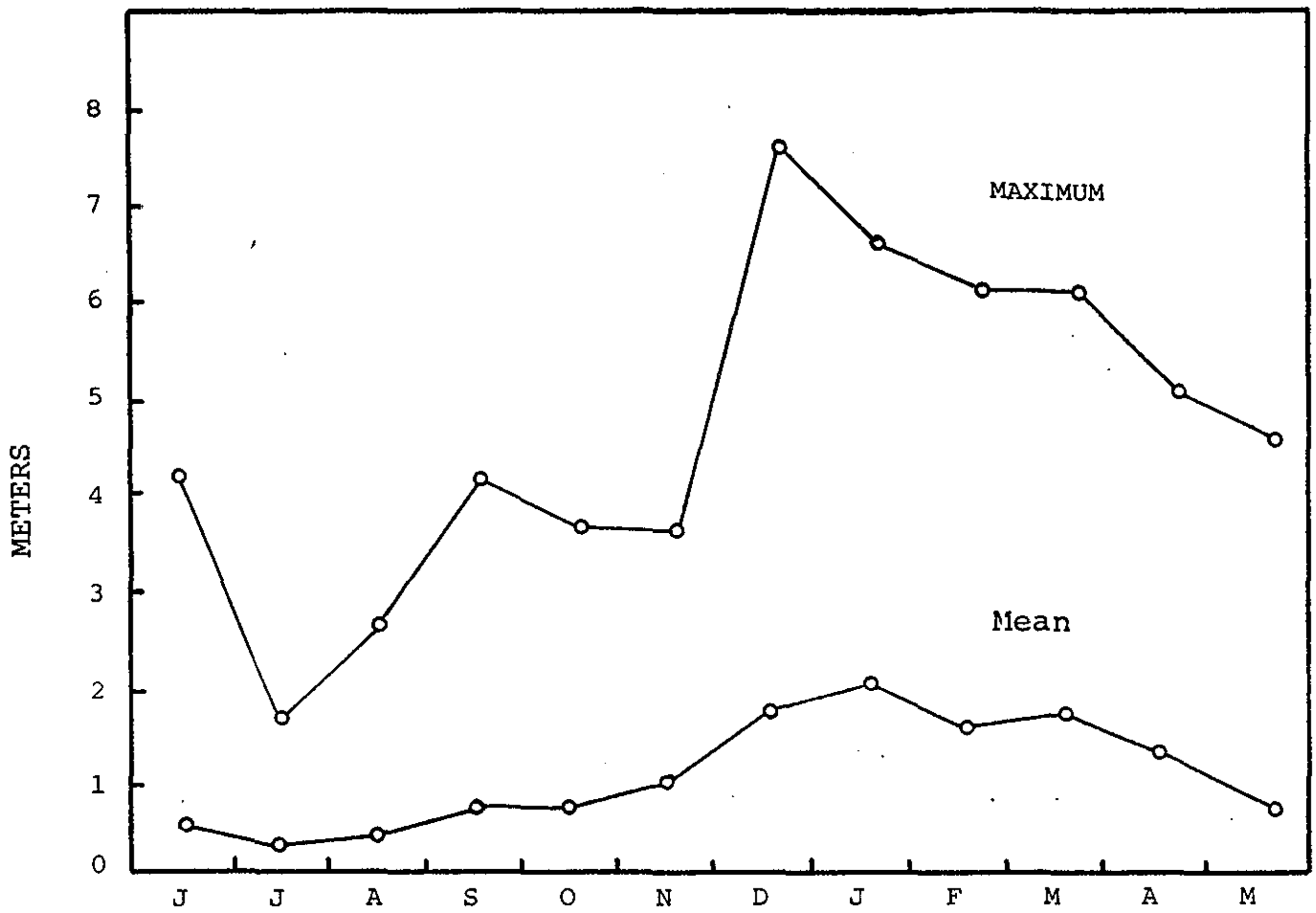


Figure V-2-6. Monthly mean and maximum significant wave heights measured at Cashes Ledge 1979-1981 (20 minute averaging period.) (NCDC, 1983)

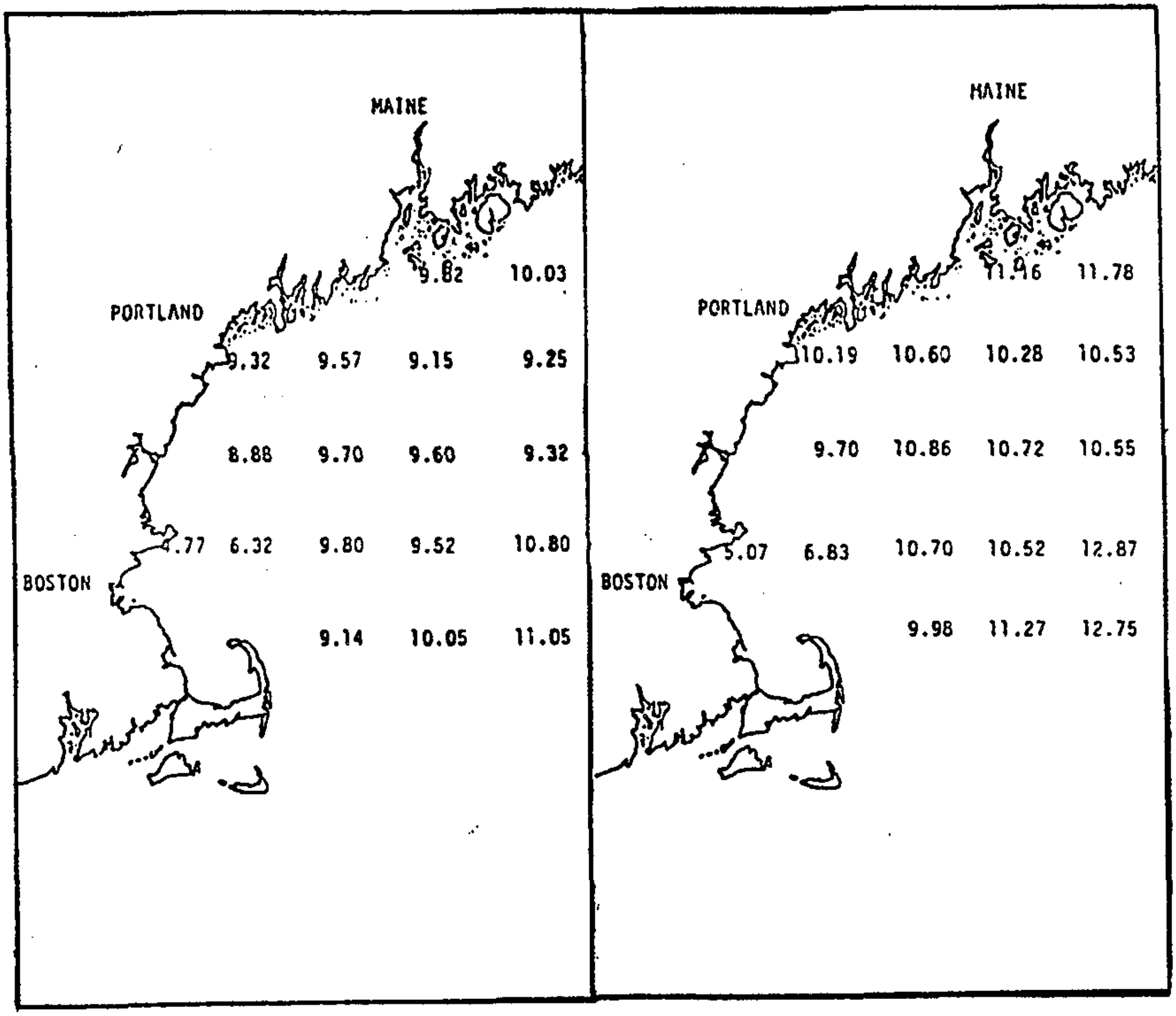


Figure V-2-7. 50 year (left) and 100 year (right) significant wave heights (in meters) in the Gulf of Maine. From Pearce and Panchang (1983)

2.3 Geology

A study by Oldale et al. (1973) provides a good introduction to the sedimentary geology of the western Gulf of Maine. Oldale used deep penetration, low resolution seismic profiles to identify major sedimentary strata. Survey lines were spaced about ten miles apart and profile 313 runs east-west about two miles south of the Cape Arundel Study site (Fig. V-2-2).

On the generalized surficial map, only bedrock is shown in the area of the study site since the veneer of unconsolidated sediment is thin and discontinuous (Fig. V-2-8). Off shore of the site, bedrock highs remain thinly covered or exposed until water depths of 120m are reached. Section 313 shows roughly 10m of sediment in a bedrock low which may be indicative of conditions at CADS.

Oldale et al. (1973) discussed the complex origin of marine sediments along the Maine coast. Initial sedimentation was by glacial rock flour carried by melt-water streams and deposited in basins. Rising sea level eroded and redeposited fine material from glacial drift. By the late Pleistocene, ice had retreated, but the land was still depressed by its weight and the sea penetrated about ten miles shoreward of the present coast. At that time blue-gray silt-clay was deposited in submerged areas. With emergence of the land both glacial and marine deposits were sources of material for erosion and transport.

A more detailed survey of unconsolidated sediments is presently underway in the area from the New Hampshire border to Cape Elizabeth, Maine and in depths of 6-90m by the Maine Geological Survey. This project is utilizing 3.5 KHz and "Geopulse" systems to produce high resolution profiles. Lane spacing in the vicinity of the disposal site is approximately 1 km.

A profile through the study area in August 1984 did not intersect the actual disposal site, and no unconsolidated sediment was identified. Sediment thickness in the general area of the site was usually less than 2m (J. Kelly, personal communication). The profiles are being analyzed, and a final report will be completed by June 1985.

Geophysical studies of the bedrock and sediment of the New Hampshire coastal area have been carried out by F. Birch (Department of Earth Sciences, UNH). Survey lanes are about 1 km apart. A "Uniboom" sonic profiler and side scan sonar were used for sediment observations. The bedrock geology has been published (Birch, 1984) and the sedimentary geology is in review. The profiles are available for inspection at the U.S. Geological Survey, Woods Hole, MA.

Because of the complex post-glacial history of this coast, it is difficult to interpret the depositional status of the sediment-filled lows surrounded by rocky bottom. There are

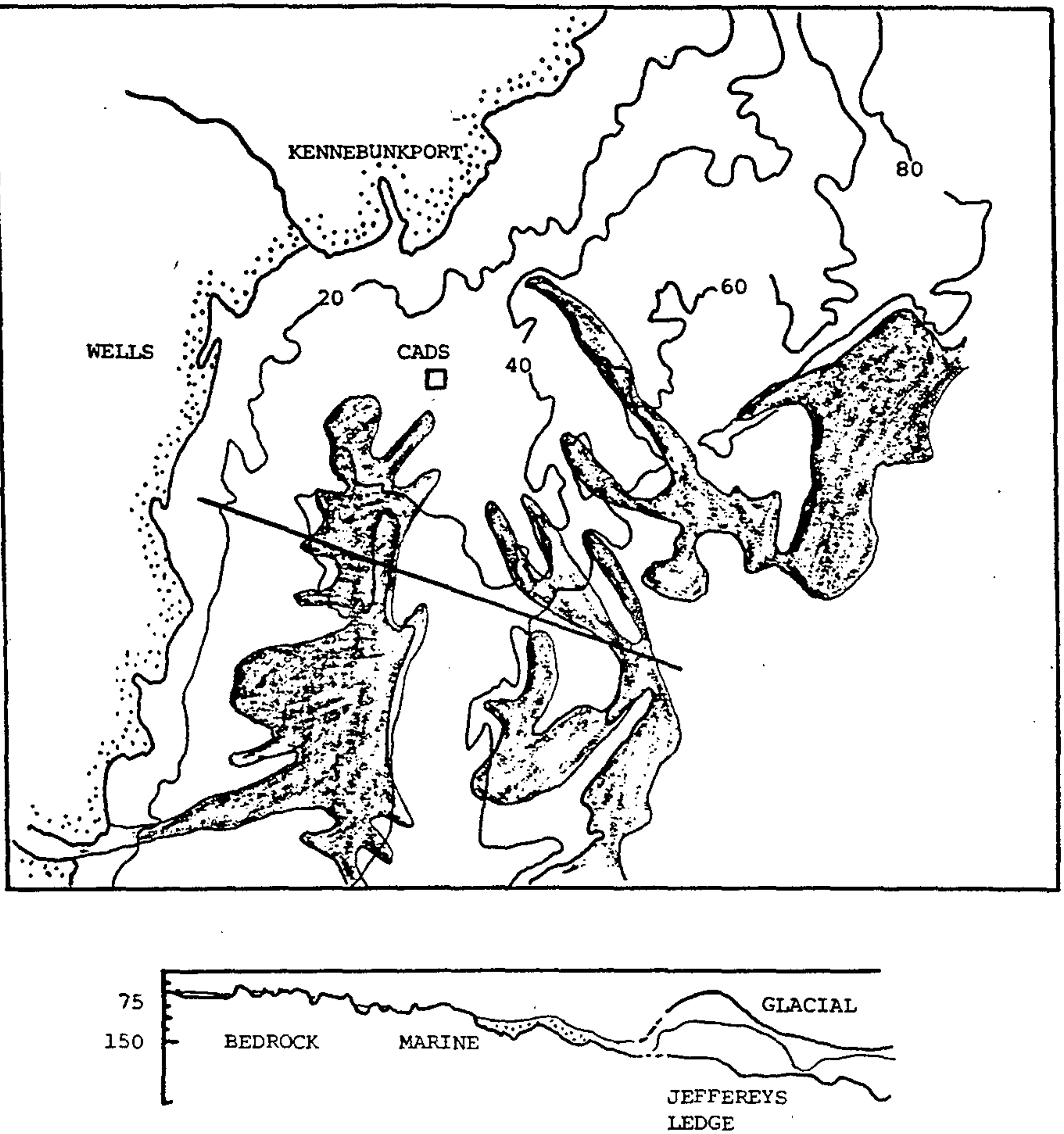


Figure V-2-8. Generalized surficial geology of the Cape Arundel area. Bedrock and thin sediment-substrate, measurable marine sediment is shaded. Study area indicated by square. Depth contours are in meters. Sediment thickness estimated on basis of sound velocity of 1500 m/sec. (Figure simplified from Oldale 1973.)

relatively deep deposits of water-born sediment in Porpoise Basin shoreward of Jeffreys Ledge (around 50m). It is not clear, however, whether all sediments in shallow locations will eventually be swept into basins or whether the thick section represents deposition during lower stands of sea level and/or greater supply of sedimentary materials. To some extent, the exposure of bedrock along the Maine coast is a function of a limited supply of sedimentary materials (F. Birch, personal communication).

The presence of large ripple marks at depths to 30m in western Gulf of Maine following a severe winter storm (L. Harris, personal communication) and the calculated effects of predicted high waves suggest that fine sediments might be eroded and transported from depths of 40m or greater. Nevertheless, silty sand and silt occurs on the bottom at these depths.

2.4 Turbidity

Some sediment will enter the water column during disposal activities and during winter storms. The pattern of natural distribution of particles in the water can give information on the potential dispersion of dredged material, the background against which changes will have to be detected, and the levels to which organisms are normally exposed. Shevenell (1974) carried out a year-long study of hydrography; transparency, and concentration of particles, plant nutrients, and chlorophyll at a grid of stations off the New Hampshire coast (Fig. V-2-9) Although the Great Bay Estuary provides both fresh water and particulate matter to Shevenell's study area, the general pattern of stratification and sediment dispersion are probably similar at the Cape Arundel site.

In the summer, the water column is strongly stratified. At depths equivalent to the Cape Arundel site, a warm surface is 10m thick in July and 30m thick in September (Fig. V-2-9). Phytoplankton and, to a lesser extent, sediment in river discharge make the surface layer relatively turbid. Water beneath the thermocline is very clean, but turbidity gradually increases near the bottom from resuspended sediments.

In the winter, the water is vertically mixed and there tends to be a horizontal decrease in suspended matter away from shore. The highest levels of suspended matter and turbidity reported by Shevenell (1974) (Fig. V-2-10) are low compared to those measured within southern New England estuaries (Pratt and Heavers, 1975; Bohlen, 1981). It is not known if any samples were obtained during or immediately after large storms.

Graham (1970) reports on surface Secchi-disc and photometer measurements taken in 1962-1965. His stations included those shown in Figure V-2-2. These measurements integrate the effects of both suspended sediment and phytoplankton. Maps for October, May and August show the Wells Bay area to have more transparent surface water than Casco Bay or the mid and eastern Maine coastal waters.

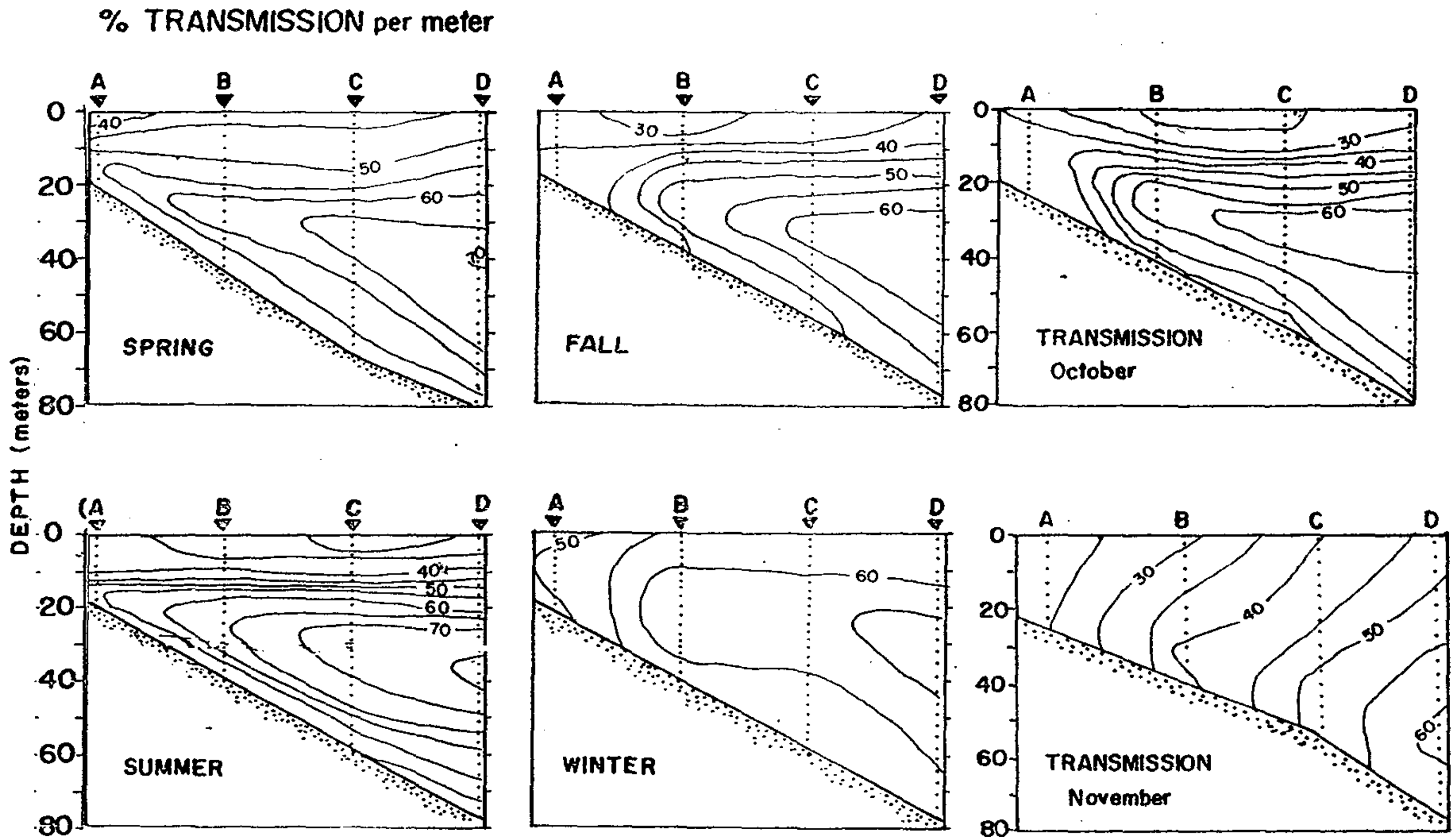


Figure V-2-9. Turbidity sections off the New Hampshire coast. Each letter represents four stations at equivalent distances offshore. Spring, Fall, Summer and Winter sections are averages of three monthly sections. From Shevenell, 1974.

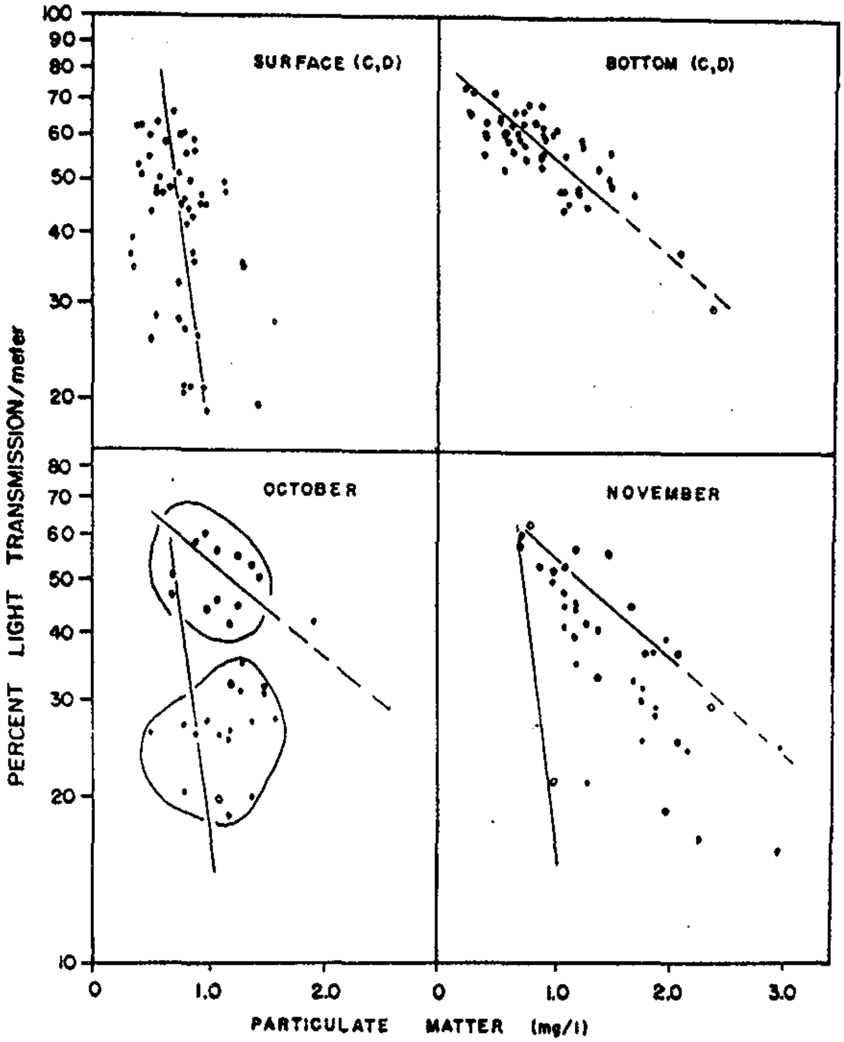


Figure V-2-10. Relationship of water transparency to particulate matter concentration off the New Hampshire coast. Upper left and right plots represent samples with high and low amounts of organic matter respectively; illustrating the ability of a low density of organics to cause a large decrease in transparency. In October, surface samples (solid circles) and bottom samples (open circles) had different characteristics. In November the particle population was well mixed. From Shevenell, 1974a.

2.5 Commercial Fisheries

It will be necessary to consult local fishermen and fishermen's associations to gather detailed information on use of the study site, seasons of use, and location of gear on routes to the site. The general pattern of fisheries in the area can be deduced from information gathered at the Isles of Shoals and Portland disposal sites and from published reports.

In the Cape Arundel area, nearshore rocky bottom is probably used exclusively by lobster fishermen. Rough bottom offshore may be used for lobster pots or gill nets. Extensive finfish dragging takes place on level bottoms offshore from the study site; however, small draggers may work inshore areas seasonally for winter flounder or northern shrimp (winter). Sea scallops may occur sporadically in this general area. Ocean quahogs have been found at depths less than 30m off Ogunquit, Maine (Maine DMR, 1977), but have not been harvested commercially.

The area from the Isle of Shoals north is mentioned as an area of abundant lobsters in early reports (Rich, 1930). A large number of lobster pot buoys were seen near the study site in March, but none were seen in June. It is presumed that many lobsterman began extensive fishing during the spring, placing their traps offshore where the lobsters had moved during the winter. During the summer, lobsters seek warm water and enter very shallow areas. At this time, most gear is placed close to shore and little, if any, would be left at depths of 30 m. Gear is moved offshore in the fall, but the number of pots fished is reduced as winter weather and the necessity of longer runs make it impracticable to fish from small boats.

Some finfish spawning activity takes place in the study area. Siver hake spawn along the whole western Gulf of Maine coast. Pollock spawns from Cape Cod to the Isle of Shoals, and Atlantic cod spawn from Cape Ann to Boon Island (TRIGOM, 1974) (Fig. V-2-11). All these species have pelagic (floating) eggs which would be little effected by sediment disposal. Atlantic herring spawn along the western Gulf of Maine coast in fall (Fig. V-2-12), (Boyer et al., 1973a, b; TRIGOM, 1974). Herring have demersal eggs which adhere to the bottom. The eggs are usually laid at depths of less than 90m in areas with high current activity and hard bottom. It is presumed that these areas are chosen to provide maximum oxygenation and minimize siltation.

Many of the finfish of commercial importance in the study area feed on fish and pelagic crustaceans (cod, pollock, hake) and would not be affected by changes in the bottom due to disposal activities. Haddock feeds on a large variety of invertebrates on both rock and soft bottoms. American plaice (gray sole), winter flounder, and skate species feed almost exclusively on the infauna of soft bottoms. Off the Isles of Shoals, gray sole is caught in patches of level bottom surrounded by rocks (Pratt, 1979). No fish food studies were found which were specific to the Cape Arundel area. Data from a NMFS (Woods

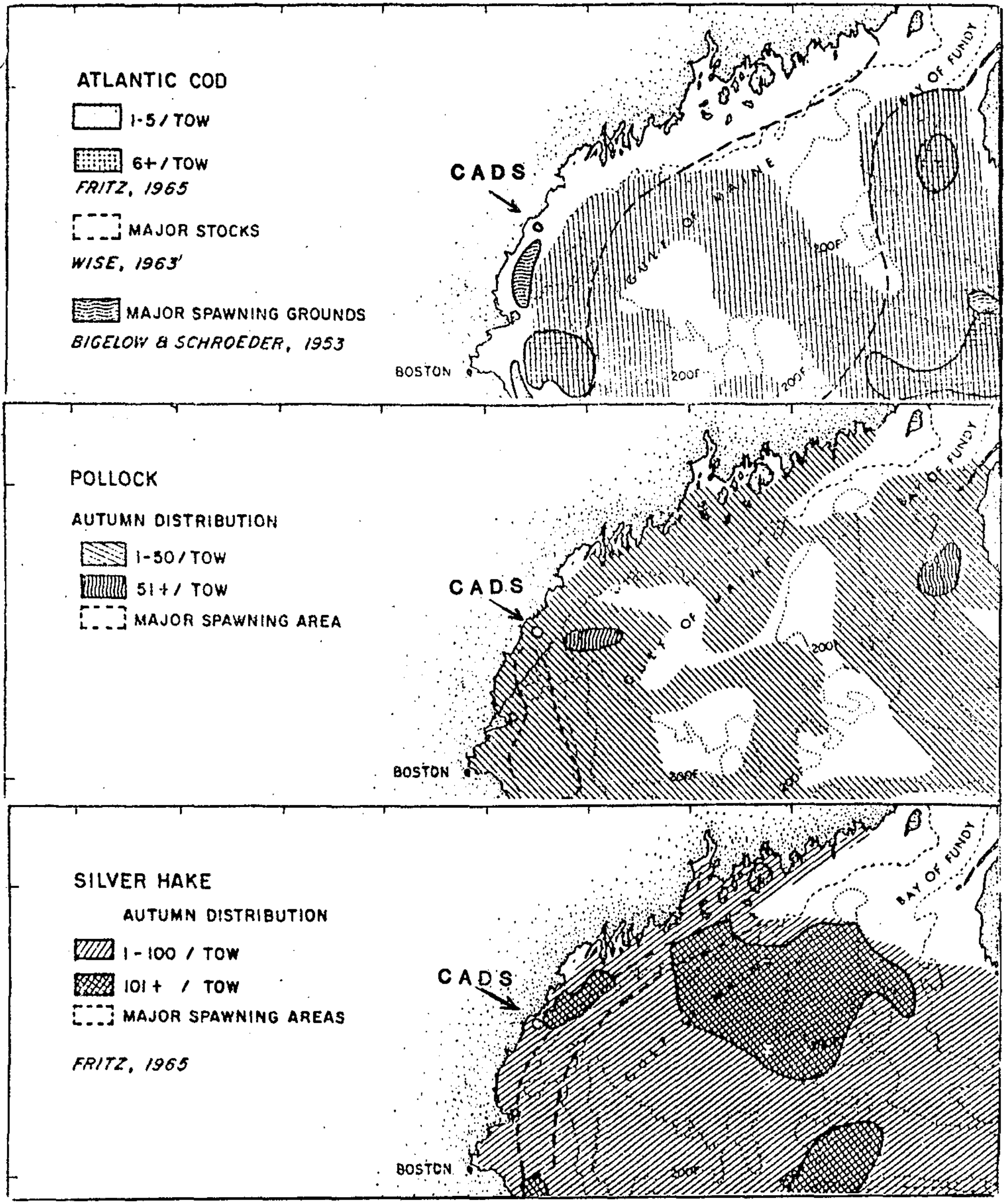


Figure V-2-11. Distribution of cod, pollock, and silver hake along the Maine coast. From TRIGOM, 1974. Cape Arundel study site indicated by arrow.

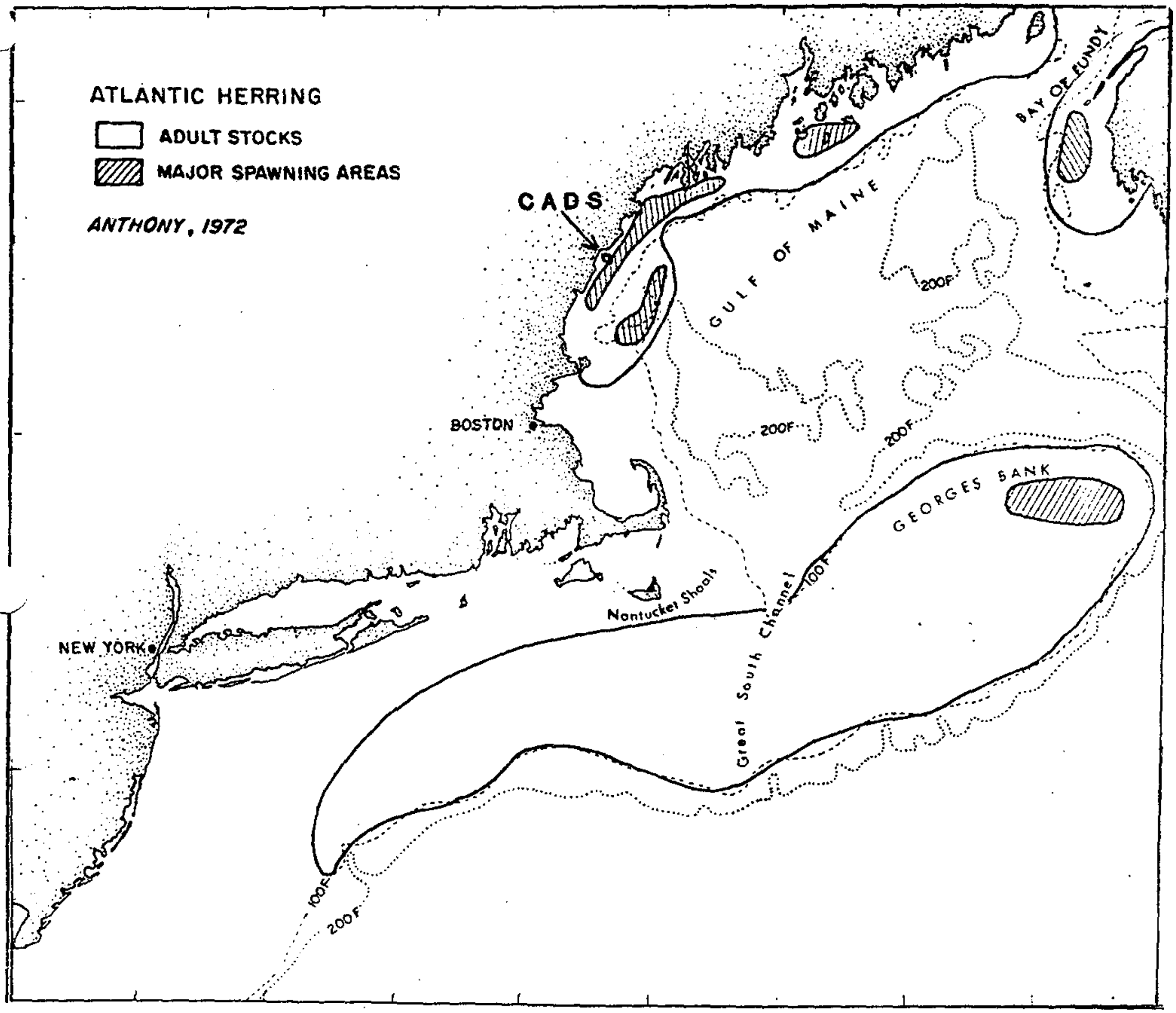


Figure V-2-12. Distribution of Atlantic herring. From TRIGOM, 1974. Cape Arundel study site indicated by arrow.

Hole) survey of fish food habits carried out in support of a benthic sampling program on Jeffreys Ledge (Hulbert et al., 1982) would be very relevant because of the similarity of that location to the Cape Arundel site. The published study by Tyler (1972) provides information on most of the fish species of concern.

3.0 SITE-SPECIFIC CONDITIONS

On 24 May 1984, SAIC began a pre-disposal site designation operation at the Cape Arundel Disposal Site (CADS). This operation was accomplished during two survey periods separated by several days and consisted of two bathymetric surveys, two side scan surveys, bottom sediment samples for verification of side scan results, identification and establishment of a reference station, and deployment of a mooring for current meter and wave gage measurements.

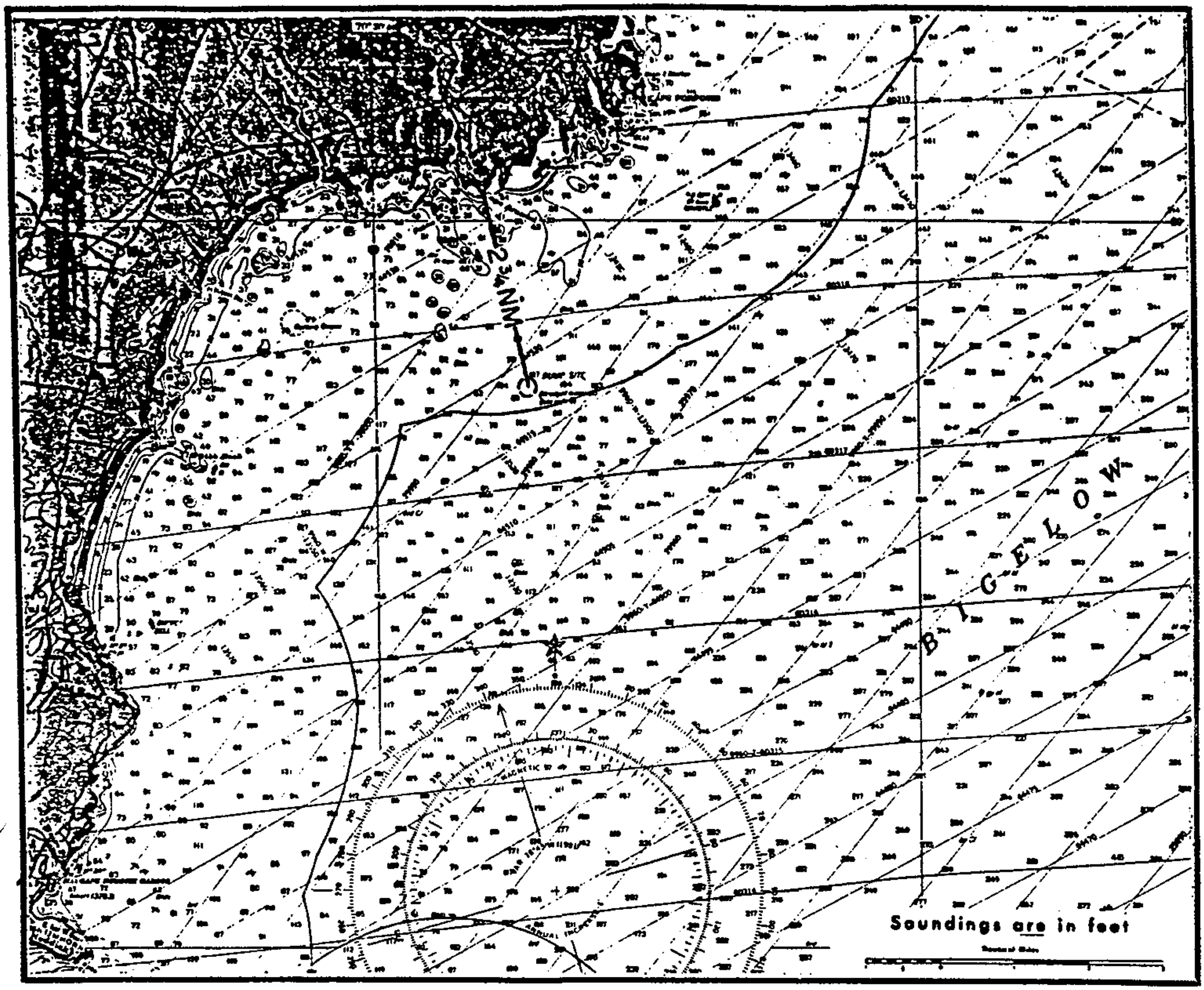
The EPA interim designated CADS is a 500 yard diameter circle centered at 43°17.8'N, 70°27.2'W (Fig. V-3-1) located approximately 2.75 NM south of Cape Arundel. During the first survey period, bathymetry, side scan and bottom sediment sampling surveys were conducted in order to determine the composition and overall geomorphology of the disposal site. During the second survey period, the study area was expanded north of the previous survey and essentially doubled the size of the overall survey effort.

3.1 Bathymetry

A bathymetric survey was performed on 24 May consisting of 25 lanes, 600 meters long, spaced 25 meters apart and centered approximately at the disposal site encompassing an area over twice that of the (circular) disposal site. Figure V-3-2 is a contour chart resulting from that survey and the CADS is represented as the large circle on the chart.

Bottom depths within the CADS range from 32 meters at the east and west margins to a maximum depth of 46 meters in the center of the NE quadrant. The contours also show the existence of a relatively broad depression about 200 meters wide in the northern part of CADS and dividing into two narrower depressions trending toward the SE and S. The latter depressions are separated by a shoal rocky area of about 37 meters.

A 3-D plot of this survey is shown in Figure V-3-3, and these sediment-covered depressions are identified as darkened areas on the figure. The topographic highs are composed of rock outcrops.



CAPE ARUNDEL, MAINE

Figure V-3-1.

NED: 19 CAPE ARUNDEL

DEPTH RANGE: 90 TO 105 FEET MLW

CENTER COORDINATES: 43°-17.8'N, 70°-27.2'W

N.O.S. CHART: 13286

DATE: 22 MARCH 1980

DESCRIPTION: THIS SITE IS A 500 YARD DIAMETER CIRCLE WITH CENTER POINT AT 43°-17.8'N, 70°-27.2'W. FROM THE CENTER POINT, LIGHTED BELL BUOY "1" BEARS TRUE 339° 30' AT 3,708 YARDS, LIGHTED WHISTLE BUOY "2CP" BEARS TRUE 46° AT 7,416 YARDS, AND BELL BUOY "2" BEARS TRUE 23° AT 7,622 YARDS.

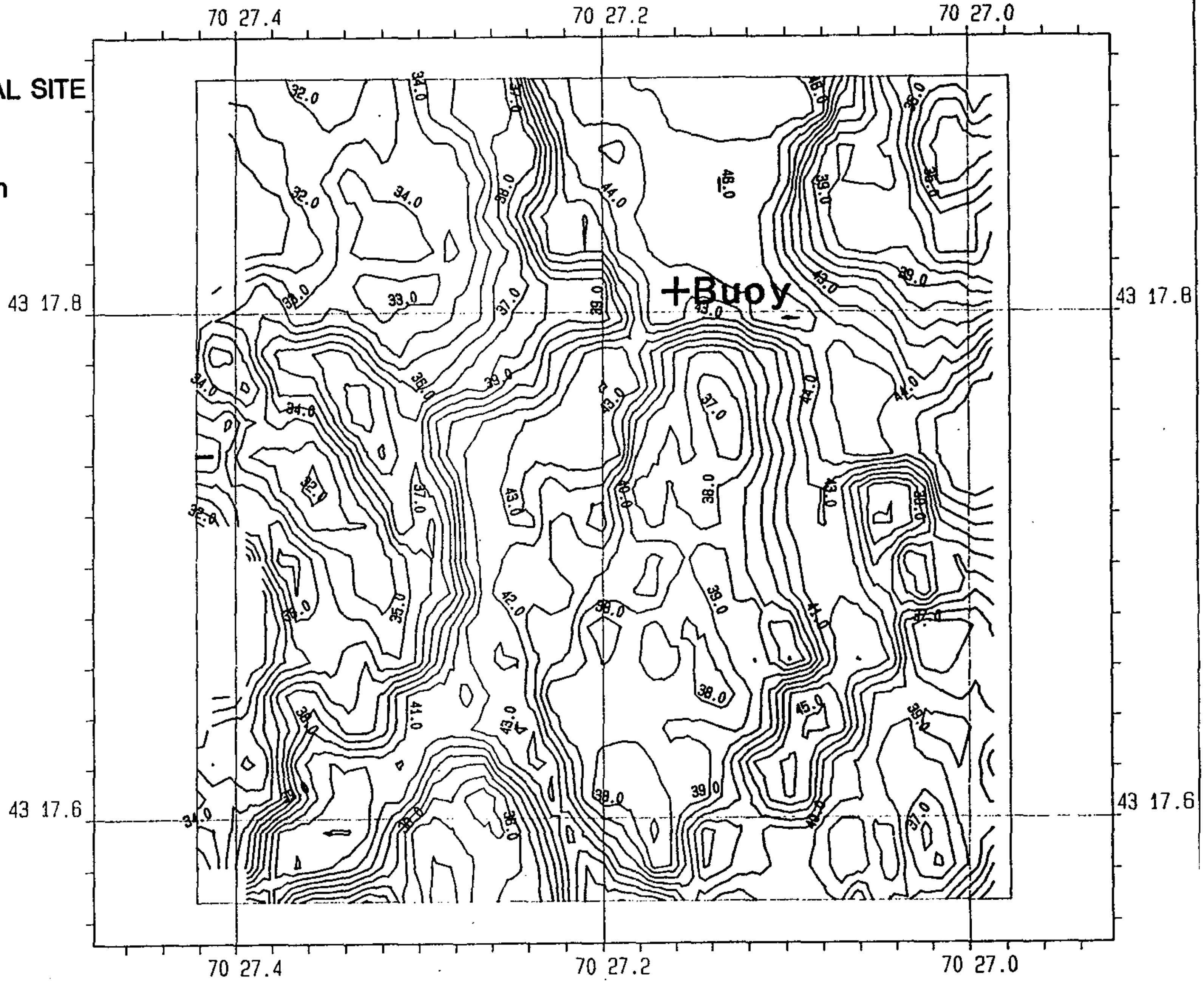
CAPE ARUNDEL DISPOSAL SITE

24 MAY 1984

CONTOUR INTERVAL: 1m

CHART SCALE: 1/3000

Figure V-3-2



0 60 120

SCALE (m)

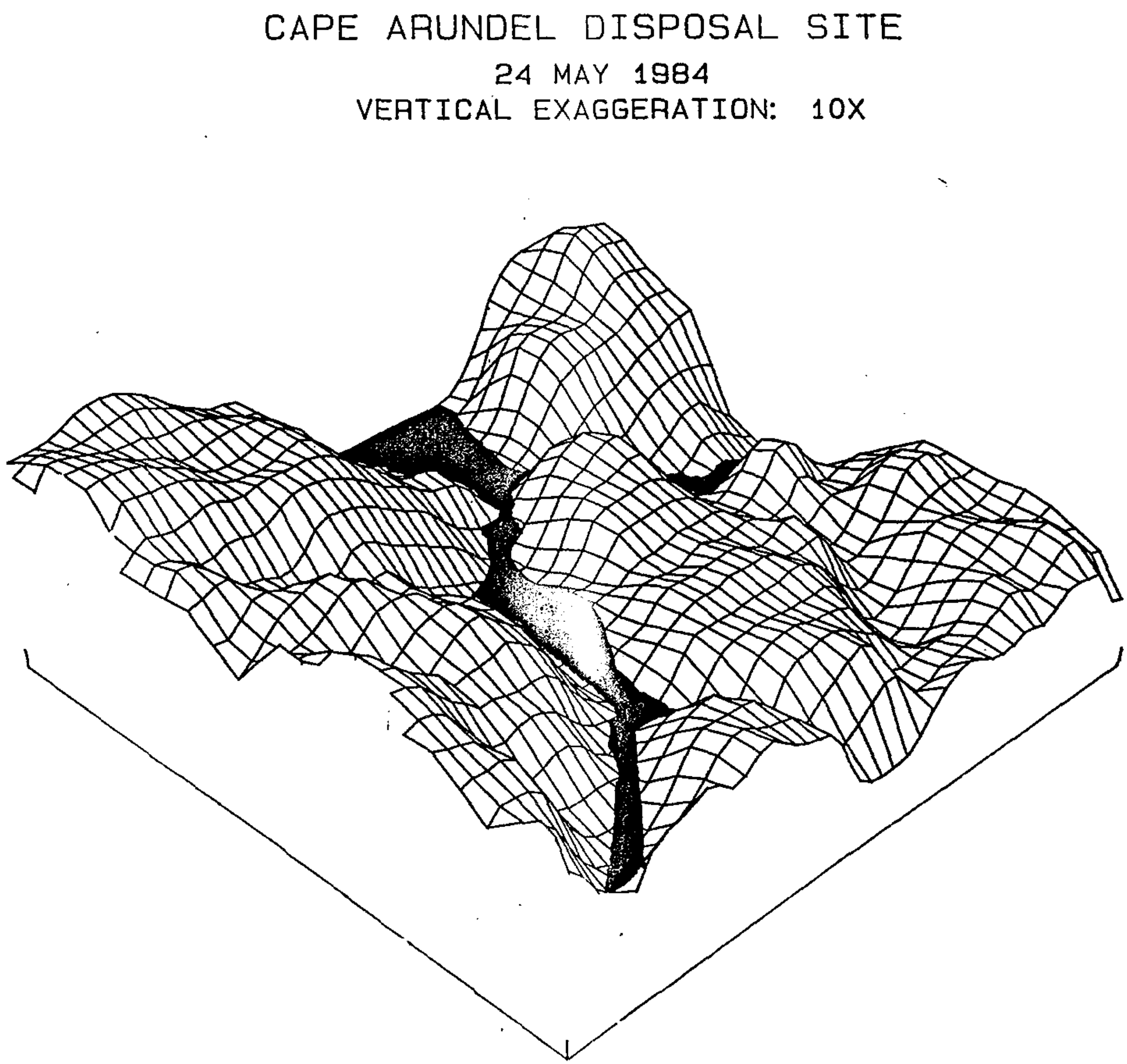


Figure V-3-3. 3-dimensional plot of Cape Arundel Disposal Site.

3.2 Side Scan

A side scan survey consisting of seven lanes, 800m long, 100 meters apart and run in a north/south direction was performed over the same area as the bathymetric survey. The records depict a bottom characterized by numerous rock outcroppings and boulders (Fig. V-3-4). A veneer of soft, less reflective bottom (Figs. V-3-5 and V-3-6) is noted in the deeper portions of the survey area and corresponds to the depression noted above on the bathymetry contour chart and 3-D plot.

3.3 Bottom Sediments

In order to confirm the results of the side scan survey, a series of 15 sediment stations was established on a grid distributed throughout the survey area (Fig. V-3-7). Where possible, samples were obtained, described and discarded. Descriptions of the sediment samples are presented in Table V3-1.

A summary of these results is presented in composite form in Figure V-3-8. A description of the sediment samples in relation to bathymetry is noted, along with reference to portions of the side scan sonar tracks that depict a soft/hard bottom condition. The area outlined in the figure depicts the extent of soft bottom and hard bottom in relation to the disposal site.

The results from the analysis of the sediment samples (Table V-3-2) conducted by NED indicate the sediment to be fairly uniform throughout the area. The one exception was the sample taken for benthic analysis (biological sample) from 100 meters east of center, where there was mostly sand and had the highest percentages of coarse and medium material. This might be the result of influence from dredged material that was deposited in 1976.

The chemical concentrations do not vary to a great extent at the stations sampled (Fig. V-3-7). Zinc concentrations at the center and 100S were higher than the other sites, most likely influenced by dredged material. The C:N ratios appear to be more characteristic of offshore sediment (> 10). The Mg:Ca ratio is an indication of the presence of shells. The low ratios at the reference site and at 100N show that the greatest amount of shell material occur at these two locations.

3.4 Survey Area Expansion

Based on the results of bathymetric and side scan surveys, a meeting was held at NED on 29 May to discuss expansion of the survey to the north in order to investigate the extent of the soft bottom depression in the NE quadrant of CADS. The result of that meeting was a decision to alter the original cruise plan and conduct additional bathymetry, side scan and sediment sampling north of but overlapping the previous survey.

These surveys were conducted on 29-30 May. The bathymetric survey consisted of 25 lanes, 600m long, running

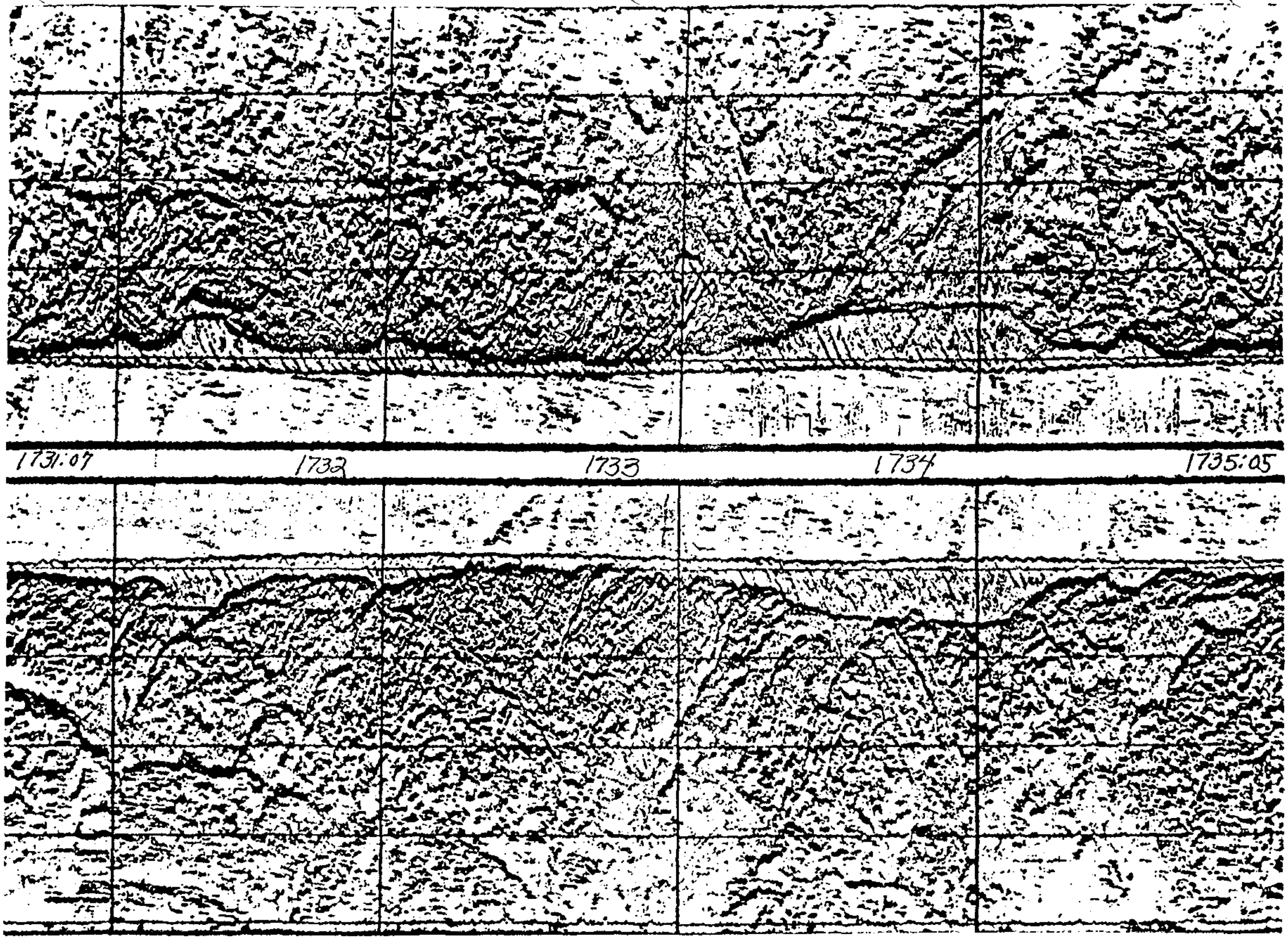


Figure V-3-4. Side scan record showing rock outcrops, CADS.

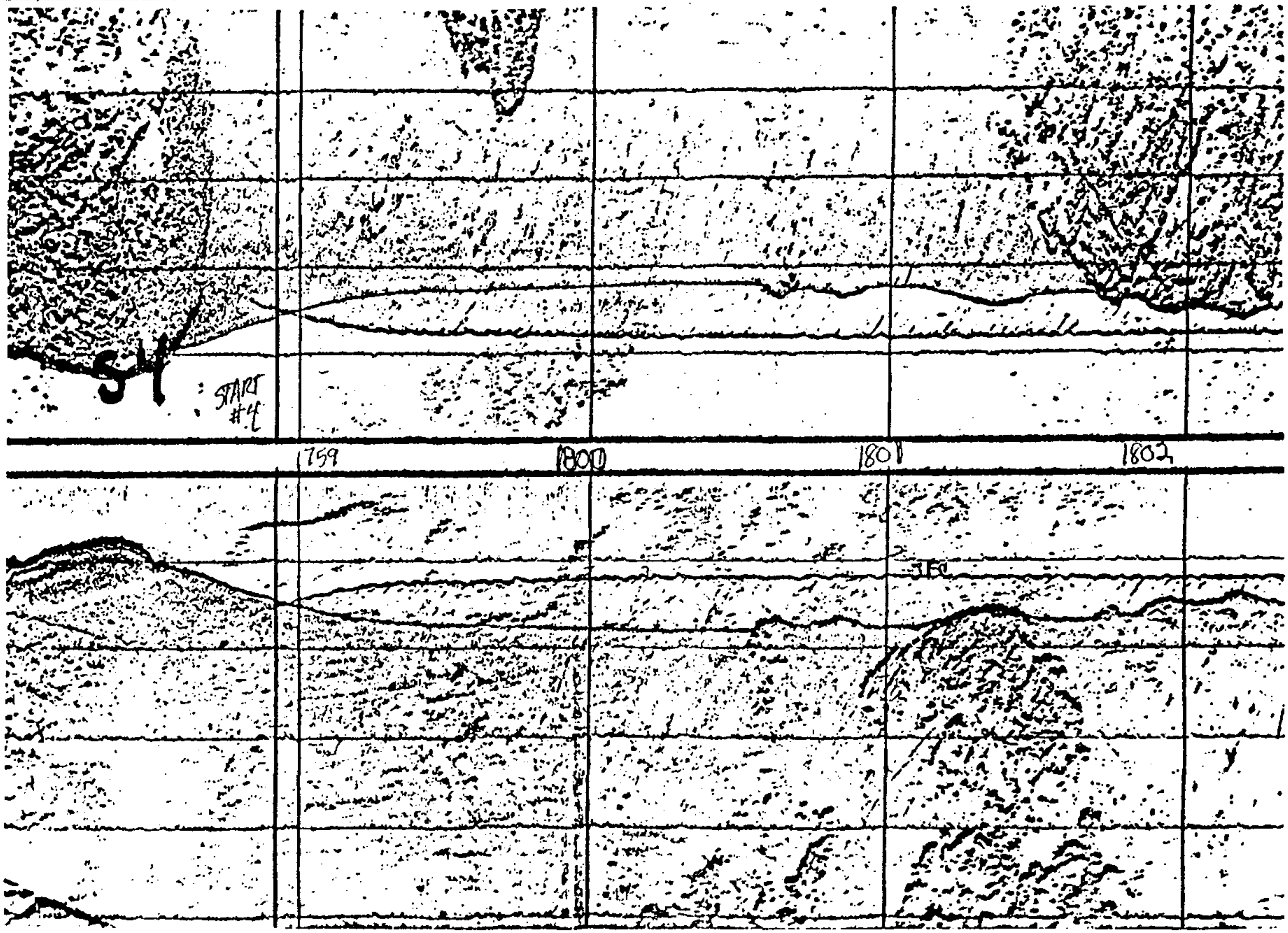


Figure V-3-5. Side scan showing soft bottom, CADS.

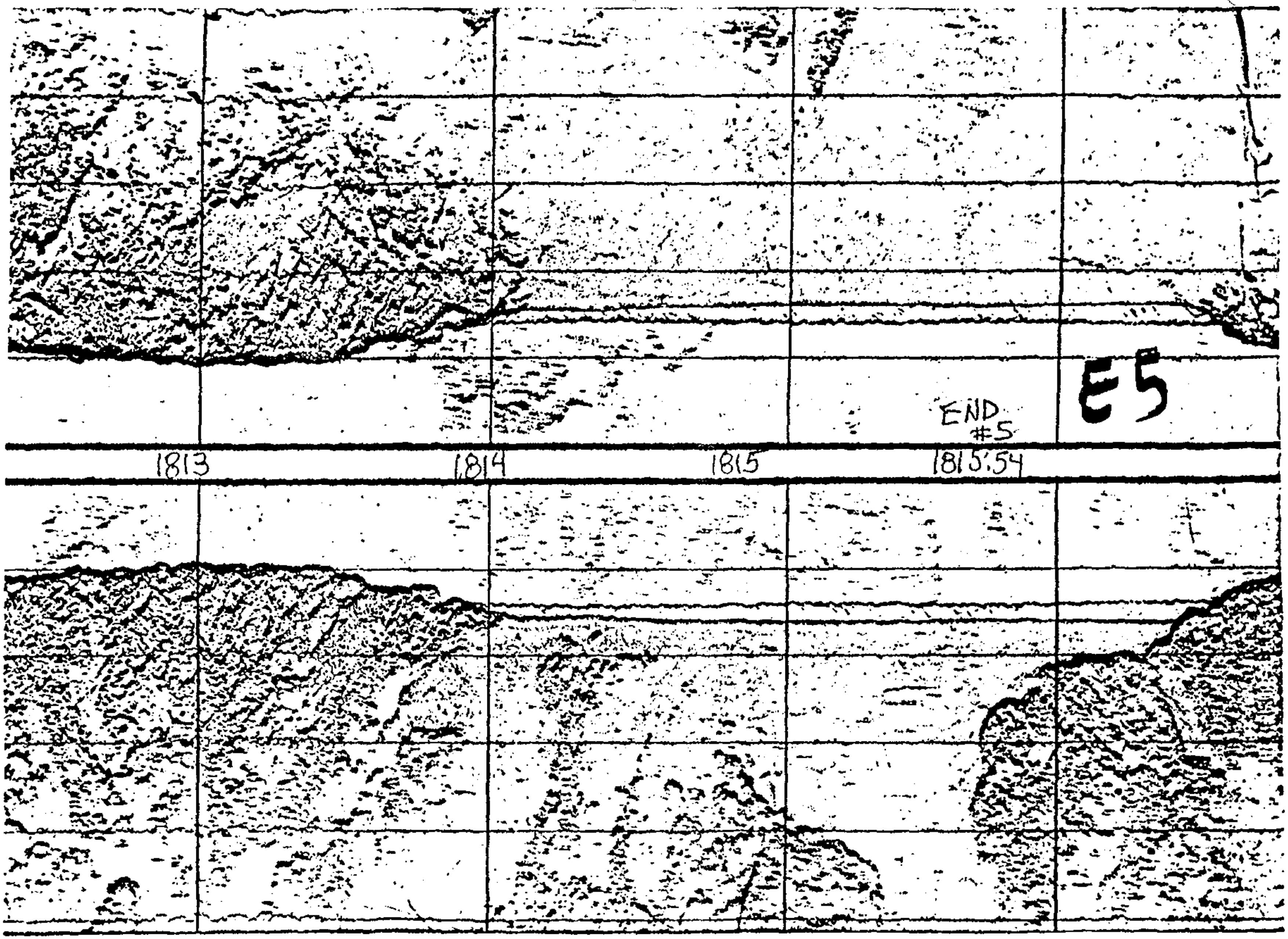


Figure V-3-6. Side scan record showing soft bottom, CADS.

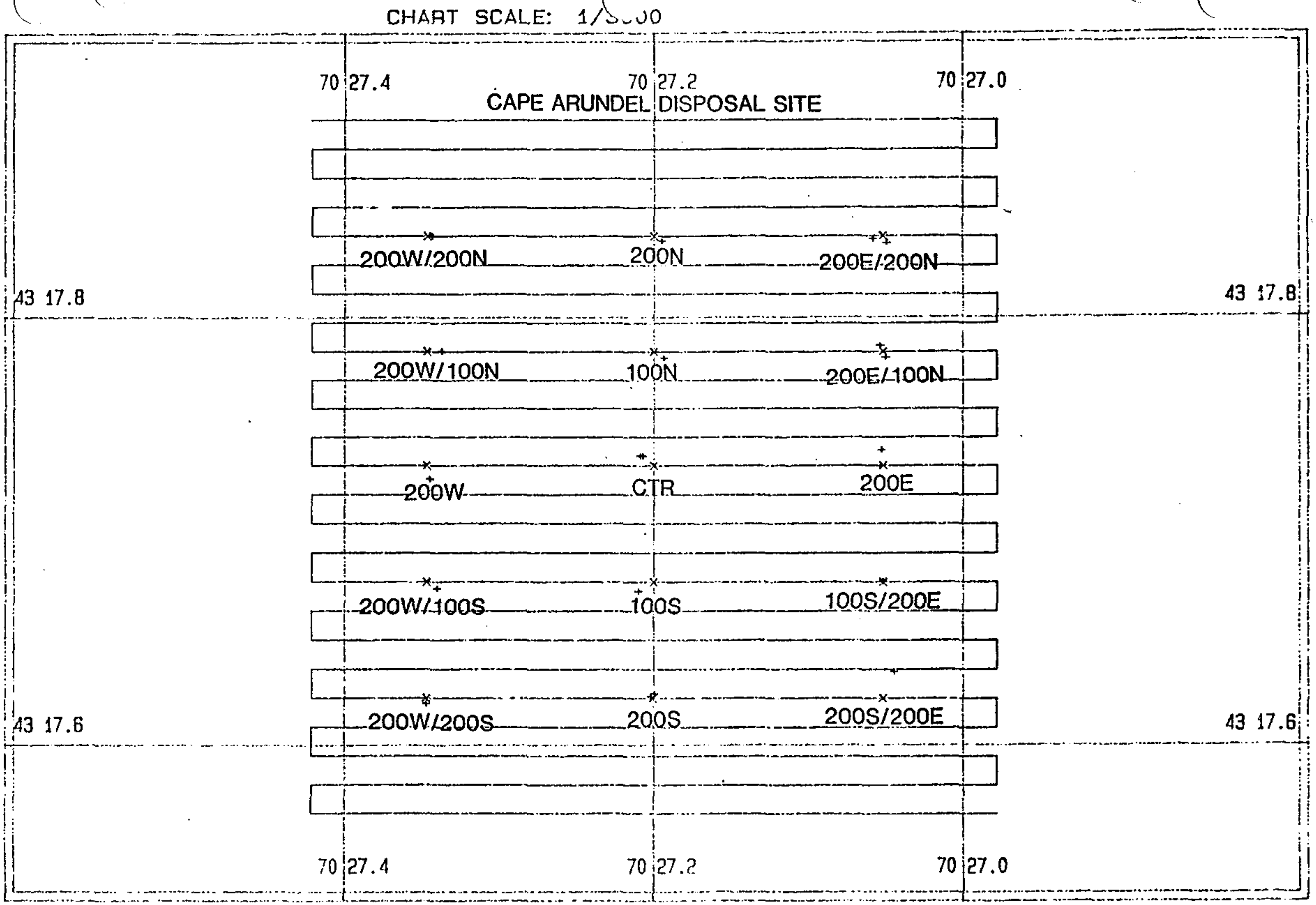


Figure V-3-7. Sediment sampling stations.

Table V-3-1

CAPE ARUNDEL DISPOSAL SITE (CADS) SEDIMENT SAMPLES

STATION	DESCRIPTION
CENTER	2.5 cm gray sandy oxidized layer over black sandy silt with gray streaks. Many worm and amphipod tubes present with live amphipods noted in surface water in grab.
100 NORTH	Uniform grayish sediment with small amounts of black silt streaks. Less biota than at center with finer grain size and no oxidized layer.
200 NORTH	Same as at center.
200 EAST/ 100 NORTH	Thin oxidized layer over dark gray mud. Many tube worms present. Sandy gray clay in bottom of grab.
200 EAST/ 200 NORTH	No sample. Hard rock bottom.
200 WEST/ 200 NORTH	No sample. Hard rock bottom.
200 WEST/ 100 NORTH	No sample. Hard rock bottom.
200 WEST	No sample. Hard rock bottom.
200 WEST/ 100 SOUTH	No sample. Hard rock bottom.
200 WEST/ 200 SOUTH	2-3 cm hard sand over dense gray silty clay. Many live amphipods present.
200 SOUTH	No sample. Hard rock bottom.
100 SOUTH	No sample. Hard rock bottom.
200 SOUTH/ 200 EAST	No sample. Hard rock bottom.
100 SOUTH/ 200 EAST	Very coarse gravel and 3-4 cm stones over medium to coarse sand. Grab 1/8 full.
200 EAST	No sample. Hard rock bottom.

SAIC™

CAPE ARUNDEL DISPOSAL SITE

24 MAY 1984

CONTOUR INTERVAL: 1m

CHART SCALE: 1/3000

Figure V-3-8

● SEDIMENT SAMPLE LOCATION

0 60 120

SCALE (m)

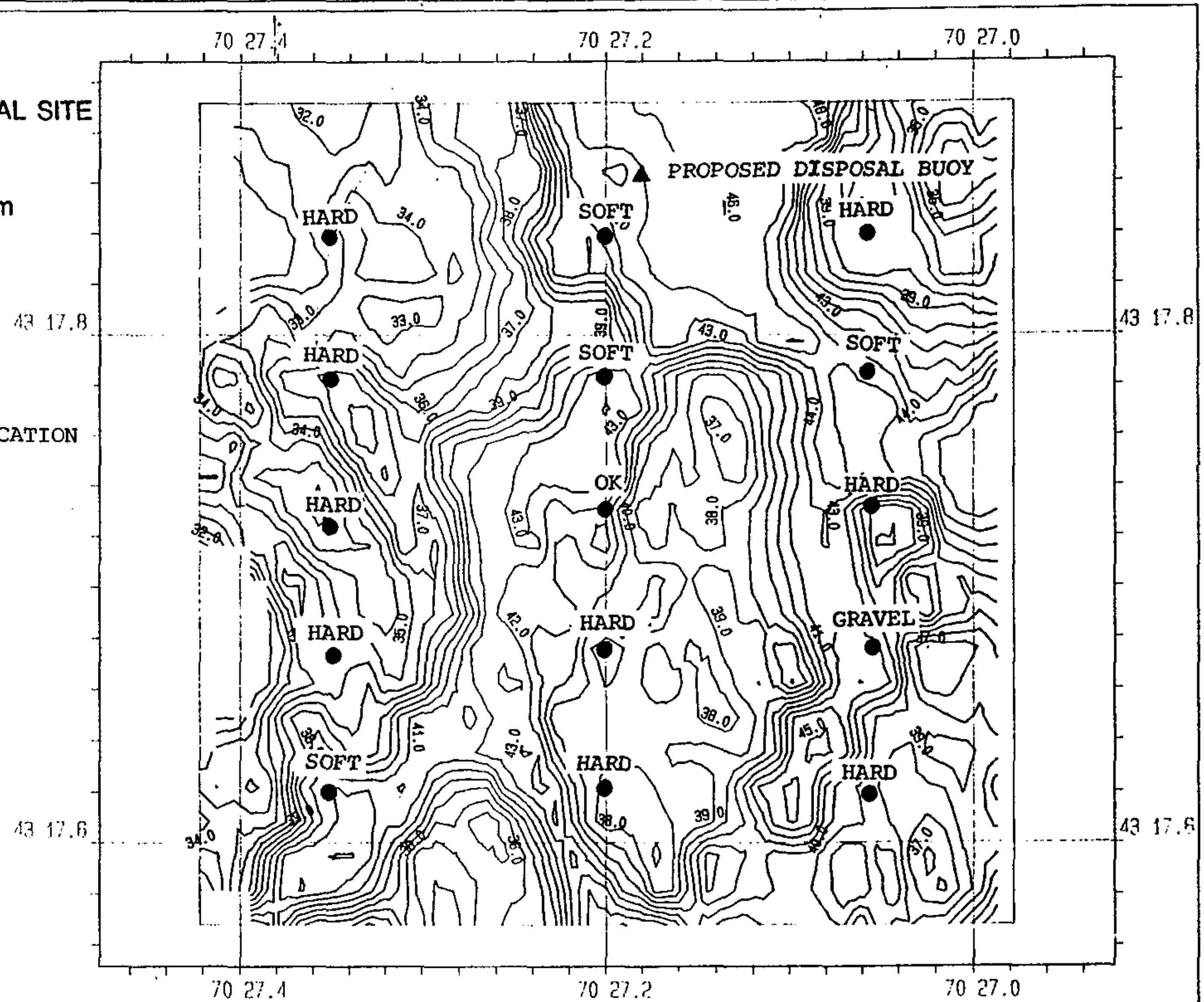


Table V-3-2

Sediment Chemistry Analyses

Cape Arundel Disposal Site
May/June 1984
Interpretation
North-South Transect

Location	ppm Oil & Grease	ppm CODx10^{-5}	ppm Fex10^{-4}	ppm Pb	ppm Zn	ppm Cr	ppm Cu	C:N	Mg:Ca
100N-A	263	0.36	1.39	18	71	32	8	9.2	3.7
B	207	0.45	1.73	42	74	46	11	9.3	1.9
C	205	0.19	1.32	34	74	37	9	7.8	1.9
Bio	466	-	1.64	34	58	44	10		4.0
CTR-A	105	0.38	1.59	32	67	44	10	8.3	5.1
B	215	0.49	1.85	36	72	25	12	8.3	8.5
C	215	0.41	1.50	26	66	43	10	8.3	7.3
Bio	300	0.47	1.33	28	57	39	9	-	7.3
A(June)	68	0.47	1.86	54	179	43	8	8.9	1.1
100S-A	168	0.50	1.64	58	112	45	11	8.2	10.8
B	214	0.54	1.53	38	135	44	13	8.4	9.7
C	343	0.50	1.51	38	86	46	10	8.8	12.8
Bio	198	-	1.76	43	88	49	11	-	5.4
REF-A	264	0.45	1.83	49	92	54	10	9.6	2.1
B	58	0.39	1.86	45	62	52	10	9.9	1.1
C	74	0.37	1.89	41	60	48	9	9.7	2.5
Bio	108	-	1.80	51	81	52	10	-	2.2

Table V-3-2 cont.

Cape Arundel Disposal Site
May/June 1984
Interpretation
Center-East

Location	ppm Oil & Grease	ppm $CODx10^{-5}$	ppm $Fex10^{-4}$	ppm Pb	ppm Zn	ppm Cr	ppm Cu	C:N	Mg:Ca
CTR-A	105	0.38	1.59	32	67	44	10	8.3	5.1
B	215	0.49	1.85	36	72	25	12	8.3	8.5
C	215	0.41	1.50	26	66	43	10	8.3	7.3
Bio	300	0.47	1.33	28	57	39	9	-	7.3
A(June)	68	0.47	1.86	54	179	43	8	8.9	1.1
50E-A	248	0.59	1.93	61	83	55	11	8.8	4.7
100E-A	225	0.45	1.43	41	80	44	10	8.8	3.8
B	136	0.34	1.22	21	62	33	8	9.0	6.2
C	287	0.42	1.47	31	69	35	8	8.5	5.3
Bio	304	-	1.44	37	57	36	8	-	7.4
REF-A	264	0.45	1.83	49	92	54	10	9.6	2.1
B	58	0.39	1.86	45	62	52	10	9.9	1.1
C	74	0.37	1.89	41	60	48	9	9.7	2.5
Bio	108	-	1.80	51	81	52	10	-	2.2

east-west, separated by 25m and overlapping the previous survey by 200m. The results of the bathymetric survey are presented in Figure V-3-9 and show the main depression trending northward maintaining a depth greater than 44 meters. Bottom relief to the east and west of the depression is similar to that observed during the 24 May survey (Fig. V-3-2). The depression maintains a uniform geometry, but widens to nearly 250m along 43°18.0' parallel.

The side scan record (Fig. V-3-10) obtained during the survey of this area, although of poor quality due to high sea state, support the findings of the previous investigation that this depression consists of a veneer of soft material and is flanked by a hard bottom composed of rock outcrops.

3.5 Reference Station

A reference sampling station adjacent to but beyond potential influence of a dredged material mound was established 1500 meters east of the center of CADS. The bottom in this area, shown on the side scan record (Fig. V-3-11), has a lithology similar to that found in the soft bottom portion of the disposal site and is separated from the disposal site by extensive rock outcrops. The sediment samples taken at the reference site are described in Table V-3-1.

3.6 Current and Directional Wave Observations

An additional visit to the site was made on 19 June 1984 and the remainder of the sediment samples were obtained. In addition, a current meter mooring was implanted at 41°18.07' Lat, 70°27.13 Long for a period of 3 weeks. The mooring was comprised of two Endeco Type 105 current meters, one near the bottom and one near the surface. Data was obtained from the bottom current meter only, and is currently being processed for subsequent analysis.

A Sea Data Model 621 directional wave and current velocity instrument was installed on 10 October 1984 on the original current meter mooring at the time the current meters were removed. This instrument is scheduled for servicing during the week of 12 November 1984, and retrieval the week of 3 December 1984 for a total sampling period of two months.

4.0 BENTHIC ORGANISMS

The sea floor within the Cape Arundel Disposal Site (CADS) is comprised primarily of outcrops with a veneer of fine sediment filling the topographic lows. The largest sediment-filled area is a depression in the northeast corner of CADS. The rock and soft bottoms within the study area support very different benthic communities. Depending on depth, current velocities and slope, hard bottoms may be dominated by mussels, tube-dwelling polychaetes, sponges and tunicates, and fleshy or encrusting algae. Soft, level bottoms support burrowing or tube-dwelling bivalves, crustaceans, and polychaetes.

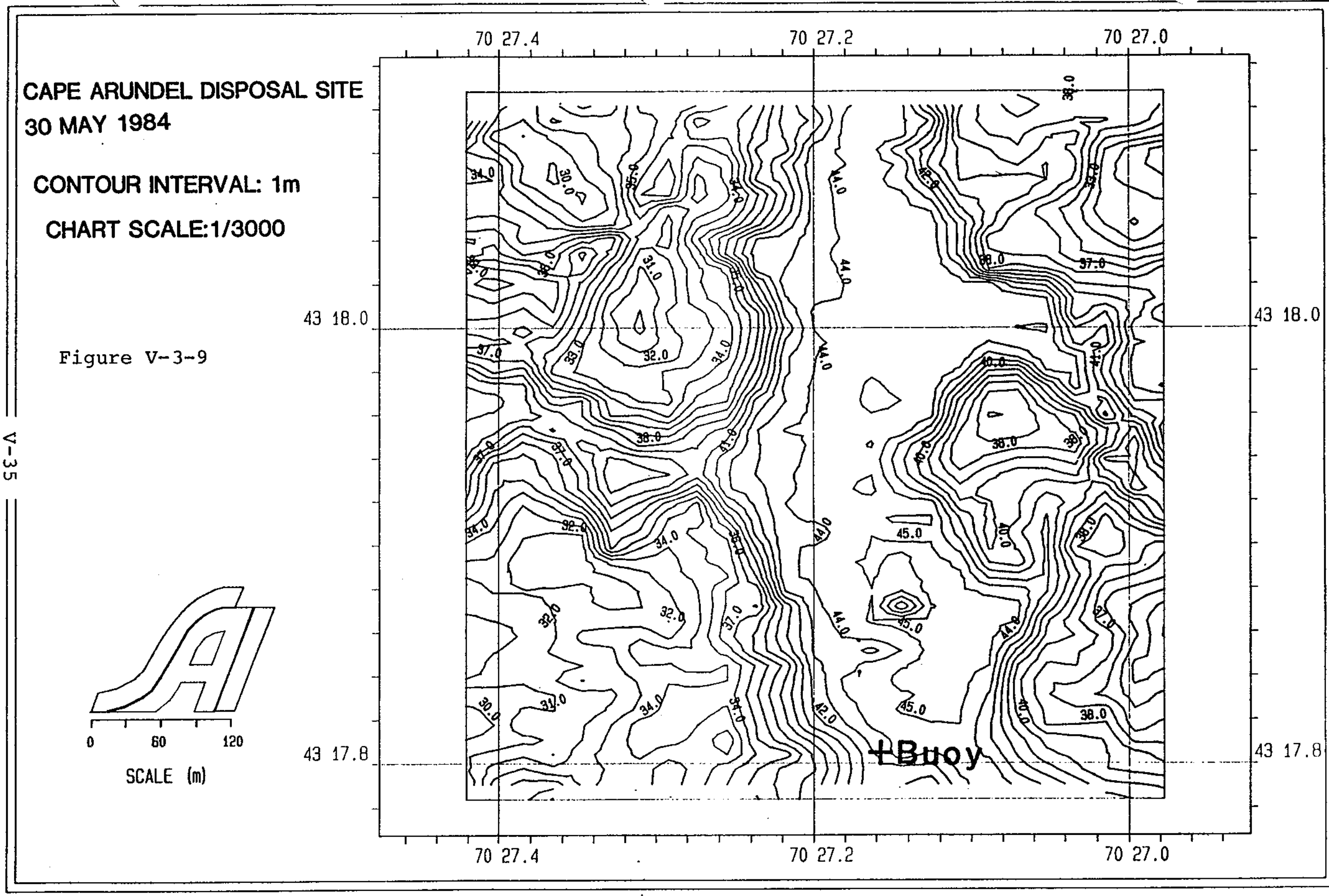

CAPE ARUNDEL DISPOSAL SITE
30 MAY 1984
CONTOUR INTERVAL: 1m
CHART SCALE:1/3000
70 27.4
70 27.2
70 27.0
43 18.0
43 17.8
+Buoy
0
60
120
SCALE (m)

Figure V-3-9

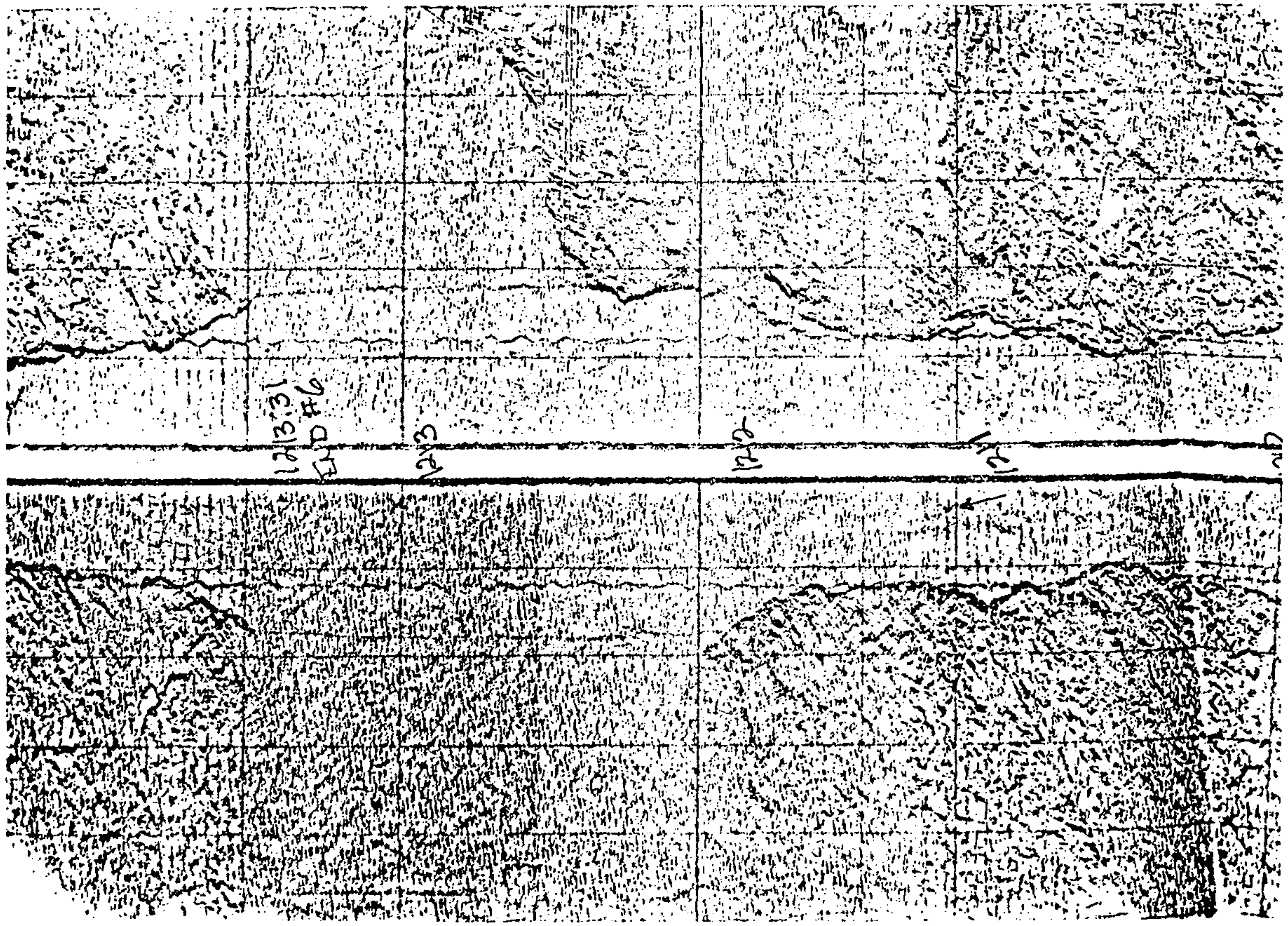


Figure V-3-10. Side scan record, 30 May 1984, CADS.

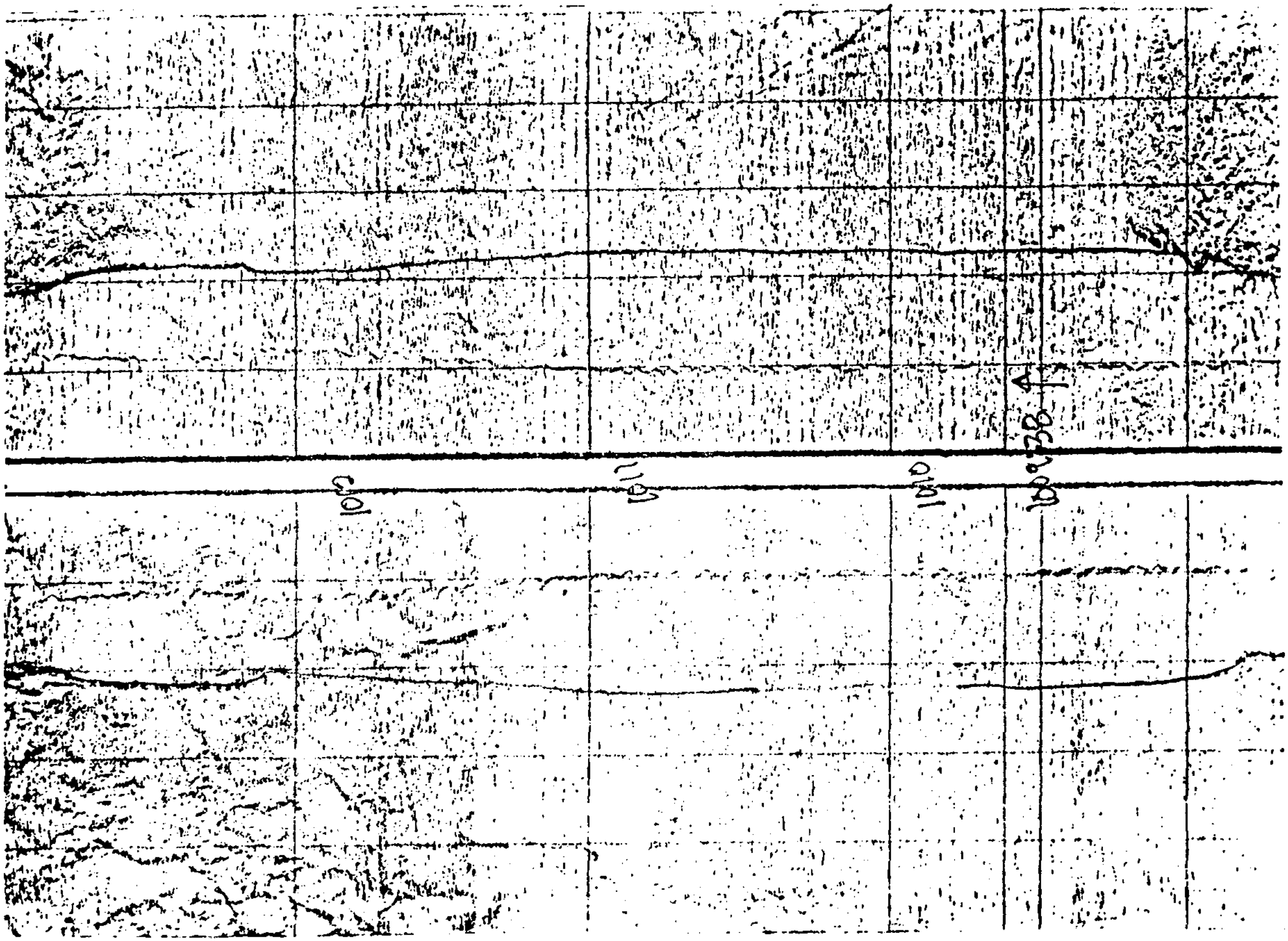


Figure V-3-11. Side scan record, Reference site.

The following sections provide a discussion of these two types of benthic environments and the organisms comprising their respective habitats.

4.1 Rocky Bottom Organisms

Much less is known about the makeup and dynamics of benthos on rocky subtidal bottoms than on either rocky intertidal or sediment covered subtidal bottoms. This is due to difficulty of access and impossibility of remote quantitative sampling. Since dredged material disposal activities requiring environmental monitoring are usually carried out at sites composed of soft bottom areas, few studies have been conducted on benthic communities associated with rocky bottoms.

4.1.1 Algae

Good light penetration in the western Gulf of Maine allows the growth of algae on hard bottoms at depths of the proposed disposal site (approximately 46 meters).

Sears and Cooper (1978) provide an excellent description of deep-water benthic algae from a location off Cape Ann and on Pigeon Hill, a portion of Jeffreys Ledge. They collected twenty species of macroscopic algae at depths between 29 and 45m. These were almost exclusively red algae. Between 29 and 37m the algal assemblage was dominated by _Ptilota serrata._ This is a fleshy and bushy algae which grows in dense stands 10-20 cm thick. Between 37 and 44m, there were fewer species and the assemblage was dominated by encrusting coralline species.

Sears and Cooper found that the composition of the assemblages were homogenous and seasonally stable and that there was a sharp demarcation between them. They suggested that the depth of light extinction for benthic algae would provide a useful bioassay for making temporal or spatial comparisons of water conditions. They emphasize that algae would integrate the effect of year-round light conditions. An algal-growth assay would have value at a disposal site where resuspension was episodic but occurred over a significant portion of a year. Sears and Cooper do not comment on the ability of _Ptilota serrata_ and other algal species to survive sedimentation, or the effect of a thin layer of sediment on the establishment of new plants.

Ptilota serrata beds provide substrate for spawning of Atlantic herring (Cooper et al., 1975), but it could not be determined whether the presence of algae was advantageous for hatching or survival of larvae.

Additional quantitative data on algal coverage at Pigeon Hill from 1978-1981 are given in Hulbert et al. (1982). Rocky areas within the Cape Arundel study area are in the depth range dominated by _Ptilota_ on Jeffreys Ledge. Algae was observed but not quantified on hard bottom at depths of 20-30m during submersible dives at the Cape Arundel site (see Volume IV, Section VI, of this report).

4.1.2 Invertebrates

During the last decade, Dr. L.G. Harris and associates at the University of New Hampshire (UNH) have developed methods for studying subtidal rocky bottoms and have carried out a variety of studies off the Isles of Shoals and on Jeffreys Ledge. Because these locations are similar in depth, water quality, and wave exposure to the Cape Arundel site, the findings should be generally applicable. The results of several UNH studies are only available as unpublished thesis or as abstracts, but many of these reports have been referenced by Hulbert et al. (1982).

Hulbert et al. provides a quantitative baseline description of the dominant faunal and floral components of communities at 33 and 42m at Pigeon Hill on Jeffreys Ledge. This description is based on quantitative samples from which organisms were removed and photographic sampling in which "key indicator species" were studied over a four-year period (1978-1981).

At 33m, horizontal surfaces were covered by an algal-polychaete tube matrix. The fleshy red algae Ptilota serrata covered 66% of the level substrate. The dominant polychaetes were the sabellid Chone infundibuliformis (a suspension feeder) occurring at a density of 254/0.25 m^2 and the terebellid Thelepus cincinnatus (a deposit feeder) occurring at a density of 164/0.25 m^2. Subdominant species included amphipods which contributed to the tube matrix. A great variety of attached and free-living taxa were found on the algae, on the polychaete tubes and in the sediment trapped by the tubes. Two species of ophiuroids (brittle stars) were numerically dominant in this community (447 and 127/0.25 m^2). Below 38m, Ptilota serrata disappears from level surfaces and polychaetes physically dominate.

At 33 m, vertical surfaces were virtually free of Ptilota serrata. Crustose coralline algae covered much of the rock surface. Dominant animals included a sessile brachiopod (Terebratulina septentrionalis) and at least nine species of sponges and seven species of tunicates covering 17.3% and 6% of the surface, respectively. There was little secondary encrustation or trapped sediment on vertical surfaces.

All feeding types were present on the substrates studied, but both level and vertical surfaces were dominated by suspension feeders. Large invertebrate predators, such as urchins, prosobranch gastropods, crabs, and lobsters were more common on horizontal surfaces. Stomach contents of adult haddock caught at Pigeon Hill showed that they fed heavily on polychaetes and ophiuroids.

Hulbert et al. chose five indicator species for long-term quantitative photographic study on the basis of abundance, large size, ease of sampling, varied trophic status, sensitivity to contamination, and existence of background knowledge of the species ecology. P. serrata was chosen as the dominant primary producer. The polychaete Chone infundibuliformis was ecologically important in providing a secondary substrate, but was variable in density. It was suggested that this species could be monitored in terms of percent cover rather than numerical abundance. Chone was also large enough to provide material for contaminant analysis. Since individuals of the brachiopod T. septentrionalis were easy to distinguish and homogeneously distributed, it was suggested that they could be monitored by direct count. The authors suggest that this species (a suspension feeder) may concentrate pollutants. (A report by Witman and Cooper (1983) gives more detailed information on the population structure of T. septentrionalis at the 33m station.) The tunicate Ascidia collosa has characteristics similar to the brachiopod. A predatory sea star, Leptasterias sp. is relatively large and abundant. The size of individuals, as well as densities, were found to reflect local conditions.

Hulbert et al. state that there are basically two "benthic seasons" at the depths studied in the Gulf of Maine. If this can be verified, it would justify twice-a-year sampling in monitoring programs, rather than the usual four times a year.

Hulbert et al. make no specific reference to the deletrious effect of sedimentation on rocky bottom fauna, although the presence of sediments is one of the determinants of community makeup. It can be hypothesized that the assemblage on horizontal bottom is adapted to recover from shallow burial or erosion and to stabilize sediment. The effects of shallow burial by unpolluted sediment from deposition of dredged material are likely to be similar to those caused by storms.

Another benthic community type is found in hard subtidal seafloor. Throughout the Gulf of Maine are beds of the large horse mussel, Modiolus modiolus. Witman (1984) reported on recently completed studies of mussel beds at 18 and 30m southeast of Star Island, Isles of Shoals. He found that the species living on and within the mussel beds made up an assemblage statistically separable from communities outside. Animals living within the beds were found to receive protection from predation of fish, crabs and lobsters. In 1982, aggregated sea urchins overgrazed the bottom in the Star Island study area, causing radical changes in community parameters outside of mussel beds. There was much less effect within the mussel beds because of physical protection.

It is likely that mussels (which have some mobility) and the infauna of the beds are able to recover from reasonable levels of episodic shallow burial, although no information on this point has been found in this literature review. The spatial complexity of mussel beds and the large number of species in the mussel bed infaunal assemblage would complicate a monitoring program where beds are found. Additional complexity would result from the patchy distribution of mussel beds and other habitat types within a small area. For any hard-bottom community type, the status of sea urchin aggregations would have to be known during each sampling period to avoid misinterpretation of the changes reported by Witman (1984).

4.2 Soft Bottom Organisms

In June 1984, five quantitative benthic samples were obtained from a soft bottom at the north edge of the Cape Arundel disposal site as part of the DAMOS program. Data on the benthic invertebrates recovered from these samples are presented here and discussed with reference to other studies in the geographical area.

4.2.1 Methods

Sample locations are shown in Figure V-3-7. All were on silty sand filling an underwater valley running northeast-southwest and were at least 50 m from surrounding rocky bottom. Samples were obtained with a 0.1 m^2 grab and sieved to 1 mm on the collection vessel. Before sorting, samples were washed on a 0.75 mm sieve. Organisms were sorted from detritus under a dissecting microscope and identified to species where possible. The individuals not identified to species were in most cases very tiny or damaged.

4.2.2 Results

Counts of organisms recovered from the Cape Arundel site are given in Table V-4-1. The table includes the names of species found in other western Gulf of Maine samples, but which were not present in the Cape Arundel samples. Table V-4-2 presents the numbers of individuals and species found in the five samples.

A general similarity exists between the stations within the proposed disposal area in numbers of individuals and species and in community makeup. The reference sample had significantly fewer species and individuals.

Polychaetes dominant in both density and number of species. The list of species (Table V-4-3) which were present at overall densities > 5/sample includes only polychaetes, bivalve mollusks, and oligochaetes.

4.2.3 Discussion

Dominant mollusks include both deposit feeders and filter feeders adapted for soft bottom. Sphenia sincira is a recently-described species which appears very much like juvenile Mya arenaria. It has been found at several locations along the eastern Maine coast (D.B. Packer, personal communication).

Many different feeding and mobility types are found among the polychaetes at the site. The presence of tube

Table V-4-1

Benthic organism count-CADS

Cape Arundel May, June 1984

	CTR	N100	E100	S100	REF
CNIDARIA					
Edwardsia elegans	.	1	.	.	.
Haloclava producta	.	.	.	.	.
Halcampa duodecimcirrata	.	.	.	1	.
Heteractis aurata	.	.	.	.	.
Ceriantheopsis americanus	.	.	.	.	.
Cerianthus borealis	.	.	2	.	.
	.	.	.	.	.
RHYNCHOCOELA	.	.	.	.	.
Cerebratulus spp.	.	2	1	1	.
Micrura sp.	4	4	6	1	.
Tubulanus pellucidus	.	.	.	.	1
Tetrastemmidae	1	.	.	.	.
Rhyncho sy	.	.	1	.	.
	.	.	.	.	.
PHORONIDA SPECIES	1	5	1	.	.
	.	.	.	.	.
APLACOPHORA SPECIES	5	2	1	.	.
	.	.	.	.	.
SCAPHOPODA	.	.	.	.	.
Siphonodentalium sp.	.	.	.	.	.
	.	.	.	.	.
GASTROPODA	.	.	.	.	.
Neptunea decemcostata	.	.	.	.	.
Colus pubescens	.	.	.	.	.
Propebela sp. (Lora sp.)	.	.	1	.	.
gastropod C	2	.	.	.	.
	.	.	.	.	.
BIVALVIA	.	.	.	.	.
Nucula annulata	2	.	.	2	.
Nucula delphinodonta	1	17	.	1	1
Nucula tenuis	2	3	.	.	.
Nuculana tenuisculata	.	1	.	.	.
Yoldia sapotilla	2	1	1	.	1
Crenella decussata	.	2	.	.	.
Astarte undata	1	1	4	1	.
Cyclocardia borealis	.	.	.	.	.
Cerastroderma pinnatulum	4	7	.	.	.
Macoma calcaria	4	8	1	5	.
Arctica islandica	.	.	.	.	.
Thyasira flexuosa	3	9	4	12	2
Mya arenaria	4	13	1	11	2
Periploma papyratium	8	8	10	1	1
Pandora gouldiana	.	.	.	.	.
	.	.	.	.	.
POLYCHAETA	.	.	.	.	.
Aphrodite hastata	.	.	1	.	.
Eteone trilineata	2	.	.	1	.
Phyllodoce arenae	2	.	.	.	.
Harmothoe extenuata	1	2	.	2	.
Hartmania moorei	.	.	.	.	.
Pholoe minuta	2	5	1	3	.
Goniada maculata	.	.	.	.	.

SAIC

Table V-4-1 cont.

Cape Arundel May, June 1984

	CTR	N100	E100	S100	REF
Nepthys incisa	7	5	5	14	.
Exogone verugera	.	.	.	.	.
Syllidae sp.	.	.	.	.	.
Harcia grayi	.	.	.	.	.
Capitella capitata	.	2	.	1	.
Heteromastus filiformis	.	.	1	.	.
Mediomastus ambiseta	15	2	5	5	1
Scalibregma inflatum	.	.	.	.	.
Scalibregma sp.	.	.	.	.	.
Clymenella zonalis	.	1	.	.	.
Madane sarsi	154	30	1	9	15
Rhodine attenuata	.	.	.	.	1
Praxillelle sp.	.	.	.	.	.
Sternaspis scutata	23	43	25	25	1
Leonice cirrata	.	.	.	.	.
Polydora quadrilabata	.	.	.	1	.
Polydora socialis	.	.	1	.	.
Prionospio steenstrupi	32	36	26	11	.
Spio setosa	8	30	21	14	3
Spiophanes bombyx	.	.	.	.	.
Apistobranchus tulbergii	2	12	3	2	.
Trochochaeta multisetosa	.	.	.	.	.
Aricidea quadrilobata	7	5	5	8	.
Aricidea jeffrisii	3	4	10	.	.
Spiochaetoperous oculatus	1	1	.	.	.
Paraonis gracilis	15	11	15	23	7
Driloneries longa	.	.	.	.	.
Lumbrineris fragilis	6	6	6	6	2
Lumbrineris tenuis	.	.	.	.	.
Ninoe nigripes	5	13	4	6	.
Stauronereis sp.	1	.	.	.	.
Scoloplos acutus	2	10	7	11	.
Chaetozone sp.	3	1	.	5	.
Cossura longocirrata	2	1	4	.	3
Tharyx A	4	15	.	.	1
Tharyx B	16	45	38	16	1
Tharyx spp.	10	14	29	19	3
Myriochele heeri	20	39	23	37	1
Owenia fusiformis	1	7	.	2	.
Pectinaria gouldii	.	.	.	.	.
Polycirrus sp.	1	.	1	.	1
Anobothrus gracilis	7	4	3	2	.
Melinna cristata	1	1	1	.	.
Terebellides stroemi	3	5	1	4	.
Terebellidae	.	.	.	.	.
Brada villosa	.	1	.	.	.
Pherusa affinis	.	.	.	.	.
Diplocirrus sp.	1	1	.	.	.
Chone infundibuliformis	.	.	.	.	.
Euchone incolor	10	4	10	9	1
polychaeta unidentified	2	.	.	.	.
	.	.	.	.	.
OLIGOCHAETA SPECIES	56	84	50	102	3

Table V-4-1 cont.

Cape Arundel May, June 1994

	CTR	N100	E100	S100	REF
SIPUNCULA	.	.	.	.	.
Phascolion strombi	.	.	.	.	.
HARPACTICOID COPEPOD	.	.	.	.	.
CUMACEA	.	.	.	.	.
Campylaspis rubicunda	.	1	.	.	.
Eudorella truncatula	2	.	.	.	.
Leucon nasicoides	.	.	.	.	.
Leucon americanus?	.	.	.	.	.
Diastylis sculpta	.	1	.	.	.
Diastylis sp	.	.	.	.	.
ISOPODA	.	.	.	.	.
Edotea montosa	10	8	.	2	1
Pleurogonium spinosssum	.	.	.	.	.
Ptilanthura tenuis	1	2	.	.	1
AMPHIPODA	.	.	.	.	.
Ampelisca agissizi	.	.	.	.	.
Ampelisca vadorum	.	.	.	.	.
Ampelisca verrilli	.	.	.	.	.
Ampelisca macrocephala	.	.	.	1	.
Haploops tubicola	4	.	.	.	.
Unciola irrorata	.	.	.	.	.
Anonyx liljeborgi	.	.	.	.	.
Anonyx sarsi	.	.	.	.	.
Hippomedon serratus	1	1	.	.	.
Orchomenella pingus	.	.	.	.	.
Monoculodes sp.	.	.	.	1	.
Monoculodes sp Notch	.	.	.	.	.
Leptocheirus pinguis	.	.	.	.	.
Photis reinhardi	1	.	.	.	.
Harpina propinqua	.	.	.	1	.
Phoxocephalus holbolli	.	.	.	.	.
Stenopleustes inermis	1	1	.	.	.
Metopella angusta	3	.	.	.	.
Corophium tuberculatum	.	.	.	.	1
Dyopedos monocantha	.	.	.	.	.
Caprella sp.	.	.	.	.	.
DECAPODA	.	.	.	.	.
Crangon septemspinosa	.	.	.	.	.
Pagarus longicarpus	.	.	.	.	.
ECHINODERMATA	.	.	.	.	.
Molpadia oolitica	.	.	.	1	.
Ctenodiscus crispatus	.	.	.	.	.
Ophiura sarsi	1	.	.	.	1
Abundance	493	536	331	381	5[illegible]

TABLE V-4-2

Number of Individuals and Species - CADS

Station	CTR	N-100	E-100	S-100	REF	TOTAL
Individuals	493	538	331	381	56	1799
Species*	58	54	40	41	24	82
*Species with more than 2 individuals						62

Table V-4-3

Dominant Species - CADS

Polychaeta	Bivalvia
Aricidae quadrilobata	Sphenia sincira
Euchone incolor	Nucula delphinodonta
Lumbrineris fragilis	Periploma papyratium
Maldane sarsi	Thyasira flexuosa
Mediomastus ambiseta	
Myriochele heeri	Oligochaeta spp.
Nephtys incisa	
Ninoe nigripes	
Paraonis gracilis	
Prionospio steenstrupi	
Scolopos acutus	
Spio pettiboneae	
Steraspis fossor	
Tharyx spp.	

dwellers, such as Maldane, Prionospio, Spio, Myriochele and Euchone and deposit feeders such as Mediomastus, Sternaspis, Aricidae, Terebellides, and oligochaetes indicate a degree of sediment stability and the deposition of fine-grained organic matter.

The only other benthos samples from the disposal site were obtained in Septembr 1975, while the area was being used for disposal of material from the Kennebunk River (NED, 1984). A few individuals were recovered which had a high likelihood of coming from low-salinity or shallow water (Scolecolipides viridis, Modiolus demissus, Mytilus edulis, Glycera dibranchiata). Many of the more abundant species were also abundant in near-shore shelf samples and in the 1984 Cape Arundel samples (Thyasira flexuosa, Periploma papyratium, Nucula annulata, Sternaspis fossor, Nephtys incisa). The "maldanid" identified is probably Maldane sarsi, found in 1984. Another group of species absent or in low densities in the 1984 samples are more representative of sandy bottoms (Astarte sp., Cerastoderma pinnulatum, Unaciola irrorata, Crenella sp.). Apparently sediment at the 1984 sample site contains more fine sediment and organic matter than some nearby areas.

Larsen (1979) carried out a quantitative study of benthos at two locations at the mouth of the Sheepscot River (Fig. V-2-2). He classified data to produce site and species groups. Several of the dominants in species groups found in deeper water (3.6 - 9.1m) were also present at the Cape Arundel site (Nephtys incisa, Sternaspis forror, Mya arenaria, Thyasira flexuosa). In the Sheepscot River, these species would be exposed to greater ranges of temperatures and salinity and higher concentrations of suspended matter than at the offshore site.

Larsen et al. (1983) report on 56 quantitative grab samples taken throughout Casco Bay at depths of 2.1 - 38.1 m as part of the Northeast Monitoring Program (NMFS). Grain size and concentration of organic carbon and heavy metals were measured at each station. Nine stations were in deeper water at the mouth of the Bay. These stations were rich in species (50-86) and had a high biomass and a relatively high proportion of crustaceans. Species groups at the deep water sites were, in most cases, not restricted to deep water. One group, N, was particularly ubiquitous. Members of this group were also found at Cape Arundel (Nucula delphinodonta, Nephtys incisa, Ninoe nigripes, Prionospio steenstrupi). Members of less ubiquitous groups found in deep samples from Casco Bay were also found at Cape Arundel, but complete identified groups were not found. Shallow water groups and a deep water sandy bottom group (G) were not found at Cape Arundel. Larsen et al. refer to group N as a "very tolerant, numerically dominant species ... typical of nearshore bottoms over a large area". They suggest that smaller groups responding to finer environmental distinctions should be used as indicators of environmental degradation.

Benthic samples have been taken at other western Gulf of Maine disposal sites as part of the DAMOS program. Data are available from the following locations: Portland, December 1980 (3 samples), May 1984 (5 samples), Isles of Shoals December 1980 (3 samples), and Boston Foul Ground, July 1982 (3 samples). Inspection of the species counts shows that tube-dwelling polychaetes also dominate these locations and only minimal numbers of mollusks and crustacea are found.

Dominance by polychaetes has a number of consequences. Dense populations of suspension feeding spionid polychaetes may inhibit settling and survival of other species. Most polychaetes will be able to recover from shallow burial. Polychaetes provide a larger portion of the diet of flounders than of "round fish," such as cod and hake.

The existence of related benthic communities at a number of dredged material disposal sites in the Gulf of Maine means that information on the response to burial, uptake of pollutants, or value to fish would be generally useful in management decisions.

There was virtually no similarity between the species found at the Cape Arundel site and those described on rocky bottoms by Hulbert et al. (1982). Although rocky bottom surrounds the site, a combination of larval and adult substrate selection and mortality on inappropriate substrate keep the benthic communities distinct.

A study of the Saco and Kennebunk estuaries (Messier, 1982) identified a community specialized for life in hard-fine sand (haustorid amphipods, the polychaete Owenia) (L. Watling, U. Maine, personal communication). These species are unrelated to those found at the disposal site. Their presence in deep water would indicate an estuarine source of sediments as in the 1975 Corps of Engineers study.

The counts of dominant species at the Cape Arundel disposal site are relatively homogeneous for benthos data. This is probably the result of sampling in a spatially restricted and homogeneous area. It is expected that surrounding level-bottom areas would have the same fauna, but with differences missing, the effects of storms or predation, and random settling or larvae. Relative abundances and densities would also be expected to vary from year to year. With this variability, subtle post-disposal effects would be hard to detect with limited numbers of samples. Gross disturbance or pollution could be detected by changes in relative abundance, large decreases in number of species and individuals, and the presence of new dominants or pollution indicator species.

5.0 SUMMARY

The surveys of the Cape Arundel Disposal Site (CADS) have indicated an area similar to that found at the Portland Disposal Site, consisting of a soft mud bottom surrounded by hard rock ledges. The success of the Portland site in containing the dredged material within the depression has shown that such areas are viable disposal locations. Although surveys north of the designated area have shown a broader depositional region, disposal must be confined to the designated site. Consequently, a taut-wire moored buoy has been deployed at 43°17.86N, 70°27.16W in the very southern extent of the depositional trough.

To successfully contain dredged material at the disposal site, careful point dumping must be conducted. Because of the preference for disposal of dredged material on sediments of similar lithology, care should be taken to avoid the hard rock strata surrounding the disposal point. Not only will this preserve potential lobster habitat, but monitoring of the site will then be possible through sampling of the soft bottom area.

Monitoring of this site should include not only standard DAMOS procedures, but whenever possible, visual observations in the surrounding hard rock region. This can best be accomplished through use of a submersible, since the depths are too large for efficient diving and the topography too rough for underwater TV.

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VI. PORTLAND DISPOSAL AREA

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VI. PORTLAND DISPOSAL AREA

1.0 INTRODUCTION

The Portland Disposal site was designated during 1977 and 1978 through a comprehensive study of potential locations and coordination with local fishing interests. The result of that effort was a site in a sandy valley at a depth slightly greater than 60 meters surrounded by hard rock ledge. This valley was located in a previously designated disposal area and has been used exclusively for disposal of Portland dredged material since 1979. A summary of the results of the site designation work was presented in the DAMOS Annual Report in 1978.

A taut-wire moored buoy was deployed ($43^{o}34.11'$N, $78^{o}01.91'$W) during August 1979 to mark the point for disposal of dredged material. Operations have continued at the site on an incremental basis since that time. During the initial stages of disposal, relatively frequent monitoring studies were conducted, particularly during 1980, however, once the general parameters of disposal at this location were understood, and potential impacts assessed as minimal, the frequency of surveys was reduced. Table VI-1-1 summarizes the surveys conducted following initiation of dredging through 1982.

This section presents an overview of all studies conducted at the Portland site through the end of 1982. Since that time, an additional DAMOS monitoring survey was conducted in May 1984 to obtain bathymetric profiles, sediment samples, and side scan records. The area was visited by the submersible "Mermaid II" in July 1984 to visually inspect and photographically record sediment conditions at the disposal site.

2.0 BATHYMETRIC SURVEYS

The contour chart for June 1979 (Fig. VI-2-1) represents the baseline survey prior to disposal at this site. Although the disposal buoy was installed in August 1979 and some disposal took place during the winter months, the survey conducted in April 1980 (Fig. VI-2-2) shows no significant changes in the topography of the site from the original survey. However, sediment samples at the disposal point did indicate the presence of dredged material. As disposal continued at a more rapid pace during spring aand summer, the survey conducted in August 1980 revealed the presence of a definite mound south of the disposal buoy reaching a thickness of four meters in some areas (Fig. VI-2-3). This thickness increased to over six meters by December 1980 (Fig. VI-2-4) and the mound was spread over a diameter of more than 200 meters.

Although the mound described above developed in the vicinity of the disposal buoy, other evidence indicates that the dredged material was spread over a somewhat larger area.

TABLE VI-1-1
DISPOSAL MONITORING STUDIES PORTLAND DISPOSAL SITE 1980-1982

April 1980	-	Joint cruise with Interstate Electronics Corp. and EPA for DAMOS monitoring and EPA Site Designation.
	-	Bathymetric survey
	-	Sediment Samples (16)
	-	Underwater TV and Photographs
	-	Mussel watch deployment
August 1980	-	DAMOS Monitoring Cruise
	-	Bathymetry and side scan
	-	Sediment samples (28)
	-	Benthic samples (4)
	-	Photography
	-	Mussel retrival
December 1980	-	DAMOS Monitoring Cruise
	-	Bathymetry
	-	Sediment Samples (24)
	-	Benthic Samples (10)
December 1981	-	DAMOS Monitoring Survey
	-	Bathymetry
	-	Sediment samples (20)
	-	Benthic Samples (5)
	-	Redeploy buoy
February 1982	-	Coring program in Portland Harbor
	-	Redeploy buoy
September 1982	-	DAMOS Monitoring Survey
	-	Bathymetry
	-	Sediment Samples (6)
	-	Benthic Samples (5)

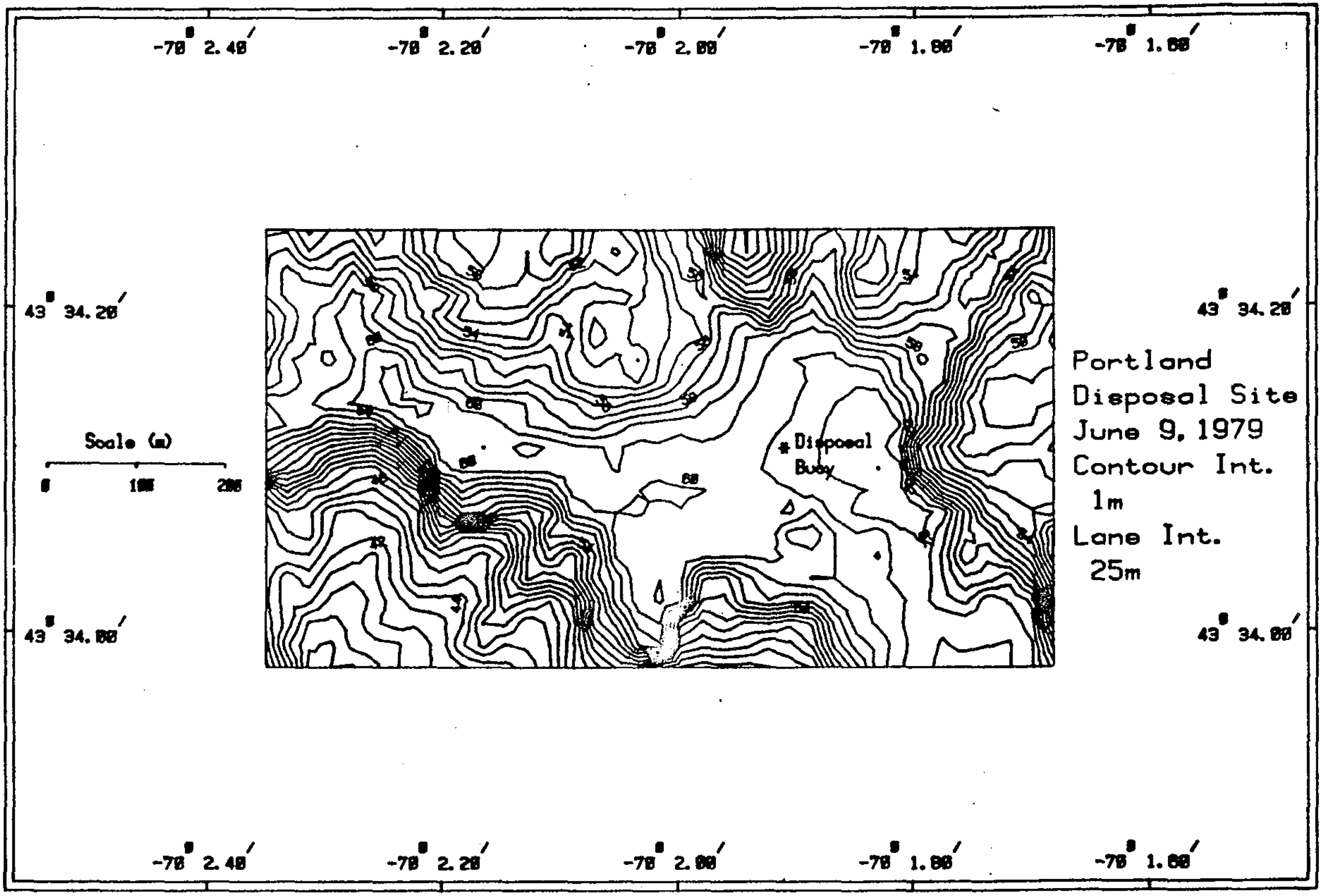

-70° 2.40'
-70° 2.20'
-70° 2.00'
-70° 1.80'
-70° 1.60'
43° 34.20'
43° 34.00'
Scale (m)
0
100
200
Disposal Buoy
Portland
Disposal Site
June 9, 1979
Contour Int.
1m
Lane Int.
25m

FIGURE VI-2-1

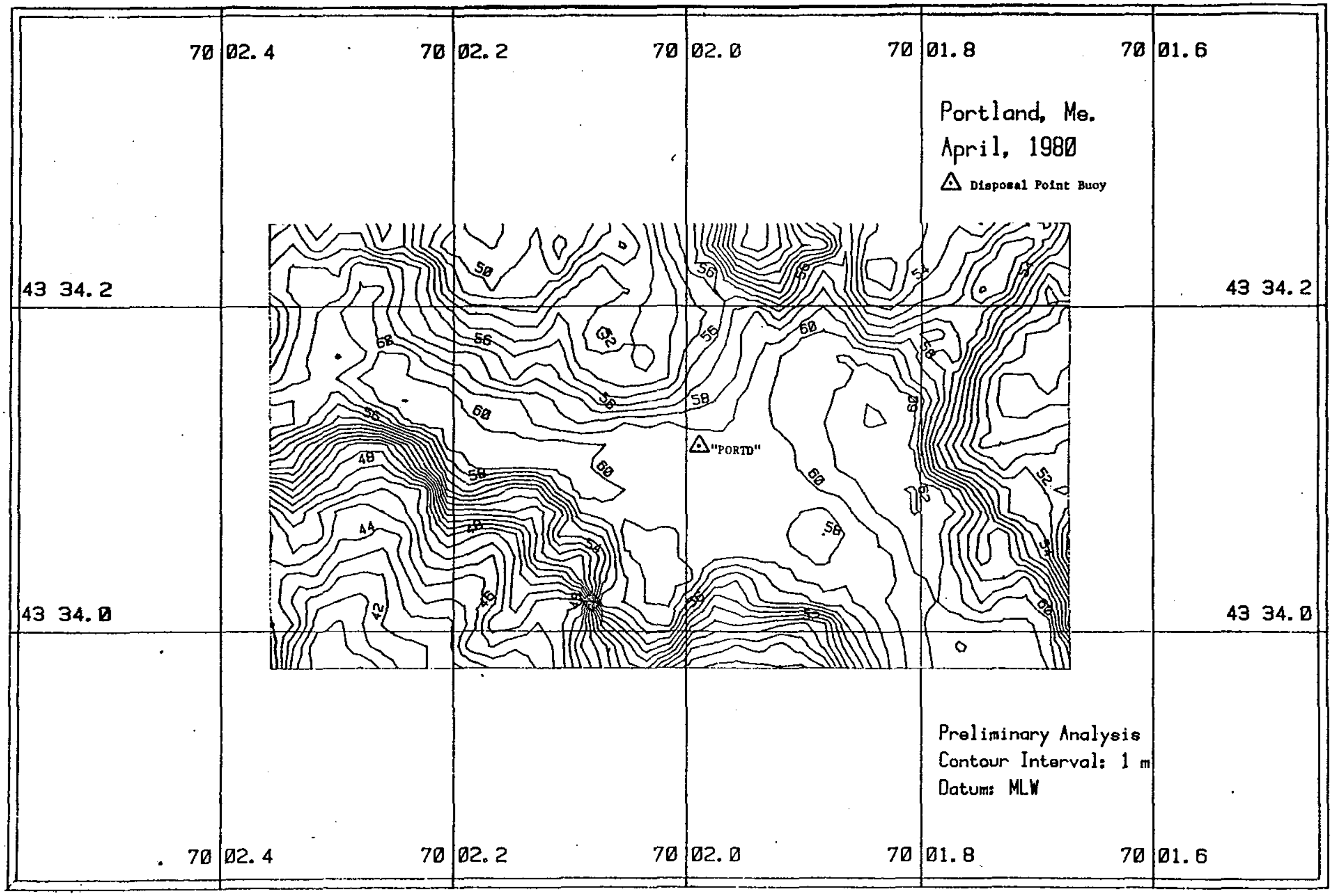

70 02.4
70 02.2
70 02.0
70 01.8
70 01.6
Portland, Me.
April, 1980
Disposal Point Buoy
43 34.2
43 34.0
"PORTD"
Preliminary Analysis
Contour Interval: 1 m
Datum: MLW

Figure VI-2-2

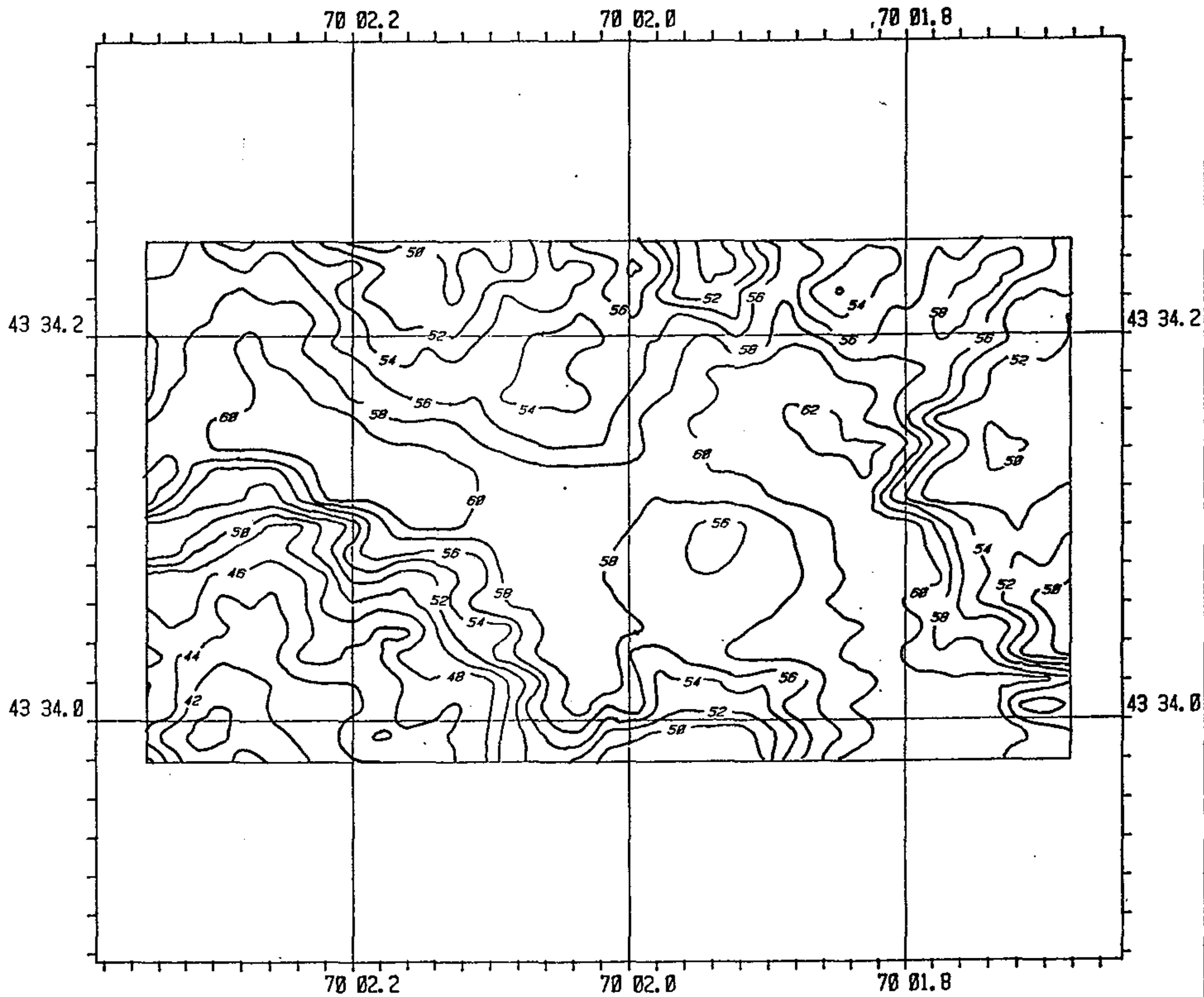
PORTLAND

AUGUST 1980

INTERVAL: .2m

SCALE 1/4000

Figure VI-2-3



0 80 160

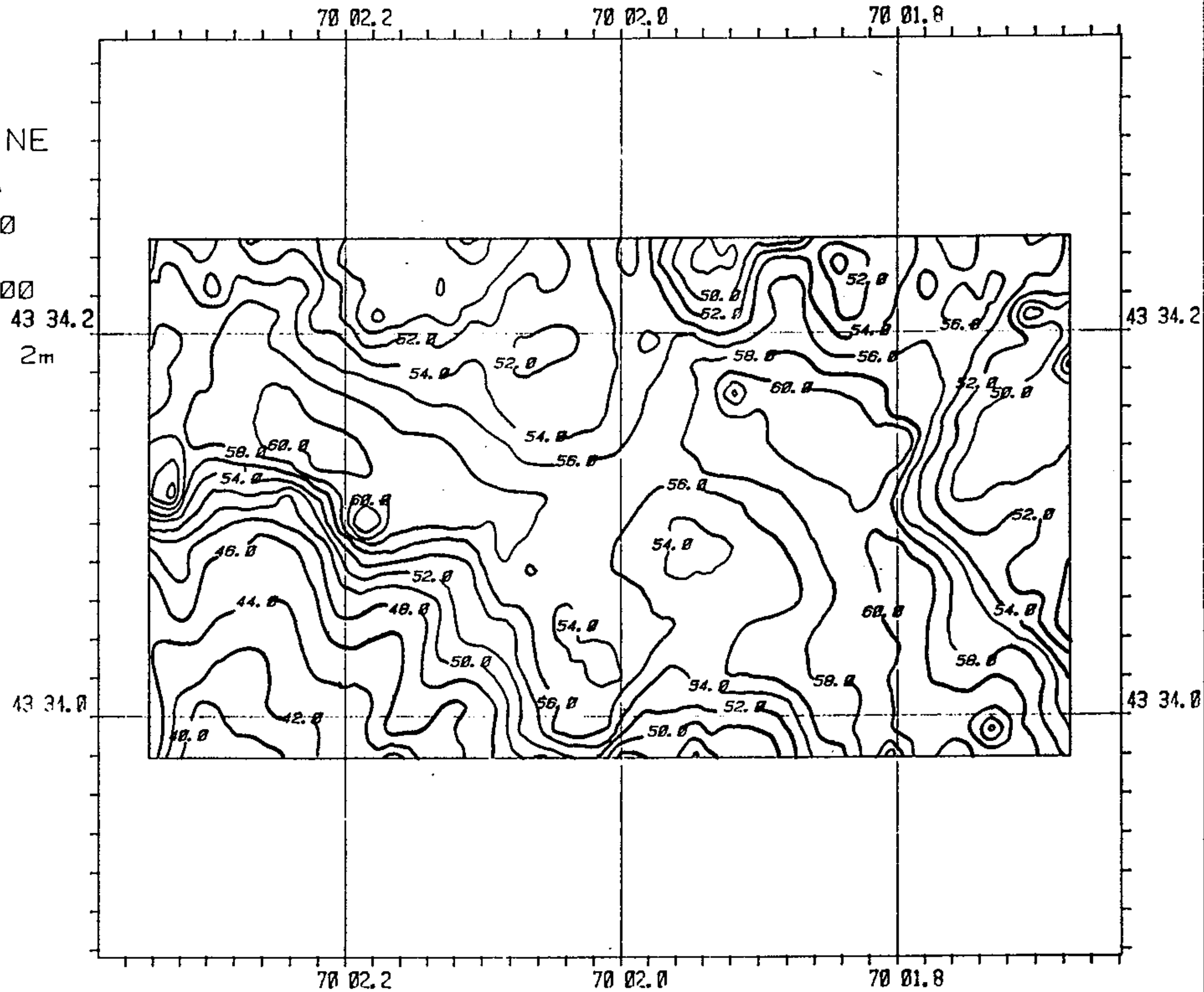
SCALE (m)

PORTLAND, MAINE
SURVEY AREA
10 DECEMBER 1980

CHART SCALE 1/4000

CONTOUR INTERVAL 2m

Figure VI-2-4



Sediment samples taken radially from the center of the disposal point indicated that dredged material extended to the margins of the valley in both the east and south directions and to a significant distance in the west direction. The only natural sediment exposed in the valley was found on the northern margin of the site.

This spread of material is probably the result of three interrelated aspects of the Portland disposal operation. First, some of the sediments dredged from this harbor were less cohesive than those found in Connecticut harbors, probably because of continued stirring by large oil tankers maneuvering in the shallow harbor. Second, these less cohesive muds were dropped through nearly three times the depth of water encountered during disposal operations in Long Island Sound. This would tend to increase dispersion through higher terminal velocities and greater entrainment of water. Finally, the location of the site in open ocean waters required disposal under adverse wind and wave conditions which prohibited the extremely accurate ($\pm$10 m) disposal operations used in the sound. At this site, the radius of dispsoal must have been on the order of $\pm$50 m relative to the disposal buoy.

The contour chart for the December 1981 survey (Fig. VI-2-5) showed no significant changes to the topography at the disposal site during that year. However, the bathymetric survey conducted in September 1982 (Fig. VI-2-6) indicates the deposition of an additional 2 m of dredged material at the disposal mound. Little additional material is evident beyond the mound, indicating increased control of the dumping operations. The most recent bathymetric survey was conducted in May 1984 (Fig. VI-2-7) and revealed the addition of as much as 5-7 meters of dredged material at the disposal site. Figure VI-2-8 is a contour difference chart of the disposal area that compares the precision bathymetric results from the September 1982 and May 1984 surveys. The disposal mound is evident just east of the center of the grid. Although this analysis provides an indication of the distribution of dredged material, because of the steep and varied topography surrounding the site, accurate measurements of sediment volume cannot be determined.

3.0 SEDIMENT CHEMISTRY

During the September 1982 monitoring cruise at the Portland disposal area, three replicate sediment samples were collected with a 0.1 m^2 Smith-MacIntyre grab at the disposal site (CTR) and at the reference station approximately 1.3 NM south of the disposal site. Table VI-3-1 contains the results of the chemical analysis by NED. Elevated concentrations are found for Zn and Cu. The values for Hg and Pb are similar to those found in other disposal areas.

The sediment at the disposal site was visually characterized as grey organic clay with traces of fine sand. Shell hash was also evident. The reference site contained

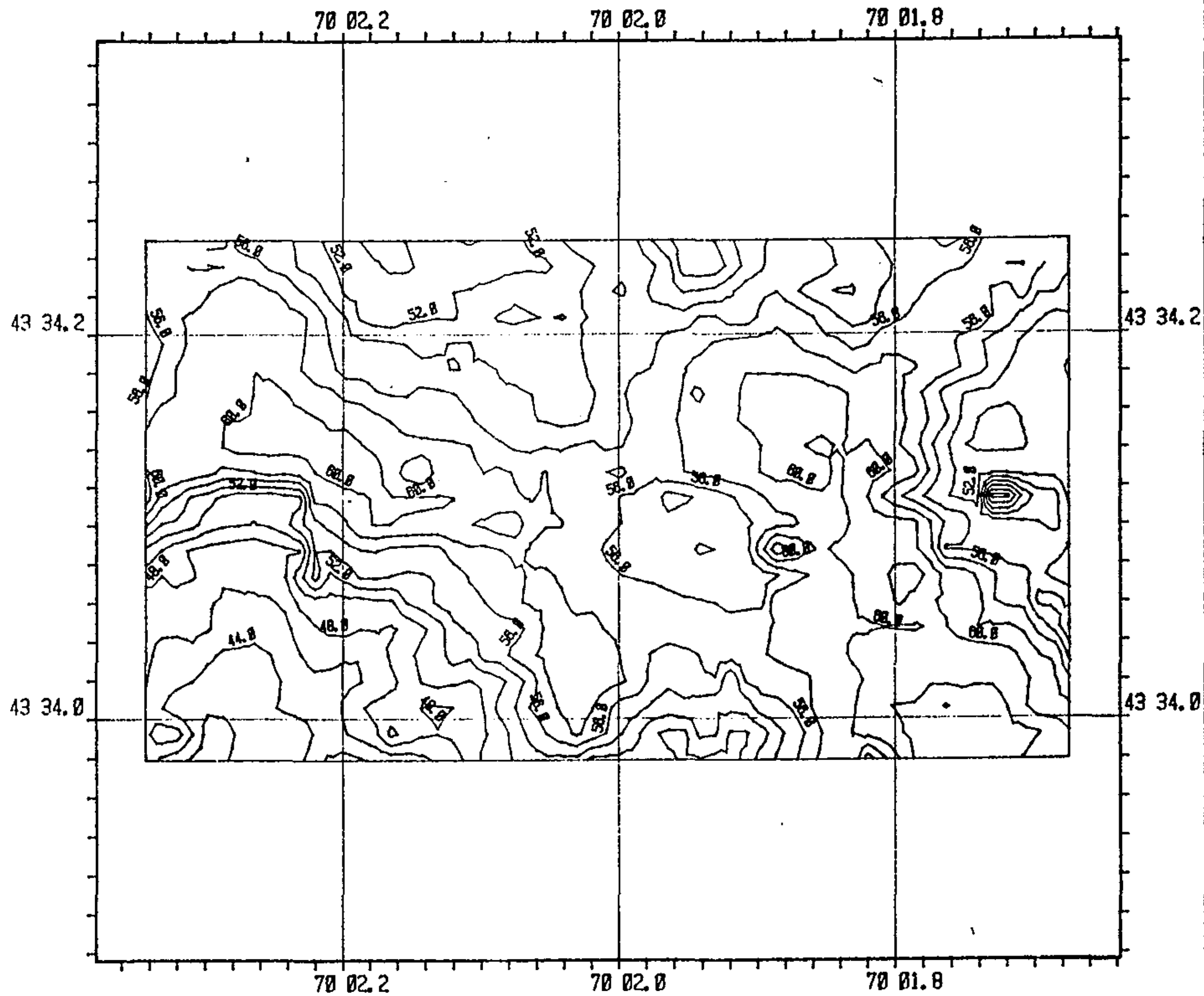
PORTLAND

DECEMBER 1981

INTERVAL: .2m

SCALE: 1/4000

Figure VI-2-5



0 80 160
SCALE (m)

PORTLAND

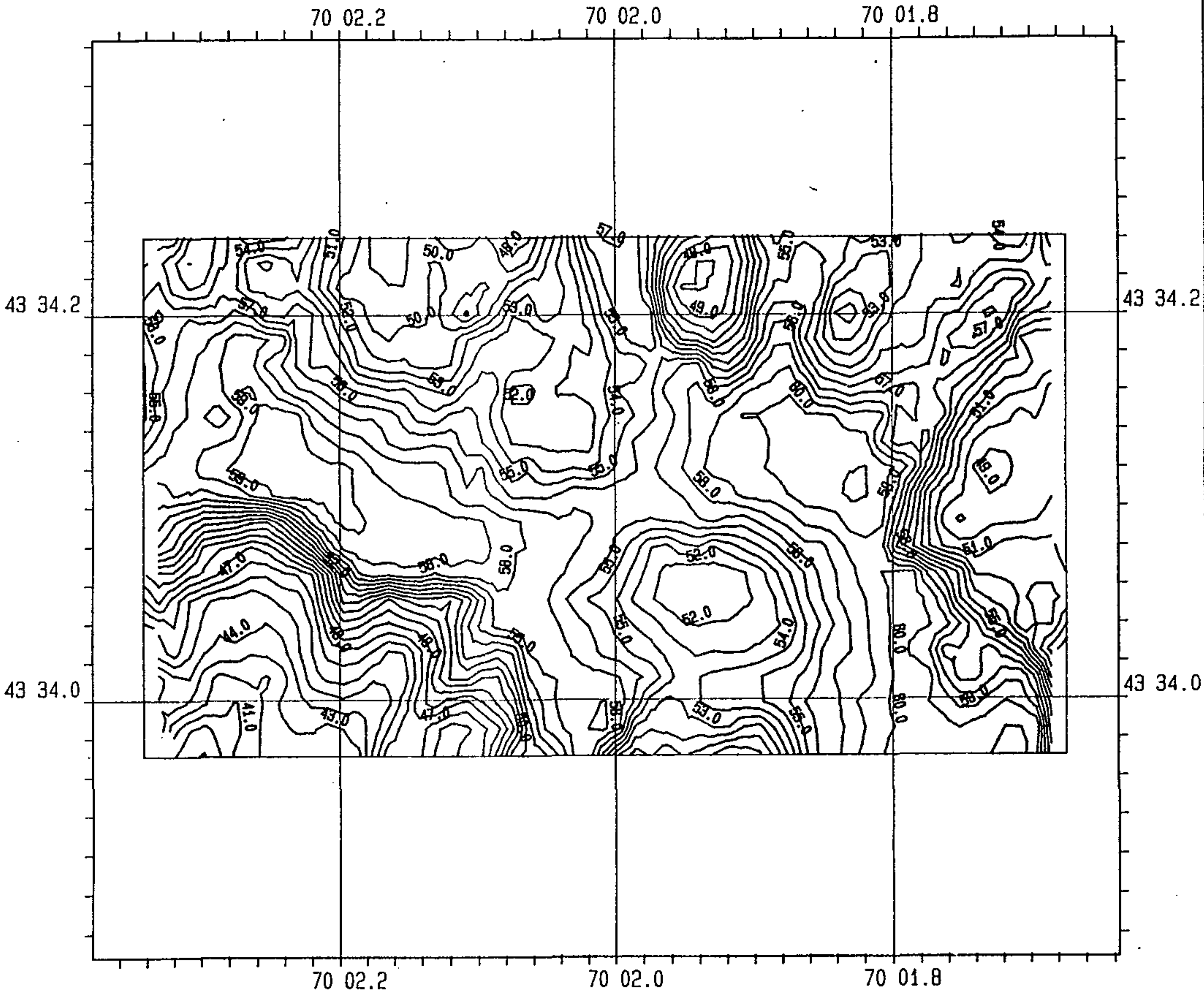
21 SEPTEMBER 1982

INTERVAL: 1.0m

SCALE: 1/4000

DATUM: MLW

Figure VI-2-6



0 80 160

SCALE (m)

PORTLAND

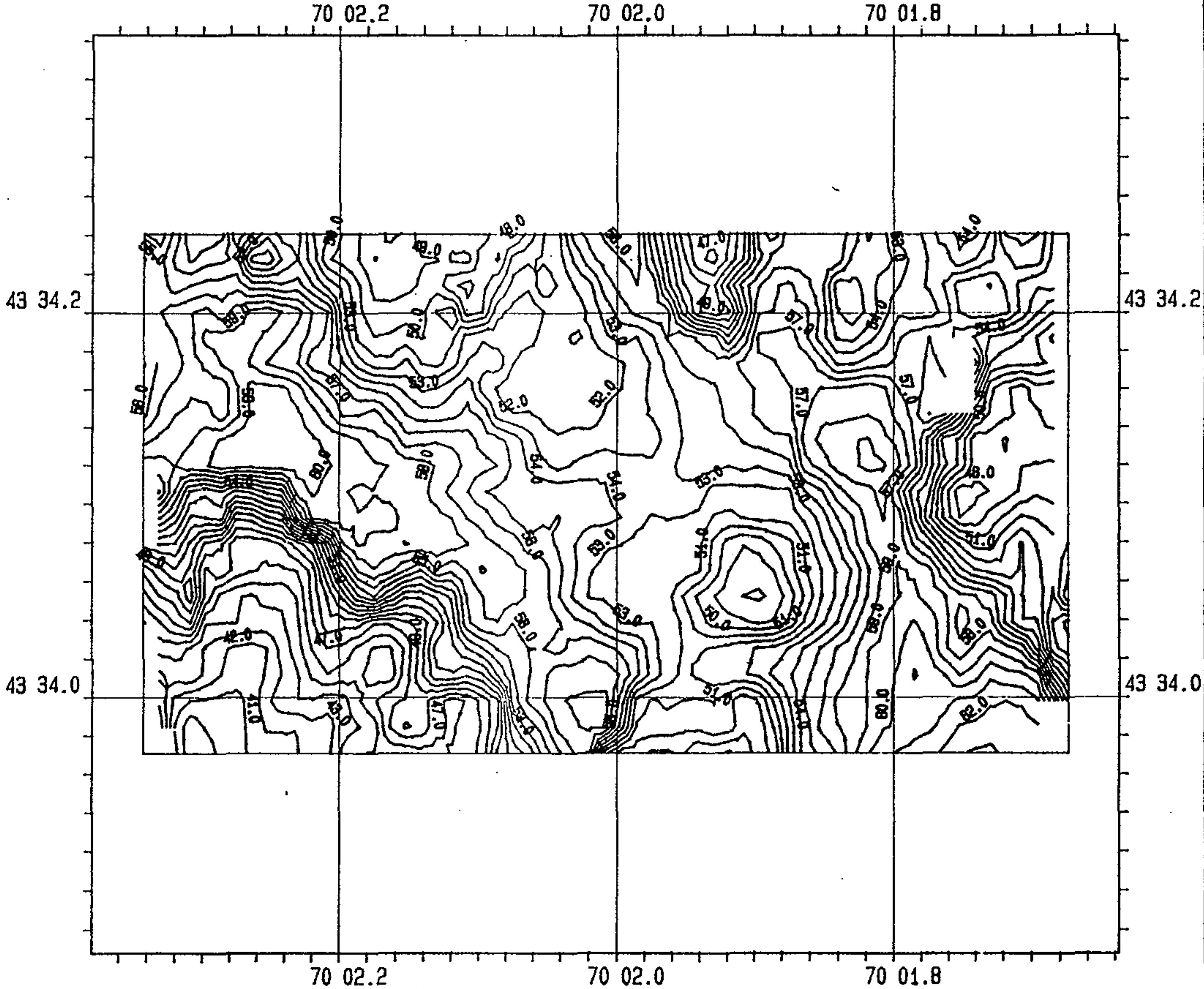
21 MAY 1984

INTERVAL: 1.0m

SCALE: 1/4000

DATUM: MLW

Figure VI-2-7



0 80 160

SCALE (m)

PORTLAND

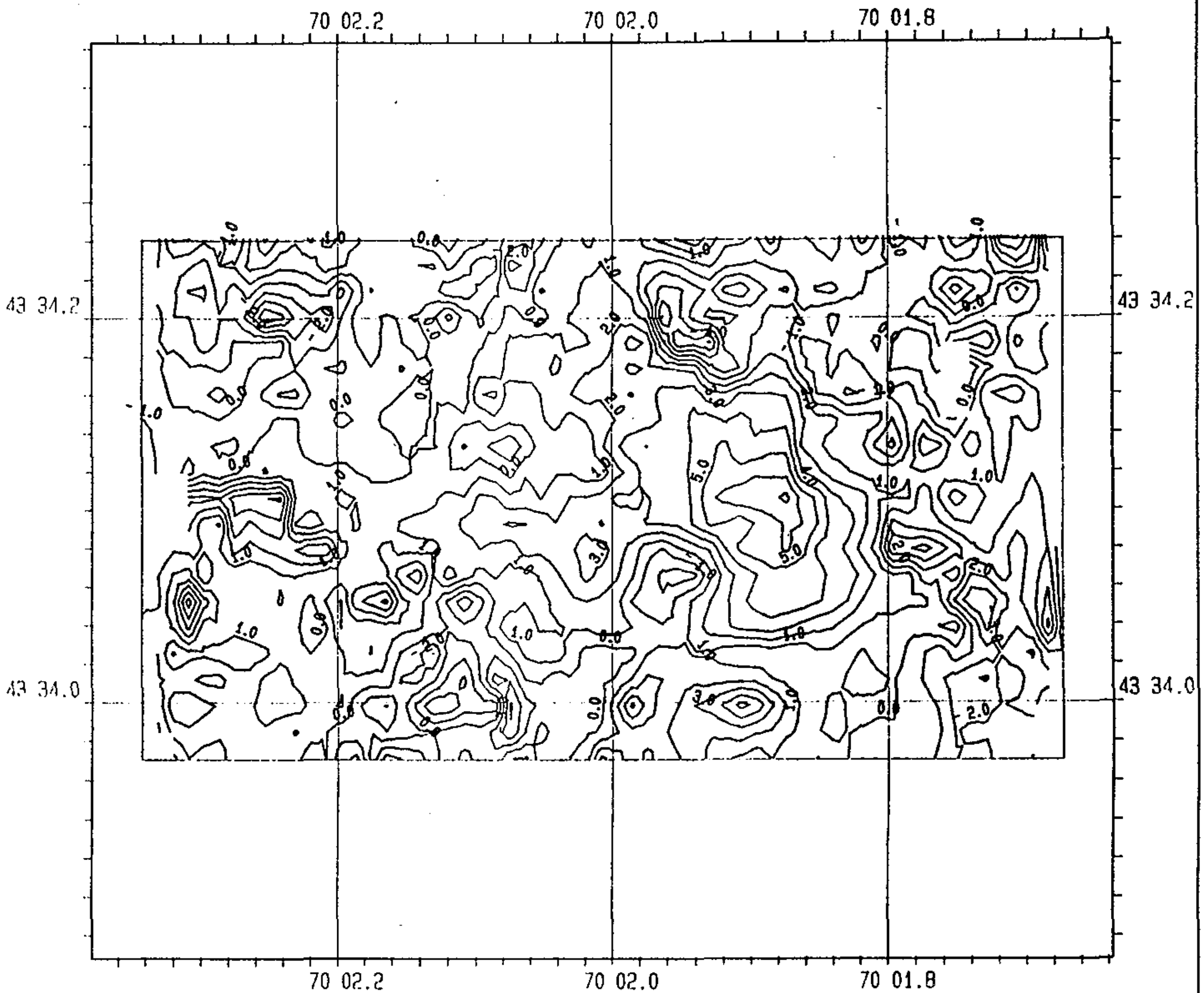
CONTOUR DIFF.

MAY84-SEPT82

INTERVAL: 1.0m

SCALE: 1/4000

Figure VI-2-8



0 80 160

SCALE (m)

TABLE VI-3-1

Concentrations of Chemicals in Sediments Collected at the Portland Disposal Site in September 1982. (Values in parts per million).

		COD	Solids	Hg	Pb	Zn	As	Cr	Cu	Mg:Ca	Total Carbon	Oil & Grease
	A	5,914	67.4	0.20	-	122	4.7	35	31	19.7	0.36	109
Center	B	43,800	64.2	0.42	84	125	5.5	29	55	11.9	1.47	4350
	C	8,829	67.8	0.13	63	445	5.2	36	46	24.4	1.12	274
	A	57,434	42.4	-	-	85	7.9	36	15	29.1	2.10	112
REF	B	47,834	48.5	-	-	78	4.7	32	14	23.0	1.88	96
	C	46,482	40.0	-	-	101	7.3	38	17	28.6	2.13	121

sediment of brown, grey organic clay with traces of fine sand. The lack of shell material could account for the higher Mg:Ca ratios.

4.0 BIOLOGICAL RESULTS

4.1 Mussel Watch

4.1.1 Introduction

The major objective of the mussel monitoring project was to ascertain whether the disposal of dredged materials would affect the levels of trace metals in mussels experimentally deployed on or near the dumpsite. An additional objective was to determine whether elevated levels of trace metals would affect the well being of the organism using the wet/dry tissue weight ratio and/or mortality as indicators. Investigations of other extrinsic factors, excluding dredging which could account for the variance observed in trace metal concentrations, constitute the third objective.

The DAMOS Mussel Watch project is based on the assumption that the trace metal residues in mussel tissue are influenced by intrinsic and extrinsic factors. The intrinsic factors are innate and physiological in nature and dictate the uptake, accumulation and attrition or depuration of the trace metals while the extrinsic factors are abiotic and physical in nature.

4.1.2 Procedures

The horse mussel, Modiolus modiolus, was collected from the reference site at Bulwark Shoals (B), bagged (20 per bag) and deployed at the Portland Disposal Site. The depth of this site (60 m) has limited the accessibility of mussel samplings by divers. The sampling was accomplished by laying down a ground line on the bottom with one end tied to the platform. The location of the platform was recorded with Loran-C. During subsequent sampling trips, the platform could be retrieved by dragging for the ground line. To insure more or less uninterrupted sampling of these two stations, a local fisherman was contracted to sample the platform on a monthly basis and also asked to ship the samples (packed in dry ice) to the Marine Sciences Institute, University of Connecticut at Noank, CT.

Upon returning to the laboratory, 12 horse mussels were pooled into three samples of 4 animals per sample. For baseline data, 8-10 replicates were used. The mussels were cleaned, measured, shucked, homogenized and lyophilized according to the established procedures for the project (see Volume IV). The wet/dry weight ratios were calculated by dividing the homogenized tissue weight with the freeze-dried tissue weight. Also, during each sampling period, the number of dead mussels per bag was recorded. These data were used to construct a cumulative mortality graph for each site. The concentration of trace metals in the mussel samples were determined by the established methods of atomic absorption spectrophotometry.

Statistical analysis of the data was carried out by applying a scheme specifically designed to eliminate or minimize the effect of intrinsic variables (e.g. wet/dry weight ratio and shell length) on the trace metal concentration in the mussels. After this was achieved, stepwise multiple regression analyses were conducted to determine whether extrinsic variables, especially disposal of dredged materials, or other variables were associated with the changing trace metal concentration in mussels.

4.1.3 Results

The trace metal concentrations (Cd, Cr, Co, Cu, Fe, Hg, Ni, Zn and V) in the tissues of Modiolus modiolus from the Portland Disposal Site and the reference site at Bulwark Shoals are presented in Table VI-4-1. Graphic representations of temporal variations of the trace metal concentrations are depicted in Figures VI-4-1 through VI-4-5. Seasonal variations in the tissue wet and dry weight ratios are shown in Figure VI-4-5. In general, the variability of trace metal concentrations at the Portland Disposal Site is greater than that of the trace metal levels at the Bulwark Shoals Site, which may be associated with the disposal operations at the dump site (Fig. VI-4-6).

The tissue wet/dry weight ratios of the horse mussels were positively correlated with most trace metals (except Cu) at Bulwark Shoals and Portland Disposal Site (Table VI-4-2). Although seasonality of the W/D ratio with a peak in August was discernible at the nearshore Bulwark Shoals reference station, no such cycle was seen in mussels maintained at the Portland Disposal Site. Bulwark Shoals, being inshore and in shallower waters, is subject to greater temperature fluctuations than the Portland Disposal Site, which is in a deep open water area and characterized by a more stable temperature regime. Since temperature is one of the major factors in controlling reproductive cycles of many marine invertebrates, it is, therefore, not unexpected to find that the W/D ratios show little or no temporal variations at the Portland Disposal Site. At Bulwark Shoals in inshore waters, spawning probably takes place during July and August as indicated by the highest W/D ratios at this time. However, at the Portland Disposal Site, an offshore deep water site where the temperature regime is more stable, spawning probably occurs in autumn.

Positive correlations between most trace metals and shell length occur in 83% of the cases; Cu is the only exception where the correlations with shell length are negative at both stations. The W/D weight ratio of M. modiolus, in general, is also a better predictor than the shell length for trace metal concentrations.

TABLE VI-4-1. A summary of trace metal concentrations in _Modiolus modiolus_ from Portland Disposal Site (Maine) and the reference site. Figures within the parentheses are 1 s.d.

Trace Metal	_Modiolus modiolus_ Bulwark Shoals	Portland
Cd	12.5(4.5)	12.9(5.7)
Cr	1.4(0.8)	2.2(2.9)
Co	0.7(0.3)	0.7(0.2)
Cu	31.0(7.3)	29.4(5.8)
Fe	132(56)	168(72)
Hg	0.389(0.169)	0.398(0.283)
Ni	3.5(1.0)	4.0(3.0)
Zn	320(73)	338(264)
V	6.9(3.6)	6.1(3.9)
n	16	12

SAIC

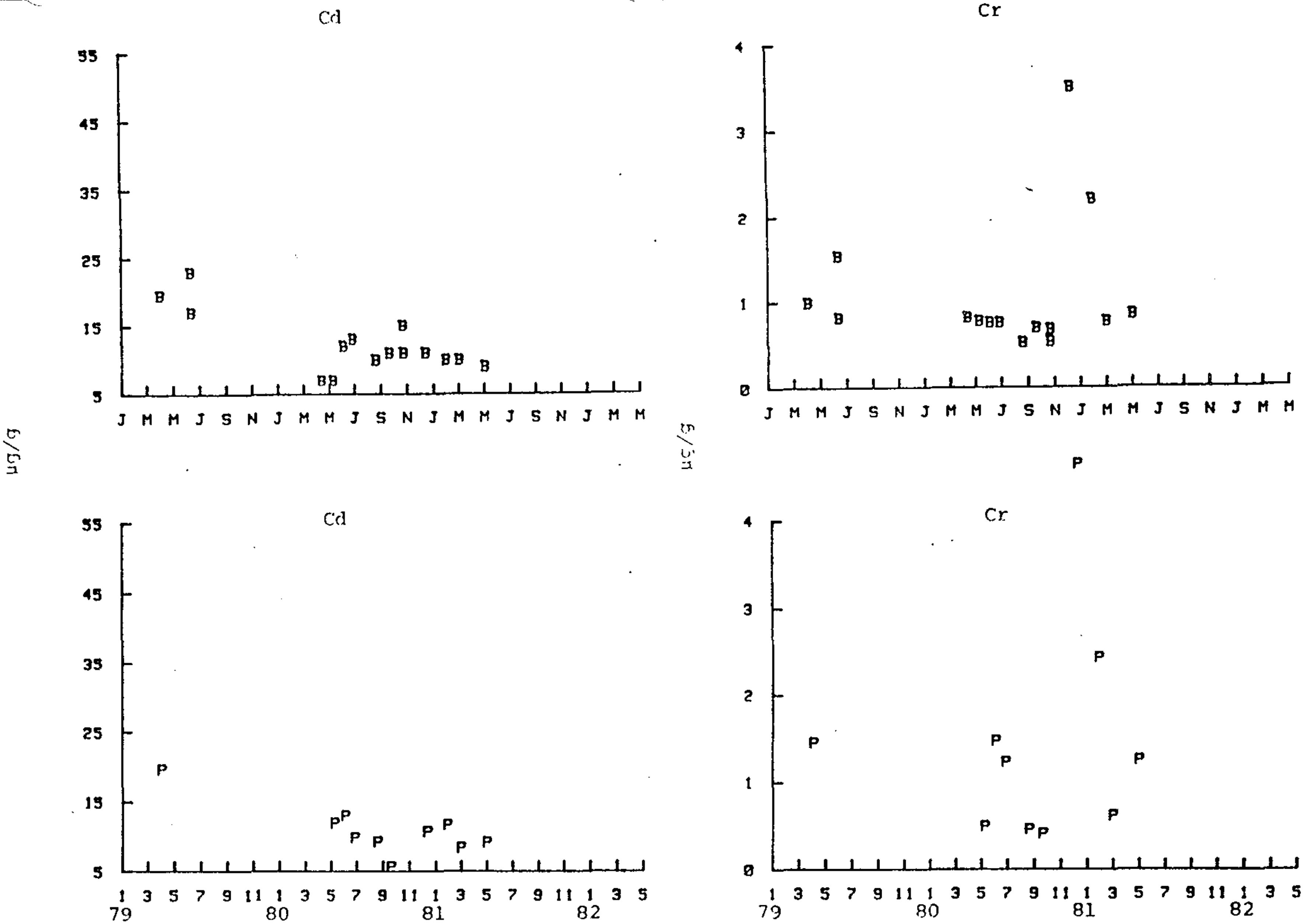


FIGURE VI-4-1. Temporal variations of cadmium and chromium concentrations in Modiolus modiolus deployed at Bulwark Shoals (B), the reference site and Portland (P) Disposal Site.

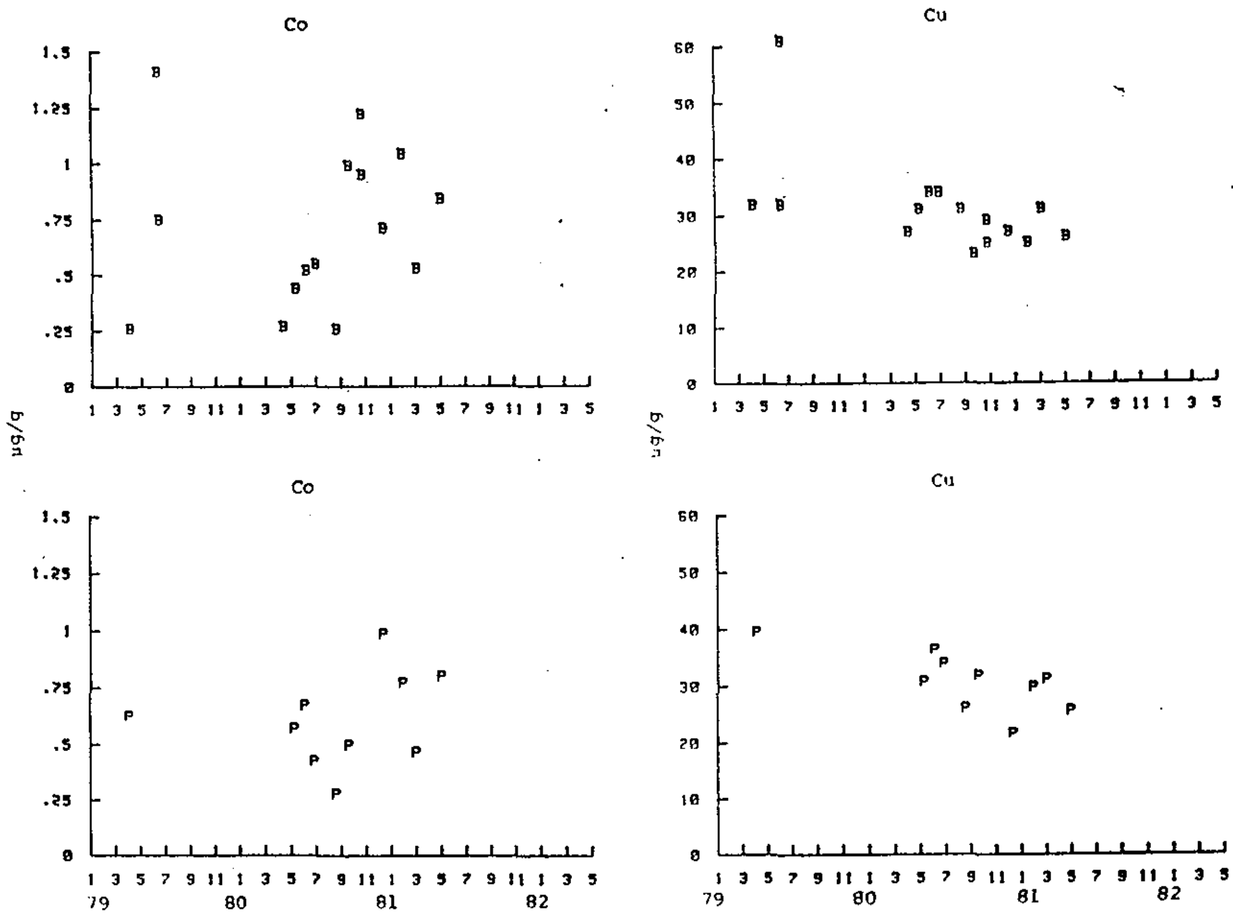


FIGURE VI-4-2 Temporal variations of cobalt and copper concentrations in Modiolus modiolus deployed at Bulwark Shoals (B), the reference site and Portland (P) disposal site.

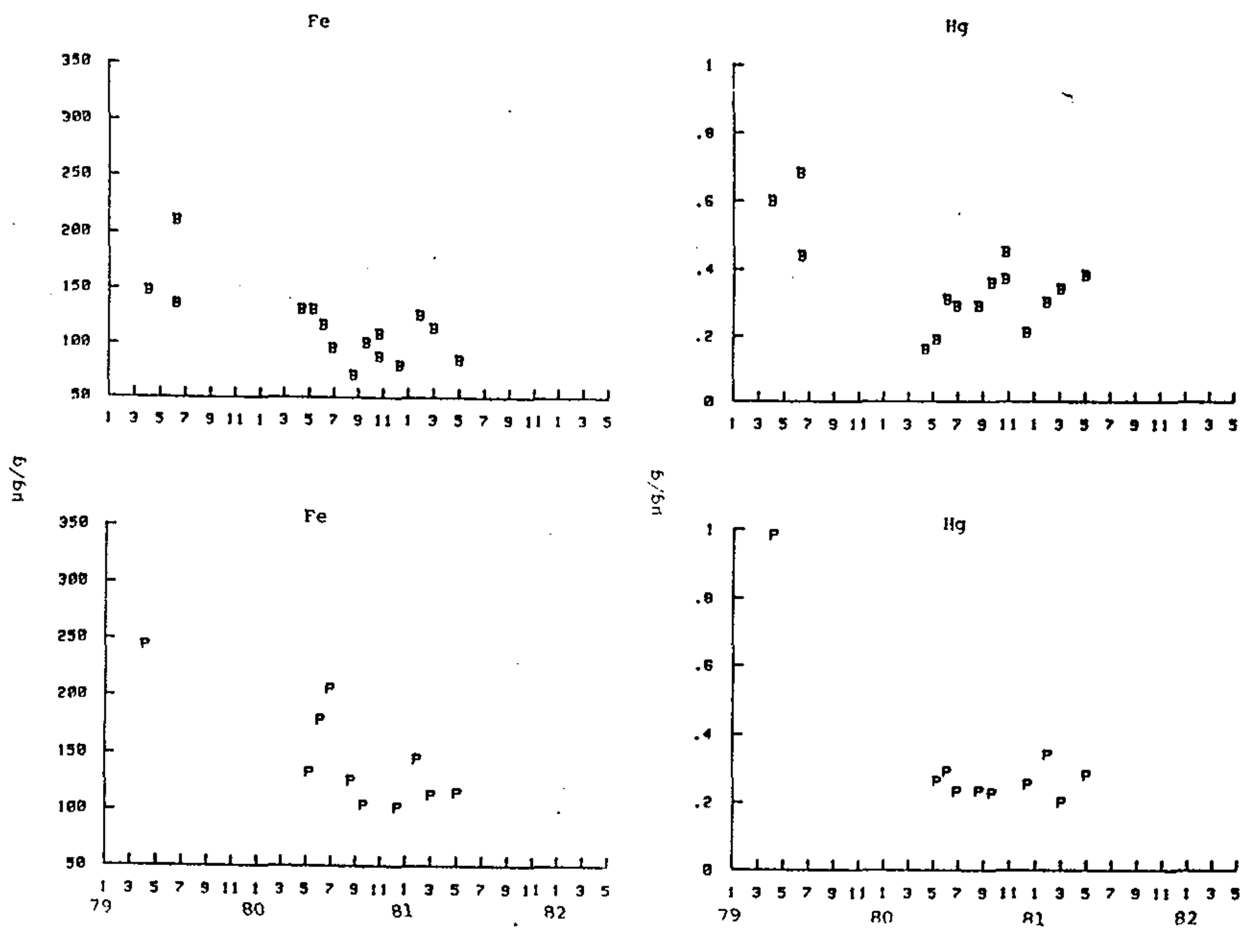


FIGURE VI-4-3. Temporal variations of iron and mercury concentrations in Modiolus modiolus deployed at Bulwark Shoals (B), the reference site and Portland (P) disposal Site.

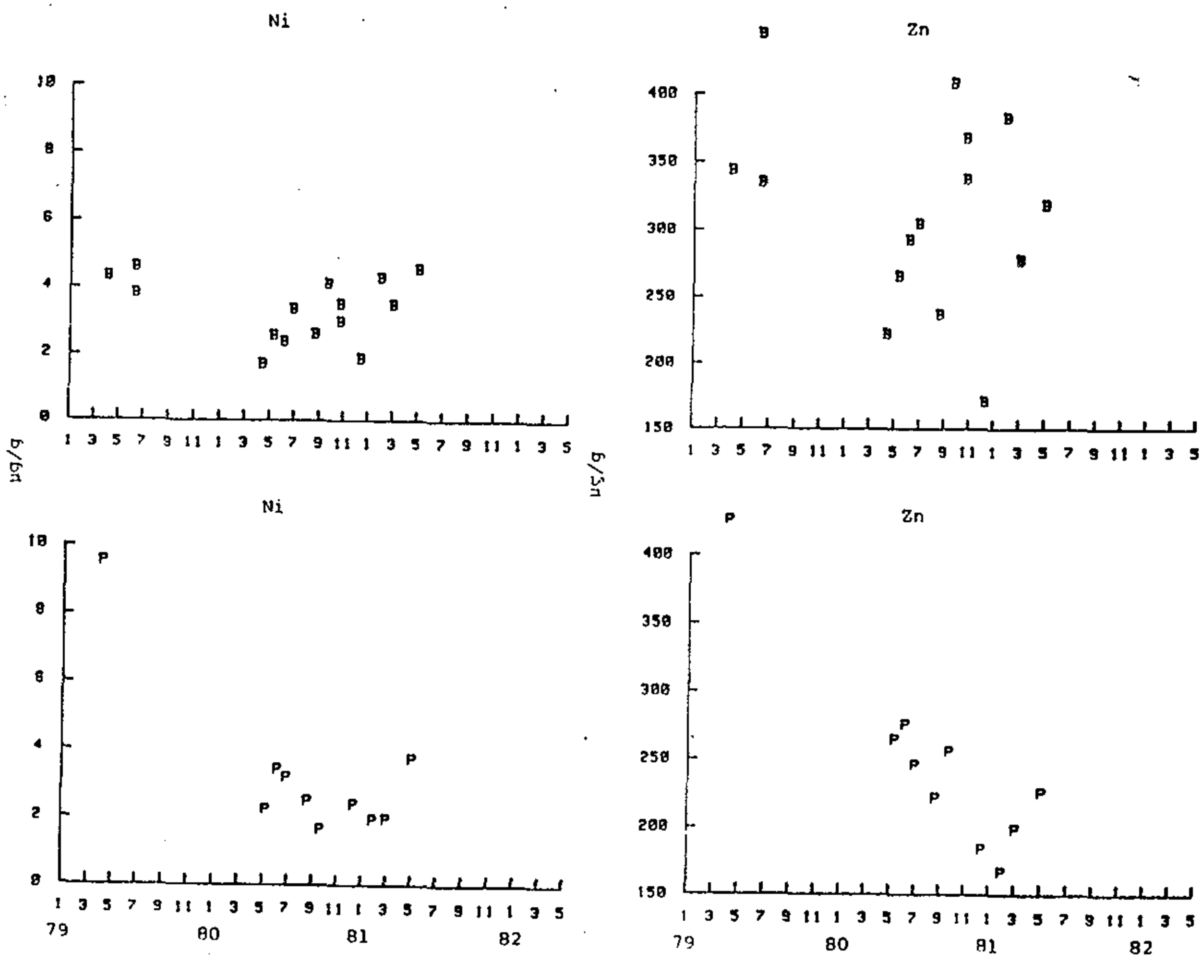


FIGURE VI-4-4. Temporal variations of nickel and zinc concentrations in Modiolus modiolus deployed at Bulwark Shoals (B), the reference site and Portland (P) Disposal Site.

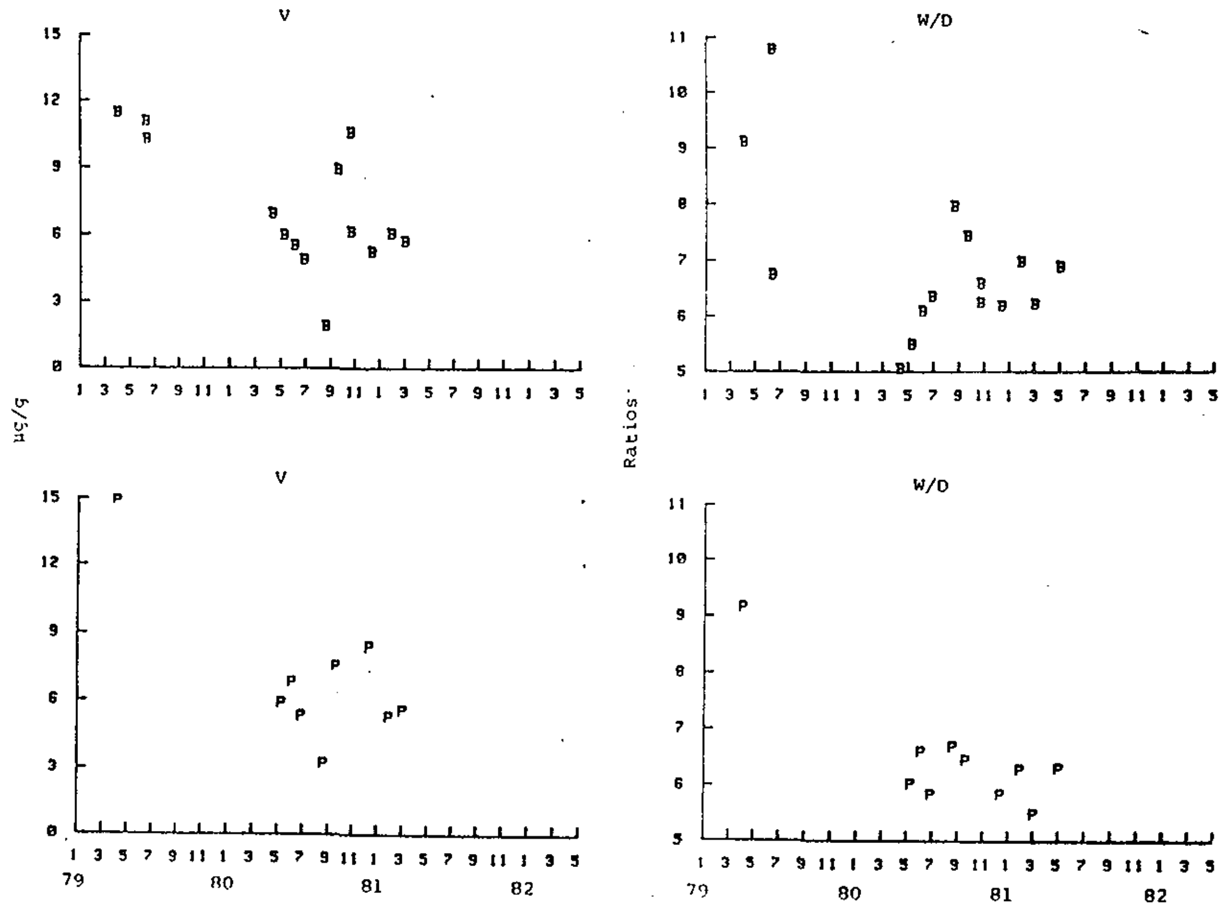


FIGURE VI-4-5. Temporal variations of vanadium concentrations and wet/dry weight ratios in *Modiolus modiolus* deployed at Bulwark Shoals (B), the reference site and Portland (P) Disposal Site.

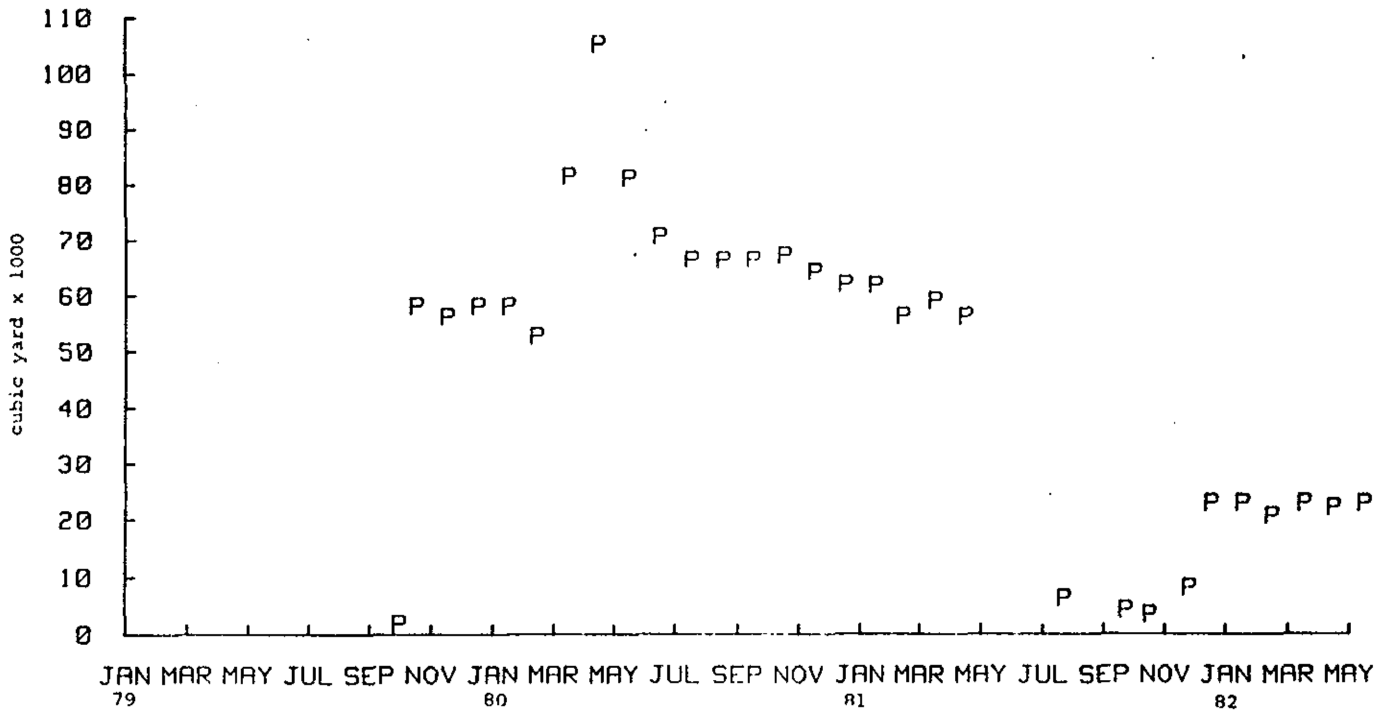


FIGURE VI-4-6. Schedule of dredged material disposal operations at Portland disposal area.

Table VI-4-2

Correlation coefficients of the intrinsic variables, wet to dry weight ratio and shell length with particulate trace metals at the two stations: Bulwark Shoals (B) and Portland (P), Maine.

Metal	Intrinsic Variables	Stations B	Stations P
Cd	W/D	.843	.795
	L	.701	-.046
Cr	W/D	.008	.989
	L	.369	.092
Co	W/D	.287	.476
	L	.338	.146
Cu	W/D	.301	-.176
	L	-.080	-.126
Fe	W/D	.605	.915
	L	.327	.073
Hg	W/D	.877	.954
	L	.602	.030
Ni	W/D	.770	.961
	L	.594	.117

SAIC

Table VI-4-3

Friedman's Test compares the concentration of a trace metal and tissue W/D ratio between Bulwark Shoals (B) and Portland (P) sites. Significance values close to or less than 0.10 suggest trace metal or W/D ratio difference between stations.

Variable	Site	Rank Sum	Friedman's Statistics	D.F.	Significance
Cd	B	14			
	P	16	.399	1	.53
Cr	B	13			
	P	20	4.45	1	.03
Co	B	17			
	P	16	.09	1	.76
Cu	B	19			
	P	14	2.27	1	.13
Fe	B	12			
	P	21	7.36	1	.007
Hg	B	17			
	P	16	.09	1	.76
Ni	B	17			
	P	16	.09	1	.76
Zn	B	17			
	P	16	.09	1	.76
V	B	16			
	P	17	.09	1	.76
W/D Ratio	B	20			
	P	16	1.33	1	.25

Friedman's test was employed to determine whether trace metal concentrations and wet/dry tissue weight ratios differ between mussels deployed at Bulwark Shoals and the Portland Disposal Site. The results are presented in Table VI-4-3. There were significant differences in trace metal concentrations ($p < .10$) between stations, specifically chromium and iron concentrations which were significantly higher at the Portland Disposal Site than at the Bulwark Shoals reference site. Copper concentrations, on the other hand, were noticeably higher at the Bulwark Shoals reference site than the Portland Disposal Site. However, none of these significant differences could be attributed to the dredged material disposal. In fact, differences observed in Cr and Fe at the Portland Disposal Site and the reference site were due to spring, fall and amino acid, or other factors which were not measured or identified. Similar considerations also apply to the difference found in Cu concentrations. Lacking simultaneous results from the two sites, the observed differences in Cr, Fe and Cu cannot be associated with the disposal operation but rather to factors which were not investigated.

4.1.4 Conclusions

At the Portland Disposal Site and the Bulwark Shoals reference site, no temporal variations in trace metal concentrations were seen in *Modiolus modiolus.* However, the W/D tissue weight ratio at Bulwark Shoals did show seasonal variations with a peak in August, but not at the Portland Disposal Site. This dissimilarity is probably due to the physical difference of the two sites, i.e. the depth and the temperature regime. As expected, spawning is closely related to W/D ratios and temperatures. There is no indication that the disposal operation has affected spawning. About 40% (median) of the variance in the trace metal concentrations at the two sites are explained by the intrinsic variables and 43% (median) by the extrinsic variables: year, spring, fall, dredged volume and amino acids. Dredged volume contributed only 2% to the total variance of this trace metal at the Portland Disposal Site. Significant differences in the concentration of Cr, Cu and Fe at the two sites are not associated with the disposal operation, but due to factors which were not measured or identified.

4.2 Benthic Community

In December 1980, replicate sediment samples were collected at the Portland reference site (1.3 NM south of the disposal site) with a 0.1 m^2 Smith MacIntyre grab in order to characterize the benthic community. Table VI-4-4 presents the species counts at Portland as well as Wellfleet and Isles of Shoals. At the end of the table, the number of species and the overall abundance are shown to be similar for Portland and Wellfleet, but significantly lower than the Isles of Shoals samples. The combination of extrinsic properties at each site could account for these differences, however, the limited amount of data prevent further conclusions.

Table VI-4-4
Species counts of benthic community.

Page 1

	Wellfleet baseline CTR 12-80 rep4	rep8	rep10	Isles of Shoal s 12-80 Reference rep8	rep9	rep10	Portland 12-80 Reference rep3	rep4	rep5
CNIDARIA	.	.	.	.	.	.	.	.	.
Edwardsia elegans	.	.	.	4	2	4	.	.	.
Haloclava producta	.	.	.	1	3	.	.	.	.
Heteractis aurata	.	.	.	.	.	.	.	.	.
Ceriantheopsis americanus	2	2	5	.	.	.	.	.	.
RHYNCHOCOELA	.	.	.	.	.	.	.	.	.
Cerebratulus spp.	.	1	.	1	4	2	.	1	2
Micrura sp.	10	9	8	3	3	.	.	.	.
Tubulanus pellucidus	.	.	.	.	.	.	.	.	.
Micrura sp.	.	.	.	.	.	.	.	.	.
Tetrastemmidae	1	.	.	.	.	.	.	.	.
Rhynchocoel tubed	.	.	.	.	.	.	.	.	.
PHORONIDA SPECIES	.	.	.	.	.	.	.	.	.
APLACOPHORA SPECIES	.	.	.	1	1	2	1	.	.
SCAPHOPODA	.	.	.	.	.	.	.	.	.
Siphonodentalium sp.	.	.	.	.	1	1	.	.	.
GASTROPODA	.	.	.	.	.	.	.	.	.
Neptunea decemcostata	.	.	.	.	3	10	.	.	.
Colus pubescens	.	.	.	1	.	.	.	.	.
Propebela sp. (Lora sp.)	.	.	.	.	.	.	.	.	.
gastropod C	.	.	.	.	.	.	.	1	.
BIVALVIA	.	.	.	.	.	.	.	.	.
Nucula annulata	.	1	.	3	3	.	.	.	3
Nucula delphinodonta	3	1	.	.	.	2	.	.	.
Nuculana tenuisculata	.	.	.	1	1	2	.	.	1
Yoldia sapotilla	.	.	.	1	6	2	.	2	.
Crenella decussata	.	.	.	.	.	.	.	.	.
Astarte undata	.	.	.	4	.	.	.	.	1
Cyclocardia borealis	4	2	.	.	.	.	.	.	.
Arctica islandica	.	.	.	.	.	.	.	.	1
Thyasira flexuosa	2	1	.	4	5	2	.	.	1

TABLE VI-4-4 cont.

Page 2

	Wellfleet baseline CTR 12-80			Isles of Shoales 12-80 Reference			Portland 12-80 Reference		
	rep4	rep8	rep10	rep8	rep9	rep10	rep3	rep4	rep5
Mya arenaria	1	1	.	.	11	3	.	3	2
Periploma papyratium	.	.	.	.	.	.	.	.	.
Pandora gouldiana	.	.	.	.	.	.	.	.	.
POLYCHAETA	.	.	.	.	.	.	.	.	.
Eteone trilineata	.	.	.	.	1	2	.	.	.
Phyllodoce arenae	.	.	.	1	.	.	.	.	.
Harmothoe extenuata	1	.	.	.	.	.	.	.	.
Hartmania moorei	1	.	.	1	1	2	.	1	.
Phloe minuta	.	1	.	1	1	.	.	.	.
Goniada maculata	.	.	.	.	2	2	.	.	.
Nepthys incisa	1	2	4	3	4	2	3	1	2
Exogone verugera	.	.	.	.	.	.	.	.	.
Syllidae sp.	.	.	.	.	.	.	.	.	.
Nereis grayi	.	.	.	.	.	1	.	.	.
Capitella capitata	2	3	1	.	.	.	.	.	.
Heteromastus filiformis	5	22	12	16	45	19	2	3	5
Mediomastus ambiseta	5	3	.	.	.	.	.	.	.
Scalibregma inflatum	.	.	.	14	2	7	.	7	4
Scalibregma sp.	.	.	.	.	.	.	.	.	.
Clymenella zonalis	.	.	.	.	.	.	.	.	.
Malandane sarsi	.	.	.	37	54	108	.	.	.
Praxillella sp.	.	.	.	.	2	.	.	.	.
Sternaspis scutata	.	.	.	37	77	26	1	.	.
Laonice cirrata	.	.	.	.	.	1	.	.	.
Polydora socialis	.	.	.	.	1	1	.	.	.
Prionospio steenstrupi	3	1	4	6	14	5	.	2	1
Spio setosa	27	32	27	161	285	96	.	1	4
Spiophanes bombyx	.	.	.	1	.	.	.	.	.
Trochochaeta multisetosa	.	.	.	.	.	.	.	.	.
Aricidea quadrilobata	.	.	.	.	3	2	.	.	.
Paraonis gracilis	1	.	.	10	10	7	.	3	7
Driloneries longa	.	.	.	.	.	.	1	.	1
Lumbrineris fragilis	.	.	1	.	.	5	.	.	.
Lumbrineris tenuis	.	.	.	.	.	.	.	.	1
Ninoe nigripes	32	40	36	7	8	4	.	10	11
Stauronereis sp.	.	.	.	.	.	.	.	.	.

TABLE VI-4-4 cont.

Page 3

	Wellfleet baseline CTR 12-80			Isles of Shoales 12-80 Reference			Portland 12-80 Reference		
	rep4	rep8	rep10	rep8	rep9	rep10	rep3	rep4	rep5
Scoloplos acutus	.	.	.	4	11	4	.	2	5
Chaetozone sp.	.	.	.	.	7	.	1	.	.
Cossura longocirrata	.	1	.	.	5	1	.	.	.
Tharyx A	.	.	.	.	3	1	.	1	.
Tharyx spp.	.	3	.	17	36	3	.	.	10
Myriochele heeri	1	.	.	120	214	101	14	27	16
Owenia fusiformis	.	.	.	.	.	.	.	.	.
Pectinaria gouldii	.	.	.	.	.	.	4	.	.
Anobothrus gracilis	.	1	.	71	166	145	1	33	73
Melinna cristata	.	.	.	3	4	3	.	.	.
Terebellides stroemi	2	4	.	3	3	35	1	.	.
Terebellidae	.	.	.	.	.	.	.	.	.
Brada villosa	.	.	.	.	1	.	.	.	.
Pherusa affinis	.	.	1	.	.	.	.	.	.
Diplocirrus sp.	.	.	.	.	.	.	.	.	.
Chone infundibuliformis	.	.	1	.	.	.	.	.	.
Euchone incolor	1	.	.	1	5	3	.	1	4
OLIGOCHAETA SPECIES	.	.	1	2	2	.	.	.	.
SIPUNCULA	.	.	.	.	.	.	.	.	.
Phascolion strombi	.	.	.	.	.	1	.	.	.
HARPACTICOID COPEPOD SPECIE	.	.	.	1	.	.	.	.	.
CUMACEA	.	.	.	.	.	.	.	.	.
Eudorella truncatula	.	.	.	.	.	.	.	.	.
Leucon nosicoides	.	.	.	.	.	.	.	.	.
Leucon americanus?	.	.	.	.	.	.	.	.	.
Diastylis sp	.	.	.	.	.	.	.	.	1
ISOPODA	.	.	.	.	.	.	.	.	.
Edotea montosa	.	3	.	.	.	.	.	.	.
Pleurogonium spinossmum	.	.	.	.	.	.	.	.	.
AMPHIPODA	.	.	.	.	.	.	.	.	.
Ampelisca agissizi	.	.	.	.	1	.	.	.	.

TABLE 4-4 cont.

Page 4

	Wellfleet baseline			Isles of Shoales			Portland		
	CTR 12-80			12-80 Reference			12-80 Reference		
	rep4	rep8	rep10	rep8	rep9	rep10	rep3	rep4	rep5
Ampelisca vadorum	.	.	.	3	3	10	.	1	.
Ampelisca verrilli	.	.	.	.	1	.	.	.	.
Haploops tubicola	.	.	.	.	.	.	.	.	.
Unciola irrorata	.	.	.	.	.	1	.	.	.
Anonyx liljeborgi	.	.	.	.	1	.	.	.	.
Anonyx sarsi	.	.	.	.	.	.	.	.	2
Hippomedon serratus	.	.	1	.	.	.	.	.	.
Orchomenella pingus	3	.	.	.	.	2	.	.	.
Monoculodes sp.	.	1	1	1	3	.	.	.	.
Monoculodes sp Notch	.	.	.	.	.	.	.	.	.
Leptocheirus pinguis	5	.	.	.	.	1	.	.	.
Photis reinhardi	.	.	.	.	.	.	.	.	.
Harpina propinqua	.	.	.	1	.	.	.	.	.
Phoxocephalus holbolli	.	.	.	2	.	.	.	.	.
Stenopleustes inermis	.	.	.	.	.	.	.	.	.
Metopella angusta	.	.	.	.	.	.	.	.	.
Dyopedos monocantha	.	.	.	.	.	.	.	.	.
Caprella sp.	.	.	.	.	.	.	.	.	.
DECAPODA	.	.	.	.	.	.	.	.	.
Crangon septemspinosa	.	1	1	.	.	.	.	.	.
Pagarus longicarpus	.	.	.	1	.	.	.	.	.
ECHINODERMATA	.	.	.	.	.	.	.	.	.
Molpadia oolitica	.	.	1	.	.	.	.	.	.
Ctenodiscus crispatus	.	.	.	.	.	2	2	1	.
Ophiura sarsi	.	.	.	.	.	3	1	1	1
HEMICHORDATA	.	.	.	.	.	.	.	.	.
Number of species	22	23	16	38	45	43	12	20	24
Abundance	113	136	105	549	1019	636	32	102	159

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Samples were again collected in September 1982 and May 1984. The May 1984 samples were rough sieved on the collecting vessel and then cleaned of clay and preservative with a 0.75 mm sieve before sorting. This procedure appears to retain more small individuals than the thorough field sieving to 1 mm used in 1980 and 1982.

Species counts for all dates are given in the Table VI-4-5. The 1980 data has been slightly modified to make it consistent with 1984 data.

Most of the species found were present at other Gulf of Maine sites studied by DAMOS. The densities and species number per sample are low relative to other sites, however. Crustacea were absent from the 1984 collection and only a single mollusk was recovered. The most abundant taxa in 1984 were small organisms which probably were not retained in the earlier samples (Paraornis, Oligochaeta). Bottom animals appear to be spatially heterogeneous at this site. Stations 1 and 5 (May 1984) had high densities of several deposit feeding polychaetes which were all much less abundant at Stations 3 and 4.

The low density of benthos at the reference site could be the result of its location along "the edge," a very heavily used trawling ground. The probable differences between the disposal and reference sites before dumping began, and the low densities and patchiness of benthos at the reference site suggest that sampling should be discontinued there. If macrobenthos sampling is continued in the Portland area, effort should be focused on the condition of the disposal area. Sampling and analysis should be coordinated with photography and diver observations.

5.0 SUMMARY

The results of the monitoring effort at Portland indicate that the selection of the disposal site in a deep valley was an excellent choice, since the steep slopes on the margins contribute to containment of the material. Furthermore, although this study indicates that disposal in deep, open ocean sites will not be as precise and concentrated as in shallower, more protected areas, a mound of dredged material was formed,. Consequently, if covering or capping operations are proposed, a relatively larger volume of clean material will be required to be certain of complete coverage.

Although the coverage of a larger area (relative to the Long Island Sound Disposal Site) was observed in the Portland area, it is important to note that the volume of material disposed at the Portland site was nearly twice that dumped at any one of the Central Long Island Sound disposal points and, therefore, more spreading would be expected based on this factor alone.

Table VII-2-2

Dominant Species - Rockland, 1984

Polychaeta	Mollusca
Anobothrus gracilis	Alvania pelagica
Cossura longicirrata	Nucula annulata
Heteromastus filiformis	Nucula delphinodonta
Lumbrineries fragilis	Periploma papyratium
Myriochele heeri	Sphenia sincira
Nephtys incisa	Thyasira flexarosa
Oligochaeta spp.	Yoldia sapotilla
Sternapsis fossor	

Table VI-4-5 (cont.)

	May 1984					Dec 1980			Sept 1982
	1	2	3	4	5	3	4	5	5
Aricidea quadrilobata	5	12	.	.	3	.	.	.	.
Chaetozone setosa	6	3	.	.	9	1	.	.	.
Clymenella sp.	1	.	.	.	.	.	.	.	.
Cossura longocirrata	6	3	.	3	.	.	.	.	.
Driloneries longa	.	.	1	.	.	1	.	1	.
Eteone trilimeata	2	.	.	1	1	.	.	.	.
Euchone incolor	6	.	.	.	1	.	1	4	.
Harmothoe	1	.	.	.	.	.	.	.	.
Hartmania moorei	4	1	.	.	.	.	1	.	.
Heteromastus filiformus	2	.	1	1	1	2	3	4	.
Lumbrineries fragilis	.	.	.	1	.	.	.	.	.
Lumbrineries tenuis	1	.	.	.	.	.	.	1	.
Maldane sarsi	1	.	.	.	.	.	.	.	.
Mediomastus ambiseta	.	.	.	.	1	.	.	.	.
Myriochele heeri	5	6	3	5	18	10	22	12	.
Nephtys ciliata	.	.	.	.	.	.	.	.	1
Nephtys incisa	2	3	2	5	6	3	1	3	3
Ninoe nigripes	14	9	1	1	44	.	10	11	4
Paraornis gracilis	152	22	23	22	59	1	3	7	.
Pectinaria gouldii	.	.	.	.	.	4	.	.	.

Table VI-4-5 (cont.)

	May 1984					Dec 1980			Sept 1982
	1	2	3	4	5	3	4	5	5
Prionospio sp.	21	2	1	.	1	.	2	1	.
Scalibregma inflatum	.	.	.	.	.	.	7	4	.
Scoloplos acutus	1	1	.	.	3	.	2	5	.
Spio pettiboneae	1	.	.	.	2	.	1	4	.
Sternaspis scutata	.	2	.	.	.	1	.	.	.
Terebellides stroemi	.	.	.	.	.	1	.	.	.
Tharyx spp.	2	2	.	.	13	.	1	10	.
OLIGOCHAETA SPP.	16	11	1	5	34	.	.	.	.
CRUSTACEA									
Ampelisca sp.	.	.	.	.	.	.	1	.	.
Anonyx sarsi	.	.	.	.	.	.	.	2	.
Diastylis sculpta	.	.	.	.	.	.	.	1	.
SIPUNCULID SP.									
ECHINODERMATA									
Ctenodiscus crispatus	.	.	.	.	.	2	1	0	2
Ophiura sarsi	3	.	1	.	1	1	1	1	1
Species	28	15	9	11	18	14	21	22	9

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The chemical composition of the sediment in the disposal area was similar to other disposal sites, although the sediment consisted of a mixture of relatively contaminated maintenance material and relatively uncontaminated new material consisting of glacial muds.

The results of the mussel watch program indicate that the disposal operations do not significantly affect the trace metal accumulation in the tissue of the horse mussel Modiolus modiolus.

The topography of the disposal site and the natural patchiness of the benthic community there may make the assessment of potential effects of disposal difficult. More effort on documenting the recolonization of the mound may be warranted.

VII. ROCKLAND DISPOSAL AREA

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VII. ROCKLAND DISPOSAL AREA

1.0 INTRODUCTION

The Rockland Disposal Site (ROCK) is located in the center of West Penobscot Bay (Fig. VII-1-1), 3.5 NM east of the Rockland Breakwater. This site was first used during October 1973 - February 1974 for disposal of approximately 69,000 m^3 of material from Rockland Harbor. The disposal site is designated on NOS Chart No. 13307 as a square 1000 yds (915 m) on a side centered at 44°07.01'N, 69°00.3'W. Water depth within the disposal area ranges from 180 to 244 feet.

Potential dredging projects from the Searsport area have created a requirement for a detailed survey of the disposal site to determine existing conditions of the bottom and, to the extent possible, the distribution of previously deposited dredged material. The last survey of this site under the DAMOS program took place in May 1978. Consequently, a more recent survey was required, which was accomplished during the period 24 September - 2 October 1984.

2.0 SURVEY RESULTS

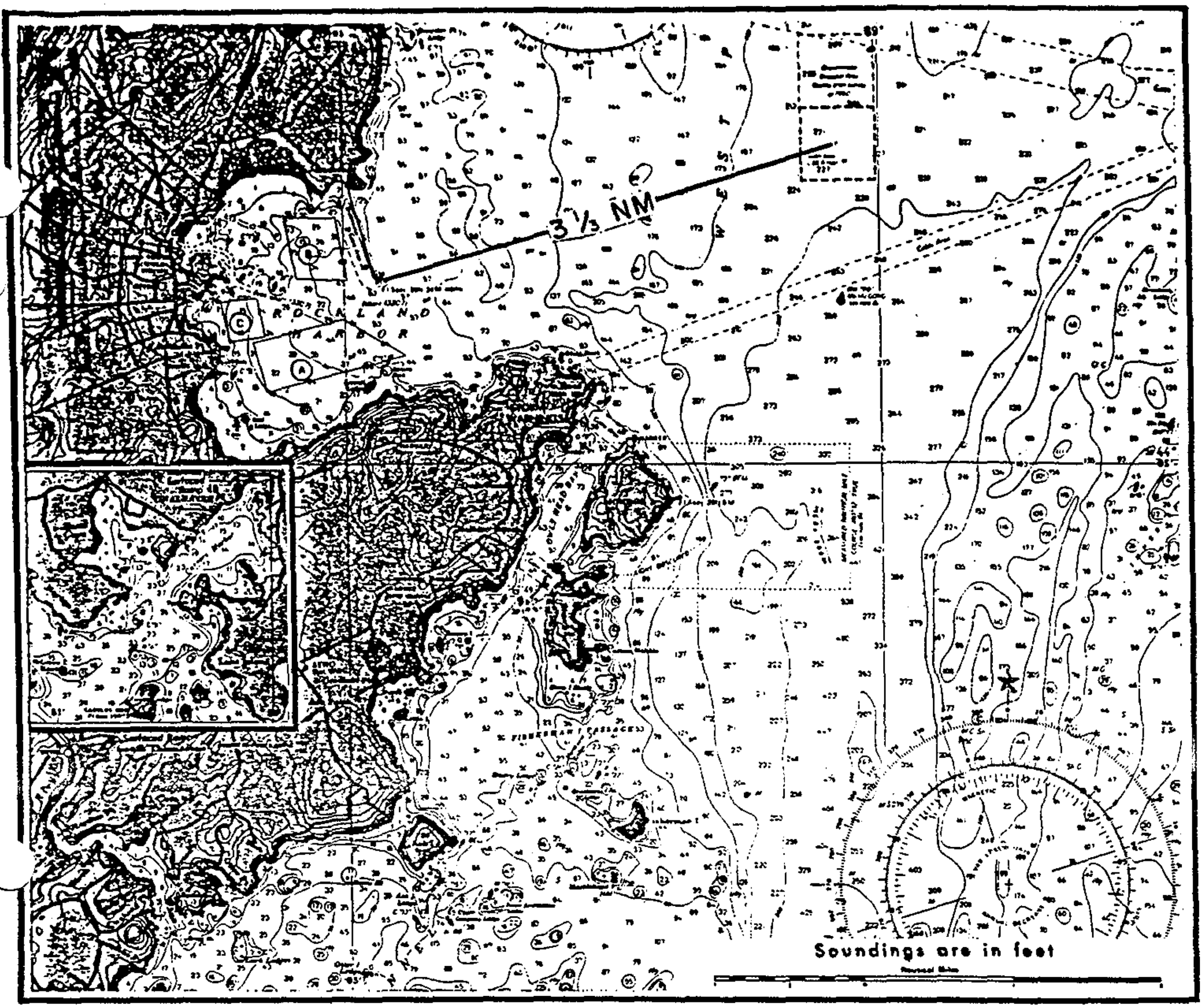
Several separate operations were conducted during the Rockland Disposal Site survey. These consisted of a precision bathymetric survey of the entire disposal site, a reconnaissance survey of benthic organisms, a combined grain size and heavy metals survey of benthic sediments, a REMOTS sediment/water interface survey, and a side scan survey. All survey operations were performed using positioning control stations at Deadman Point and Owls Head Light. The coordinates of these stations are:

DEAD, 1982
44°10'17.815"N, 69°03'17.790"W

OWLS HEAD LIGHT
44°05'31.55"N, 69°02'40.62"W

The station at Deadman Point was established by NOAA in 1982 and was therefore not used during surveys prior to that date. The position of the Rockland Disposal Buoy was found to be 44°07.162N, 069°00.393W.

The following sections provide a discussion of each of the survey operations, including charts and figures where appropriate.



ROCKLAND, MAINE

Figure VII-1-1. Rockland Disposal Area

NED: 24 ROCKLAND
DEPTH RANGE: 221 TO 266 FEET MLW
CENTER COORDINATES: 44°-07.1'N, 69°-0.3'W

N.O.S. CHART: 13306
DATE: 31 JANUARY 1981

DESCRIPTION: THIS SITE IS 1/2 NAUTICAL MILE SQUARE WITH CENTER AT 44°-07.1'N, 69°-0.3'W AND SIDES RUNNING TRUE NORTH-SOUTH, EAST-WEST. FROM THE CENTER POINT, ROCKLAND BREAKWATER LIGHT BEARS TRUE 253° AT 6,680 YARDS, OWLS HEAD LIGHT BEARS TRUE 225° AT 4,800 YARDS, AND BREWSTER POINT LEDGE BUOY "1" BEARS TRUE 284° AT 5,871 YARDS.

2.1 Bathymetry

A bathymetric survey was performed of an area 1200 m by 1200 m centered on the disposal site. The survey, comprised of 50 lanes, 1200 m long, spaced 25 meters apart, was accomplished using a 24 kHz fathometer system operating in conjunction with the SAIC Navigation and Data Acquisition System which is based on the HP 9920 microcomputer system.

Figure VII-2-1 shows the bathymetric survey area in relation to the disposal site, the present location of the disposal buoy and the location of the Reference Site established for the sediment sampling program.

A contour chart of depths on the disposal site is shown in Figure VII-2-2. The site is characterized by a depression which is well-defined in the northern portion of the site, but widens and shoals toward the south completely losing its identity over the southern half of the site. A small mound is noted at the center of the depression along the north boundary of the site, and may be associated with previous disposal operations. Depths range from about 55 meters (180 ft) to 74.5 meters (244 ft) within the surveyed area.

2.2 Benthic Community Survey

A sampling grid (Fig VII-2-3) was established consisting of 17 stations and a reference station located 2000 meters to the east of the center of the disposal site. Samples were collected at each station with a 0.1 m^2 Smith MacIntyre grab sampler and washed on 0.5 mm and 1.0 mm sieves on the research vessel. In the laboratory, the preserved samples were resieved on a 0.75 mm screen before examination, and then sorted under binocular microscopes, identified, and counted. All organisms and sieve residues were preserved and archived.

Counts of macrobenthic species are given in Table VII-2-1. Stations are identified by a simplified code (400 N/400 W becomes 400NW). Several Tharyx species have been combined in anticipation of more complete descriptions than are now available (J. Black, pers. comm.). A total of 79 species are reported in Table VII-2-1. Of these, 30 occurred at average densities of >1/sample (standard deviation given). Table VII-2-2 lists fifteen species found at densities > 4/samples.

Cossura and Oligochaeta (deposit feeders) and Alvania (ectoparasite?) are small species retained on a .75 sieve, but which usually pass through a 1.0 mm sieve. Nucula annulata, a deposit feeder, was the most abundant species present. Taxanomically related N. delphinodonta and Yoldia sapotilla were also among the dominants. The remaining bivalves (Periploma, Sphenia, and Thyasira) are suspension feeders specialized for life on soft sediment. The most abundant polychaete, Anobothrus gracilis is a relatively large tube dweller. Heteromastus, Nephtys, and Sternapsis are deposit feeders while Lumbrineries is a predator. Crustacea are not important at this location,

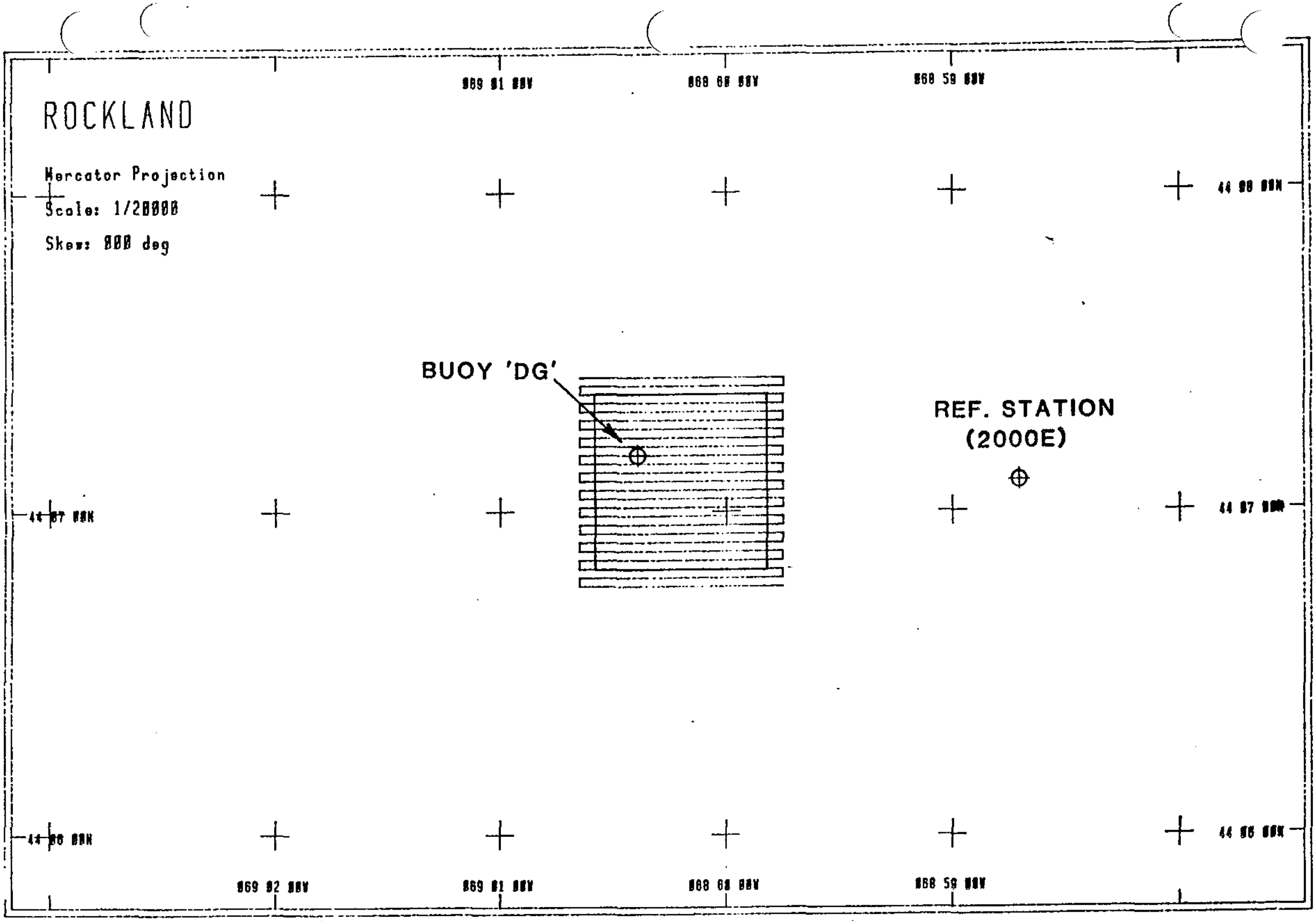


Figure VII-2-1. Bathymetric survey grid, Rockland.

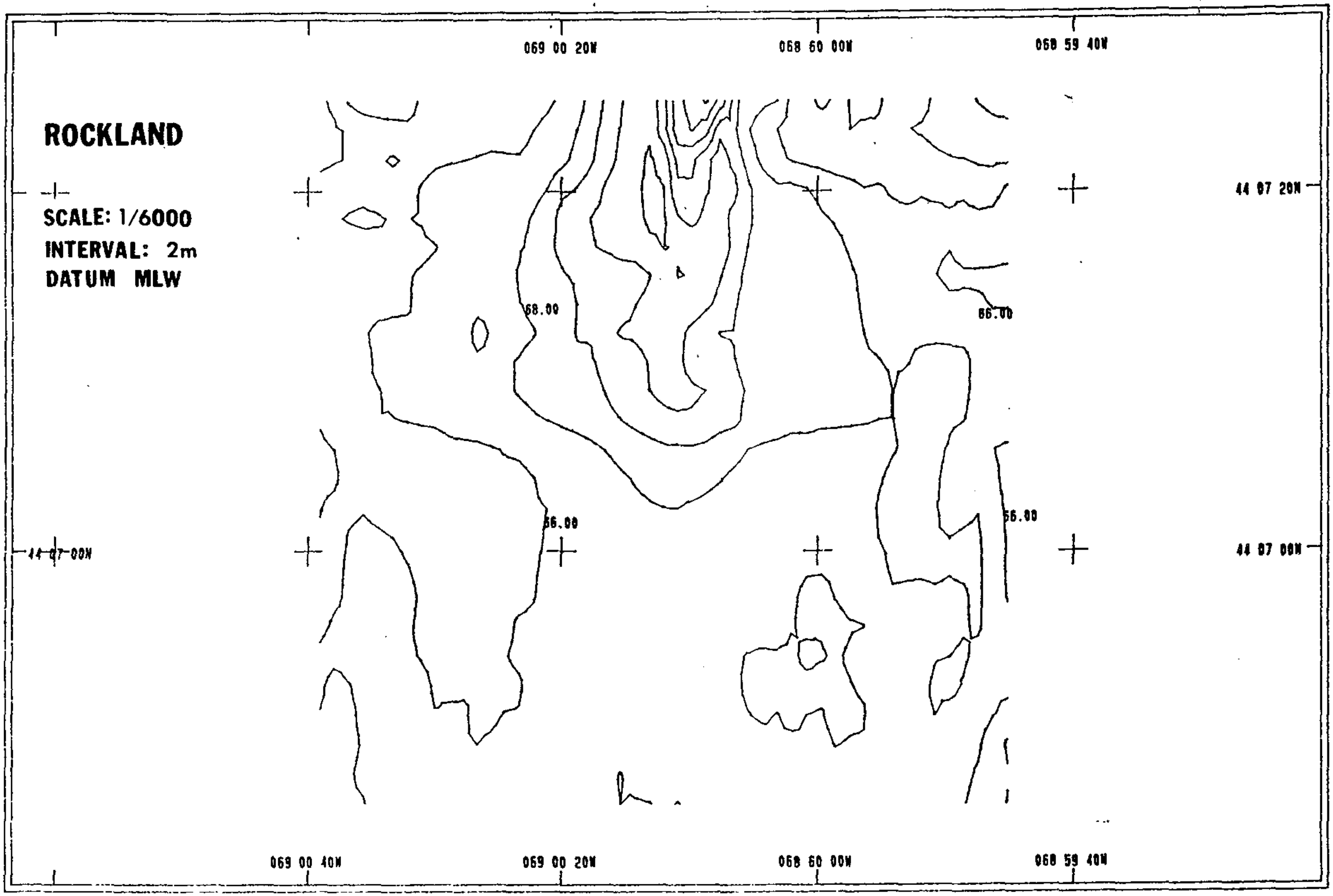


Figure VII-2-2. Bathymetric contour chart, Rockland.

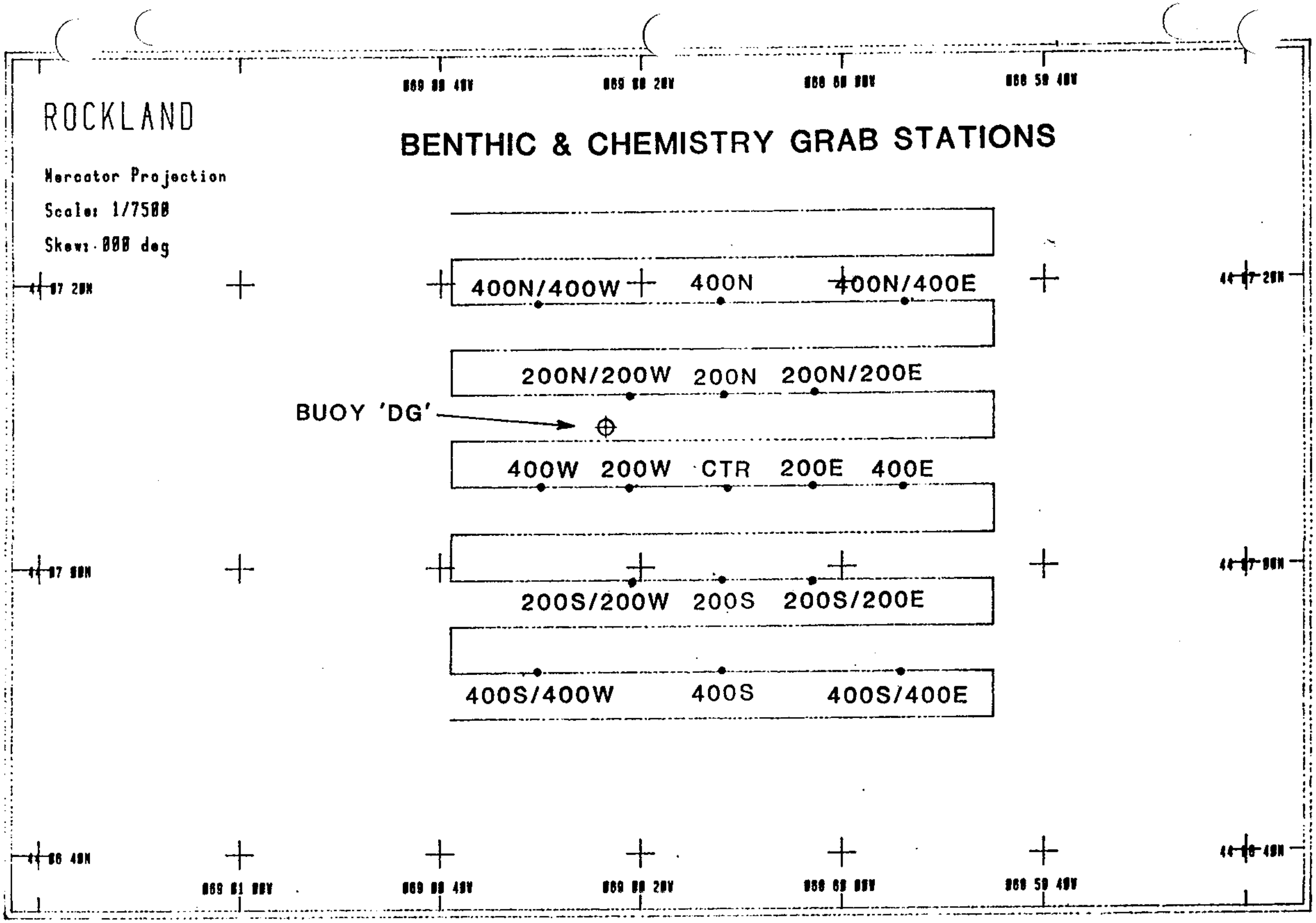


Figure VII-2-3. Sediment sampling station locations.

Table VII-2-1

Benthic Species Counts for Rockland Disposal Area, September 1984

	200									400								2000 E				
	N	NE	E	SE	S	SW	W	NW	CTR	N	NE	E	SE	S	SW	W	NW	A	B	C	MEAN	S.D.
CNIDARIA																						
Edwardsia elegans	1	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	0.2	
Halcampa duodecimcerrata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	0.05	
RHYNCHOCOELA	.	.	1	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	0.2	
Cerebratulus sp.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	1	.	1	0.2	
Micura RS	.	1	1	.	1	.	1	.	.	3	3	3	1	.	1	1	2	2	1	2	1.2	1.0
Micura RB	.	1	.	1	.	.	.	4	.	.	.	1	.	1	.	.	.	.	.	.	0.4	
Tetrastemmidae	.	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.35	
Rhynchocoela SY	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	0.1	
MOLLUSCA																						
Aplacophora sp.	2	1	1	1	2	.	.	3	1	.	1	3	.	1	.	.	3	1	.	.	1	1.1
GASTROPODA																						
Acteocina canaliculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	0.05	
Alvania pelagica	2	24	24	37	22	30	3	5	41	.	14	25	48	12	19	17	19	18	25	20	20.3	12.7
Cylichnella alba	.	1	1	3	1	3	1	.	2	.	.	.	.	.	.	.	.	.	.	.	0.6	
Propebela gouldii	.	1	1	.	.	.	.	2	.	.	1	2	.	2	3	.	.	.	1	.	0.65	
BIVALVIA																						
Arctica islandica	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	0.1	
Astarte undata	.	.	1	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	2	1	0.25	
Cerastroderma pinnatulum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	0.05	
Crenella decussata	.	.	.	.	.	.	.	1	.	.	.	.	11	.	.	.	.	.	.	.	0.6	
Cardita borealis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	0.05	
Lyonsia arenosa	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	0.05	
Macoma sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	2	.	.	.	0.2	
Modiolus modiolus spat	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	0.05	
Nucula annulata	771	768	753	695	817	616	548	434	1214	620	689	764	1185	762	436	632	443	527	1411	653	737	260
Nucula delphinodonta	35	52	28	45	26	50	28	18	57	14	24	47	47	47	17	43	62	19	102	16	38.8	21
Nucula tenuis	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	0.05	
Nuculana tenuisulcata	.	.	1	1	1	.	.	1	.	.	1	1	.	3	1	2	.	.	2	3	0.85	
Periploma papyratium	4	8	12	3	10	15	11	10	17	7	9	5	3	5	14	6	20	.	1	2	8.1	5.5
Sphenia sincira	2	2	33	7	7	14	.	5	5	3	3	2	4	4	10	3	5	5	7	4	6.3	7.0
Thracia conradii	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	0.1	
Thyasira flexuosa	26	27	31	31	39	49	40	47	68	23	37	43	27	43	16	28	45	11	20	18	35.5	13.5
Yoldia myalis	.	3	.	1	.	.	1	.	2	.	2	4	1	.	3	2	2	.	1	1	1.6	1.2
Yoldia sapotilla	23	18	11	16	11	18	10	38	20	19	9	25	21	15	7	21	20	13	11	12	17	7.1

Table VII-2-1 (cont.)

	200									400								2000 E				
	N	NE	E	SE	S	SW	W	NW	CTR	N	NE	E	SE	S	SW	W	NW	A	B	C	MEAN	S.D.
POLYCHAETA																						
Amphaereta arctica	2	2	2	1	1	.	2	1	2	1	.	3	.	.	.	.	1	1	.	3	1.1	1.0
Anobothrus gracilis	49	62	48	63	50	58	79	109	84	52	110	154	89	61	19	59	84	52	66	46	69.7	29.5
Aricidea quadrilobata	.	3	.	.	1	.	.	2	10	2	3	4	3	1	2	2	1	2	3	3	2.1	2.2
Chaetozone setosa	1	12	6	7	8	1	3	3	9	2	2	3	.	1	2	7	1	.	1	3	3.6	3.4
Clymenella zonalis	.	.	.	.	.	1	.	1	1	.	.	1	.	.	.	2	.	1	.	.	0.35	
Cossura longicirrata	.	7	5	6	6	2	3	.	38	2	4	.	1	4	7	2	.	4	1	2	4.7	8.9
Diplocirrus hirsutus	.	.	.	.	1	1	1	2	.	.	.	.	2	1	.	1	.	1	1	.	0.55	
Drilonereis longa	.	.	1	1	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	1	0.25	
Ephesiella minuta	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	0.05	
Eteone sp.	.	6	2	1	5	4	1	1	.	8	.	2	4	3	4	1	4	3	4	2	2.8	2.1
Eteone trilineata	.	1	.	.	2	1	1	.	.	.	.	.	.	.	.	1	.	.	.	.	0.3	
Euchone incolor	1	7	1	3	2	6	4	1	18	2	1	.	.	2	.	3	.	3	5	6	3.3	4.0
Hartmani moorei	1	2	.	.	.	2	1	1	2	.	2	.	.	.	1	.	1	.	1	.	0.7	
Harmothoe sp.	.	.	.	.	.	.	.	1	.	.	.	1	.	2	.	.	1	.	.	.	0.25	
Heteromastus filiformis	3	7	4	1	8	3	7	4	4	5	5	5	2	5	10	7	10	1	3	1	4.8	2.7
Lumbrineries fragilis	1	2	2	7	3	5	8	9	6	6	4	6	5	4	2	3	4	4	3	1	4.3	2.2
Mediomastus ambiseta	.	.	.	.	3	1	5	3	10	1	2	3	.	3	1	1	1	1	.	.	1.8	2.4
Myriochele heeri	2	6	13	9	6	7	8	6	4	4	2	13	4	4	6	9	11	5	15	5	7.0	3.7
Nephtys incisa	17	46	22	28	37	18	16	13	77	37	21	14	42	35	22	20	13	36	36	30	29.0	15.3
Ninoe nigripes	2	1	1	4	1	5	7	3	3	2	.	2	2	1	4	.	8	6	6	3	3.6	2.4
Ophioglycera gigantea	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	0.1	
Paranaites speciosa	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	0.05	
Paraonis gracilis	1	3	.	1	3	.	1	1	7	1	1	1	2	2	2	.	2	1	1	2	1.6	1.5
Pherusa affinis	2	3	1	.	1	.	.	.	.	3	1	1	2	.	.	1	2	.	3	.	1.0	1.1
Phloe minuta	2	2	1	1	4	2	2	3	2	.	2	2	.	1	.	.	.	.	.	2	1.3	1.2
Polycirrus sp.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	.	.	.	.	1	.	0.2	
Prionospio sp.	.	.	.	1	.	1	.	.	2	.	.	.	.	.	.	.	.	.	1	.	0.25	
Spio pettibonese	.	1	1	1	2	1	1	2	.	.	3	4	.	.	1	3	.	.	.	.	1.0	1.2
Spiochaetopterus oculatus	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	0.15	
Sternapsis scutata	46	51	30	24	22	43	43	39	43	24	41	36	23	24	19	19	29	8	28	24	30.8	11.3
Syllis cornuta	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	0.05	
Terebellides stroemi	2	4	3	2	5	2	1	3	5	3	1	5	3	2	.	6	6	1	.	.	2.7	2.0
Tharyx spp.	.	2	.	.	2	.	.	.	2	1	2	2	1	3	1	.	.	.	1	.	0.85	
Trichobranchus glacialis	2	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	0.35	
Trochochaeta multisetosa	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	1	.	1	.	0.2	
OLIGOCHAETA SP.	4	61	19	17	41	23	21	1	319	16	15	15	23	29	19	14	40	17	37	21	34.3	68.6
CRUSTACEA																						
CUMACEA																						
Diastylis polita	1	1	.	.	.	.	.	.	1	.	.	.	.	2	.	1	.	.	.	.	0.3	
Diastylis sculpta	.	1	.	2	1	2	.	1	.	.	1	.	.	.	1	2	.	1	3	.	0.75	
Eudorella hispida	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	0.05	
Leptostylis longimana	.	1	.	.	1	1	1	.	.	.	.	.	.	.	1	.	.	1	.	.	0.3	

Table VII-2-1 (cont.)

	200 N	200 NE	200 E	200 SE	200 S	200 SW	200 W	200 NW	CTR	400 N	400 NE	400 E	400 SE	400 S	400 SW	400 W	400 NW	2000 E A	2000 E B	2000 E C	MEAN	S.D.
AMPHIPODA																						
Caprella sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	0.1	
Corophium tuberculatum	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	
Dulichia monocantha	.	.	.	.	.	1	.	.	1	1	.	1	.	.	1	1	2	.	3	.	0.55	
Stenopleustes inermis	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.05	
DECAPODA																						
Crangon septimspinosa	.	.	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.15	
SIPLUNCULOIDEA																						
Phascoloscon	.	.	.	2	.	.	.	2	.	.	.	1	.	.	.	.	.	.	.	.	0.25	
PHORONIDEA																						
Phoronis mulleri	.	2	.	3	.	2	1	.	.	.	.	.	1	.	1	1	1	1	.	.	0.65	
ECHINODERMATA																						
Asterias vulgarus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	0.05	
Ctenodiscus crispatus	.	1	.	1	.	.	1	.	.	.	2	1	1	2	1	.	3	.	.	.	0.65	
Molpadia oolitica	.	1	1	.	.	.	.	.	.	1	.	.	1	.	1	.	.	1	.	.	0.3	
Ophiura sarsi	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	0.05	
SPECIES PER SAMPLE	27	42	37	41	38	35	36	41	38	29	36	38	32	39	37	36	36	34	37	29		

Table VII-2-2

Dominant Species - Rockland, 1984

Polychaeta	Mollusca
Anobothrus gracilis	Alvania pelagica
Cossura longicirrata	Nucula annulata
Heteromastus filiformis	Nucula delphinodonta
Lumbrineries fragilis	Periploma papyratium
Myriochele heeri	Sphenia sincira
Nephtys incisa	Thyasira flexarosa
Oligochaeta spp.	Yoldia sapotilla
Sternapsis fossor	

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probably because of the softness of the bottom. The amphipods present are probably all associated with objects projecting from the bottom. The cumaceans probably enter this area from adjacent sandy bottoms during nocturnal swimming. Large deposit-feeding sea stars (Ctenodiscus) and sea cucumbers (Molpadia) average less than one/sample, but probably have important effects on the structure and function of the benthic community at this site (Young and Rhoods, 1971).

Visual examination of the counts do not reveal any obvious difference in makeup of the benthic community between deeper (400 N, 200 N, CTR) and shallower stations (400 NW, W, SW, SE, E), between study area and reference area, or between stations with evidence of dredged material (200 N, NW) and "normal" stations.

The predominance of deposit feeders at the disposal site is a function of both the softness of the sediment which excludes many suspension feeders and the availability of organic matter as food. The community at the Rockland site has some of the same dominants as were found at Cape Arundel off the western Maine coast, but shows evidence of a softer bottom and more deposit feeding. Rockland shares a number of species with the depositional area of Cape Cod Bay (JRB, 1984) including the large holotharian Molpadia. Two northern species Anobothrus and Sphenia are absent from Cape Cod Bay, however.

Four of the stations sampled by Kyte (1974) are on soft bottom within a few miles of the Rockland site. Despite possible differences in sieve size and in species identification, it can be seen that the same community existed as was sampled in the present study.

During the summer of 1982, 49 stations were sampled in Penobscot Bay under the NOAA Northeast Monitoring Program (NMP). Data on trace metals and PCBs at these stations has been published (Larsen et al., 1983, Larsen et al., 1984). Data on macrobenthos will be available in 1985. Molpadia and Nucula were found at many deep stations (P.F. Larsen, pers. comm.). The complete data should indicate the extent to which the disposal area is characteristic of the rest of the deep portions of the Bay and suggest the effect that changes in grain size may have on faunal composition.

The studies of Kyte and Larsen and the present study all suggest the presence of a spatially and temporally homogeneous community in the deep part of Penobscot Bay. This should aid in the detection of effects caused by renewed use of the disposal site.

2.3 Sediment Chemistry Survey

The sampling grid established for the Benthic Sediment Survey (Fig. VII-2-3) was also used to obtain sediment chemistry samples. Three grabs were taken at each station; the first sample was subsampled for grain-size and heavy metals, the remaining two grabs were subsampled for heavy metals only. Each sample was individually placed in plastic containers and marked according to sample type and position as noted in Figure VII-2-3. These samples and a sample log have been delivered to the New England Division for analysis.

2.4 REMOTS Survey

A REMOTS survey (Fig. VII-2-4) was conducted over a grid similar to the sediment sampling surveys, except a slightly more dense sampling interval was used in the N/S, E/W transects. Samples were taken to 800 meters north and south of survey center and 600 meters east and west of center. The 800 meter sample stations were taken in order to assess the potential effects of the relatively strong north-south tidal currents on the distribution of dredged material during the disposal operation. Three to five replicate samples (photographs) were taken at each station depending on frame count and penetration depth of the REMOTS camera.

Grain size distributions throughout the survey area are uniform, with all replicates showing major modes in the silt-clay (> 4 phi) class and ranges extending into the very fine sand (4-3 phi) or fine sand (3-2 phi) classes. These larger grain size fractions are frequently found at the water-sediment interface, or in feeding voids, and appear to be fecal pellets produced by head-down deposit-feeders (Fig. VII-2-5). Thick layers (up to 2.37 cm) of relatively large grained fecal pellets (4-2 phi) are present at eight stations (400E, 200E, 400N/400W, 1000N, 200N, 100N, 800S).

Figure VII-2-6 shows the frequency distribution of boundary roughness values for all replicates in the survey area. The major mode for boundary roughness is in the 0.4 cm and 0.8 cm classes, indicating that the seafloor in this area is, for the most part, physically and biologically undisturbed. However, there are several instances of anomalously high boundary roughness values, notably in one replicate from each of the following stations: 600N, 200N/200E, 600S, and 800S (Fig. VII-2-7). Unusually high boundary roughness values in one replicate from station 600S and from station 800S indicate that the southern end of the north-south transect may be more subject to physical disturbance than the rest of the site.

Figure VII-2-8 shows the frequency distribution of RPD depths for all replicates. Figure VII-2-4 shows the mapped distribution of mean RPD depths for each station. The major mode for RPD depth is in the 7.1-9.0 cm class interval, with values ranging between 1.6 cm and 19.65 cm. RPD's are generally deeper at this site than those measured in surveys of disposal sites and the surrounding seafloor in Long Island Sound. It is clear that the relatively small amounts of dredged materials disposed at this site on two occasions in the last ten years have had, for the most part, little or no long-term impact on RPD depths as measured in this survey. However, six replicates from stations

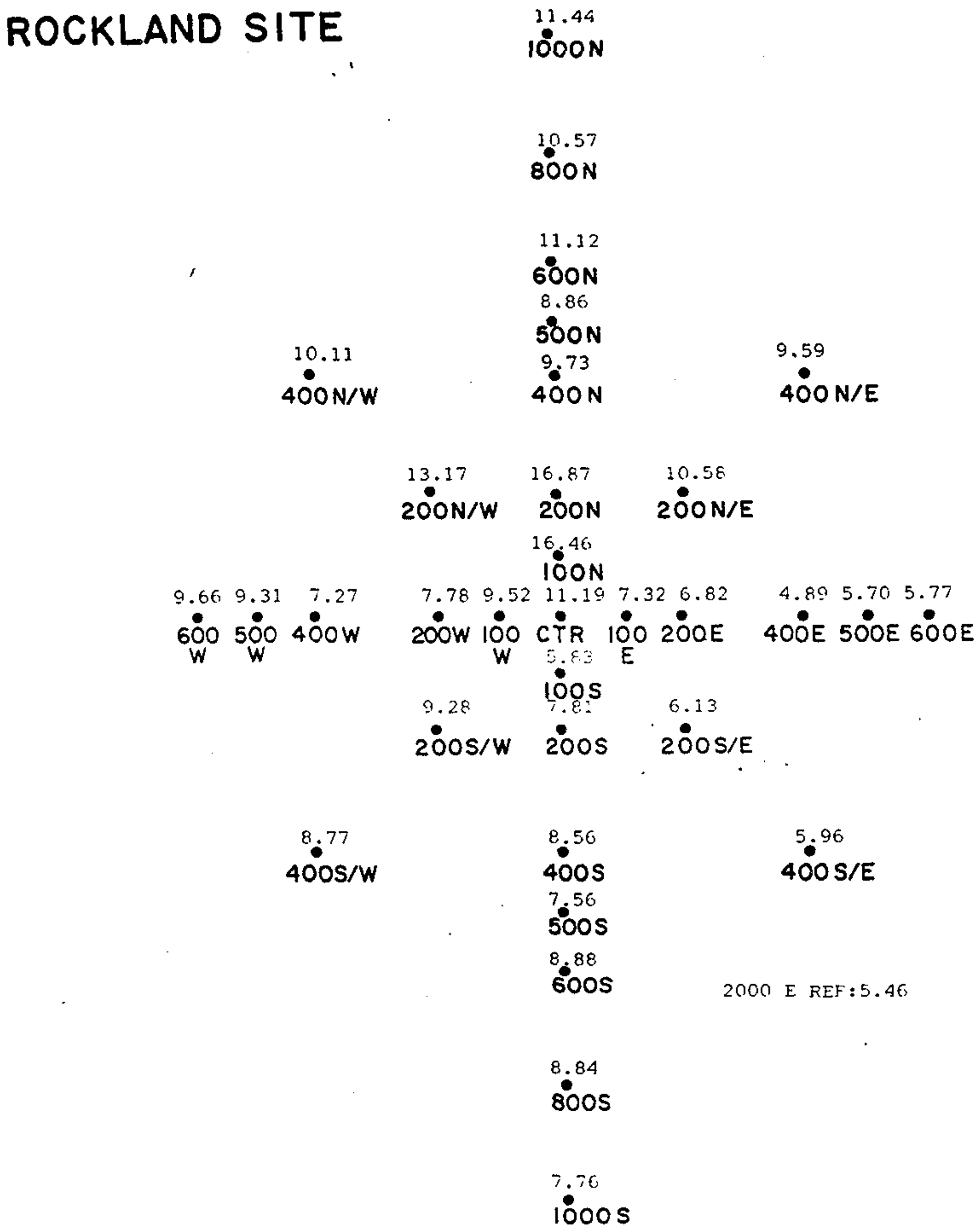

Figure VII-2-4. Mean depth of the apparent redox potential discontinuity for all stations in the Rockland site (cm).

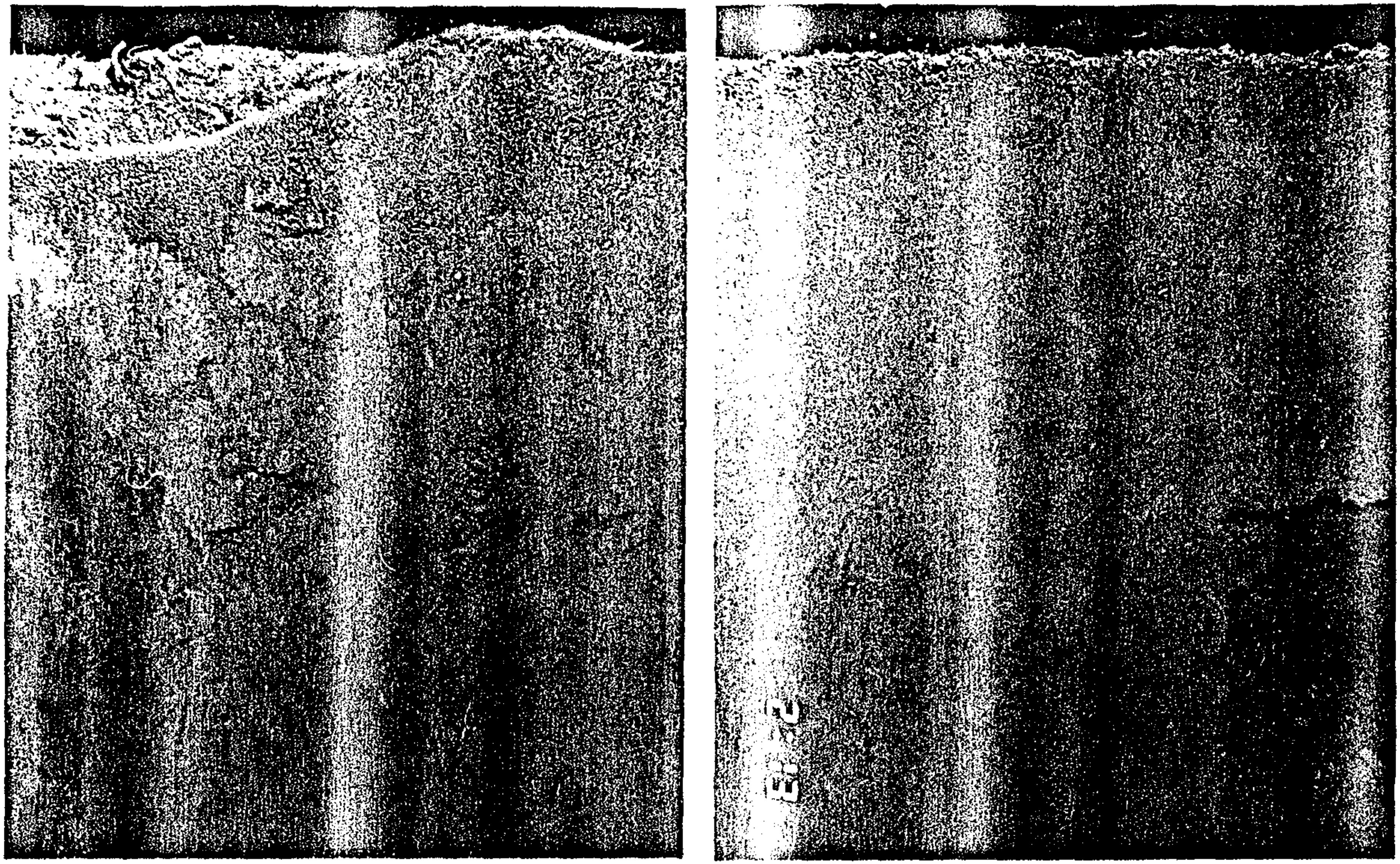

Figure VII-2-5. REMOTS images A) from station 400N and 400W showing a fecal layer at the sediment-water interface, and B) from station 600W showing fecal pellets concentrated in a feeding void at depth.

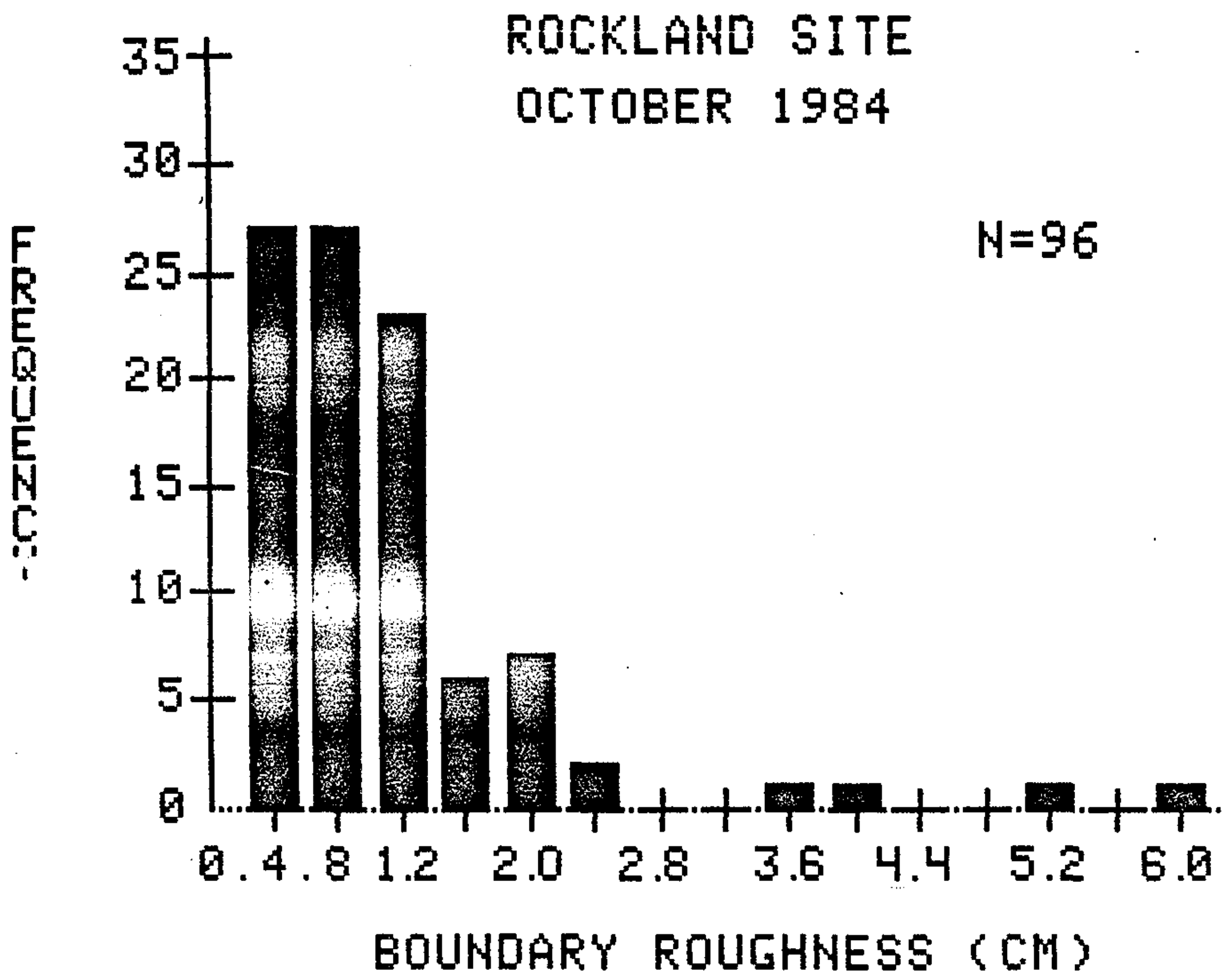

Figure VII-2-6. Frequency distribution of small-scale boundary roughness values for all replicates.

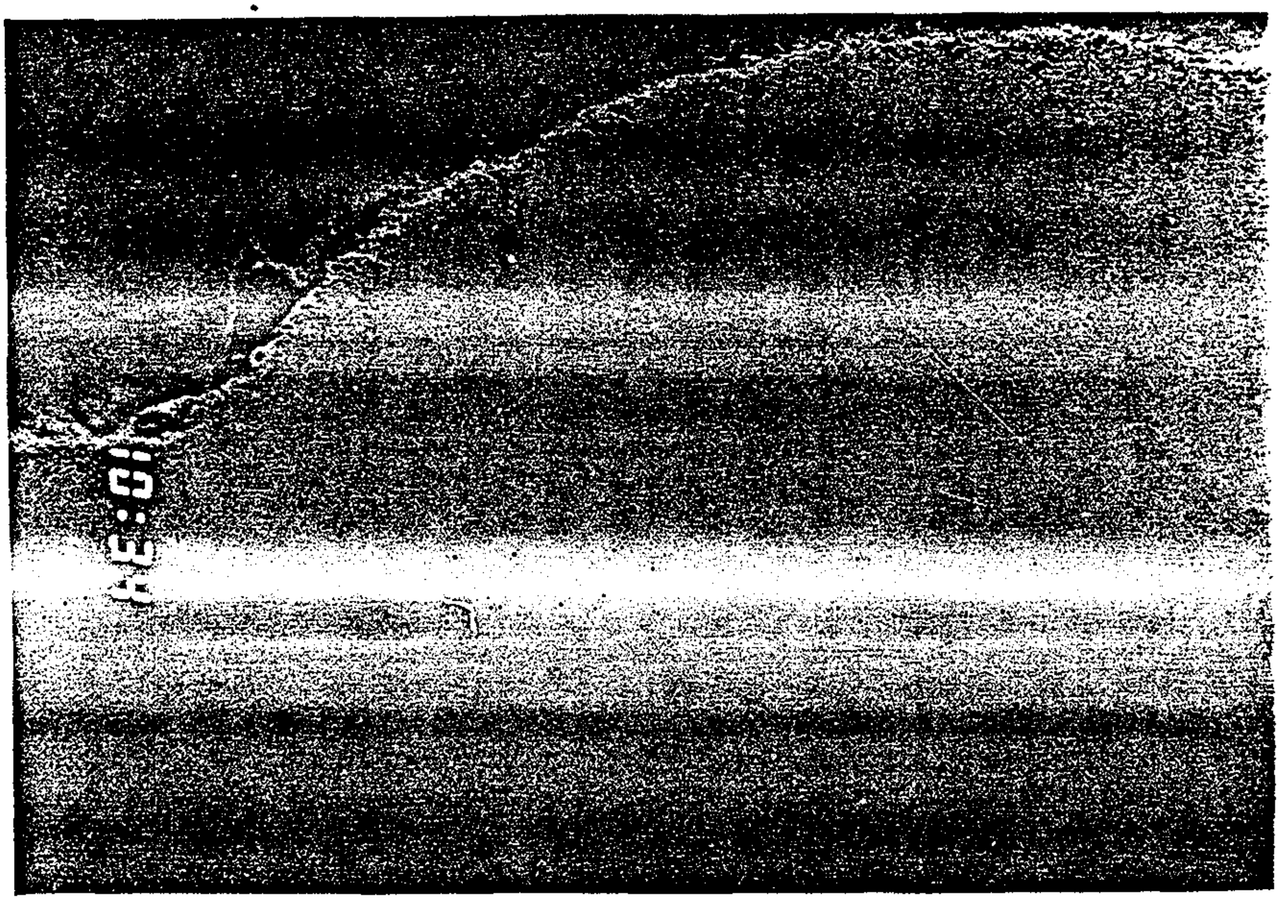

Figure VII-2-7a. REMOTS images showing unusually rough small-scale topography at Station 600S.

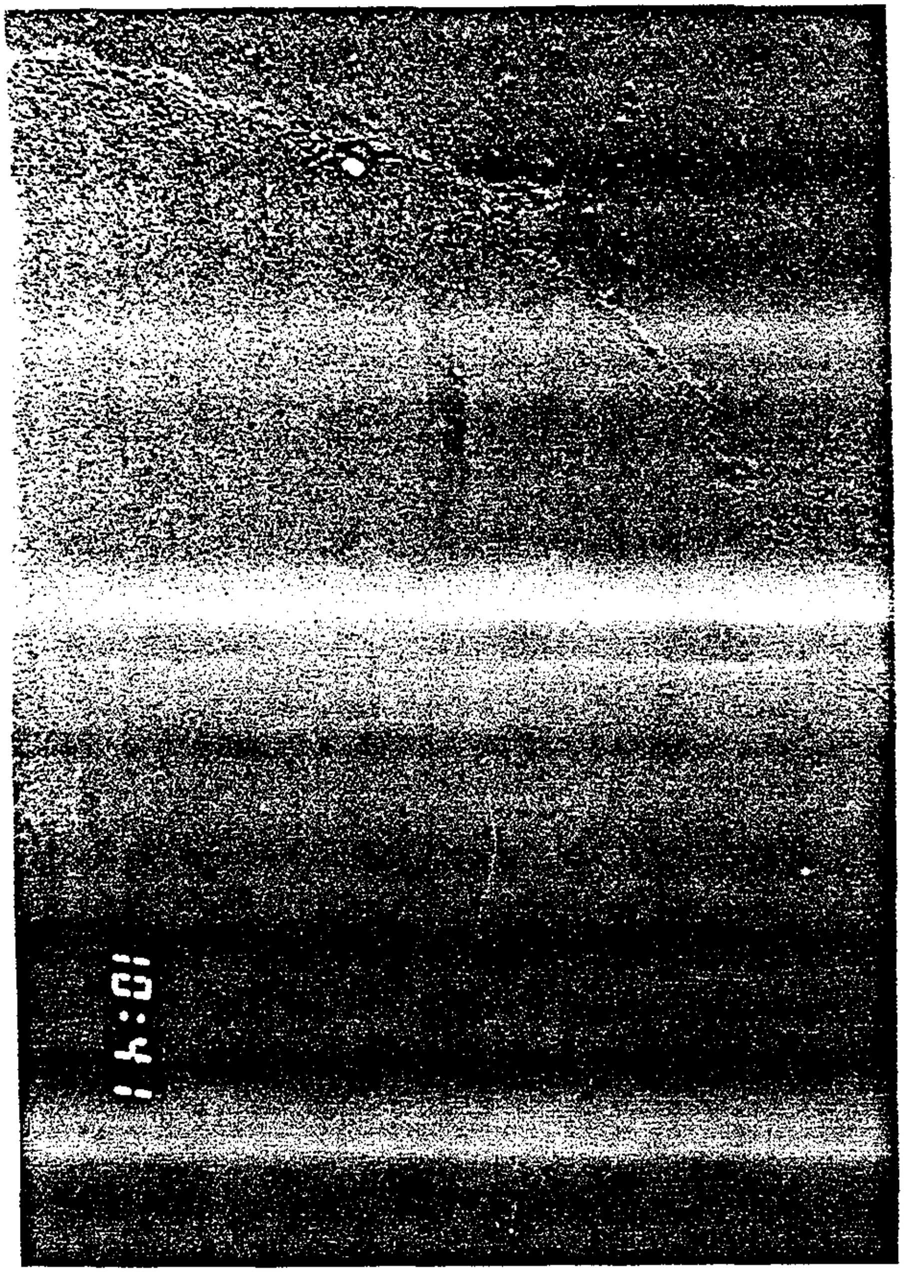

Figure VII-2-7b. REMOTS image showing unusually rough small-scale topography at station 800S.

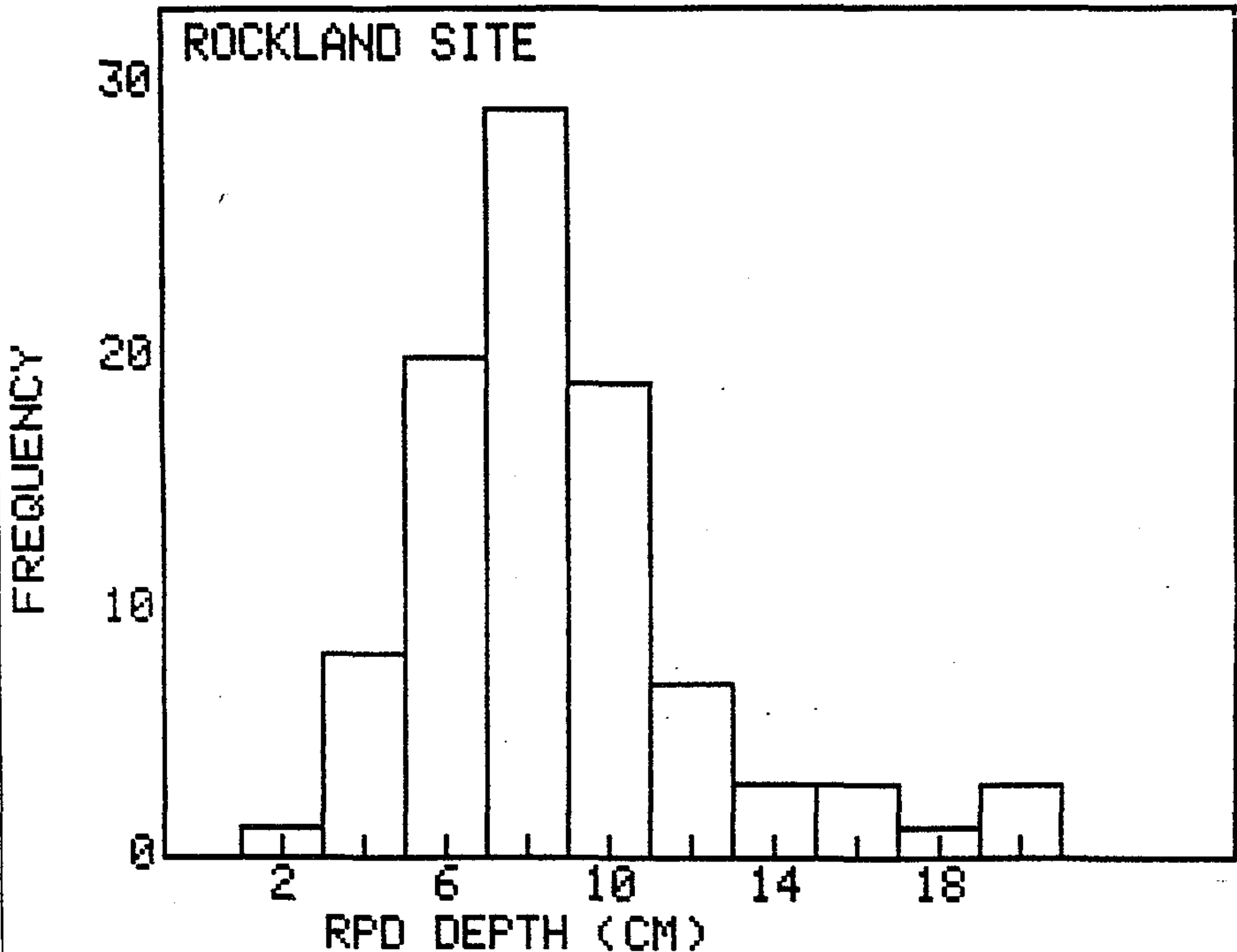

Figure VII-2-8. Frequency distribution of RPD depths for all replicates (n=95) in the Rockland site.

in the south and east sections of the sampling grid show RPD's in which the area of oxidized sediment is "streaked" with reduced sediment extending upwards, in some cases to the sediment-water interface (Fig. VII-2-9). The replicates where streaks of reduced sediment are visible within the oxidized layer are from stations 100E, 200E, 400E, 2000E REF, 100S, and 200S/200E. The origin of this phenomenon is due mainly to the bioturbational activities of "conveyor belt" deposit-feeders. These organisms appear to have conveyed reduced sediment from below the RPD into the oxidized layer (Fig. VII-2-9a). In replicates from stations 2000E REF and 200S/200E, it appears that the streaking may be related to the introduction of reduced mud clasts at the sediment surface (Fig. VII-2-9b). Reduced sediment may be "streaked" downwards by the penetration of the REMOTS optical prism into the bottom

Although RPD values are high throughout the survey area, they are depressed relative to the rest of the site at stations where a "streaked" oxidized layer is visible in one replicate. The mean RPD for the six stations mentioned above where streaks of reduced sediment are visible within the oxidized layer is 6.1 cm, while for the rest of the site it is 9.6 cm. This difference is significant ($p = .001$, Mann-Whitney U-test). Mud clasts are visible in at least one replicate in each of the six stations, suggesting that relatively shallow RPD's may be related to a higher degree of physical disturbance at these stations. Alternately, the shallower RPD's measured at these stations may result from the introduction of reduced sediment from depth into the oxidized layer.

Figure VII-2-10 shows the mapped distribution of successional stages in the survey area. Because Stage III successional seres are widespread, only those replicates that are not in Stage III are represented on this map. For all replicates not represented in this figure, the successional stage is III-I. Stage III successional seres are present in at least one replicate at all stations in the site. Maldanid polychaetes, indicators of a Stage III successional sere, are visible in many replicates. Stage III successional seres are not visible in only four replicates from the north-south transect of the sampling grid (15 stations), while along the shorter east-west transect (11 stations), nine replicates do not show evidence of Stage III successional seres. The low-order successional stages found in these isolated replicates are probably due to localized physical or biological disturbance, and do not appear to be related to dredged material disposal. The presence of shallow-dwelling bivalves in one replicate from station 400N suggests that this replicate is transitional between Stage I and Stage II.

Figure VII-2-11 shows the frequency distribution of benthic indices for all replicates in which benthic index could be calculated. Figure VII-2-12 shows the mapped distribution of benthic index values. The benthic index reflects depth of RPD and successional stage. The bimodal frequency distribution in Figure VII-2-11 can be attributed to the frequency of occurrence of Stage I and Stage III successional seres; the benthic index

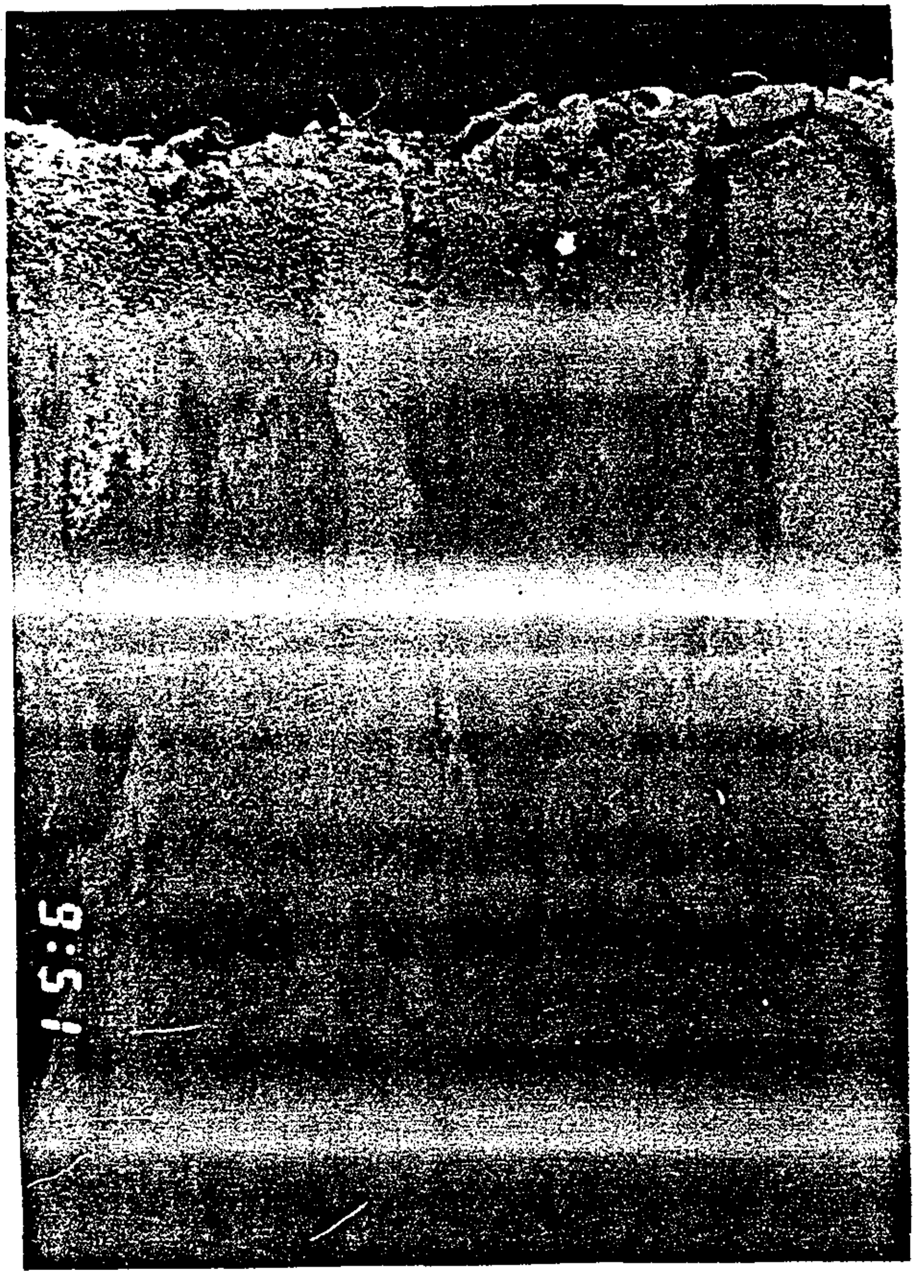

Figure VII-2-9a. Station 100S in which streaks of reduced sediment appear to be the result of the bioturbational activities of head-down deposit-feeders.

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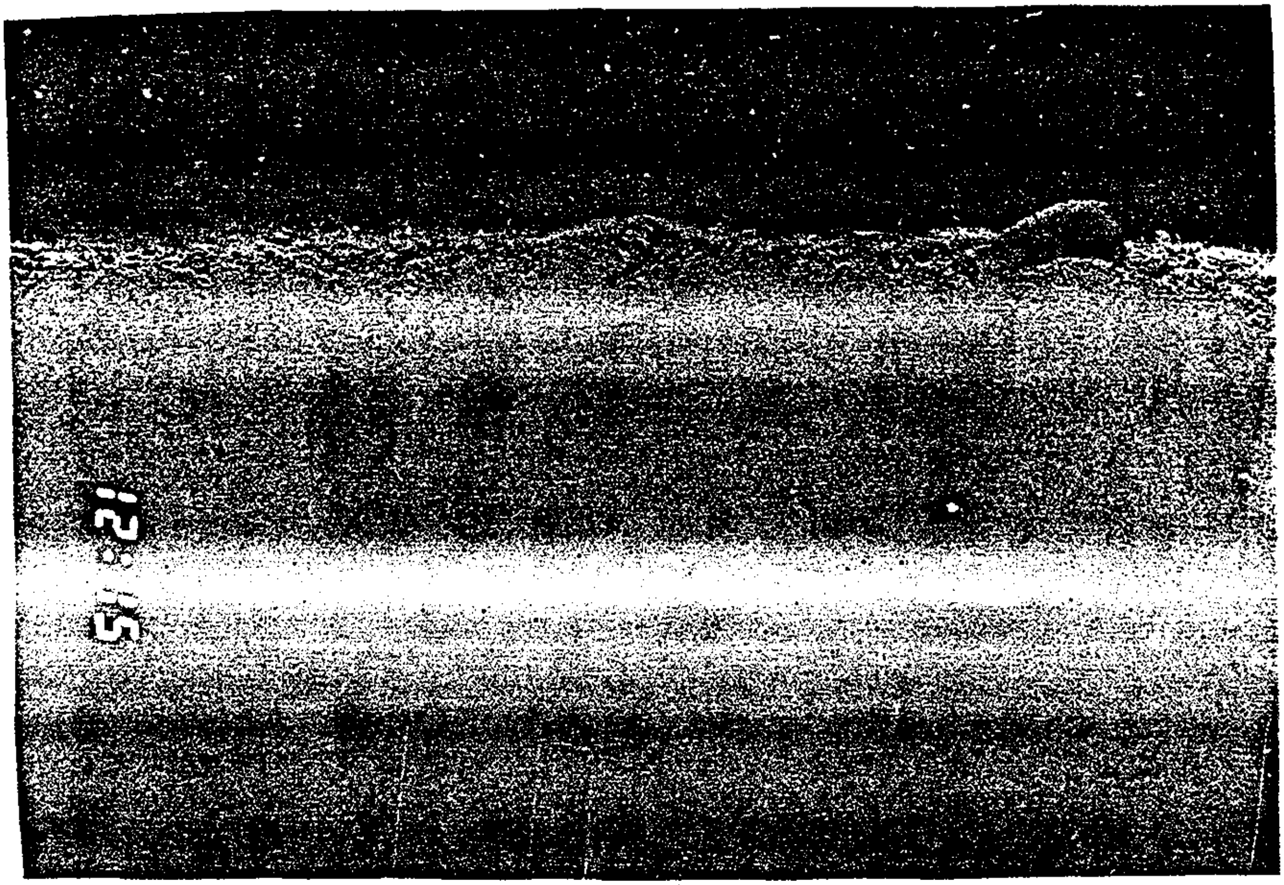

Figure VII-2-9b. Station 2000E REF in which streak at right appears to originate from a reduced mud-clast at the sediment surface.

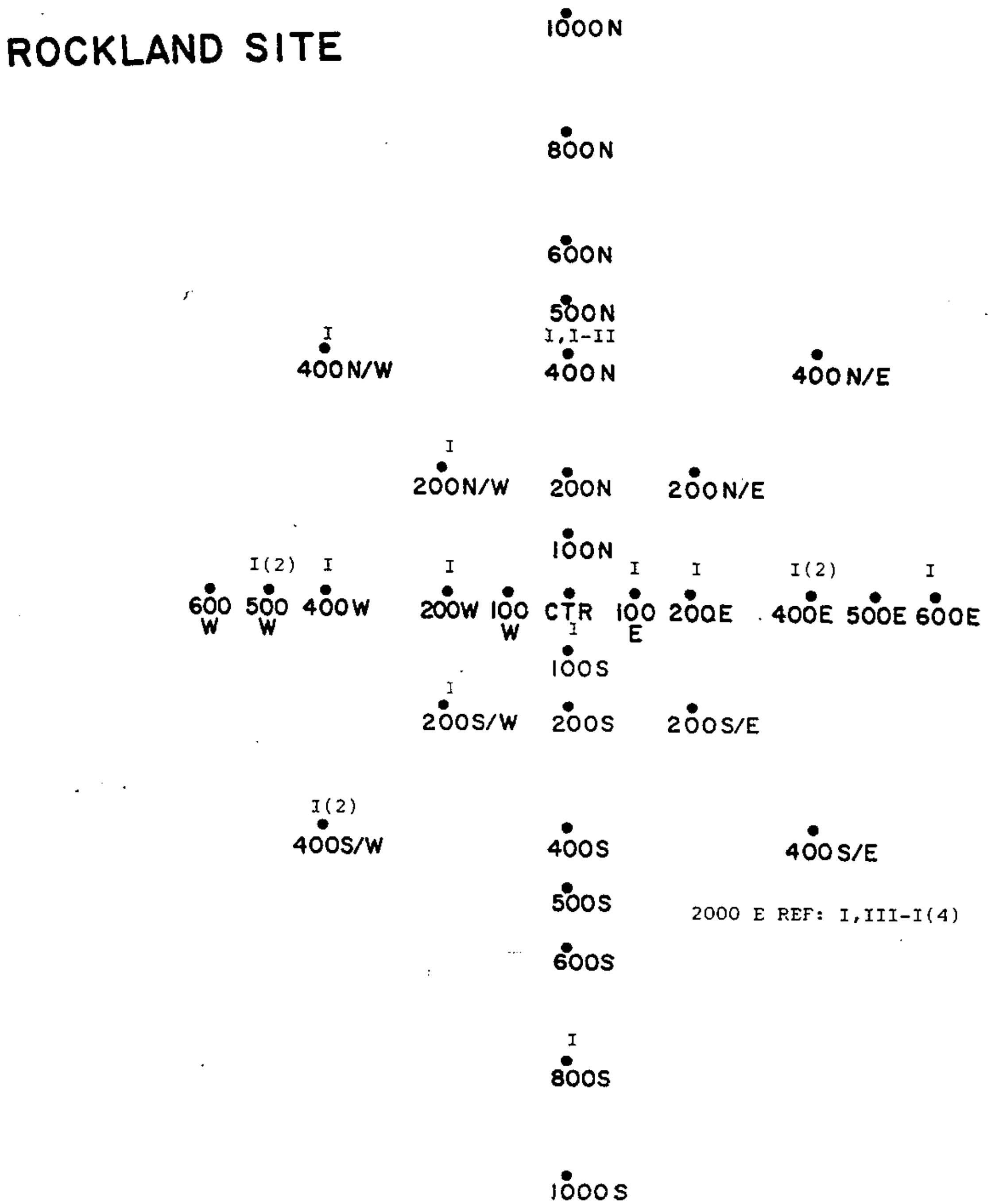

Figure VII-2-10. Distribution of apparent successional seres. Only those replicates not in Stage III-I are depicted. The number in parentheses represents the number of replicates in that successional stage.

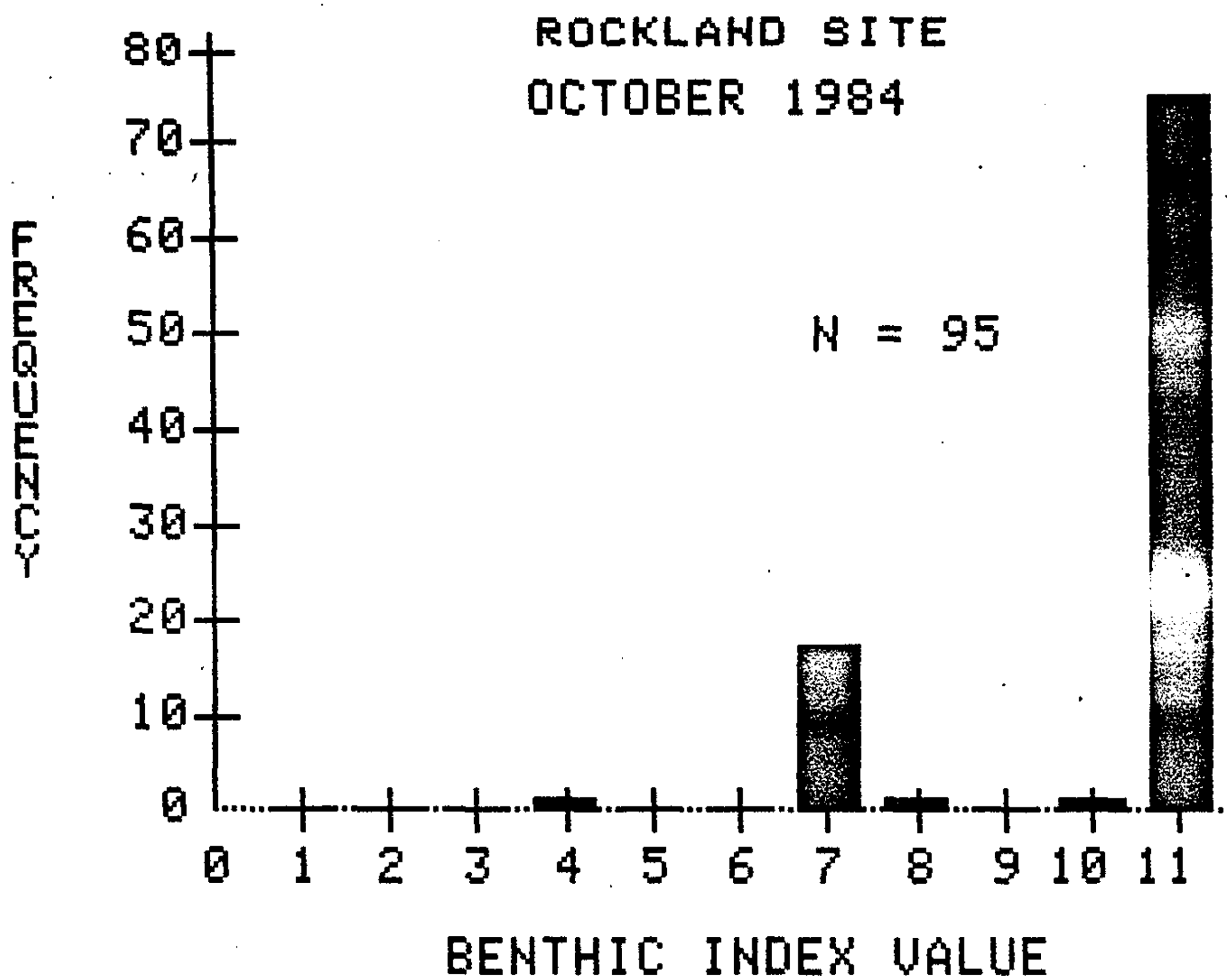

Figure VII-2-11. Frequency distribution of benthic indices for all replicates in which benthic index could be established.

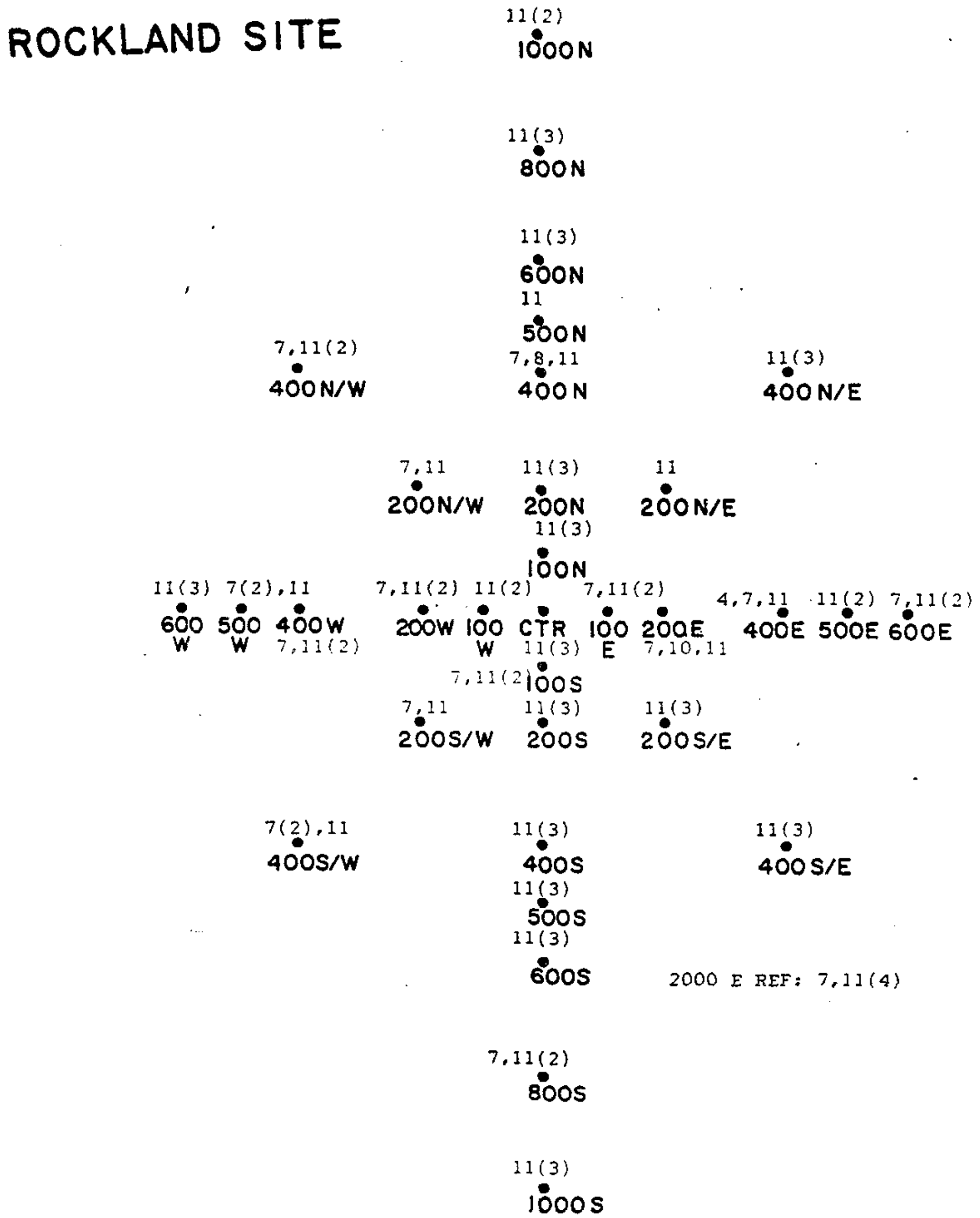

Figure VII-2-12. Distribution of benthic indices. The number in parentheses indicates the number of replicates at a station with a given benthic index.

for all but two replicate images received the highest possible rating (6) for RPD depth. When RPD depths are greater than 3.75 cm, differences in RPD depth are not detected by the benthic index. The only replicate with a benthic index less than 7, at station 400E, shows an apparent RPD depth of 1.6 cm. All other benthic indices are greater than or equal to 7, with the major mode at 11, reflecting the predominance of Stage III successional seres.

The spatial distribution of benthic indices shows no clear trends, reinforcing the interpretation that patchiness in benthic index values is due to localized natural disturbance. At least one replicate from each station in the site has a benthic index of 11. The generally high benthic indices throughout the survey area demonstrate that disturbance of any kind has been infrequent, allowing the development of mature successional assemblages dominated by head-down deposit-feeders.

2.5 Side Scan Survey

A side scan survey was attempted during the last day of operation, but steadily deteriorating weather did not permit completion and only three lanes (100 meters apart) were completed. However, because of increasing seas and difficulty in maintaining the proper base course, the side scan records were of poor quality. Consquently, the survey was postponed until the following day, but weather conditions were worse and a decision was made to postpone the survey to a later date.

3.0 SUMMARY

Precision bathymetric survey techniques were used to document the bottom characteristics at the Rockland site. The site includes a well-defined depression in the northern portion of the area and a small mound at the center of the depression that may be the result of previous disposal.

The benthic community at the disposal site is dominated by deposit feeders, which are characteristic of the soft sediment and availability of organic food there. Previous studies in the area have also determined the community to be spatially and temporally homogeneous.

The REMOTS survey has also characterized the bottom sediment at the disposal site. The grain-size major mode for all replicates in the survey area is >4 phi (silt-clay). Ranges extend into the 4-3 phi (very fine sand) and 3-2 phi (fine sand) classes, largely in the form of fecal pellets at the sediment-water interface or in feeding voids. Boundary roughness values, with the major mode extending across two class intervals (0.4 cm and 0.8 cm), indicate the infrequency of severe physical disturbance or biogenic reworking in most of the survey area. However, anomalously high boundary roughness values at four stations suggests that physical disturbance and/or creation of small-scale relief by organisms has occurred in patches. The major mode for RPD depths is in the 7.1 - 9.0 class range. In the six stations where the oxidized layer is "streaked" with reduced sediment, RPD's are significantly shallower. Stage III successional seres are present at every station in the site, although at some stations the distribution of Stage III organisms appears to be patchy. The major mode for benthic index is 11. High benthic indices throughout the site indicate that the impact of dredged material disposal has been minimal, allowing the development of Stage III assemblages in the absence of disturbance.

4.0 REFERENCES

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