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MIRAMICHI INNER BAY SEDIMENT STABILITY STUDY

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Summary

During 4-9 November 1991 the Acadia Centre for Estuarine Research of Acadia University and the Atlantic Geoscience Centre of the Bedford Institute of Oceanography jointly conducted a preliminary field study of sediment stability at Dump Site B in the inner Miramichi Bay, New Brunswick. The objectives of the study were to (1) obtain direct *in situ* measurements of the strength and erodibility of surface sediments; (2) obtain measurements of sediment pore pressures, liquefaction potentials, and short-term consolidation rates; (3) make direct observations as to the presence or absence of fluid mud layers; (4) investigate sub-surface geotechnical and geochemical sediment properties that relate to preexisting events at the disposal site and which affect overall stability of the bed; and (5) investigate biological characteristics that influence or provide information on sediment stability.

A total of 20 stations were sampled. The most extensive sampling was carried out at 12 stations, four located at a control site north of Reach 22, four located at Dump Site B within or near the area of a 1990 spoils mound, and four located within or near the dredged channel. The sampling protocol at each station consisted of obtaining gravity core samples for sediment index properties, Van Veen grab samples for organic content, grain size and settling rate analyses, Eckman grab samples for biological analyses, CTD profiling for salinity and temperature measurements, Sea Carousel deployments for measurements of sediment strength and erodibility, and Lancelot deployments for pore pressure, liquefaction potential and short-term consolidation rate measurements.

The sediments consisted of very loose to loose sandy silts and silty sands with only a small clay-sized fraction. Sediment organic contents were high (3-11 percent) and varied little with depth within the top 10 cm. The high organic content had a strong influence on sediment characteristics. Sediment water content and plastic and liquid limits were much higher than what would be expected on the basis of grain size alone, and sediment bulk densities were very low. Natural water contents were equal to or in excess of the liquid limit and decreased with depth indicating that the seabed was normally consolidated prior to sampling. Plasticity indices ranged from 39 to 106 percent.

Results of the biological survey revealed very little difference between the control, Dump and channel sites. Chlorophyll *a* and dissolved carbohydrate levels were relatively low at all sites and it is unlikely that benthic diatoms are abundant or active enough to influence sediment stability. Benthic macrofauna samples were dominated by burrowing forms, mainly polycheates, but one

suspension feeder, the bar clam (*Spisula solidissima*), was found to be relatively abundant indicating that chronically high suspended sediment loads are probably not characteristic of the sites studied.

Sea Carousel measurements indicated the most stable sediments to be at the 1990 spoils mound on Dump Site B. This site exhibited the highest critical shear stress for erosion and the lowest erosion rates. The friction angle was also high and there was a linear increase with depth in sediment shear strength suggesting that the sediment was consolidated and not in a fluidized state. A station located within Dump Site B, but at the periphery of the spoils mound, exhibited significantly lower cohesion, higher erosion rates and lower friction angles suggesting that it was much less consolidated. The lowest cohesion and highest erosion rates were observed at the channel sites. At both channel sites cohesion was virtually absent and erosion rates were high. Failure took place by aggregate release from the bed rather than as discrete particles. Video observations showed the bed to behave not as a viscous fluid, but as a gel which appeared to be held together by organic fibers within the sediment. The control site exhibited cohesion and erosion characteristics intermediate between the 1990 spoils mound and channel sites. Natural variability at the control site, however, was high.

Lancelot results indicated that the seabed is generally composed of incompressible material with a low clay content. Densities ranged from loose to medium-dense. Excess pore water pressures were in the order of 0 to 3 cm at all sites indicating the presence of a well consolidated soil structure. Penetration pore pressure responses suggested a very loose, variable silty seabed with depth. No natural liquefaction events were detected during the study period, but low-level differential pore pressures were observed as a result of minor wave loading events.

No evidence for the presence of a fluid mud layer was found at any of the sites studied. Based on the combined results of all measurements it appears unlikely that the sediments at the sites studied could ever exist as dense mud suspensions except perhaps for short periods of time during ship passage or storm events.

CONTENTS

1. INTRODUCTION

During 1981-83 a capital dredging programme was undertaken in the Miramichi Bay and Estuary to deepen the navigable channel. Since that time, maintenance dredging has been required to ensure adequate depths for ship passage. Most of the material dredged from the inner bay during the capital programme, and all of the spoils from maintenance dredging, have been deposited at a designated disposal site (Dump Site B) in the inner bay. Examination of cores from this site and nearby areas, together with other information, has given rise to the perception that the disposal site is unstable, and that much of the dredged material may have been remobilized, either as bedload or in suspension, to other parts of the estuary.

To address this concern, during November 4-9, 1991, the Acadia Centre for Estuarine Research and the Atlantic Geoscience Centre of the Bedford Institute of Oceanography jointly carried out a preliminary field survey at Dump Site B and other selected areas of the inner Bay. The objectives of the survey were to:

(1) obtain direct *in situ* measurements of the strength and erodibility of surface sediments;

(2) obtain measurements of sediment pore pressures, liquefaction potentials, and short-term consolidation rates;

(3) make direct observations as to the presence or absence of fluid mud layers;

(4) investigate sub-surface geotechnical and geochemical sediment properties that relate to pre-existing events at the disposal site and which affect overall stability of the bed; and

(5) investigate biological characteristics that influence or provide information on sediment stability.

The results of the study are presented in five sections. The first provides an overview of the locations of the specific sites chosen for study and the sampling protocol employed at each site. The second section summarizes sediment properties. The third and fourth sections provide information on the biological parameters and the dynamic sediment properties of each site, and the final section makes recommendation for future studies.

2. STUDY SITES AND SAMPLING PROTOCOL

A total of 20 stations were occupied during the study. The location of each station is shown in Figure 2.1 (contained in the map pocket following the appendices). Table 2.1 presents a summary of the activities carried out at each station. Appendix A provides a detailed description of station locations and activities. The major portion of the field study centered around deployments of Lancelot, Sea Carousel and SOBS. The type of information obtained by each of these instruments is described in Section 5.

The most extensive sampling was carried out at 12 stations, four at a control site just north of Reach 22, four at Dump Site B in the area of a 1990 spoils mound, and four within the dredged channel (Figure 2.2). The two channel stations were selected partly on the basis of their sediment characteristics. The most easterly site, within Reach 22, is in an area where channel slumping has been observed to occur and contains silty material. The other site, within Reach 20, contains finer, more clay-like material. The sampling procedure at each station consisted of obtaining gravity core samples for sediment index properties, Van Veen grab samples for organic content, grain size and settling rate analyses, Ekman grab samples for biological analyses, CTD vertical profiling for salinity and temperature measurements, and Lancelot and Sea Carousel deployments.

SOBS deployments were carried out two stations, one at the control site and one at Dump Site B. Long-term (18-22 hrs) Lancelot deployments were carried out on three occasions at stations located in the control, Dump Site and channel areas.

3. SEDIMENT PROPERTIES

3.1. Index Properties

Van Veen grab samples were subsampled at sea for subsequent grain size distribution (percent gravel/sand/silt/clay). The gravity cores were later split at the Atlantic Geoscience Centre, photographed, logged and subsampled for index properties including grain size, water content and bulk density. The sediments were unsuitable for undrained shear strength testing by laboratory vane due to their coarse texture. A summary of the laboratory data is given in Appendix B. Appendix C presents the results graphically. Core photographs are presented in Appendix D. Two distinct lithologies were noted which correspond to the two-coloured stratigraphy evident in the core photos. Black-coloured strata are high in organic content and represent relatively

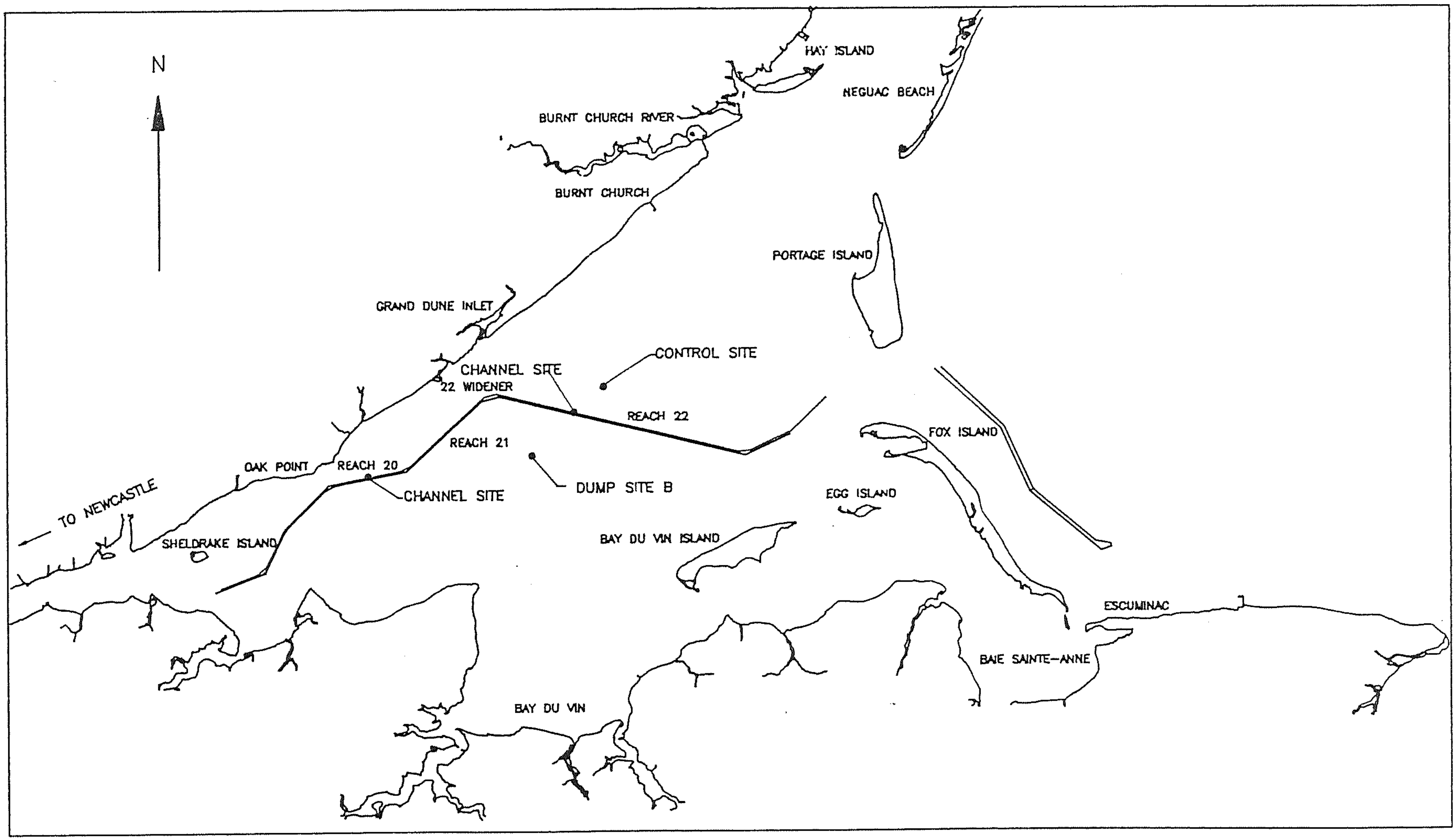


Figure 2.2 Location of Study Sites.

Table 2.1. Summary of station locations and samples collected (CTD - salinity temperature profiles; GC - gravity core; VV - Van Veen grab; EK - Ekman grab; SOBS - Submersible Observatory of Benthic Stability; LAN - Lancelot; SC - Sea Carousel).

DAY	STA	POSITION (GPS)		CTD	GC	VV	EK	SOBS	LAN	SC
Nov. 5	1	47 08 20.5N	65 09 25.0W	X	X	X	XX	X	X	X
"	2	47 08 25.5N	65 09 90.2W							X
Nov. 6	3	47 05 58.1N	65 15 21.6W		X					
"	4	47 05 59.6N	65 13 53.4W		X					
"	5	47 06 53.7N	65 13 49.1W		X					
"	6	47 06 59.3N	65 11 04.9W		X					
"	7	47 07 12.8N	65 11 00.5W	X	X	X	X		X	X
"	8	47 07 08.8N	65 11 07.5W							X
"	9	47 07 09.3N	65 11 04.0W	X	XX	X	X		X	X
"	10	47 07 10.1N	65 11 05.5W			X			X	
"	11	47 06 59.5N	65 11 05.8W	X			X			X
Nov. 7	12	47 06 58.9N	65 11 06.0W					X		
"	13	47 07 40.7N	65 10 08.1W	X	X	X	X		X	X
"	14	47 07 55.1N	65 10 02.7W				X			X
"	15	47 08 21.5N	65 09 20.2W				X		X	X
"	16	47 08 22.3N	65 09 19.1W				X			X
"	17	47 06 33.1N	65 15 40.8W						X	
Nov. 8	18	47 06 30.2N	65 15 29.4W	X	X	X	X			X
"	19	47 06 43.8N	65 15 10.6W				X			X
"	20	47 06 39.0N	65 15 19.0W						X	

TABLE 2.2 SUMMARY OF STATION LOCATIONS IN NAD 1927 UTM CO-ORDINATES

STATION	UTM CO-ORDINATES (m)	
	Easting	Northing
1	336440.0	5222652.0
2	336556.0	5222802.0
3	328774.0	5218498.0
4	330672.0	5218468.0
5	330722.0	5220171.0
6	334281.0	5220225.0
7	334189.0	5220386.0
8	334171.0	5220391.0
9A	334197.0	5220406.0
9B	334231.0	5220398.0
10	334177.0	5220408.0
11	334247.6	5220211.3
12	334242.9	5220192.9
13	335498.7	5221449.1
14	335624.9	5221890.5
15	336542.6	5222680.0
16	336566.5	5222704.7
17	328429.3	5219561.0
18	328666.9	5219464.8
19	329075.3	5219873.0
20	328894.0	5219730.0

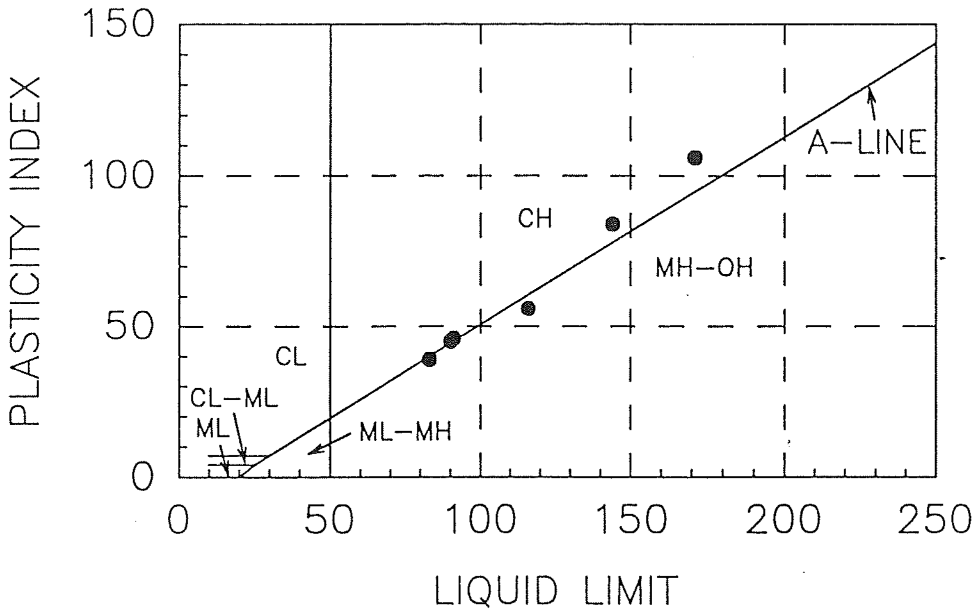
undisturbed seabed conditions whereas the lighter structureless olive-green units possibly indicate recent liquefaction events.

Generally, the samples consisted of very loose to loose sandy silts and silty sands with only a small clay-sized fraction (about 10 percent by weight). Natural water contents (W_n) were equal to or in excess of the liquid limit (W_l), verifying the observation that the seabed was normally consolidated prior to sampling. Water contents decrease with depth corresponding to an increase in bulk density (ρ_s), indicating that the section was undergoing normal consolidation. (Note that the Atterberg limits from the Van Veen subsamples are superimposed on the downcore water content graphs.)

Plastic limits (W_p) are high for sandy silt, but are undoubtedly affected by the high organic contents, which likewise produced very high water contents. The clay content is insufficient to cause the observed plasticity behavior, if one neglects the organic material contribution.

Figure 3.1 illustrates the results of the Atterberg Limits testing carried out on the Van Veen samples in plasticity chart form. This format is generally used to classify fine-grained sediments in terms of their plasticity (the range of water contents over which the sediment behaves as a plastic solid). The data points all plot along the Casagrande A-line in the CH to MH-OH regions, indicating that the sediments were of high plasticity and organic content. Plasticity indices ranged from 39 to 106 percent, with the higher values corresponding to Van Veen samples 13 and 18 which were taken in Reach 22 and Reach 20, respectively. It is noteworthy also that the Sea Carousel results (Section 5.2.1) indicated a fluidized bed at both of these stations, which in itself implied high water contents as a direct consequence. The downcore graphs of natural water content shown in Appendix C reveal that the highest surficial water contents were indeed found at stations 13 and 18, confirming the previous finding.

The overall high water contents clearly support the Lancelot and Sea Carousel findings (Section 5) wherein the seabed is found to be comprised of very loose to loose sandy silts with a minor clay content, and which are prone to liquefaction such as might occur under cyclic wave loading. Remoulded shear strengths would be substantially lower than the peak undisturbed strength, depending on the length of time between loading events and the rate of vertical consolidation. Lancelot results indicate very rapid consolidation rates such as one might expect with a sandy silt grain size distribution. The distinction between a fluidized silt bed and a viscous fluid clay layer is discussed in the next section.



<u>Unified Soil Classification System</u>

CL Clay, low plasticity
CH Clay, high plasticity
ML Silt, low plasticity
OL Organic sediment, low plasticity
OH Organic sediment, high plasticity

Figure 3.1. Plasticity chart showing Atterburg limits.

3.2. Organic Content

Sediment samples for determination of organic content were collected from Van Veen grab samples, each of which was sub-sampled at depths of 0, 5 and 10 cm. Organic content was measured by loss on combustion.

Sediment organic content is high at all sites (Figure 3.2) and varies little with depth (Figure 3.3). Both of these observations suggest a large long-term input of organic matter into the Bay and may be a result of accumulation of pulp mill effluents or other industrial wastes.

3.2.1. Effect of Organic Matter

Organic matter has been shown to significantly alter geotechnical properties by absorbing water and causing clays to aggregate, forming an open fabric. This leads to exceptionally high water contents and abnormally low bulk densities, yet produces an increase in the peak shear strength (Keller, 1982). Post-failure shear strength is markedly reduced however, resulting in a large loss in strength after failure and large flow-type slides. Additionally, in areas of excess pore pressure (areas of high wave activity or where sediments possess low permeability), stability characteristics are further degraded through a reduction in the effective stress within affected parts of the seabed (upper few meters). Post-failure mobility of organic sediments is high, owing to the high water contents and large strength loss.

Keller (1982) and McDonald (1983) found that within the uppermost few decimetres in organic-rich sediments, water content and bulk density varied linearly with organic carbon content. The reason for this is explained later. Casagrande (1948) introduced the system now widely used in geotechnical engineering to classify fine-grained sediment according to its plasticity behavior which is in itself controlled by the presence and activity of clay minerals. It will also be shown that in the case of the Miramichi sediments, the plasticity approach leads to misleading assumptions regarding sediment composition that were in contradiction with textural analyses.

The plastic and liquid limits (Atterberg limits) are the water contents at which remoulded sediment undergoes a dramatic transformation in behavior from a brittle to a plastic solid and then to a viscous fluid. It is common to find water contents in excess of the liquid limit within fine-grained sediments directly underlying the seabed; such sediments are prone to liquefaction and will experience subsequent rapid downslope movement if remoulded. The difference between the liquid and the plastic limit is termed the plasticity index, and is a measure of the range of water

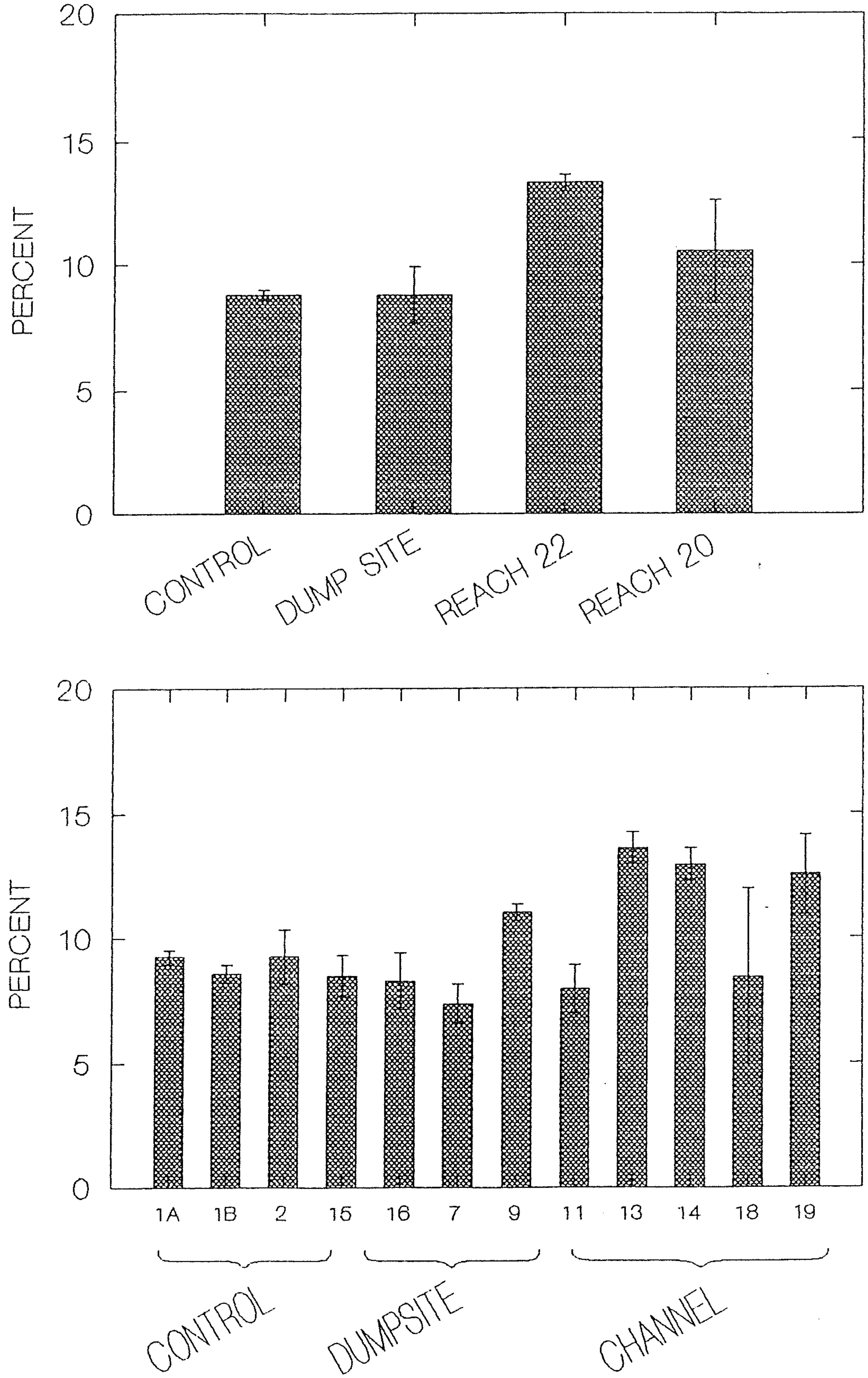


Figure 3.2. Sediment organic content as percent of dry weight.

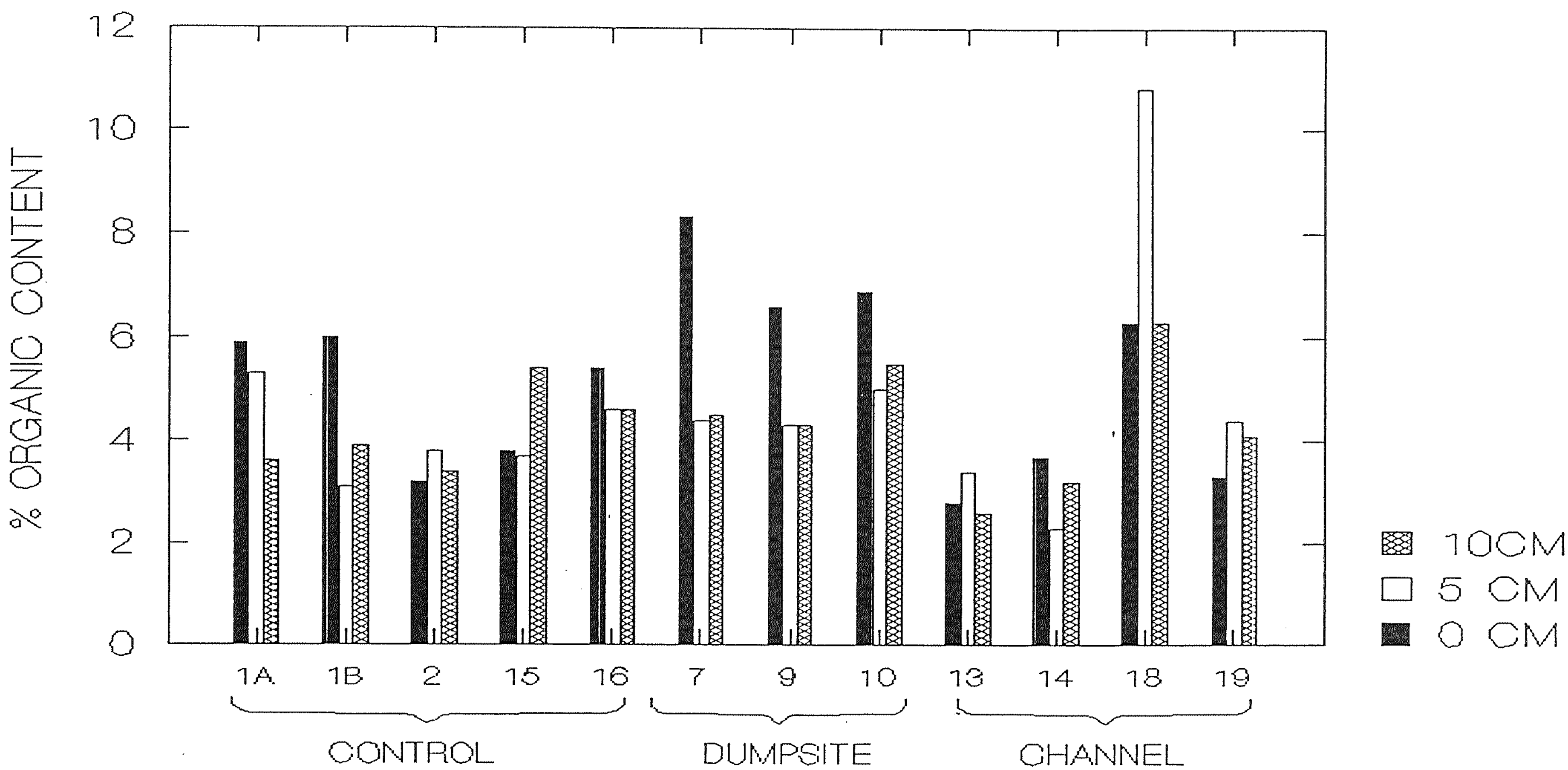


Figure 3.3. Variation in sediment organic content with depth.

contents over which a sediment exhibits plastic behavior. Data from the six Van Veen samples are plotted in Figure 3.1. Note again the very high plasticity indices and liquid limits, with the sediments being classified as clays of low to high plasticity, according to the Casagrande system.

The Atterberg limits express the ability of a sediment particle to attract and bind water to its surface; active clay minerals can bond more water and can have water contents of more than 800 percent by weight. Keller (1982) found that organic matter had the same effect once it comprised more than 5 percent of the sediment by weight, below which clay mineralogy dominated plasticity and shear strength behavior for fine-grained sediments.

The grain size distributions for the gravity cores in fact indicated that very little clay (about 10 percent) existed within the sampled study areas, which directly contradicts the Atterberg limits results for identical subsamples. It is, therefore, extremely important to resolve this apparent contradiction, as there have been questions regarding the capacity of these sediments to exist as flocculated viscous but mobile mud layers. It is useful to compare the Miramichi index properties for the least disturbed cores (Van Veen samples) to the relationships established by Keller (1982) and Busch and Keller (1982) in order to determine the origin of the very high water contents and low bulk densities noted from analysis of the gravity cores.

Figure 3.4 shows a plasticity chart after Busch and Keller (1982) as a function of organic content with the Miramichi Atterberg limits results superimposed. There is some degree of scatter; however, the standard deviation is no worse than for the empirical dataset generated by Busch and Keller (1982). Figure 3.5 illustrates the effect of organic carbon on the natural (undisturbed) water content, once again the Miramichi values plot around the line given by Keller (1982).

This exercise served to illustrate the importance of organic matter in creating the very loose conditions found in the Miramichi Inner Harbor study area, and verifies the low clay content; which also explains why high plasticity indices were observed.

Fluid mud has been defined as a dense sediment suspension having concentrations between 10 and 480 g/litre, corresponding to bulk densities ranging between 1.03 and 1.30 g/cm^3 (Faas, 1985); Nichols (1985) observed concentrations ranging from 3 to 320 g/litre. More recently, Faas (1991) used the liquid limit as a criterion to predict the occurrence of fluid mud suspensions for several estuarine systems. Therein, he found that the liquid limit represented the phase transformation from an unstructured to a structured (fluid mud) suspension. We have shown that the real situation can be more complex, requiring more stringent examination of the data.

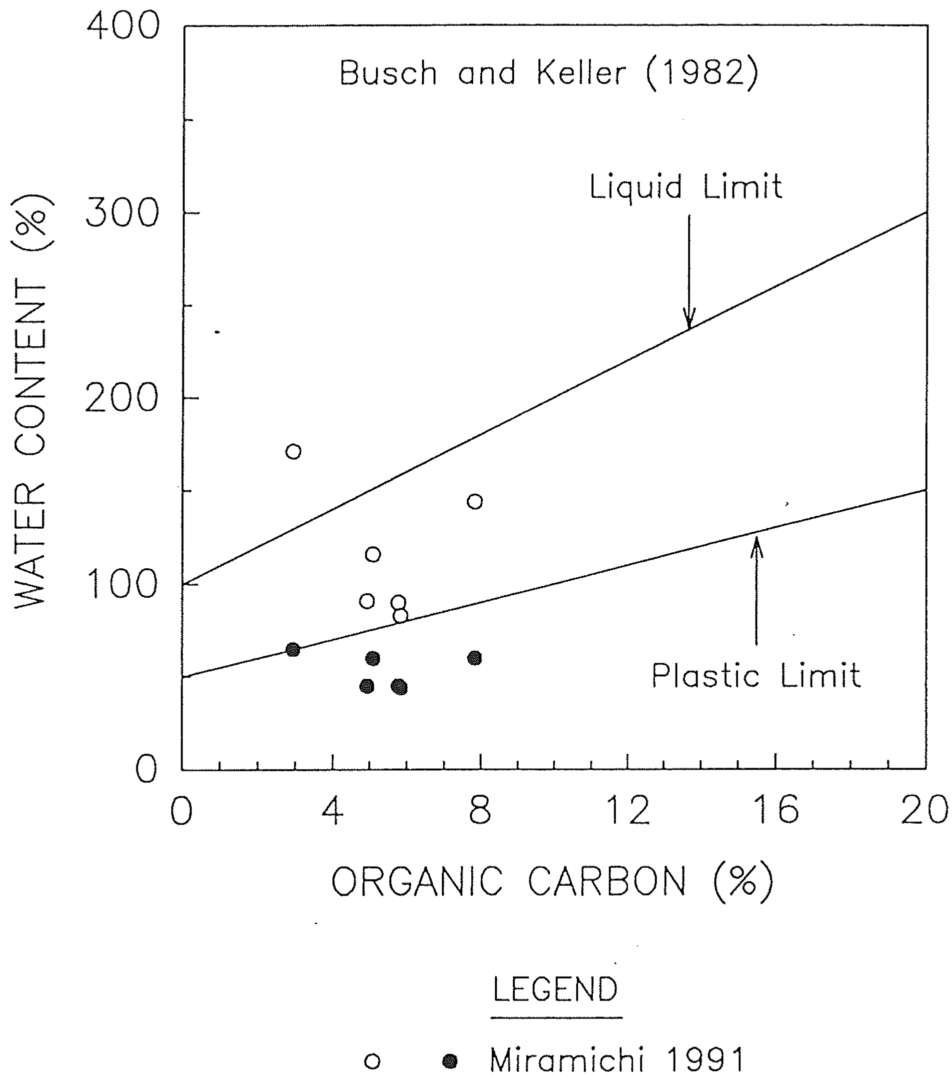

400
300
200
100
0
WATER CONTENT (%)
Busch and Keller (1982)
Liquid Limit
Plastic Limit
0
4
8
12
16
20
ORGANIC CARBON (%)
LEGEND
Miramichi 1991

Figure 3.4

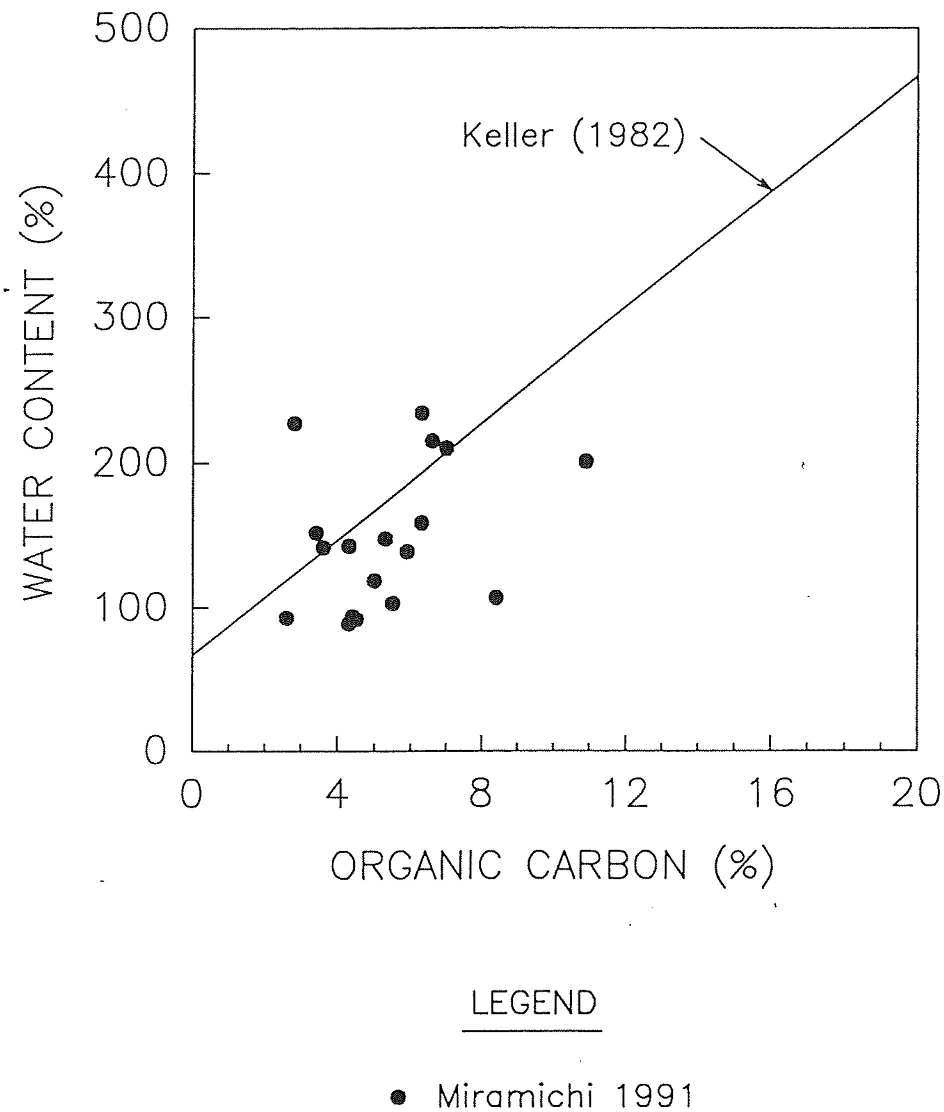

500
400
300
200
100
0
WATER CONTENT (%)
Keller (1982)
0
4
8
12
16
20
ORGANIC CARBON (%)
LEGEND
Miramichi 1991

Figure 3.5

3.3. Sediment Settling Rates

Analysis of Van Veen grab samples for determination of sediment settling rates are being carried out. The results will be issued as a separate report (Amos *et al.*, 1992).

4. BIOLOGICAL CHARACTERISTICS

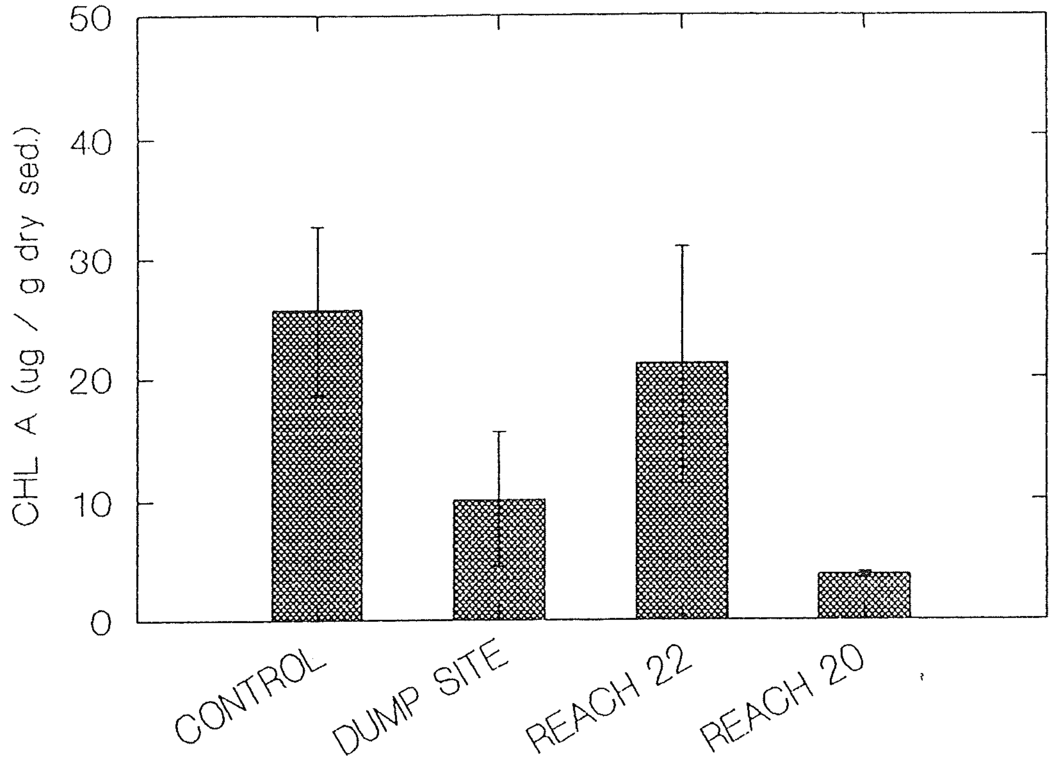
Investigations of biological characteristics at each site were limited to factors that are known to either affect or provide information on sediment stability. These included measurements of sediment chlorophyll *a* and dissolved carbohydrate concentration and macrofauna numbers and species composition. Sediment chlorophyll *a* concentration provides information on the occurrence of benthic diatoms which have been shown to excrete organic compounds important in enhancing sediment cohesion, and dissolved carbohydrate concentration can often provide information on the amount of excretory products present. Macrofauna numbers and species composition can provide indirect information on sediment stability since many benthic organisms can exist only in stable substrates and under conditions of low suspended sediment concentrations.

Attempts were also made to determine if a filamentous algal layer, as described in the Philpott report (Philpott, 1978), exists at the sediment water interface.

4.1. Sediment Chlorophyll *a*

Sediment chlorophyll *a* samples were collected by subsampling the upper 5 mm of Van Veen grab samples using a 1.2 cm dia core sampler. Samples were stored frozen in 20 ml scintillation vials until analysis in the laboratory. Chlorophyll *a* concentration was measured photometrically after extraction in 90 percent acetone for 24 hr followed by centrifugation.

Chlorophyll *a* concentrations varied considerably between sites. The highest concentrations were observed at the control site and the lowest at Reach 20 (Figure 4.1). Concentrations at Dump Site B and Reach 22 were intermediate but significantly less than at the control site. At all sites chlorophyll *a* levels are relatively low compared to levels typical of intertidal and shallow water sediments (usually >50 μg g dry sediment^{-1}), and it is unlikely that the numbers of benthic diatoms are great enough to influence sediment properties. The levels observed at the two channel sites are probably not due to the presence of diatoms since it is unlikely that there is sufficient light available for photosynthesis at the depth of these stations (>10 m). Sediment grab samples often contained fragments of eel grass (*Zostera marina*) and it is likely that this is responsible for a major portion the chlorophyll *a* measured.



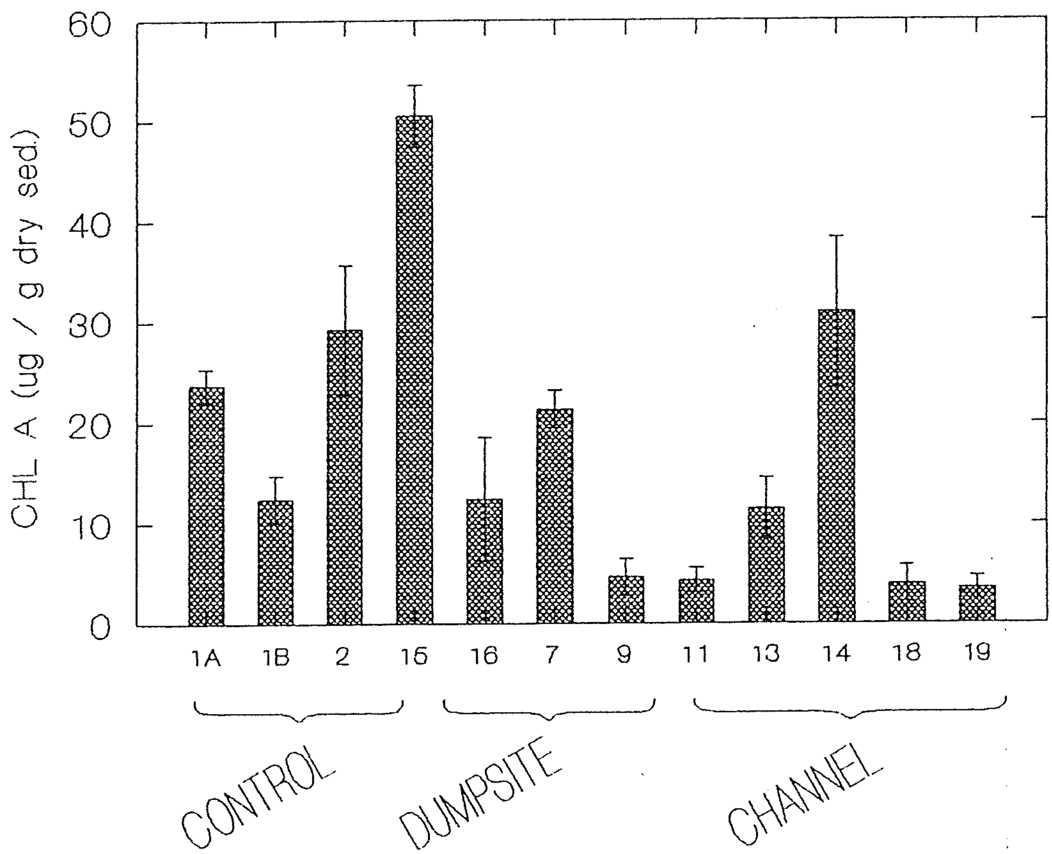


Figure 4.1. Sediment chlorophyll a concentrations at each site.

There was no evidence of the presence of a filamentous benthic algal layer at any of the sites studied.

4.2. Sediment Dissolved Carbohydrates

Dissolved carbohydrate samples were collected and stored in the same manner as chlorophyll *a* samples. Concentration was measured photometrically using the phenol-sulphuric acid procedure (Kochert, 1978).

Dissolved carbohydrate levels were greatest at the control site. All other sites exhibited about equal concentrations which were about one-half of the control site values (Figure 4.2). In general, dissolved carbohydrate levels exhibited the same trends as chlorophyll *a* concentrations suggesting that their source is related to diatom excretion products. The levels measured, however, were much lower than those usually found in intertidal and shallow subtidal environments.

4.3. Benthic Macrofauna

Benthic macrofauna samples were collected with a 0.025 m^{-2} Ekman grab and sieved through a 850 μm screen.

A total of 24 different species were collected, but of these only eight species accounted for most of the organisms collected (Table 4.1). There was very little variation among stations in either the total number (Figure 4.3) or species composition (Figure 4.4) of the more abundant organisms. Polychaetes, most of which were omnivorous or predatory, dominated all sites. Mollusks, both gastropods and bivalves, were next in abundance. Three species of suspension feeders were present; *Mytilus edulis*, the blue mussel, *Balanus balanoides*, a barnacle and *Spisula solidissima*, the bar clam. Neither *M. edulis* or *B. balanoides* were abundant at any of the sites, probably more because of the lack of a hard substrate than the presence of high suspended sediment concentrations. The bar clam, which is a burrowing organism requiring a soft substrate, was relatively abundant at all sites, and most abundant at the Dump site (Figure 4.5).

4.4. Summary

The results of the biological survey indicate very little difference between the control, Dump Site and channel sites. Chlorophyll *a* and dissolved carbohydrate levels are relatively low at all sites and it is unlikely that benthic diatoms are abundant or active enough to influence sediment

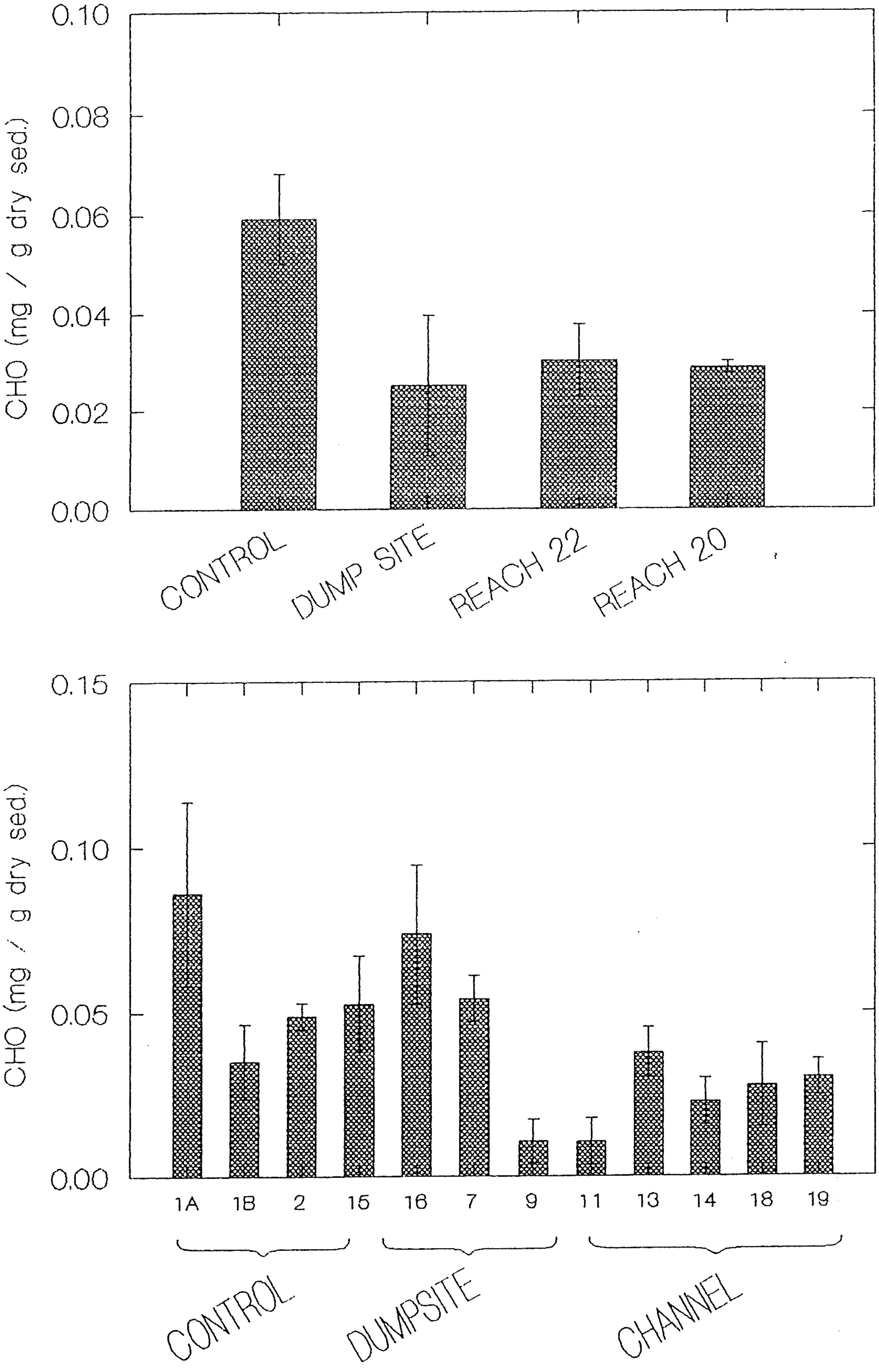


Figure 4.2. Sediment dissolved carbohydrate concentrations at each site.

Table 4.1. Benthic macrofauna species.

Class Polychaeta
- * *Ninoe nigripes*
- * *Scoloplos robustus*
- * *Aglaphamus neotenus*
- *Eteone longa*
- * *Polydora ligni*
- *Nereis diversicolor*
- *Capitella capitata*
- *Cistena sp.*
- *Prionospio steenstrupi*

Class Gastropoda
- * *Retusa canaliculata*
- * *Nassarius trivittatus*
- *Crepidula fornicata*
- *Littorina obtusata*
- *Turbonilla interrupta*

Class Pelecypoda
- * *Spisula solidissima*
- * *Tellina agilis*
- *Mya arenaria*
- *Mytilus edulis*
- *Yoldia limatula*

Phylum Rhynococoela
- *Cerebratulus lacteus*

Class Crustacea
- *Crangon septemspinosa*
- *Ampelisca macrocephala*

Class Cirripedia
- *Balanus bolanoides*

Class Hydrozoa
- *? Obelia sp. ?*

*most abundant species

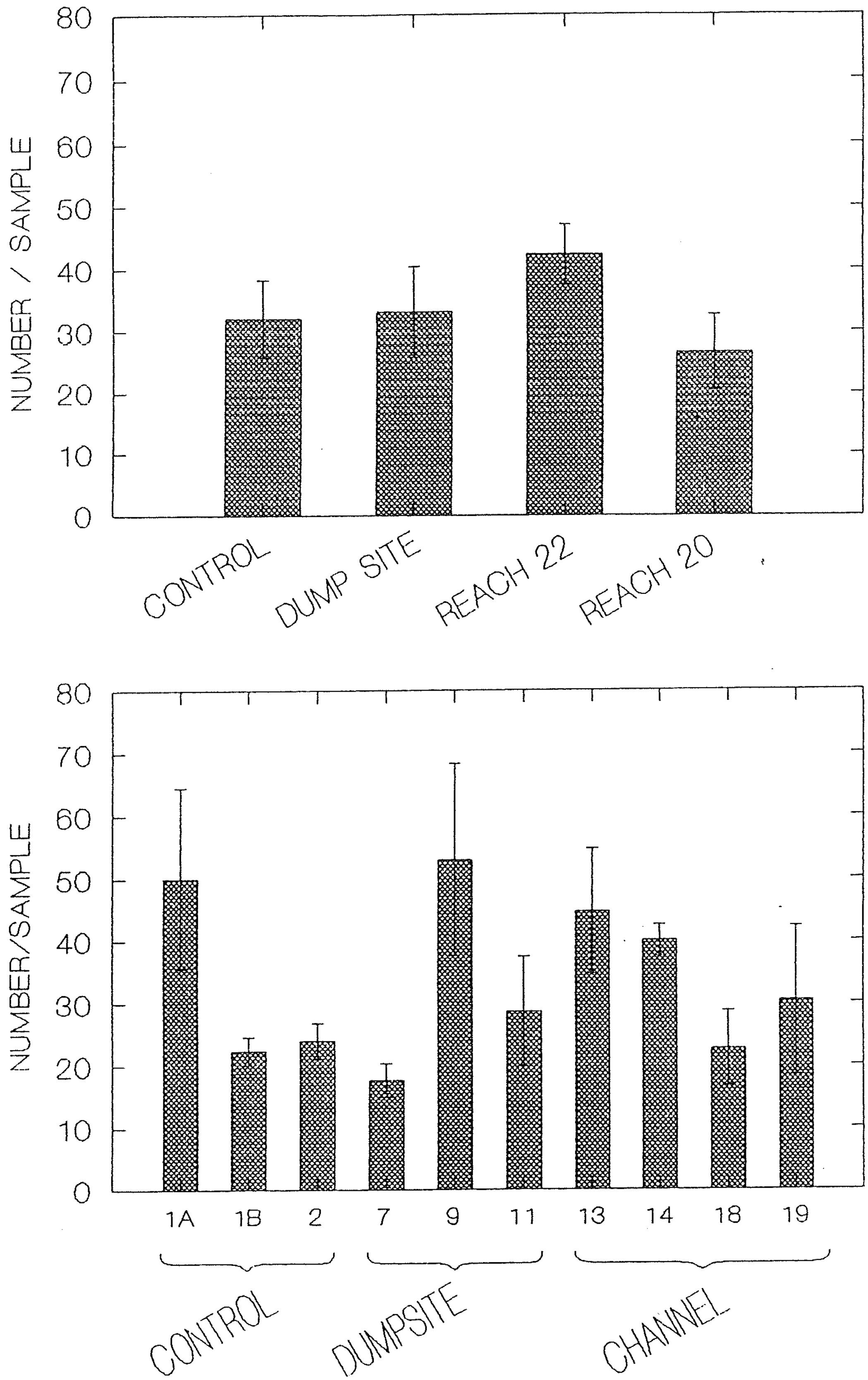
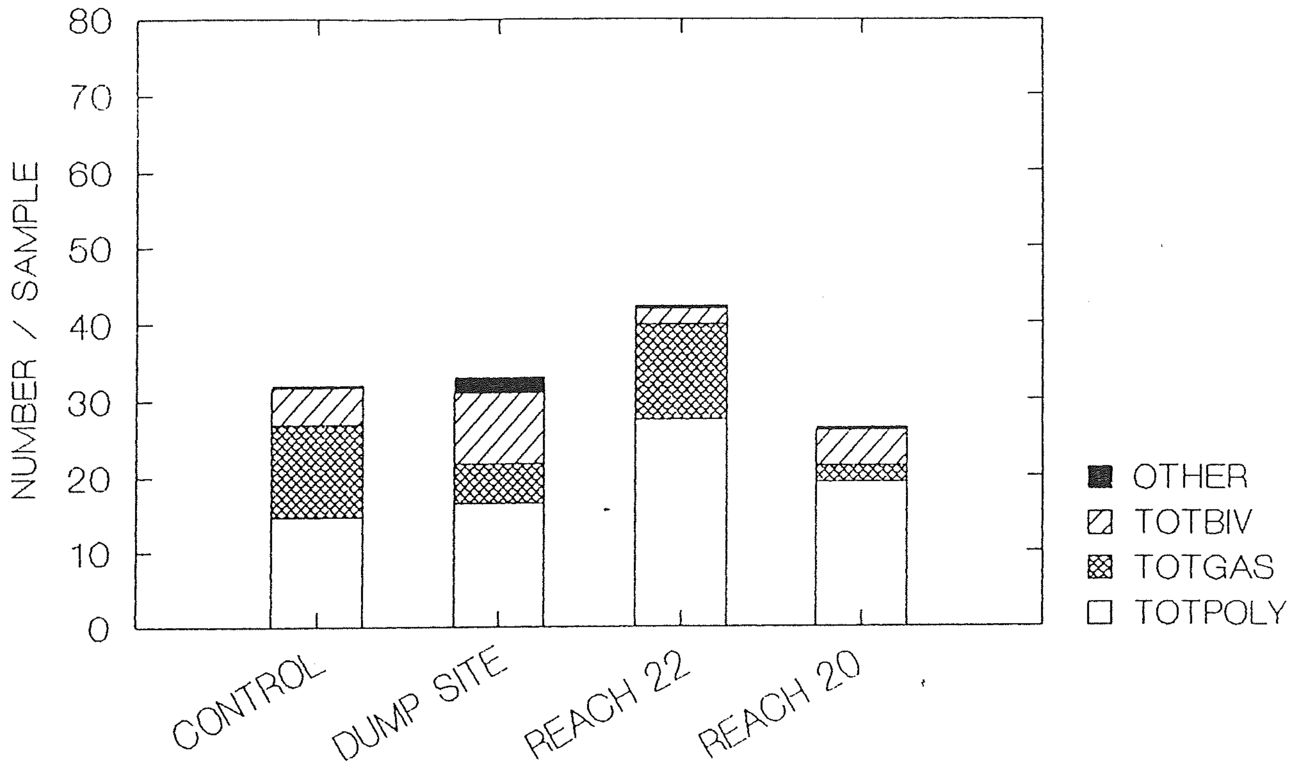


Figure 4.3. Macrofauna numbers at each site.



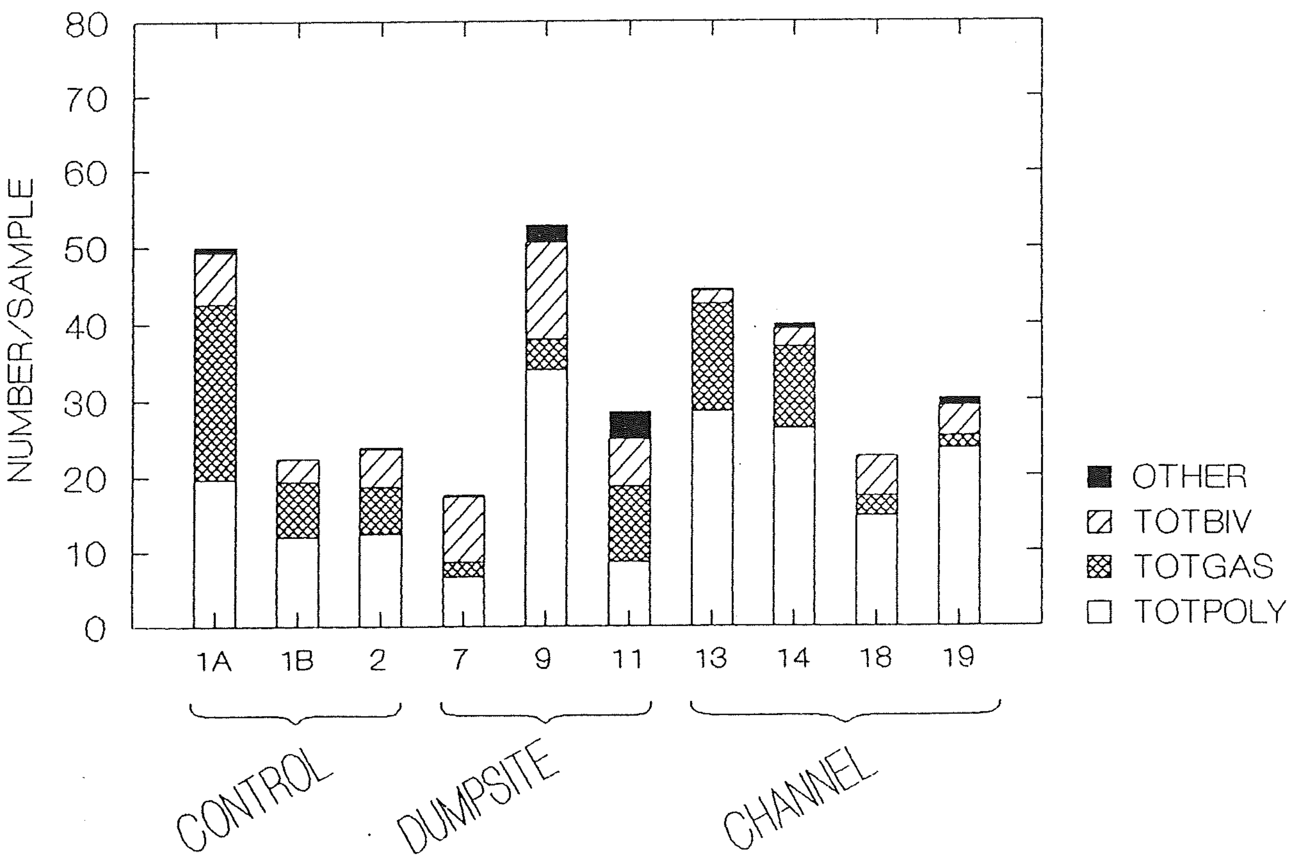


Figure 4.4. Numbers of major macrofauna groups at each site.

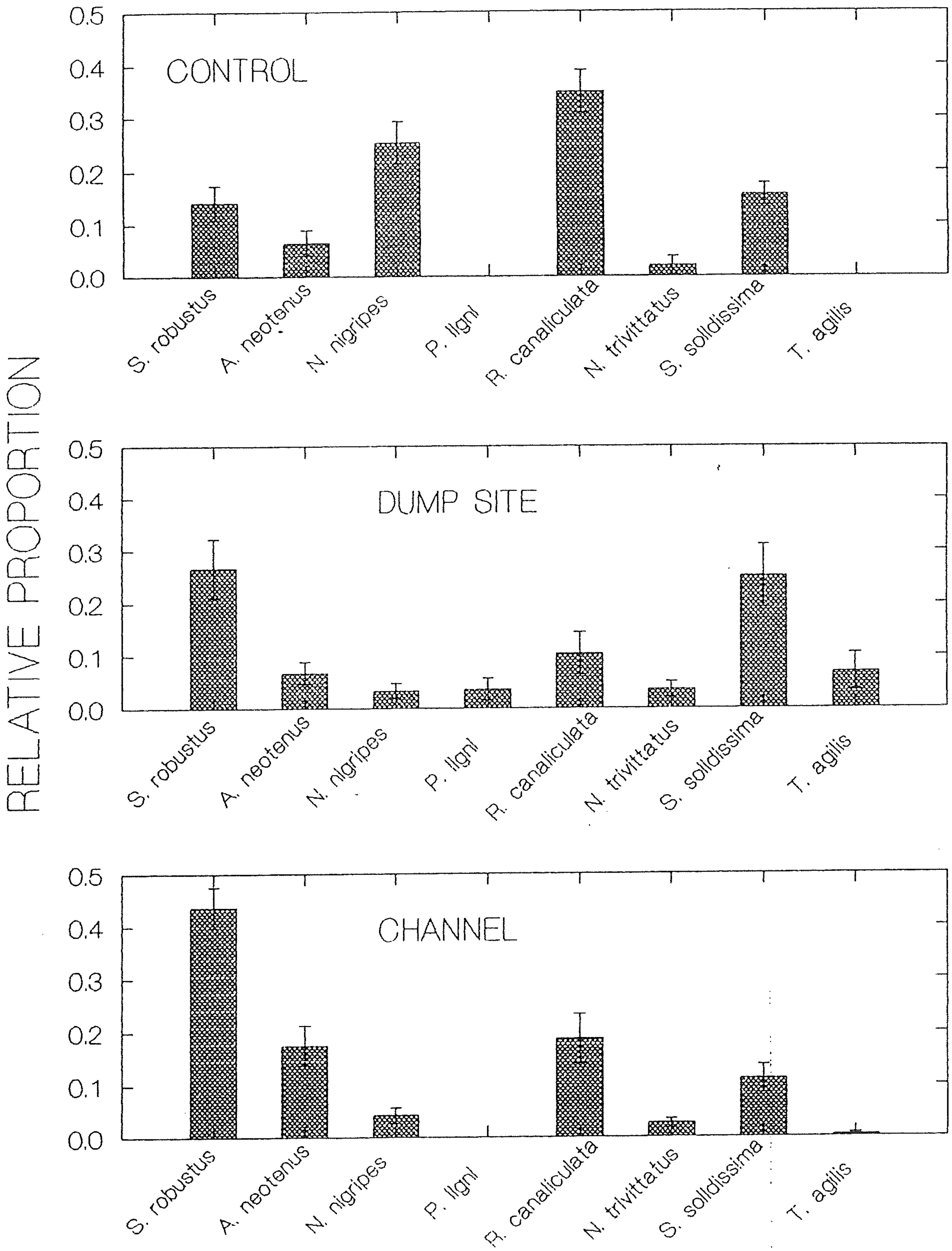


Figure 4.5. Relative proportions of most abundant macrofauna at each site.

stability. The presence of suspension feeders, mainly *S. solidissima*, provides some indication that chronically high suspended sediment levels are not present at any of the sites studied.

5. SEDIMENT DYNAMICS

5.1. Sea Carousel

5.1.1. System Configuration

Sea Carousel, named after the carousels of Postma (1967) and Hydraulic Research Limited (Burt, 1984), is a benthic annular flume designed for field use in intertidal and subtidal settings. The carousel is 1.0 m in radius with an annulus 0.15 m wide and 0.30 m high (Figure 5.1). It weighs approximately 150 kg in air and 40 kg in water and is made entirely of aluminium. Flow in the annulus is induced by rotating a movable lid that is driven by a 0.35 hp DC motor powered from the surface. Eight small paddles, spaced equidistantly beneath the lid, induce a flow of water in the annulus. The width of the annulus (D) was made 0.15 m to give a relative roughness (e/D) $\approx$ 0.004 (where the wall roughness, e $\approx$ 0.0006 m; after Shames, 1962). The water depth in the annulus was minimized to 0.25 m to ensure conditions for Nikuradse's "rough-pipe zone of flow" wherein changes in wall friction factor with changes in Reynolds number are at a minimum (Shames, 1962).

A schematic diagram of the Sea Carousel configuration is shown in Figure 5.2. It is equipped with three optical backscatter sensors (OBS's; Downing, 1983). Two of these are located non-intrusively on the inner wall of the annulus at heights of 0.03 and 0.18 m above the skirt (the skirt is a horizontal flange situated around the outer wall of the annulus 0.04 m above the base; it was designed to standardize penetration of the flume into the seabed; see Figure 5.1). The third OBS detects ambient particle concentration outside the annulus, or it may be used to detect internal sediment concentration at a height between the other two. The OBS sensors give linear responses to particle concentration (of a constant size) for both mud and sand over a concentration range of 0.1 to 50 g/L (Downing and Beach, 1989). They are unaffected by flows below 1.5 m/s and are stable through time. A sampling port is situated in the outer wall of the annulus at a height of 0.2 m above the skirt through which water samples can be drawn to calibrate the three sensors under well mixed conditions.

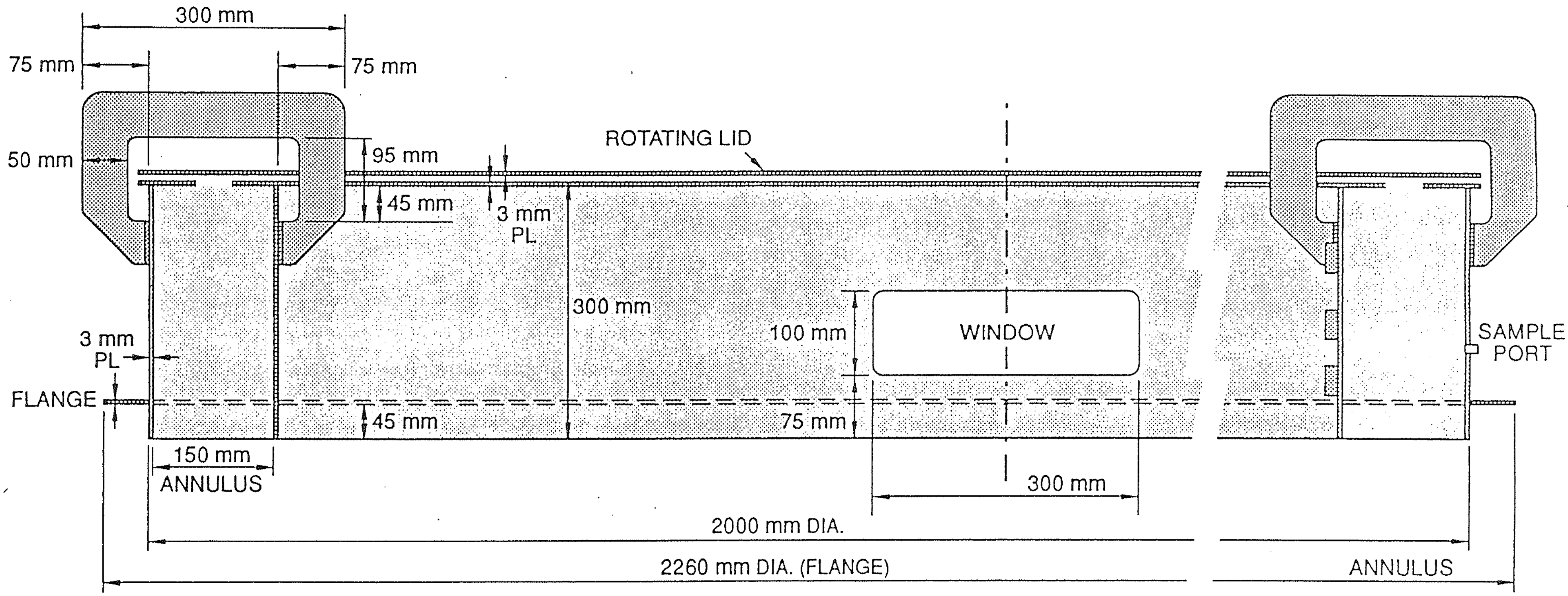


Figure 5.1. Sea Carousel

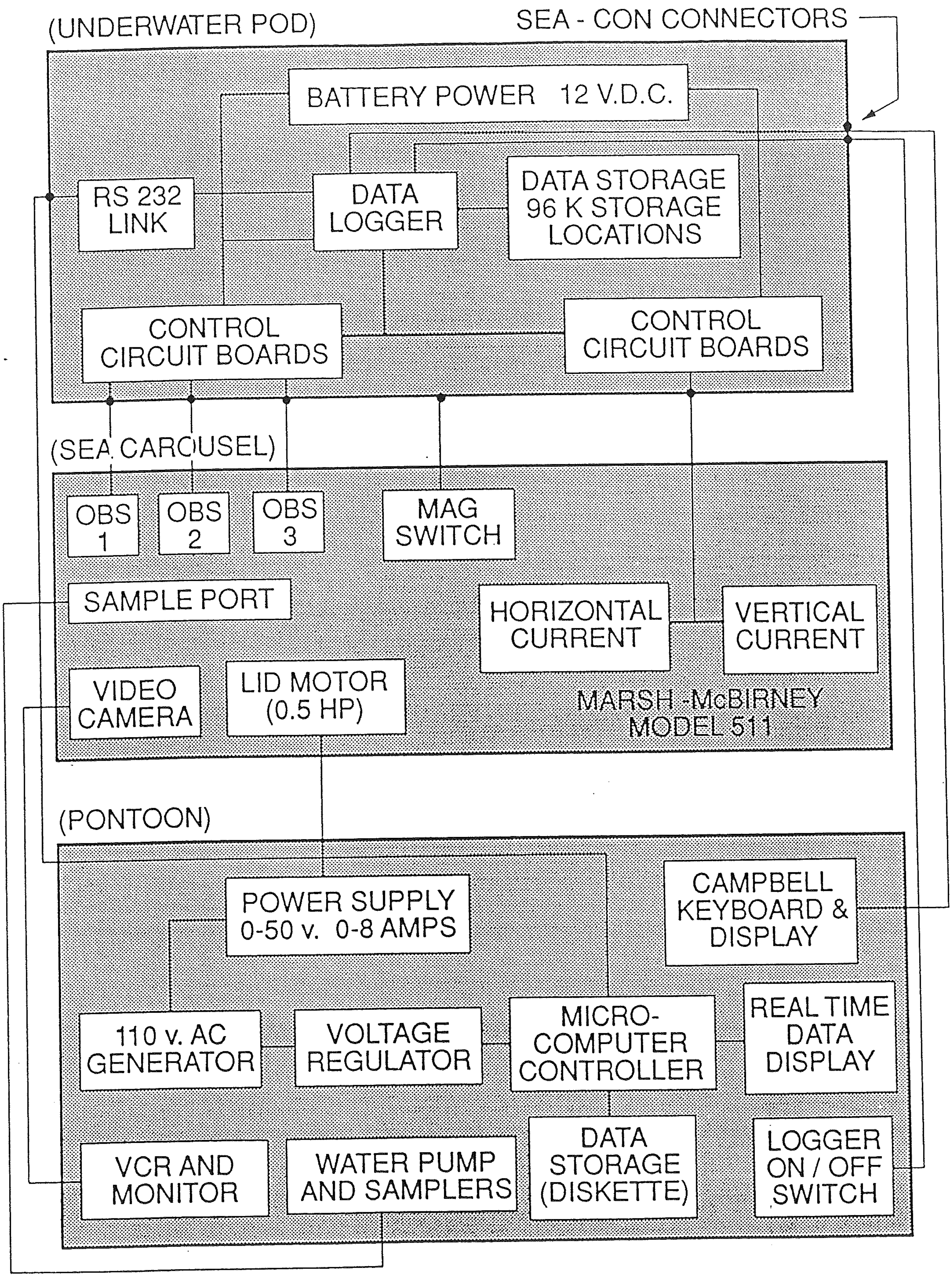


Figure 5.2. Schematic of Sea Carousel configuration.

A Marsh/McBirney current meter (Model 511) is located on the centerline of the annulus at a height of 0.16 m above the skirt. It was used to detect the instantaneous azimuthal and vertical components of flow within the annulus (U_y and U_w respectively). Mean tangential lid rotational speed ($\bar{U}_r$) is detected through a shaft end-coder that runs on the lid. Controller boards for each sensor and the necessary power (12 VDC) are derived from an underwater pod located above the annulus. Output voltages from all sensors are digitized and transformed to scientific units on a Campbell Scientific CR10 data logger and stored on a Campbell Scientific SM192 storage module (storage capacity of 96,000 data values), also located in the underwater pod. The data logger is interrogated and programmed from the surface using a microcomputer linked to the data logger through an RS232 interface. Maximum sampling rate of all channels is approximately 2 Hz, whereas U_y and U_w may be logged at rates up to 10.66 Hz. All channels may be monitored and displayed on the surface computer allowing the operator to control the experiment interactively. Bed shear stress is varied in time by varying the power supplied to the underwater motor up to 350 watts via a surface power supply. The data stored from each deployment may be downloaded remotely through the RS232 cable at the end of each experiment and the storage module re-initialized.

A window is located in the inner flume wall for purposes of observing and recording the mechanics of bed failure. A perspex wedge at the base of the window sections the sediment upon deployment. Thus the upper 20 mm of sediment and the lower 10 cm of the water column can be viewed in section. Visual observations are made using an Osprey underwater SIT black and white camera, displayed using a monitor. Light is provided by two 100 watt underwater lights powered from the surface. The housing has a lens that corrects for underwater geometric distortions and so is suitable for accurate image scaling. The camera lens is located approximately 20 mm from the window. Horizontal and vertical scale lines are present on the window and situated within the field of view. The camera images 30 frames/s. A co-axial cable connects the camera to a surface monitor for real-time detection. Video records are stored on a standard VHS video cassette recorder also at the surface. Sequential video images are digitized for particle trajectories at varying heights above the bed. From these, velocity profiles are constructed.

The root-mean-square value of the time and width averaged friction velocity ($\bar{U}_{*rms}$) is correlated with $\bar{U}_y$. The relationship of U_{*rms} and U_y is good, and takes the form:

$$\bar{U}_{*rms} = 0.0167 + 0.097\bar{U}_y \text{ (m/s; } r^2 = 0.96) \qquad (1)$$

Thus $\bar{U}_{*rms}$ is used as the standard hydrodynamic measure in this study. By manipulation of the quadratic stress law a drag coefficient (C_d) relating U_y and U_* is derived:

$$U_{*rms} = \sqrt{\tau/\rho} \quad (2)$$

$$\text{and } \tau = C_d \rho \bar{U}_y^2 \quad (3)$$

$$\text{thus } C_d = \tau/\rho\bar{U}_y^2 = \bar{U}_{*rms}{}^2/\bar{U}_y^2 \quad (4)$$

This results in a value of $C_d = 4.0 \times 10^{-2}$ and a corresponding C_{d100} of 1.3×10^{-3}. The latter coefficient falls within the range of values detected over flat bed in the field observations of Sternberg (1972).

Water samples were pumped at intervals from a port located in the side of Sea Carousel at a height of approximately 20 cm above the bed. These water samples were then filtered for total suspended particulate matter in order to calibrate the OBS sensors and to provide sample material of suspended material. A detailed description of the system is given in Amos *et al.* (in press) and results measured in the Bay of Fundy are presented in Amos *et al.* (in review).

5.1.2. SOBS

SOBS (Submersible Observatory of Benthic Stability) is a benthic tripod equipped with six Optical Backscatter Sensors (OBS's) that detect sediments in suspension (Figure 5.3). The sensors are arranged in a logarithmic progression from a height of 10 cm above the bed to 200 cm (item 6). Sensor 1 (10 cm) looks downwards and is designed to detect ripple mobilization and bedload transport. From it we can obtain the onset of bed motion. Sensors 2 - 6 are arranged to monitor in the horizontal at heights above the bed of 11 cm, 38 cm, 82 cm, 136 cm, and 200 cm respectively. Data from each sensor are logged on an underwater Tattletale at a rate of 1 Hz (item 5). At this rate, the instrument can collect data for 19.3 days before saturating memory. An underwater video camera (Sony V101, item 1) and Amphibico flood lights (item 2) are also located on the tripod. The camera can burst sample the bed at programmable intervals and durations. This is controlled by the underwater Tattletail. A scale is located in the field of view for reference (item 7). Finally, an InterOcean S4 current meter (item 3) is mounted on a independent frame to provide data on wave height, and mean currents. The current meter is programmed independently of the SOBS system. Power is provided by a submersible 12 v battery pack (item 4). The whole system is weighted at the feet for stability (items 8 and 9).

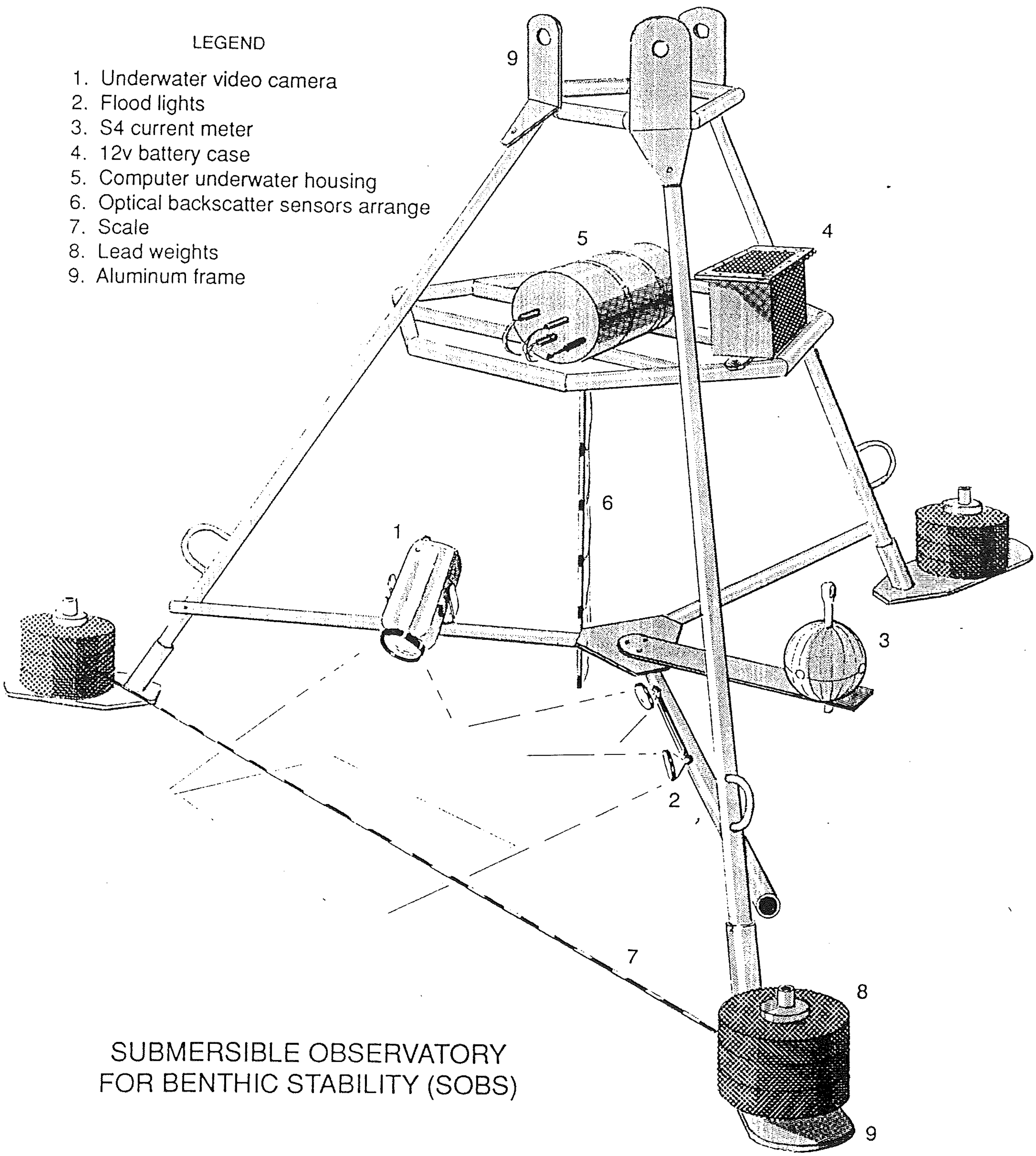

LEGEND
1. Underwater video camera
2. Flood lights
3. S4 current meter
4. 12v battery case
5. Computer underwater housing
6. Optical backscatter sensors arrange
7. Scale
8. Lead weights
9. Aluminum frame
9
5
4
6
1
3
2
7
8
9
SUBMERSIBLE OBSERVATORY
FOR BENTHIC STABILITY (SOBS)

Figure 5.3

The SOBS is normally deployed with a 50 m ground line, and is marked with a header float (Figure 5.4). The current meter frame is usually located at the end of the ground line, and is also marked with a header float.

5.1.3. Lancelot

Lancelot is a tethered or remotely-operated piezometric sensor system that is used to investigate *in situ* pore water pressure in a number of difficult geological environments. The tool can assess liquefaction conditions caused by dynamic build-up of pore water pressure, consolidation rates by evaluation of the penetration pressure decay curves, and the *in situ* steady-state pore pressure which governs the state of effective stress (Christian and Heffler, in review). Similar tools have been developed for deep-sea applications (Davis *et al.*, 1991; Schultheiss, 1990a, 1990b; and Bennett *et al.*, 1989, 1990).

Figure 5.5 illustrates the various components of the tool, consisting of an outer weight stand and cage containing the telescoping probe and electronics package. The outer weight stand is only used in deep-water deployments to assist penetration; a 2 m-wide base is substituted in shallow waters to provide resistance to overturning under storm conditions and to reduce vertical stress imposed on the seabed. The entire system in shallow-water mode only weighs 20 lbs submerged (vertical stress of 100 Pa, which is equivalent to a head of 1 cm of water). The device comprises a Tattletale 4 datalogger that can store data on differential and absolute pressure derived from transducers that sample at rates programmed by the operator. For example, it can store data at 4 samples per second continuously for 1.5 hours, or at varying rates in burst sample mode for more extended periods of time.

Christian *et al.* (in prep.) describe the device in detail in terms of its technical components. Lancelot measures vertical tilt in two directions (pitch and roll), vertical acceleration, absolute pressure (water depth), and differential pore pressure at the filter tip embedded beneath the seabed relative to the water column above. Electronic noise in the data acquisition package is extremely low being at the digital limit of 1 bit.

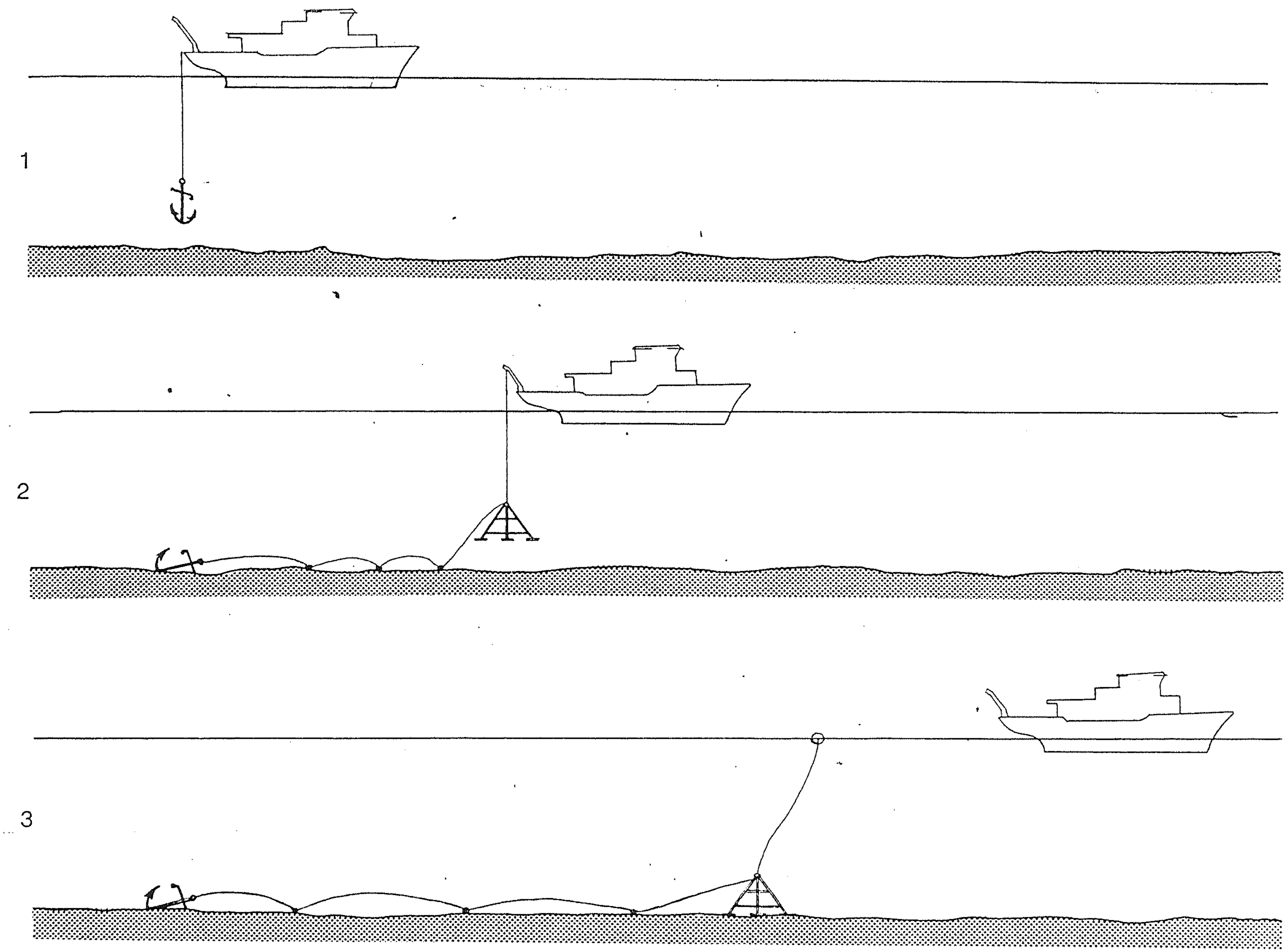


Figure 5.4

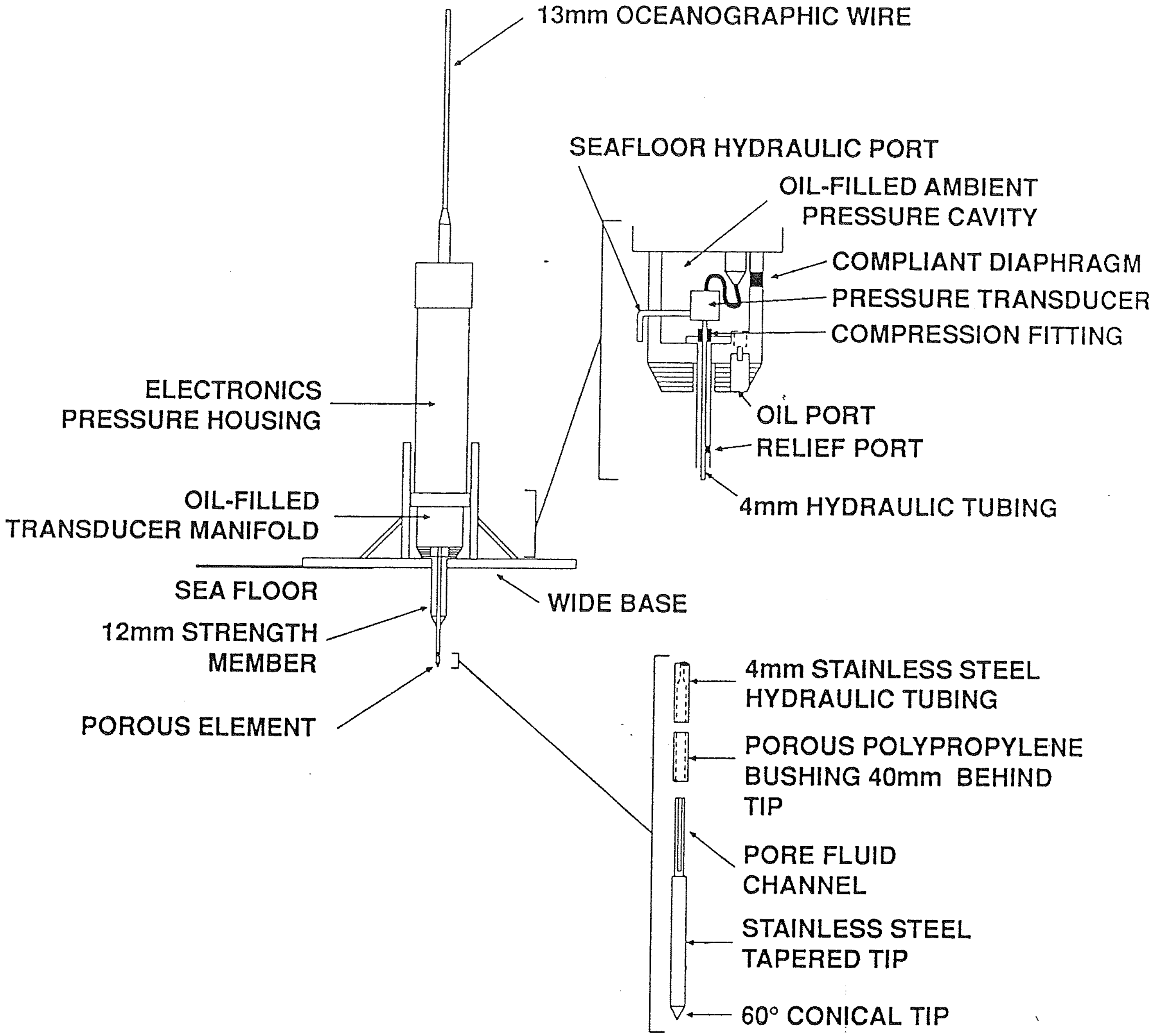


Figure 5.5. LANCELOT

5.2. RESULTS

5.2.1. Sea Carousel

5.2.1.1. Deployments

Sea Carousel was deployed successfully at 10 locations in the central Miramichi estuary. Four deployments were made on Dump site B; three on material dumped in 1990 (MIR7, MIR8, and MIR9), one on undisturbed material adjacent to the 1990 dump site (MIR11). Four deployments were made in the dredged navigation channel: 2 in the outer silty channel (Reach 22 near buoy 40; MIR13 and MIR14), and 2 in the clayey inner channel (Reach 20 near buoy 48; MIR18 and MIR19). Finally, 2 deployments were made on the control site north of the navigation channel (MIR15 and MIR16). The locations of the Sea Carousel sites are listed in Table 5.1.

5.2.1.2. Calibration

Approximately eight water samples were pumped during the course of each deployment. The times of pumping and the total suspended sediment concentration (dry weight) is given in Table 5.2. Suspended mass measured on the filtered samples were regressed against the OBS voltage readings to derive total suspended mass in the flume. Plots of the regression analysis for the dump site, the navigation channel, and the control site are shown respectively in Figures 5.6, 5.7, and 5.8.

The calibration functions so derived were as follows:

DUMP SITE $SSC(1) = 4.01(OBS1\ voltage) - 60;\ r = 0.95$ (5)

DUMP SITE $SSC(3) = 2.92(OBS3\ voltage) - 60;\ r = 0.93$ (5a)

CHANNEL $SSC(1) = 2.56(OBS1) + 0.0008(OBS1)^2 - 4.5e\text{-}7(OBS1)^3;\ r = 0.95$ (6)

CHANNEL $SSC(3) = 3.14(OBS3) - 0.0009(OBS3)^2 + 1.8e\text{-}7(OBS3)^3;\ r = 0.87$ (6a)

CONTROL SITE $SSC(1) = 1.88(OBS1) + 0.0023(OBS1)^2;\ r = 0.97$ (7)

CONTROL SITE $SSC(3) = 1.17(OBS3) + 0.0016(OBS3)^2;\ r = 0.95$ (7a)

Table 5.1. The location of Sea Carousel sites occupied in this study recorded using a Trimbell GPS navigation receiver.

STATION	LATITUDE	LONGITUDE
DUMP SITE B		
MIR7	47° 7' 12.8"	65° 11' 00.5"
MIR8	47° 7' 06.8"	65° 11' 07.5"
MIR9	47° 7' 07.1"	65° 11' 08.0"
PERIFERAL TO DUMP SITE B		
MIR11	47° 6' 59.4"	65° 11' 05.6"
OUTER CHANNEL		
MIR13	47° 7' 50.6"	65° 09' 57.5"
MIR14	47° 7' 55.2"	65° 10' 02.4"
INNER CHANNEL		
MIR18	47° 6' 41.6"	65° 15' 16.9"
MIR19	47° 6' 43.8"	65° 15' 10.6"
CONTROL SITE		
MIR15	47° 8' 21.5"	65° 09' 20.2"
MIR16	47° 8' 22.3"	65° 09' 19.1"

Table 5.2. The analyses of water samples pumped from the Sea Carousel during the course of the 10 deployments.

TIME (AST)	SSC (mg/L)	TIME (AST)	SSC (mg/L)	TIME (AST)	SSC (mg/L)
MIR7		MIR8		MIR9	
1203	16.5	1313	24.7	1527	24.4
1209	76.7	1323	82.0	1544	264.6
1219	90.9	1336	145.5	1600	388.8
1224	109.6	1338	152.0	1616	305.1
1233	138.8	1344	216.0	1625	246.9
1236	314.3	1354	111.4	1633	316.0
1247	168.6			1644	609.7
MIR11		MIR13		MIR14	
1749	63.5	1350	21.3	1439	53.5
1802	351.5	1352	478.5	1441	1444
1822	388.6	1355	590	1447	1967
1832	433.7	1358	1564	1452	2059
1840	637.1	1358B	1901	1458	2959
1854	1065.1	1403	2572	1503	2893
1903	1276.6	1403B	2920	1511	3376
1912	1285.1	1413	3044	1516	3320
				1522	3160
MIR15		MIR16		MIR18	
1627	40.0	1745	24.6	1111	11.3
1632	402.8	1747	17.7	1131	684.5
1637	378.0	1759	361.0	1135	1861
1639	927.5	1808	840.9	1146	4127
1644	1069	1814	926.9	1153	5269
1649	1414	1818	1003	1204	4413
1654	1760	1824	1130	1213	3559
1659	1411	1829	1019	1224	1982
1705	1251	1834	1225		
MIR19					
1242	753.5				
1253	3156				
1257	4564				
1302	5002				
1305	9192				
1316	3944				

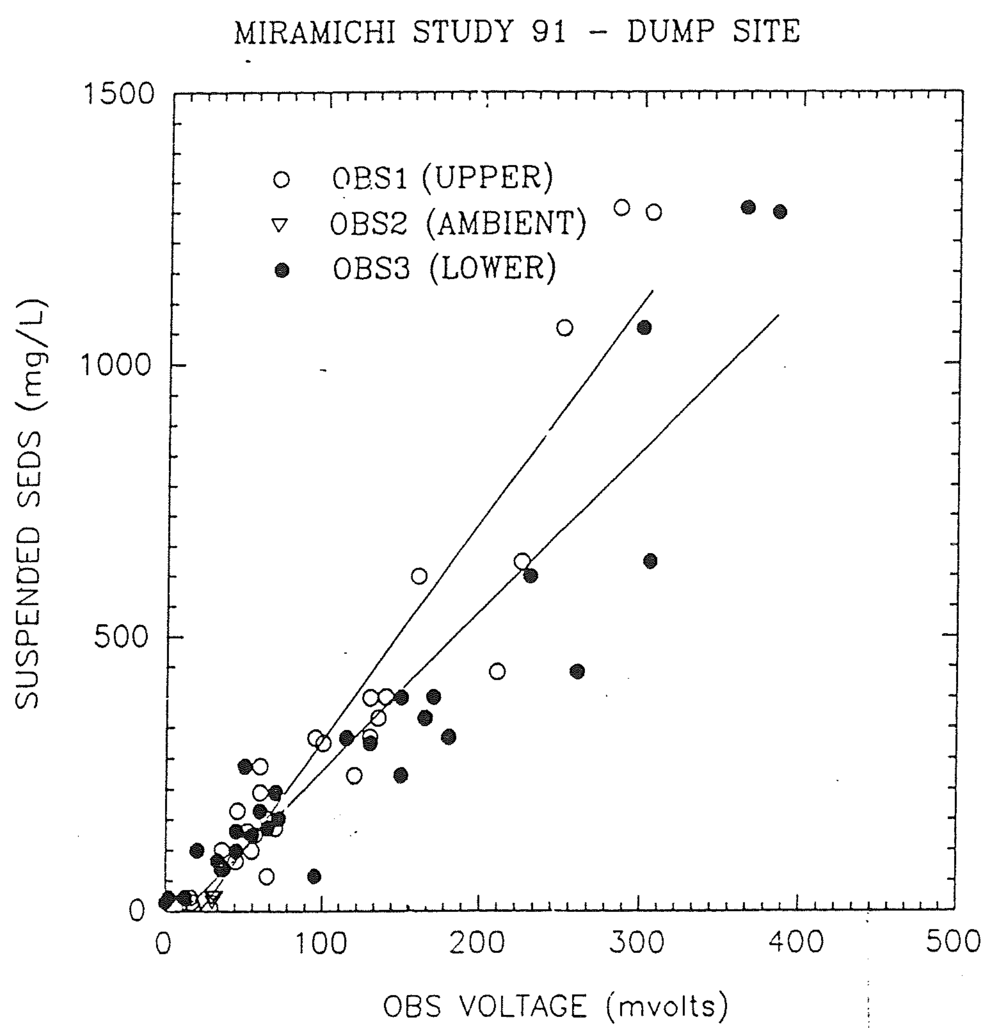


Figure 5.6. Calibration of OBS for Dump Site deployments.

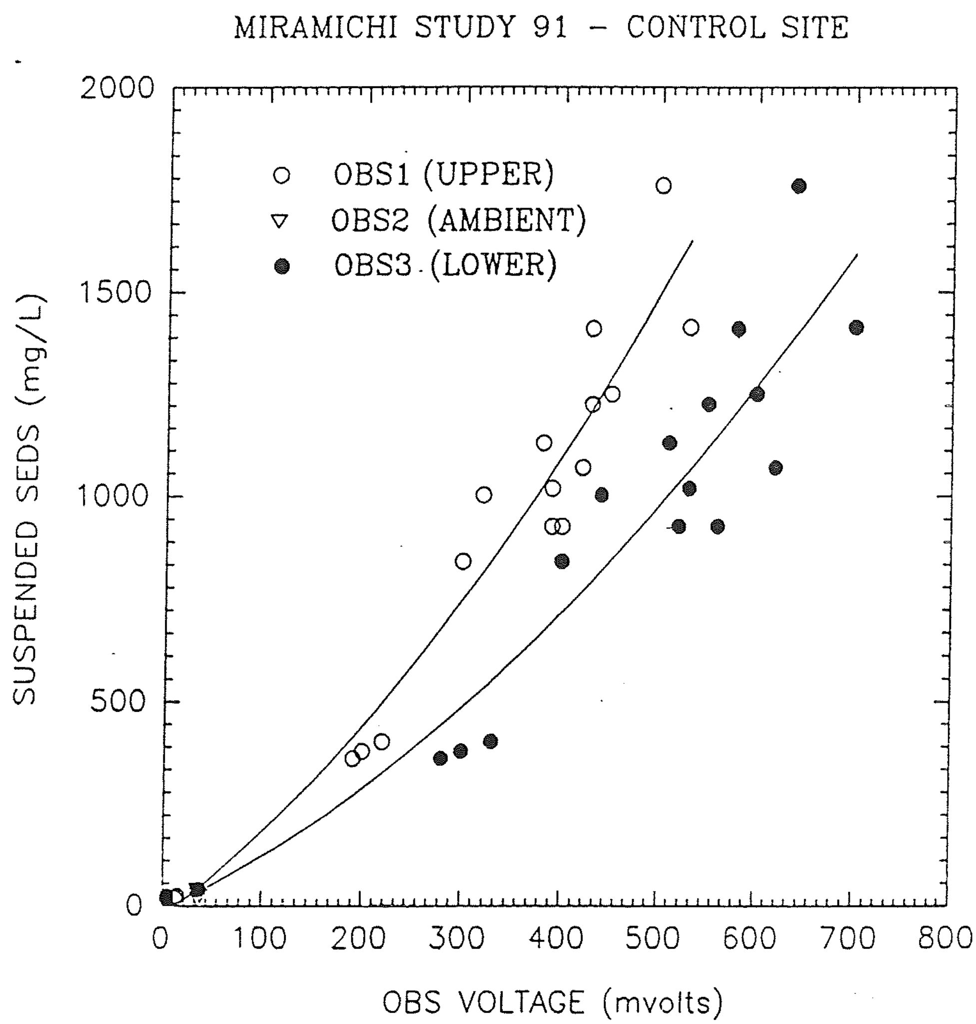


Figure 5.7. Calibration of OBS for Control Site deployments.

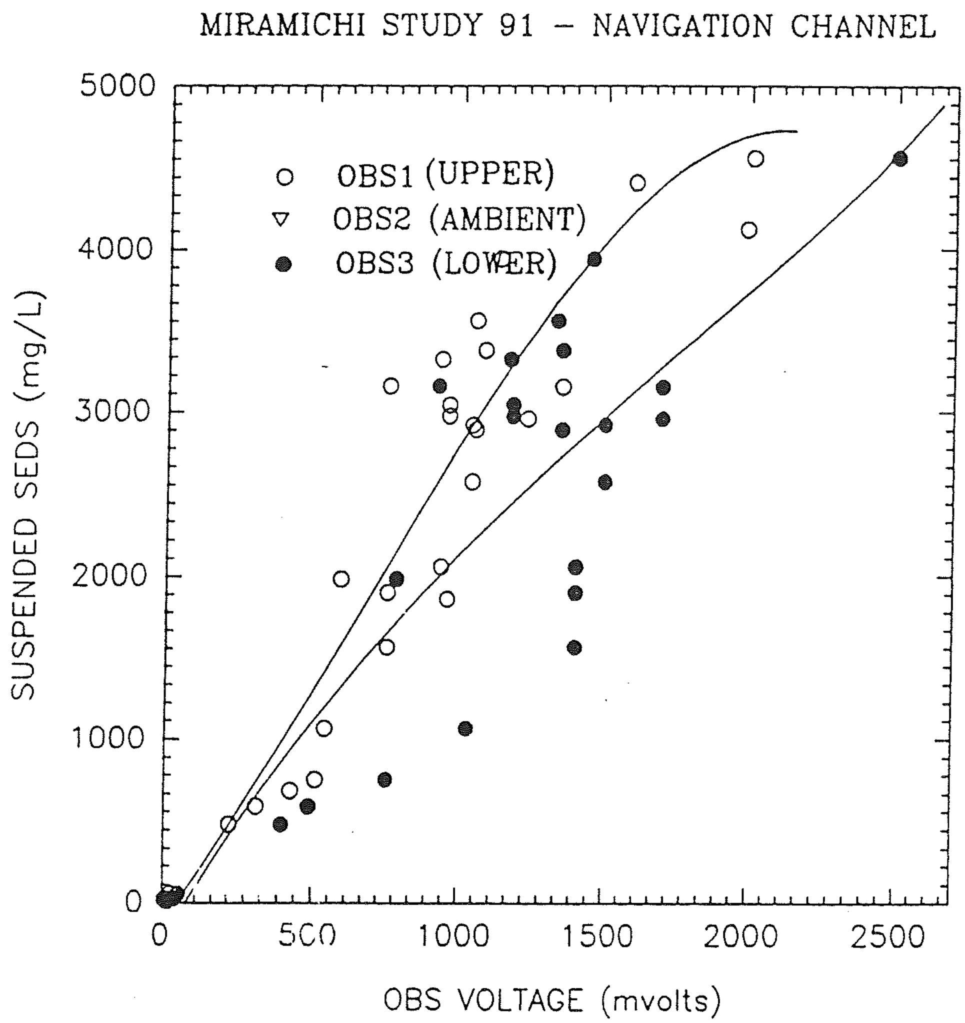


Figure 5.8. Calibration of OBS for channel deployments.

SSC(1) and SSC(3) refer to the suspended sediment concentration inside the annulus recorded by the upper and lower sensors respectively. OBS sensor 2 was situated outside the annulus and gave a measure of the ambient bottom water suspended concentration. Only one ambient water sample was collected during the course of each experiment.

5.2.1.3. Site Results

The results of the Sea Carousel deployments provide information on:

(1) the presence or absence of a fluid mud layer at the time of deployment (as seen on the video camera);

(2) cohesion (or resistance to erosion) of the existing surface of the seabed;

(3) the resistance of the seabed to scour to depths of approximately 5 cm below the seabed; and

(4) the density of the bed (through the internal friction angle), i.e., consolidated, unconsolidated, or gel states.

The stresses imposed on the bed are artificial, however, the bed responses are real and representative. We emphasize that to put these results into a long-term context specific to Miramichi we need to know the return interval of each imposed bed stress. This can only be derived from long-term measures of the wave and current conditions.

Three illustrations for each deployment site are given in the Appendix E. These are:

1. (A) the time series of azimuthal and vertical current speed induced in the flume (m/s); (B) the raw and cumulative suspended sediment concentration from the 3 OBS's (mg/L); and (C) the erosion rate (differential in sediment concentration in $kg/m^2/s$);

2. Results of the deployment shown on a Mohr-Coulomb plot (applied bed stress (Pa) versus effective stress (Pa)). The effective stress is proportional to depth in the sediment. The solid lines in the figures trace the failure envelope of the sediment with depth (i.e., increase in sediment shear strength). The slope of the line is the friction angle of the sediment and is a direct indicator of sediment density; and

3. The relationship of erosion rate to applied bed shear stress. This relationship is important to the prediction of bed stability.

5.2.1.3.1. Summary

The main parameters derived from this study are: cohesion or surface shear strength, also known as the critical shear stress for erosion; internal friction angle; density profile with depth; and erosion rate as a function of applied bed stress. Table 5.3 summarizes the results derived from the 10 deployments of Sea Carousel.

Good results were obtained from the 10 Sea Carousel deployment sites. Our tentative results show that the sediments at all sites were mobilized during the deployment of the Sea Carousel. The most stable sediments were found at dump site B (90). This is illustrated by the high friction angle (suggesting they are the most densified sediments measured), the highest critical shear stress for erosion, and the lowest erosion rates. We found no evidence at this site for the presence of a fluid mud layer.

5.2.1.3.2. Dump Site

Deployments MIR7, 8, and 9 were located on the 1990 dump site within dump site B. We found no evidence on the video for the existence of a fluid mud layer at these sites at the time of deployment. In all tests we detected a measurable cohesion of the seabed (0.7 - 1.5 Pa). Erosion rates were less than 1×10^{-3} kg/m^2/s and typically $2 - 3 \times 10^{-4}$ kg/m^2/s. The friction angle was high in all cases and showed a linear increase with depth in sediment shear strength. This suggests the sediment was consolidated and was not in a fluidized state. Erosion took place in Type II fashion (chronic erosion). That is, once failure occurred the erosion process continued as long as the applied stress continued. The highest erosion rates were associated with removal of the very surface layer. Beyond this, erosion rate showed a high degree of scatter when plotted against applied stress. An "eyeball" fit through the scatter suggests that erosion rate was independent of absolute applied bed stress. Further study to plot erosion as a function of excess bed shear stress (the incremental increase of the stress only) yielded no better fits.

MIR11 was located on the periphery of the 1990 dump site. It showed the lowest cohesion (0.4 Pa), and the highest erosion rates ($2 - 4 \times 10^{-3}$ kg/m^2/s) in this region. The erosion character was of Type II. The site was, therefore, the least stable seabed monitored in this region and would

Table 5.3. Summary of results from the 10 Sea Carousel sites reported in this study.

STATION	COHESION (Pa)	EROSION RATE (kg/m²/s)	APPARENT FRICTION ANGLE (degrees)
DUMP SITE B (90)			
MIR7	1.5	3.5×10^{-4}	60
MIR8	0.8	$2 - 3 \times 10^{-4}$	55
MIR9	0.7	1×10^{-3}	44(26)[1]
PERIFERAL TO DUMP SITE B (90)			
MIR11	0.4	1×10^{-3}	4 (NEAR FLUIDIZED BED)
OUTER CHANNEL (REACH 22)			
MIR13	0.5	2×10^{-3}	0 (FLUIDIZED BED)
MIR14	0.0	$2\text{-}4 \times 10^{-3}$	0 (FLUIDIZED BED)
INNER CHANNEL (REACH 20)			
MIR18	0.0	$2\text{-}3 \times 10^{-3}$	0 (FLUIDIZED BED)
MIR19	0.0	$3\text{-}5 \times 10^{-3}$	0 (FLUIDIZED BED)
CONTROL SITE			
MIR15	1.0	1×10^{-3}	3.6(22)
MIR16	0.0	1×10^{-3}	14

[1] The bracketed value in the friction angle column indicates a change in friction angle with depth in the sediment.

be subject to chronic erosion. The internal friction angle of 4^{o} was very close to a fluidized state, and suggested that this bed had not consolidated to the extent of the 1990 dump site material. Erosion rate versus bed shear stress showed a high degree of scatter and no relationship to applied bed stress.

5.2.1.3.3. Channel Sites

The outer channel (Reach 22) was surveyed during deployments MIR13 and 14. No evidence of a fluid mud layer was detected at either site on the video. Cohesion was virtually absent. That is, erosion began even at the lowest applied stresses. Erosion exhibited both Type I and Type II characteristics. Peaks in the erosion rate were up to 4×10^{-3} kg/m^2/s. These are amongst the highest measured in the entire survey. Failure took place by aggregate release from the bed rather than as discrete particles. These aggregates moved as saltation load along the bed whereupon corrasion disaggregated them. The disaggregated material thereafter moved in suspension. This impacts the choice of settling velocity that one uses in numerical prediction. Clearly a higher settling rate is required than is predicted by Stoke's settling of disaggregated particles. The Mohr-Coulomb plots indicated a friction angle of zero; i.e., the weight of the sediment was supported by the pore pressure and the bed was fluidized. Video observations showed, however, that the bed was not behaving as a viscous fluid (as might be supposed) but was exhibiting behavior diagnostic of a gel. This gel appeared to be held together by organic fibres within the sediment.

The inner channel (Reach 20) was surveyed during deployments MIR18 and 19. No evidence for a fluid mud layer was detected on the video at either of these sites. The seabed possessed no cohesion (resistance to erosion at low stresses), although the same gel-like qualities (as seen in the outer channel) of the bed were observed. The bed was characterized principally by Type II erosion. The greatest erosion rates were associated with the very surface sediments (0.1 kg/m^2/s). Beneath this layer erosion rate decreased to 2 - 5×10^{-3} kg/m^2/s. The erosion rate was independent of the applied bed shear stress. Again, the erosion process took place by releases of aggregates that moved in saltation along the bed without the development of a fluid mud layer.

5.2.1.3.4. Control Site

MIR15 and 16 were undertaken within the area of the control site. It was chosen to be representative of a natural seabed within the Miramichi estuary. No evidence for a fluid mud layer was detected at either site. A high degree of variability in cohesion (up to 1.0 Pa) was measured which in both cases was lower than that measured at dump site B (90). The erosion rate also showed a high degree of variability with depth and with applied stress. It appeared to increase with depth to a local maximum of 0.01 $kg/m^2/s$ and thereafter decreased to a constant value of 1×10^{-3} $kg/m^2/s$; this latter value was independent of applied bed shear stress. The friction angle was intermediate between those of the channel and those of the dump site, and reached a maximum value of 26°. Changes in friction angle with depth and between the two sites illustrated a complex bed microfabric and a complex depositional history for the area.

5.2.2. SOBS

5.2.2.1. Control Site

Deployed: 1135 AST, 5 November, 1991

Recovered: 1015 AST, 7 November, 1991

The video camera was set up to record for 10 seconds every 5 minutes. The OBS sensors were logged continuously at 1Hz. The S4 current meter logged two horizontal components of flow and water depth every 2 seconds at a height of 50 cm above the seabed.

The tripod and current meter were pulled over during the deployment of the system. Consequently, no meaningful data were recovered at this site. The camera system worked well but was pointing upwards and showed only the water column. The current meter experienced interference, presumably because some if its electrodes were in the sediment.

5.2.2.2. Dump Site

Deployed: 1235 AST, 7 November, 1991

Recovered: 1630 AST, 8 November, 1991

The video camera was set up to record for 10 seconds every 5 minutes. The OBS sensors were logged continuously at 1Hz. The S4 current meter logged two horizontal components of flow and water depth every 2 seconds at a height of 50 cm above the seabed.

Data from the SOBS system are inconclusive regarding whether or not the system operated correctly. As a result, they are not presented. The video camera unfortunately did not work. The current meter gave good results and the time series of the currents and water depth are shown in Figure 5.9. This Figure shows current speed, current direction, and water depth for the 28 hour deployment. Notice that the currents rarely exceed 0.2 m/s. Compare this to the erosion at Sea Carousel site MIR9. Notice that there is virtually no erosion at this velocity suggesting that under normal tidal conditions the dump site is stable. The peaks in current speed and the rotation of the current direction is not strongly linked to tidal elevation. Clearly, the currents in Miramichi bay are complex and not driven purely by the tides.

5.2.3. Lancelot

Lancelot calibration graphs are given in Appendix F; penetration records are also shown in Appendix F. Table 5.4 summarizes key deployment data for all Lancelot stations. Table 5.5 summarizes the interpretation of sediment type based upon the penetration pore pressure data. The general finding was that the seabed ranged from a fine sandy silt to silt with a trace of clay; several deployments indicated a bottom density ranging from very loose to medium-dense. Cobbles damaged the filter tip during several deployments, significantly altering penetration response but not the longer-term measurements.

5.2.3.1. Penetration Pore Pressures

Negative differential pore pressure spikes develop in dense, dilatant sediments subjected to rapidly-applied shearing stresses. This was found to occur in the early stages of all Miramichi Lancelot deployments, indicating that the seabed is generally composed of incompressible material with a low clay content.

The height of an initial positive differential pore pressure spike in loose (contractant) coarse-grained or soft fine-grained (cohesive) sediment is indicative of a threshold for liquefaction; note that this then corresponds to an undrained failure around the probe. Subsequently, the bed reconsolidates and differential pore pressure drops to the stable value, which may be in excess of the hydrostatic reference if the seabed is underconsolidated. The zero excess pore pressures recorded at sites LAN7 and LAN13 indicate the sediments to be in equilibrium over the long-term.

Table 5.6 summarizes the magnitude of the penetration pore pressure spike (du) and the inferred *in situ* undrained shear strength (S_u) at 50 cm below seabed (where applicable). S_u can be estimated from the height of the initial pore pressure spike according to Vesic (1972); also Bennett *et al.* (1985) and Esrig *et al.* (1977):

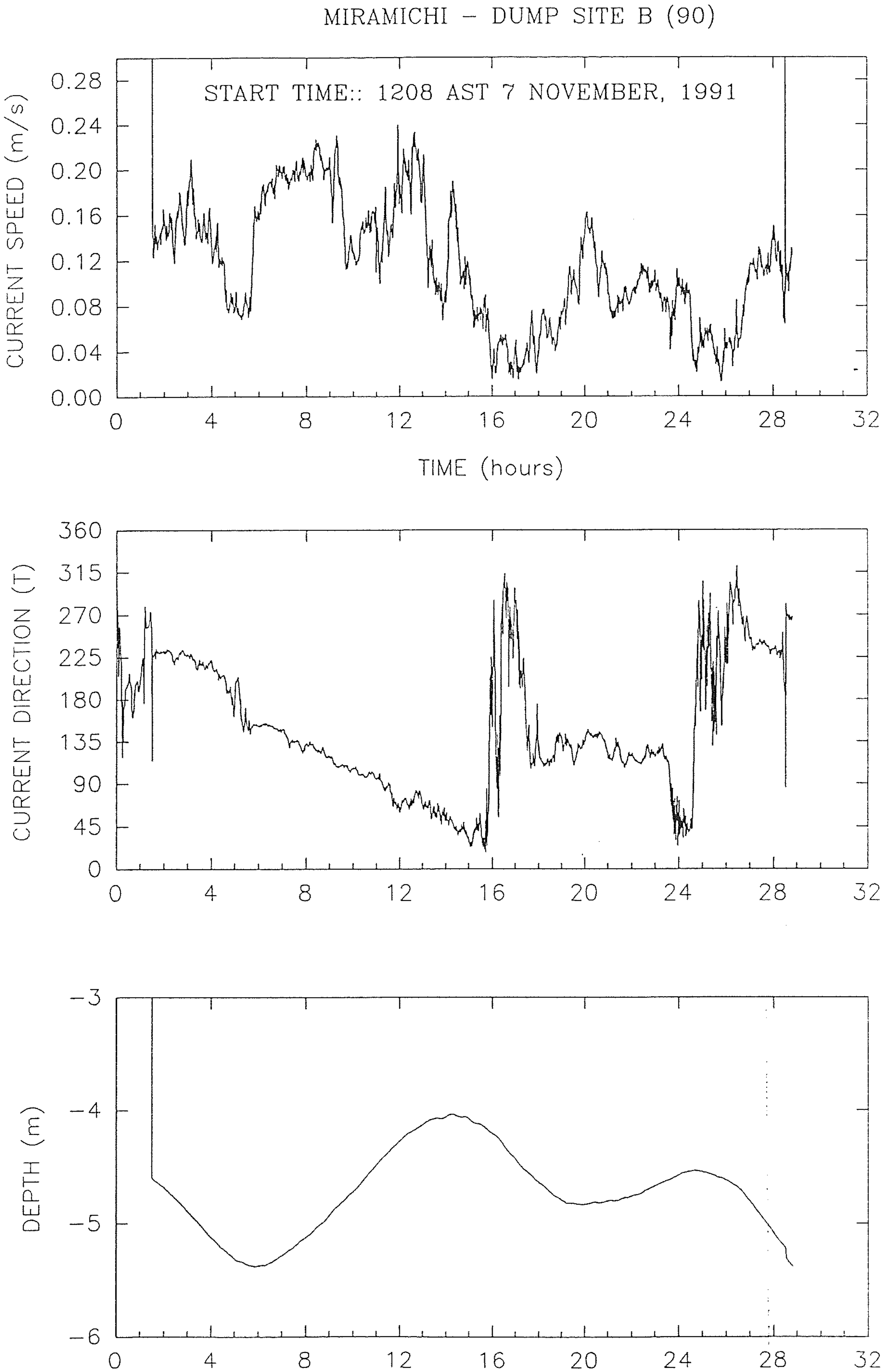


Figure 5.9. Time series of current speed, current direction and water depth at Dump Site.

Table 5.4. A summary of the deployments of Lancelot in this study.

STATION	START TIME	END TIME	SCANS/SECOND
LAN1	Nov. 5 11:58:02	Nov. 6 10:12:42	4
LAN7	Nov. 6 11:24:56	Nov. 6 13:49:37	2
LAN9	Nov. 6 15:14:53	Nov. 6 17:10:52	2
LAN10	Nov. 6 17:25:31	Nov. 7 11:07:24	4
LAN13	Nov. 7 13:28:00	Nov. 7 14:40:21	4
LAN15	Nov. 7 16:07:42	Nov. 7 17:36:00	2
LAN17	Nov. 7 19:38:17	Nov. 8 14:07:10	4
LAN20	Nov. 8 14:59:13	Nov. 8 16:47:02	2

Table 5.5. A summary of inferred sediment types based upon the Lancelot data.

STATION	SEDIMENT TYPE (inferred)	SEABED DENSITY (inferred)	EXCESS PORE PRESSURE
CONTROL SITE			
LAN1	Silt	Medium Dense	1 cm
LAN15	Silt, some clay	Very Loose	3 cm
DUMP SITE B			
LAN7	Silty Sand	Loose	0
LAN9	Silty Sand, some Clay	Loose	2 cm
LAN10	Silty Sand, with Clay	Loose	2 cm
OUTER CHANNEL (REACH 22)			
LAN13	Fine Sand, some Silt	Medium Dense	0
INNER CHANNEL (REACH 20)			
LAN17	Silt	Very Loose	1 cm
LAN20	Silt	Medium Dense	1 cm

Table 5.6. Estimates of undrained strength based upon Lancelot data recorded in this study.

STATION	TIDAL STAGE	du cm	S_u kPa	P_v' kPa	SITE
LAN1	flood/ebb	(-)[1]	NA	NA	CONTROL
LAN7	flood	3.6	1.59	6.36	DUMP SITE B
LAN9	Turning	(-)	NA	NA	DUMP SITE B
LAN10	ebb	5.0	2.21	8.84	DUMP SITE B
LAN13	flood	(-)	NA	NA	OUTER CHANNEL (REACH 22)
LAN15	Unknown	9.6	4.24	16.96	CONTROL
LAN17	ebb/flood	5.0	2.21	8.84	INNER CHANNEL (REACH 20)
LAN20	flood	(-)	NA	NA	INNER CHANNEL (REACH 20)

[1] Negative values of excess pore pressure were observed during penetration. Therefore no strength interpretations were done.

$$S_u = F\ du \quad (8)$$

where F is a coefficient varying between 3 and 6, depending on plasticity. For the silty sediments encountered in this study, a mean value of 4.5 was adopted. For almost the entire study, surface wave activity was minimal to non-existent. Stresses and pressures are therefore expressed in this report as equivalent heads of water for comparison to surface wave height as follows:

$$du_{eq} = 100\ du / 9.81 \quad (9)$$

where du is a pressure in kPa and du_{eq} is the same pressure expressed in cm of head. So equation (8) becomes

$$S_u = 0.44145\ du \quad (10)$$

Skempton (1970) observed that undrained shear strength in a fully consolidated soil deposit was governed by the effective stress (P') where

$$P' = 4\ S_u \quad (11)$$

In situ effective vertical stress is also calculated directly from the saturated bulk density (ρ_s), the density of seawater (ρ_{sw}), the gravitational constant (g) and the burial depth (Z) according to Terzaghi and Peck (1967) where

$$P_v' = (\rho_s - \rho_{sw})\ g\ Z - u_e \quad (12)$$

where u_e is the excess pore pressure, which is zero for an equilibrium condition. Then, by rearranging equation (12)

$$\rho_s = (P_v' + u_e) / (g\ Z) + \rho_{sw} \quad (13)$$

Equation (11) can be used to estimate the vertical effective stress from the penetration record of LANCELOT, which can then be compared to the fully consolidated estimate produced from bulk density measurements, or alternatively, equation (13) can be used to predict the *in situ* density, which can then be compared to measured density data.

Note that LAN1, LAN10 and LAN17 were overnight deployments and were sampled in burst mode. The effective stress was calculated from equation (12), ranging between 0.5 and 3 kPa for a point 50 cm below the mudline and densities varying from 1.1 to 1.6 g/cm^3. Effective stress estimates calculated using equation (11) are listed in Table 6 along with the Lancelot shear strength and pore pressure data used. P_v' is overestimated by this approach by about a factor of 4, probably indicating that penetration was not entirely undrained, hence the empirical correlation developed for clays (equation 8) is not directly applicable for the silty sediments encountered in the Miramichi. For this reason, estimates of bulk density using equation (13) are unreliable for these sediments.

5.2.3.2. Wave Loading and Liquefaction

Lancelot has the capability of resolving excess or differential pore pressure within the seabed to within 1 mm of head over a total range of 4 m. The capability to measure surface wave height on the absolute pressure transducer is not as high, being 2.2 cm over a total range of 25 m.

Small surface waves overnight at the LAN10 site did not register on the absolute pressure channel, therefore they were attenuated, and therefore very small. However, a differential pore pressure within the seabed was set up that oscillated about the long-term value of 2 cm (from 1 to 3 cm). Wave period was about 2.5 seconds, which is in the right range for small surface waves. This oscillation would eventually lead to liquefaction if it were to reach a critical value wherein the pore pressure momentarily supported the buoyant weight of the sediment column above the point of measurement (-50 cm), in the manner described by Clukey *et al.* (1985). The point of liquefaction can be assumed to be roughly equivalent to du, which was 5 cm for LAN10. The inference from this observation is that the bed was nearly liquefied by a small surface wave. One could imagine the effect that large waves would have, as often develop during storms. The net result would be widespread liquefaction during the storm event.

LAN17 produced a dataset that was also remarkable in that the liquefaction threshold was about 3.5 cm, with a very rapid dissipation stage after penetration. This indicated a very loose deposit, probably composed of silt (at 50 cm burial). Long-period seiche waves (again less than 2 cm in surface amplitude) or infra-gravity waves developed during the overnight burst sampling, perhaps in response to the incoming tide. The internal wave amplitude was very low, about 4 mm with a period of 1.7 minutes. The long-term differential pore pressure du was negative, indicating that the seabed was dilating (expanding) in response to a shearing stress, much in the same way as it does when it is dense and incompressible yet must deform around a penetrating probe. The seabed in essence "stiffened" during this loading event.

5.2.3.3. Discussion

The direction and magnitude of the pore pressure differential spike upon insertion gave information on the "state" of the seabed over the depth of penetration. The data for the Miramichi Bay indicated that in general, sediments were very loose to loose; several locations were more dense. Density plays an important role in determining how a sedimentary deposit will behave under cyclic loading; dense sediments dilate or expand, creating negative pore pressures which increase the effective stress; hence they become stronger until the loss of interlocking (failure) strength. Loose deposits contract during shear, resulting in residual excess pore pressure which needs time to dissipate; these deposits therefore experience a reduction in effective stress and become weaker during loading.

Accurate measurements of density are extremely difficult in coarse-grained sediments, which unfortunately remould very easily when sampled, even using the best-available techniques. Indirect penetration techniques minimize sampling disturbance by sensing the response of the sediment ahead of and around a probe as it goes into the undisturbed deposit. Efforts are ongoing to correlate penetration data with sediment density and grain size.

With soft cohesive or loose cohesionless deposits it is possible to estimate the undrained shear strength at failure as previously discussed, and therefore place a limit on the threshold for liquefaction. Cyclic loading of the seabed by waves can lead to liquefaction and loss of integrity if the sediment is unable to dissipate excess pore pressures rapidly enough. Lancelot is useful in detecting the threshold for liquefaction, as well as monitoring the buildup of excess pore pressures during various loading events. The rate of decay of penetration pore pressure can be used in a quantitative way to calculate the time-rate of consolidation which can then be used to determine the capacity to dissipate pore pressures developed under cyclic loading.

The long-term differential pore pressure allows an interpretation of the time-dependent state of consolidation of a sediment deposit, wherein a fully consolidated package will be at equilibrium; an underconsolidated deposit will show some residual pore pressure still to be dissipated.

Post-liquefied sediment shearing resistance is governed by residual parameters since particle interlocking has been removed; mobility is greatly enhanced and flowslides will occur at slope angles in excess of the residual friction angle. Detailed laboratory analyses can provide this type of information, but are beyond the scope of this study at present.

From the field results obtained with Sea Carousel and from laboratory consolidation and classification testing, it now appears unlikely that the sampled sites as they presently exist in this study could ever exist as dense mud suspensions except for very short periods of time; plasticity behavior and therefore rheology is unimportant and is due only to the unoxidized high organic carbon content within the sediment. In any case, the suspended material remains a sandy silt or a silty sand and there is no evidence to support the existence of clay-dominated behavior within the studied areas.

6. RECOMMENDATIONS FOR FURTHER STUDY

Because of time and funding constraints, this project was carried out over a short time period and at a limited number of sites and represents an initial "scoping" step toward providing the specific information required by authorities responsible for management of the dredging programme. Although considerable information was obtained, a more extensive programme is required to further validate and amplify the results obtained, particularly with regard to the characteristics and fate of recently deposited sediments. The following are recommendations for future study:

(1) This study of dump site B (90) was undertaken one year after dumping took place. Consolidation of this material has clearly taken place. In order to put our results into context a laboratory study of consolidation rates of dump material is necessary.

(2) We measured the stability of dump site B, but only the 1990 dumped material. In view of the complexity of dumping and the variety of dumped material it would be wise to monitor other dumps within dump site B.

(3) Variability of the natural seabed was high. Unfortunately, we base this on only two stations. Tentatively, the natural bed appears less stable than does the dump site. Approximately 5 - 10 more stations would be valuable to define more conclusively the natural bed stability, and to show more clearly the relative stability between dumped and natural material.

(4) We could not find any evidence of fluid muds anywhere in the estuary. The fluid state may well occur under severe storms, under dredging of channel material, or during the passage of a ship. The conditions under which a fluid mud might develop are presently unknown but are suspected at very high concentrations (>40 g/l) and in the presence of high amounts of organic matter. We recommend the deployment of SOBS near the channel for up to one month and possibly to coincide with dredging, in order to evaluate the potential for fluid mud generation. Even when fluidized, the bed does not behave as a viscous fluid, but possesses elastic properties that suppress the resuspension process. Are these properties typical of all parts of the channel, what causes it, and what bed stresses overcome it if any ?

(5) We recommend both SOBS and Sea Carousel deployments during a period of dumping of dredged material in order to detect the level of suspended solids in the water column. Do fluid muds develop during the dumping process, and if so, how persistent are they ?

(6) In order to put our results into a long-term context, percentage exceedence plots of wave climate and current speed should be compiled. From these percentage exceedence plots, long-term bed stability can be defined.

(7) Lancelot has been used in shallow-water mode to successfully monitor cyclic loading events in the Miramichi estuary; preliminary findings are that the seabed is easily liquefied. Penetration pore pressure responses suggest a very loose, variable silty seabed at depth. Undrained strengths are very low, estimated at less than 5 kPa at 50 cm depth. No natural liquefaction events were detected during the study period, but low-level differential pore pressures developed during two deployments due to minor wave loading events. Surface wave activity was small to non-existent overall. Future studies should involve longer-term deployments of Lancelot to capture the seabed response under transient loading generated by storms and ship passage, particularly adjacent to the channel. This will require upgrading of the memory capacity to 20 mbytes, but will allow for 28-day deployments with continuous sampling at a rate of 2 scans per second.

(8) Stability analyses of the seabed adjacent to the ship channel should be carried out as part of a future study to assess the potential for chronic failure under larger wave loading events.

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APPENDIX A

CRUISE LOG

Cruise Log

Miramichi Sediment Stability Study
Acadia Centre for Estuarine Research

November 5-8, 1991

Date	Time	Operation	Sample No.	Depth	Position (GPS)	
Nov. 5	0740	Depart Mill Brook Wharf	-	-	-	-
"	0850	Approach Channel Buoy M40	-	-	47 04 30.8N	65 10 48.3W
"	0905	Arrive Control Site; Establish Station 1	-	17'	47 08 33.8N	65 09 46.5W
"	0945	VanVeen Grab Sample	-	-	-	-
		Bulk Sediment	VV1	-	-	-
		Organic Content	OC1	-	-	-
		Consolidation	CON1	-	-	-
"	1005	Gravity Core Sample	GC1	17'	47 08.18N*	65 09.14W*
"	1029	Ekman Grab Sample	-	17'	47 08.20N*	65 09.14W*
		Dissolved Carbohydrate	DCHO1A	-	-	-
		Chlorophyll a	CHL1A	-	-	-
		Macrofauna	BIO1A	-	-	-
"	1135	Deploy SOBS/S4	-	17'	47 08.22N*	65 09 16W*
"	1150	Abort SOBS Deployment (anchor	-	-	-	-
		caught in ground line)	-	-	-	-
"	1145	Deploy SOBS/S4	-	17'	47 08.22N*	65 09.17W*
"	1200	Deploy Lancelot	-	17'	47 08 18.2N	65 09 15.9W

*LORAN Positions (GPS not available)

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	1300	Deploy Sea Carousel	-	24'	47 08.19N	65 09.26W
"	1300	CTD Deployment	CTD1A	-	-	-
"	1330	Sea Carousel Deployment Terminated (Power shut-down)	SC1A	-	-	-
"	1355	Sea Carousel Redeployed	-	25'	47 08 25.5N	65 09 90.2W
"	1400	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCHO1B	-	-	-
		Chlorophyll a	CHL1B	-	-	-
		Macrofauna	BIO1B	-	-	-
"	1520	Sea Carousel Deployment Terminated Successfully	SC1	-	-	-
"	1630	CTD Deployment	CTD1B	-	-	-
"	1640	Sea Carousel Deployed	-	25'	47 08 25.5N	65 09 90.2W
"	1650	Sea Carousel Deployment Terminated (Camera light malfunction)	-	-	-	-
"	1705	Sea Carousel Redeployed	-	24'	47 08 25.5N	65 09 90.2W
"	1820	Sea Carousel Deployment Terminated Successfully (But video malfunction)	SC2	-	-	-
Nov. 6	0740	Depart Mill Brook Wharf	-	-	-	-
"	0855	Gravity Core Collected @ Station 3 (DRW Site # 4)	GC3	15.0	47 05 58.1N	65 15 21.6W

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	0905	Gravity Core Collected @ Station 4 (DPW Site # 7)	GC4	16.0	47 05 59.6N	65 13 53.4W
"	0917	Gravity Core Collected @ Station 5 (DPW Site # 6)	GC5	24.0	47 06 53.7N	65 13 49.1W
"	0950	Retrieve Lancelot From Station 1	LAN1	-	-	-
"	1035	Gravity Core Collected @ Station 6 (DPW Site # D13)	GC6	18.0	47 06 59.3N	65 11 04.9W
"	1040	Arrive 1990 Dump Site - Establish Station 7	-	18.0	47 07 00.1N	65 11 01.1W
"	1044	VanVeen Grab Sample	-	18.0	47 07 00.1N	65 11 01.1W
		Bulk Sediment	VV7	-	-	-
		Organic Content	OM7	-	-	-
		Consolidation	CON7	-	-	-
"	1059	Gravity Core Sample	GC7	18'	47 07 00.1N	65 11 01.1W
"	1125	Deploy Lancelot	-	18'	47 07 04.0N	65 11 07.7W
"	1135	Lancelot Deployment Aborted	-	-	-	-
		(ground line caught in anchor line)	-	-	-	-
"	1148	Redeploy Lancelot	-	18'	47 07 11.6N	65 11 02.4W
"	1201	Sea Carousel Deployed	-	18'	47 07 12.8N	65 11 00.5W
"	1210	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCH07	-	-	-
		Chlorophyll a	CHL7	-	-	-
		Macrofauna	BIO7	-	-	-

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	1250	Sea Carousel Deployment Terminated	SC7	-	-	-
"	1312	Sea Carousel Deployed	-	19'	47 07 08.8N	65 11 07.5W
"	1350	CTD Deployment	CTD7	-	-	-
"	1400	Sea Carousel Deployment Terminated	SC8	-	-	-
"	1425	Lancelot Retrieved	LAN7	-	-	-
"	1436	VanVeen Grab Sample	-	20'	47 07 09.3N	65 11 04.0W
		Bulk Sediment	VV9	-	-	-
		Organic Content	OC9	-	-	-
		Consolidation	CON9	-	-	-
"	1447	Collect Gravity Core	GC9A	20'	47 07 07.6N	65 11 06.9W
"	1450	Collect Gravity Core	GC9B	20'	47 07 07.3N	65 11 06.9W
"	1514	Lancelot Deployed	-	20'	47 07 07.1N	65 11 08.0W
"	1535	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCH09	-	-	-
		Chlorophyll a	CHL9	-	-	-
		Macrofauna	BIO9	-	-	-
"	1537	Deploy Sea Carousel	-	20'	47 07 07.1N	65 11 04.6W
"	1615	CTD Deployment	CTD9	-	-	-
"	1654	Sea Carousel Deployment Terminated	SC9	-	-	-
"	1705	Lancelot Retrieved	LAN9	-	-	-
"	1720	VanVeen Grab Sample	-	21'	47 07 06.9N	65 11 07.4W
		Bulk Sediment	VV10	-	-	-
		Organic Content	OC10	-	-	-
		Consolidation	CON10	-	-	-

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	1725	Lancelot Deployed	-	21'	47 07 10.1N	65 11 05.5W
"	1744	Establish Station 11 (drifted from Station 10)	-	21'	47 07 00.3N	65 11 03.0W
"	1748	Deployment of Sea Carousel	-	21'	47 06 59.5N	65 11 05.8W
"	1812	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate Sample	DCHO11	-	-	-
		Chlorophyll a Sample	CHL11	-	-	-
		Macrofauna Sample	BIO11	-	-	-
"	1820	CTD Deployment	CTD11	-	-	-
"	1925	Sea Carousel Deployment Terminated	SC11	-	-	-
"	1935	Depart for Mill Brook Wharf	-	-	-	-
Nov. 7	0840	Depart Mill Brook Wharf	-	-	-	-
"	1000	Arrive Control Site	-	-	-	-
"	1025	Retrieve SOBS/S4	SOBS1	-	-	-
"	1026	Depart for Dump Site	-	-	-	-
"	1058	Recover Lancelot	LAN10	-	-	-
"	1235	Deploy SOBS/S4	-	18'	47 06 58.9N	65 11 06.3W
"	1257	VanVeen Grab Sample	-	31'	47 07 40.7N	65 10 08.1W
		Bulk Sediment	VV13	-	-	-
		Organic Content	OC13	-	-	-
		Consolidation	CON13	-	-	-
"	1307	Gravity Core Sample	GC13	35'	47 07 40.7N	65 10 08.1W
"	1330	Deploy Lancelot	-	35'	47 07 40.7N	65 09 48.7W

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	1346	Sea Carousel Deployment	-	35'	47 07 50.6N	65 09 57.5W
"	1350	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCHO13	-	-	-
		Chlorophyll a	CHL13	-	-	-
		Macrofauna	BIO13	-	-	-
"	1415	Sea Carousel Deployment Terminated	SC13	-	-	-
"	1415	CTD Deployment	CTD13	-	-	-
"	1437	Sea Carousel Deployment	-	36'	47 07 55.1N	65 10 02.7W
"	1445	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate Sample	DCH014	-	-	-
		Chlorophyll a	CHL14	-	-	-
		Macrofauna	BIO14	-	-	-
		Organic Content	OC14	-	-	-
"	1526	Sea Carousel Deployment Terminated	SC14	-	-	-
"	1550	Lancelot Recovered	LAN13	-	-	-
"	1607	Lancelot Deployed	-	25'	47 08 22.3N	65 09 20.0W
"	1623	Sea Carousel Deployment	-	25'	47 08 21.5N	65 09 20.2W
"	1640	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCH015	-	-	-
		Chlorophyll a	CHL15	-	-	-
		Macrofauna	BIO15	-	-	-
		Organic Content	OC15	-	-	-
"	1705	Sea Carousel Deployment Terminated	SC15	-	-	-
"	1730	Lancelot Recovered	LAN15	-	-	-

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
"	1745	Sea Carousel Deployment	-	25'	47 08 22.3N	65 09 19.1W
"	1800	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCHO16	-	-	-
		Chlorophyll a	CHL16	-	-	-
		Macrofauna	BIO16	-	-	-
		Organic Content	OC16	-	-	-
"	1846	Sea Carousel Deployment Terminated	SC16	-	-	-
"	1940	Lancelot Deployed (Channel edge near M49 Buoy)	-	30'	47 06 33.1N	65 15 40.8W
Nov. 8	0915	Depart Mill Brook Wharf	-	-	-	-
"	1014	Arrive Channel Site (@ M49 Buoy)	-	-	-	-
"	1050	VanVeen Grab Sample	-	34'	47 06 30.2N	65 15 29.4W
		Bulk Sediment	VV18	-	-	-
		Organic Content	OC18	-	-	-
		Consolidation	CON18	-	-	-
"	1056	Gravity Core Sample	GC18	35'	47 06 41.5N	65 15 17.7W
"	1107	Sea Carousel Deployment	-	35'	47 06 41.0N	65 15 15.9W
"	1115	Sea Carousel Deployment Terminated (Problem with cable tension)	-	-	-	-
"	1123	Sea Carousel Redeployed	-	36'	47 06 42.0N	65 15 15.9W
"	1130	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCHO18	-	-	-
		Chlorophyll a	CHL18	-	-	-

DATE	TIME	OPERATION	SAMPLE NO.	DEPTH	POSITION (GPS)	
		Macrofauna	BIO18	-	-	-
"	1150	CTD Deployment	CTD18	-	-	-
"	1231	Sea Carousel Deployment Terminated	SC18	-	-	-
"	1240	Sea Carousel Deployed	-	33'	47 06 43.8N	65 15 10.6W
"	1245	Ekman Grab Sample	-	-	-	-
		Dissolved Carbohydrate	DCHO19	-	-	-
		Chlorophyll a	CHL19	-	-	-
		Macrofauna	BIO19	-	-	-
		Organic Content	OC19	-	-	-
"	1337	Sea Carousel Deployment Terminated	SC19	-	-	-
"	1405	Lancelot Recovered	LAN17	-	-	-
"	1500	Lancelot Deployed	-	34'	47 06 39.0N	65 15 19.0W
"	1615	SOBS/S4 Recovered from Station 12	SOBS12	-	-	-
"	1645	Retrieve Lancelot	LAN20	-	-	-
"	1650	Depart for Mill Brook Wharf	-	-	-	-

APPENDIX B

TABULAR SUMMARY OF SEDIMENT INDEX PROPERTIES

NOTE: SAMPLES COVER 2 cm DEPTH RANGE

MOISTURE CONTENT

JOB No. MIRAMICHI 1991

DATE 6·2·92

Boring No.	Sample No.	Depth (m)	Description	Tare No.	Wet Wt. + tare (gm)	Dry Wt. + tare (gm)	UNIT VOL. (cm³)	Tare Wt. (gm)	Bulk Density (gm/cm³)	W %
GC-1	—	0.02	8.58 sed on lid	136	62.343	56.344	8.58	52.026	1.202	139
"	—	0.07	" "	157	61.903	55.132	"	50.552	1.323	148
"	—	0.12	"	123	64.110	57.434	"	52.718	1.328	142
"	—	0.17	"	140	61.535	54.329	"	50.817	1.249	205
"	—	0.22	"	36	61.343	54.035	"	50.490	1.265	206
"	—	0.27	"	101	62.780	55.952	"	51.163	1.354	142
"	—	0.32	"	162	63.143	56.515	"	51.060	1.408	122
"	—	0.37	"	111	62.109	55.527	"	49.965	1.415	118
"	—	0.42	"	160	63.059	56.860	"	50.151	1.504	92
"	—	0.47	"	149	63.426	56.901	"	51.190	1.426	114
"	—	0.52	NA wc only NA	127	66.273	59.132	"	52.296	—	104
GC-7	—	0.02	8.58	143	64.135	57.783	"	51.848	1.432	107
"	—	0.07	" sed on lid	156	64.950	58.812	"	52.314	1.473	94
"	—	0.12	"	153	64.557	58.466	"	51.841	1.482	92
GC-9A	—	0.02	" sed on lid	115	61.808	54.467	"	51.057	1.253	215
"	—	0.07	"	108	61.878	55.117	"	50.397	1.338	143
"	—	0.12	"	104	63.558	57.513	"	50.736	1.494	89
"	—	0.17	"	117	63.682	57.839	"	51.219	1.452	88
"	—	0.21	"	134	65.889	60.877	"	52.035	1.615	57
GC-9B	—	0.02	"	155	60.117	54.060	"	51.182	1.041	210
"	—	0.07	"	132	63.899	57.521	"	52.156	1.369	119
"	—	0.12	"	147	62.896	56.590	"	50.451	1.450	103
"	—	0.17	"	138	63.249	56.766	"	51.023	1.425	113
GC-13	—	0.02	"	150	62.572	55.206	"	51.959	1.237	227
"	—	0.07	"	161	62.522	55.663	"	51.144	1.326	152
"	—	0.12	"	159	64.069	57.907	"	51.279	1.372	93
"	—	0.17	"	129	63.050	56.670	"	50.623	1.448	105
"	—	0.22	"	107	63.569	57.602	"	50.397	1.535	83
"	—	0.27	" sed on lid	163	63.885	58.168	"	50.310	1.582	73
"	—	0.32	"	105	63.479	57.619	"	50.102	1.559	78
"	—	0.37	"	12	63.584	57.695	"	50.292	1.549	79
"	—	0.42	"	135	63.427	57.557	"	50.080	1.555	79
"	—	0.47	"	103	64.708	58.978	"	51.220	1.572	74

MOISTURE CONTENT

JOB No. MIRAMICHI 1991

DATE 6·2·92

Boring No.	Sample No.	Depth (m)	Description	Tare No.	Wet Wt. + tare (gm)	Dry Wt. + tare (gm)	Weight Water (gm)	Tare Wt. (gm)	Wt. Dry Soil (gm)	W %
GC-18	—	0.02	8.58	144	61.485	54.083	"	50.918	1.231	234
"	—	0.07	"	113	61.440	54.206	"	50.605	1.263	201
"	—	0.12	"	122	63.700	56.713	"	52.319	1.326	159
"	—	0.17	"	114	62.888	56.229	"	50.999	1.386	127
"	—	0.22	"	119	63.463	56.849	"	51.331	1.414	120
"	—	0.27	"	128	64.159	57.666	"	51.982	1.419	114
"	—	0.32	"	116	63.154	56.896	"	50.436	1.482	97
"	—	0.37	"	141	64.799	58.455	"	52.173	1.471	101
"	—	0.42	"	139	64.005	57.609	"	51.404	1.469	103
"	—	0.47	" Sed on lid	133	63.223	57.238	"	50.267	1.510	86
"	—	0.52	"	102	62.853	56.473	"	50.975	1.384	116

PROGRAM	CORE	DEPTH (m)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	SPECIFIC GRAVITY
MIR91	GC-01	0.00	0	34	57	10	0	0	0.00
MIR91	GC-01	0.05	0	28	62	10	0	0	0.00
MIR91	GC-01	0.10	0	25	66	10	0	0	0.00
MIR91	GC-01	0.15	0	30	59	11	0	0	0.00
MIR91	GC-01	0.20	0	30	55	15	0	0	0.00
MIR91	GC-01	0.25	1	26	61	11	0	0	0.00
MIR91	GC-01	0.30	0	19	71	10	0	0	0.00
MIR91	GC-01	0.35	0	18	72	10	0	0	0.00
MIR91	GC-01	0.40	0	19	70	11	0	0	0.00
MIR91	GC-01	0.45	0	23	67	10	0	0	0.00
MIR91	GC-01	0.50	0	26	62	12	0	0	0.00
MIR91	GC-07	0.00	0	37	54	9	0	0	0.00
MIR91	GC-07	0.05	0	36	54	10	0	0	0.00
MIR91	GC-07	0.10	0	52	39	9	0	0	0.00
MIR91	GC-09A	0.00	0	49	41	10	0	0	0.00
MIR91	GC-09A	0.05	0	48	44	8	0	0	0.00
MIR91	GC-09A	0.10	0	40	52	7	0	0	0.00
MIR91	GC-09A	0.15	0	38	53	9	0	0	0.00
MIR91	GC-09A	0.20	0	57	35	8	0	0	0.00
MIR91	GC-09B	0.00	0	36	54	10	0	0	0.00
MIR91	GC-09B	0.05	0	40	51	9	0	0	0.00
MIR91	GC-09B	0.10	0	39	52	9	0	0	0.00
MIR91	GC-09B	0.15	0	55	39	6	0	0	0.00
MIR91	GC-13	0.00	0	42	47	12	0	0	0.00
MIR91	GC-13	0.05	0	27	61	11	0	0	0.00
MIR91	GC-13	0.10	0	22	68	10	0	0	0.00
MIR91	GC-13	0.15	0	25	63	12	0	0	0.00
MIR91	GC-13	0.20	0	24	67	9	0	0	0.00
MIR91	GC-13	0.25	0	27	64	9	0	0	0.00
MIR91	GC-13	0.30	0	26	64	9	0	0	0.00
MIR91	GC-13	0.35	0	18	73	9	0	0	0.00
MIR91	GC-13	0.40	0	22	67	11	0	0	0.00
MIR91	GC-13	0.45	0	21	67	12	0	0	0.00
MIR91	GC-18	0.00	0	44	45	10	0	0	0.00
MIR91	GC-18	0.05	0	31	61	8	0	0	0.00
MIR91	GC-18	0.10	0	39	51	10	0	0	0.00
MIR91	GC-18	0.15	0	32	60	9	0	0	0.00
MIR91	GC-18	0.20	0	27	61	13	0	0	0.00
MIR91	GC-18	0.25	0	21	67	12	0	0	0.00
MIR91	GC-18	0.30	0	28	64	8	0	0	0.00
MIR91	GC-18	0.35	0	24	65	11	0	0	0.00
MIR91	GC-18	0.40	0	24	65	11	0	0	0.00
MIR91	GC-18	0.45	0	39	53	8	0	0	0.00
MIR91	GC-18	0.50	0	29	60	10	0	0	0.00
MIR91	VV-01	0.00	0	29	62	9	45	91	2.57
MIR91	VV-07	0.00	0	35	57	8	45	90	2.53
MIR91	VV-09	0.00	0	41	51	8	60	116	2.54
MIR91	VV-10	0.00	0	41	52	7	44	83	2.57
MIR91	VV-13	0.00	0	43	46	11	65	171	2.51

PROGRAM	CORE	DEPTH (m)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	SPECIFIC GRAVITY
MIR91	VV-18	0.00	0	40	51	9	60	144	2.45

(1)

MARITIME TESTING (1985) LIMITED
Suite 116 , 900 Windmill Road
Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

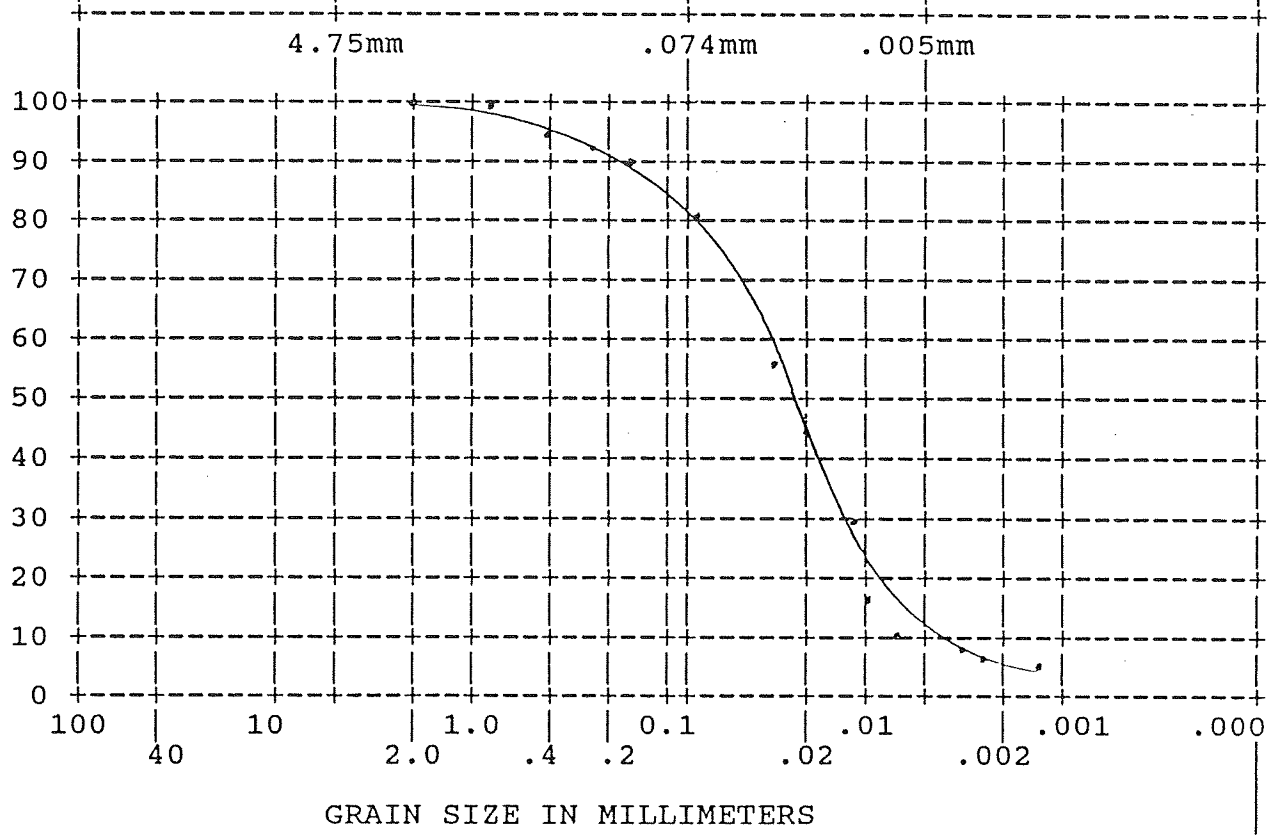
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91 DATE TESTED : 01/30/92

BH_CORE : GC-01 UP_DEPTH : 0.30 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	93
0.16	90
0.072	80.8
0.0312	56.4
0.0210	45.0
0.0131	29.1
0.0097	16.6
0.0070	11.3
0.0034	7.9
0.0026	7.2
0.0014	6.1



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(2)

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Suite 116 , 900 Windmill Road
Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

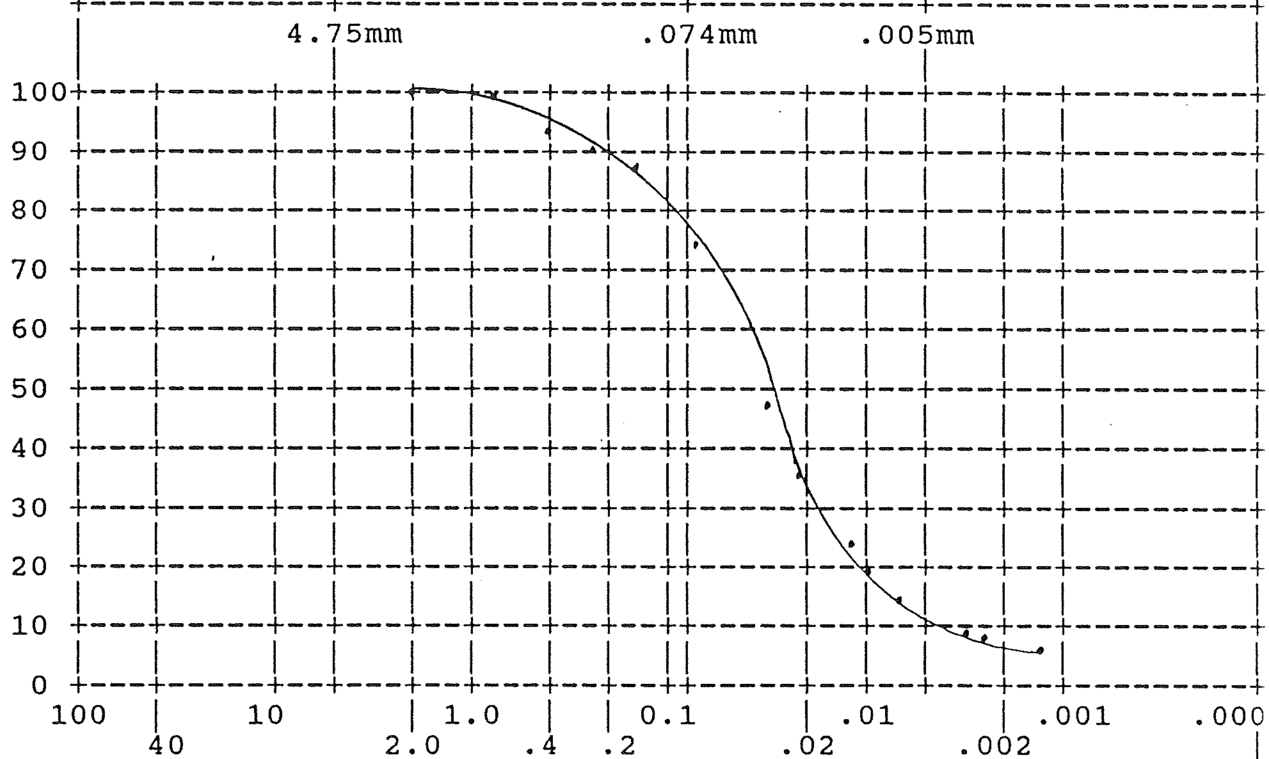
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91 DATE TESTED : 01/30/92

BH_CORE : GC-01 UP_DEPTH : 0.50 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	94
0.25	91
0.16	88
0.072	73.9
0.0332	47.1
0.0220	35.8
0.0133	23.5
0.0096	19.0
0.0069	14.2
0.0033	8.5
0.0026	8.0
0.0014	7.0

GRAVEL SIZES | SAND SIZES | SILT | CLAY



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ______________________

CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(3)

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Suite 116 , 900 Windmill Road
Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

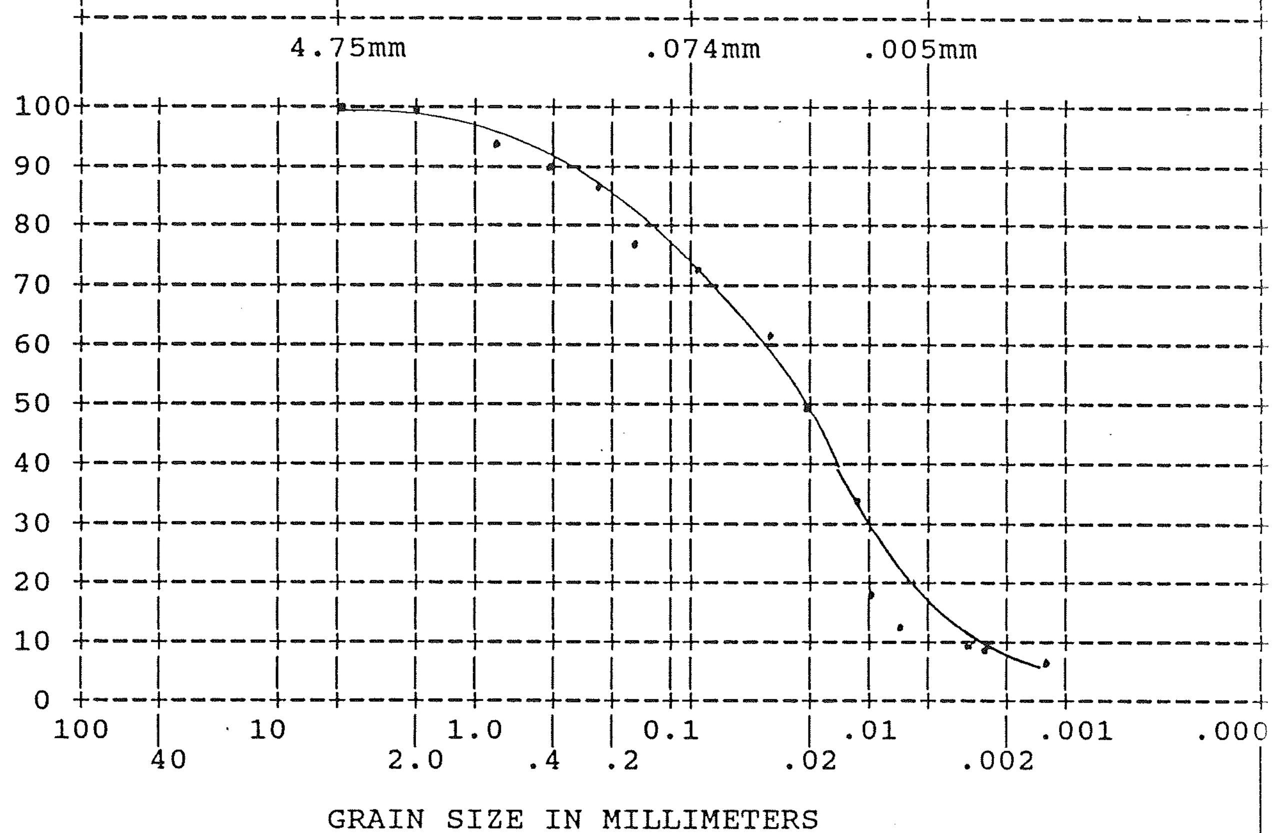
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/30/92

BH_CORE : GC-01 UP_DEPTH : 0.25 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	99
0.8	94
0.42	90
0.25	87
0.16	77
0.072	72.7
0.0316	62.0
0.0212	48.6
0.0130	33.6
0.0097	18.1
0.0070	12.6
0.0033	9.8
0.0026	8.7
0.0014	7.2



COMMENTS :

CHECKED BY : ________________________ CERTIFIED BY : ________________________

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

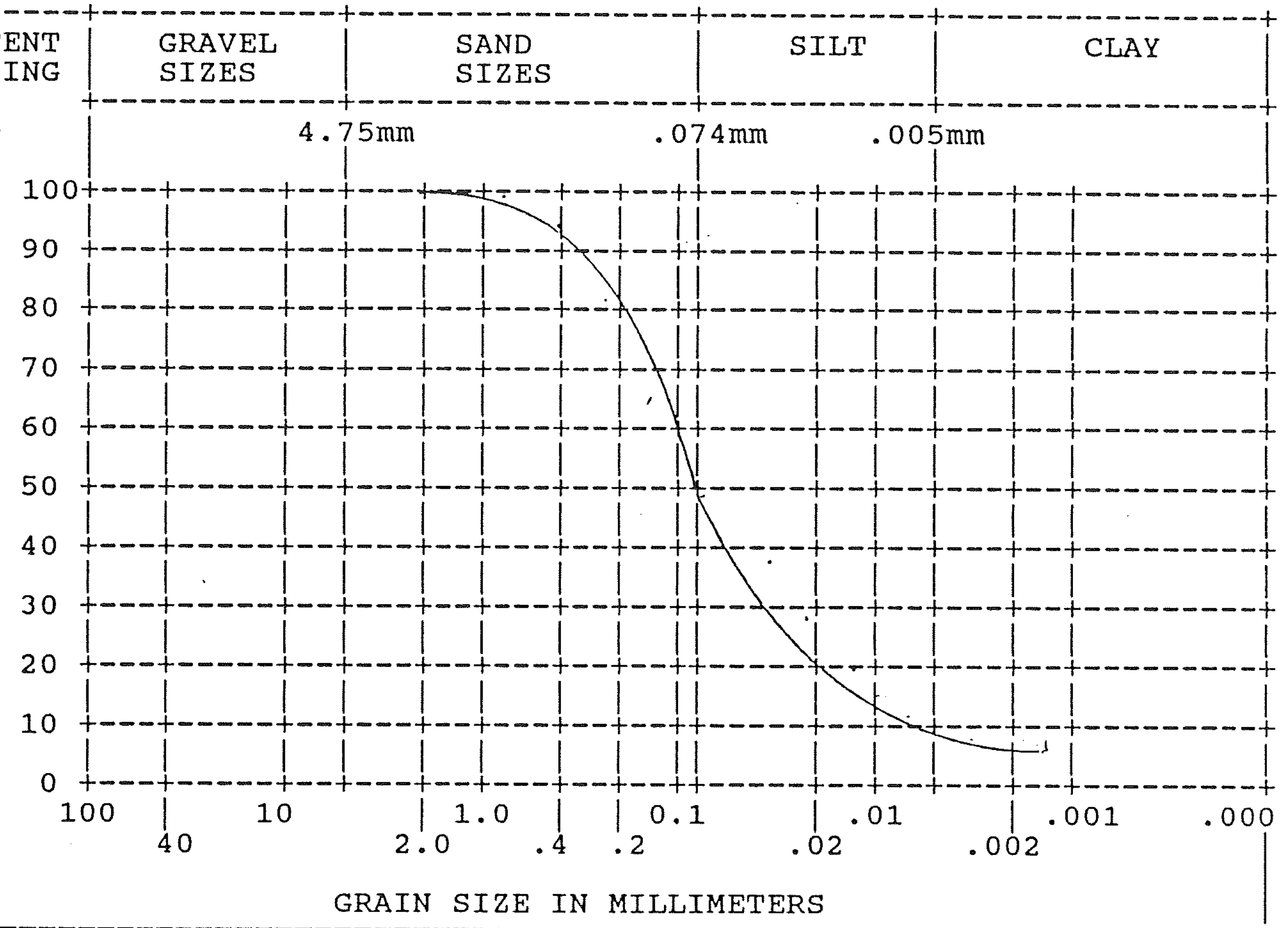
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-07 UP_DEPTH : 0.10 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	94
0.25	82
0.16	65
0.072	47.9
0.0350	37.0
0.0230	28.1
0.0137	19.7
0.0098	15.0
0.0069	11.6
0.0034	6.9
0.0026	6.4
0.0014	5.9



COMMENTS :

CHECKED BY : ________________________ CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(5)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

FILE : NAO0750
DATE : 01/31/92

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

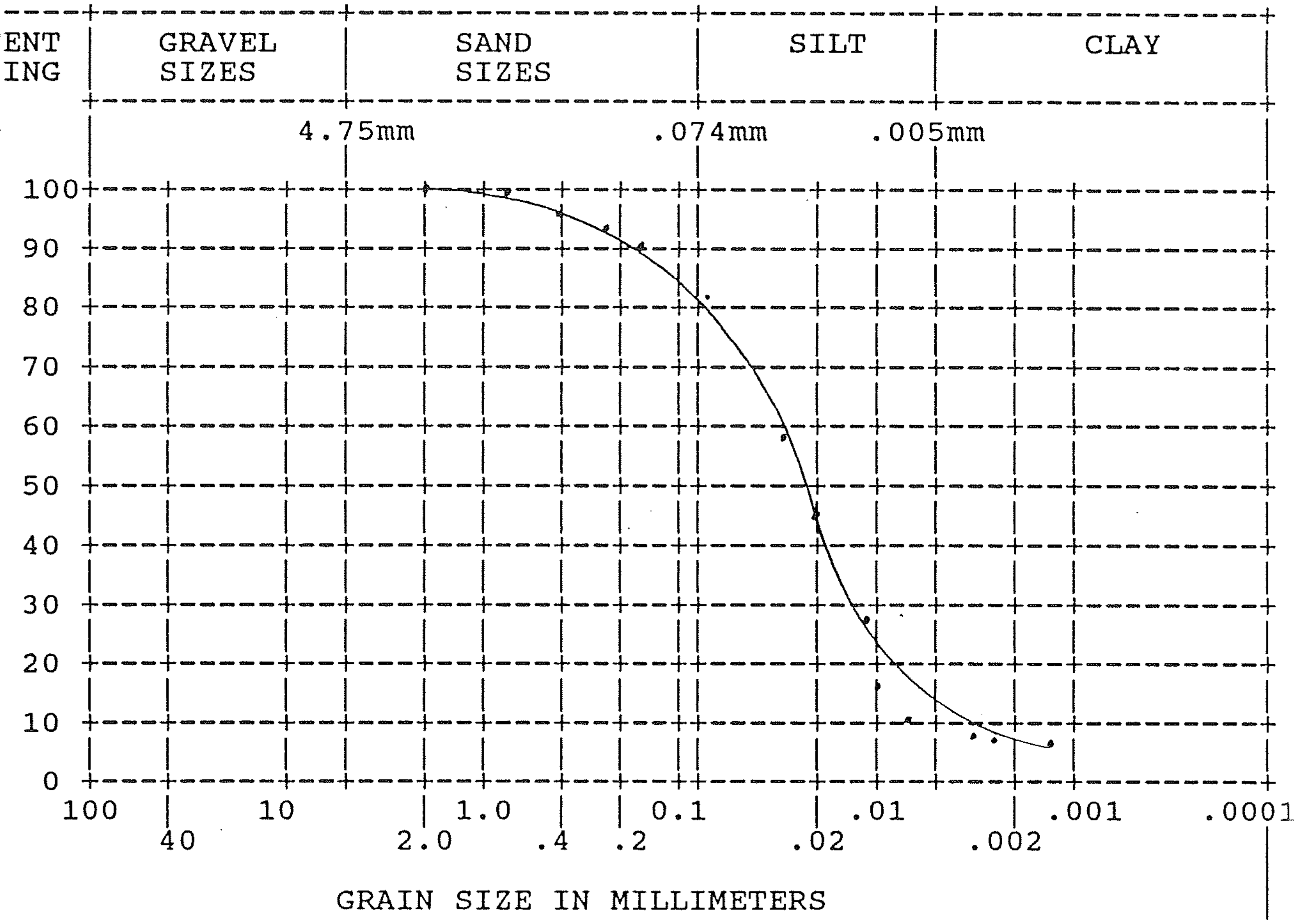
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.35 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	94
0.16	91
0.072	81.6
0.0310	57.5
0.0210	45.0
0.0131	28.4
0.0097	15.9
0.0069	11.1
0.0034	8.1
0.0026	7.7
0.0014	7.0



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(6)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

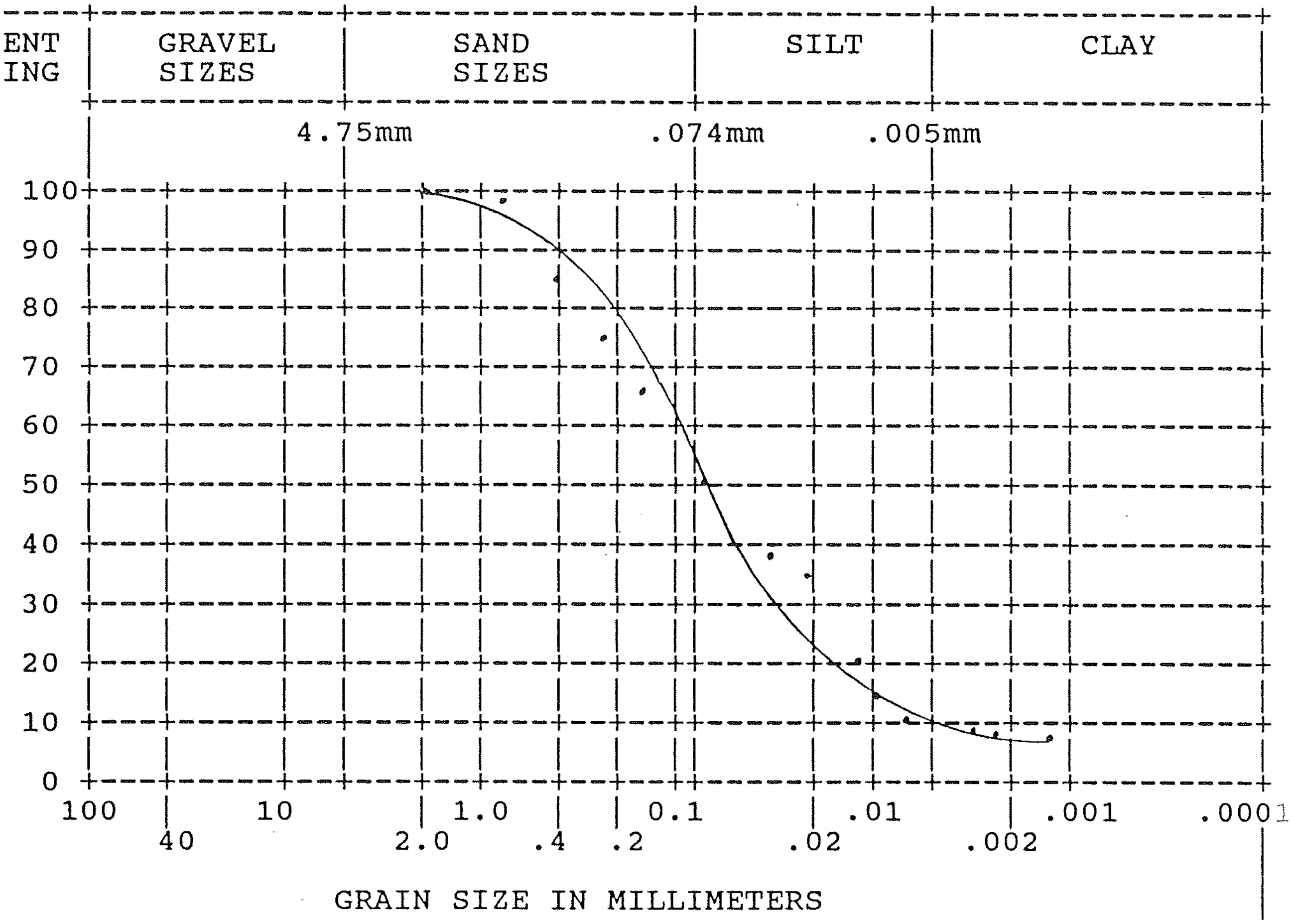
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-09A UP_DEPTH : 0.00 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	85
0.25	75
0.16	66
0.072	51.0
0.0342	38.4
0.0219	35.3
0.0134	21.0
0.0097	15.0
0.0068	11.4
0.0033	8.6
0.0025	8.3
0.0014	7.8



COMMENTS :

CHECKED BY : ______________________

CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(7)

MARITIME TESTING (1985) LIMITED
Suite 116 , 900 Windmill Road
Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

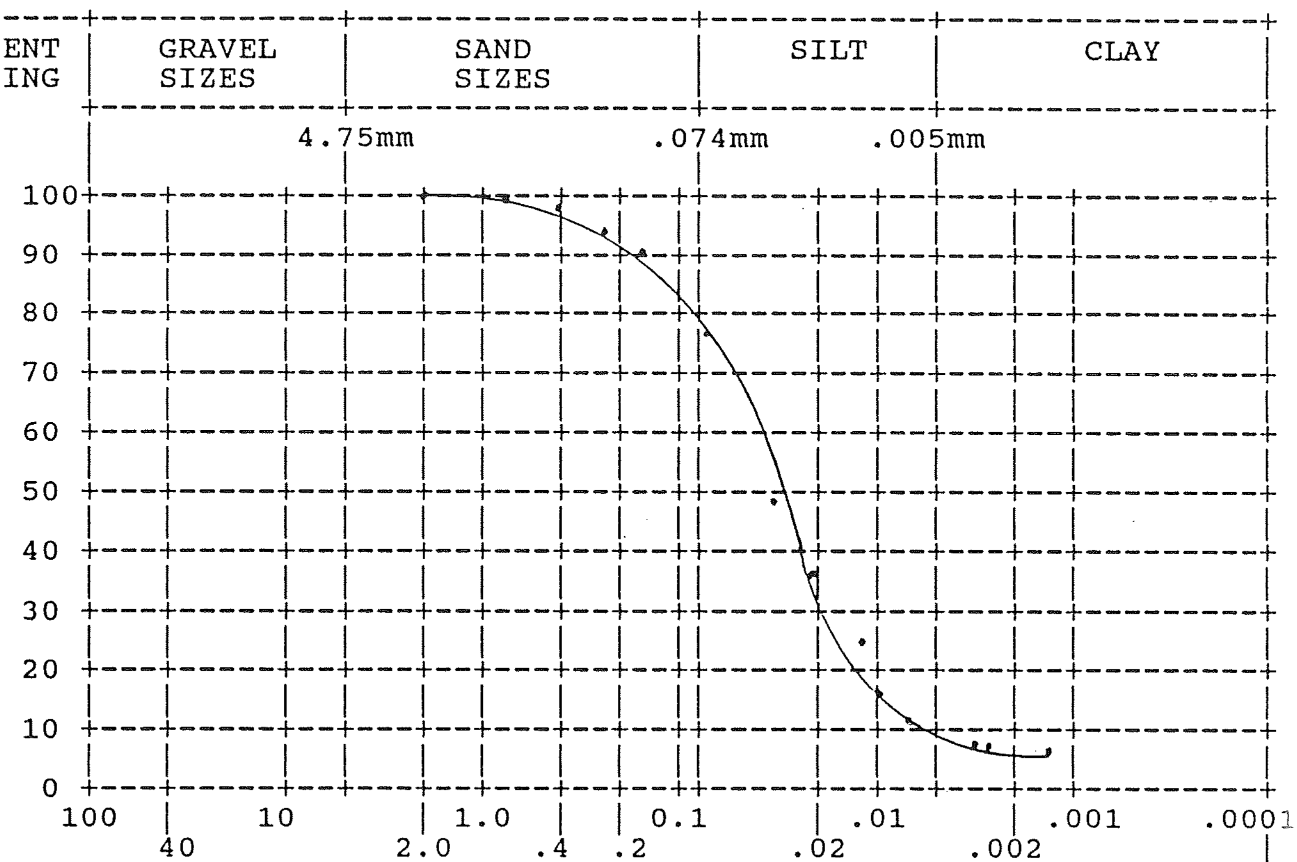
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.45 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	97
0.25	94
0.16	91
0.072	76.9
0.0328	48.0
0.0219	35.9
0.0132	24.9
0.0096	16.4
0.0068	11.8
0.0033	7.5
0.0026	7.2
0.0014	6.7



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(8)

MARITIME TESTING (1985) LIMITED
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Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

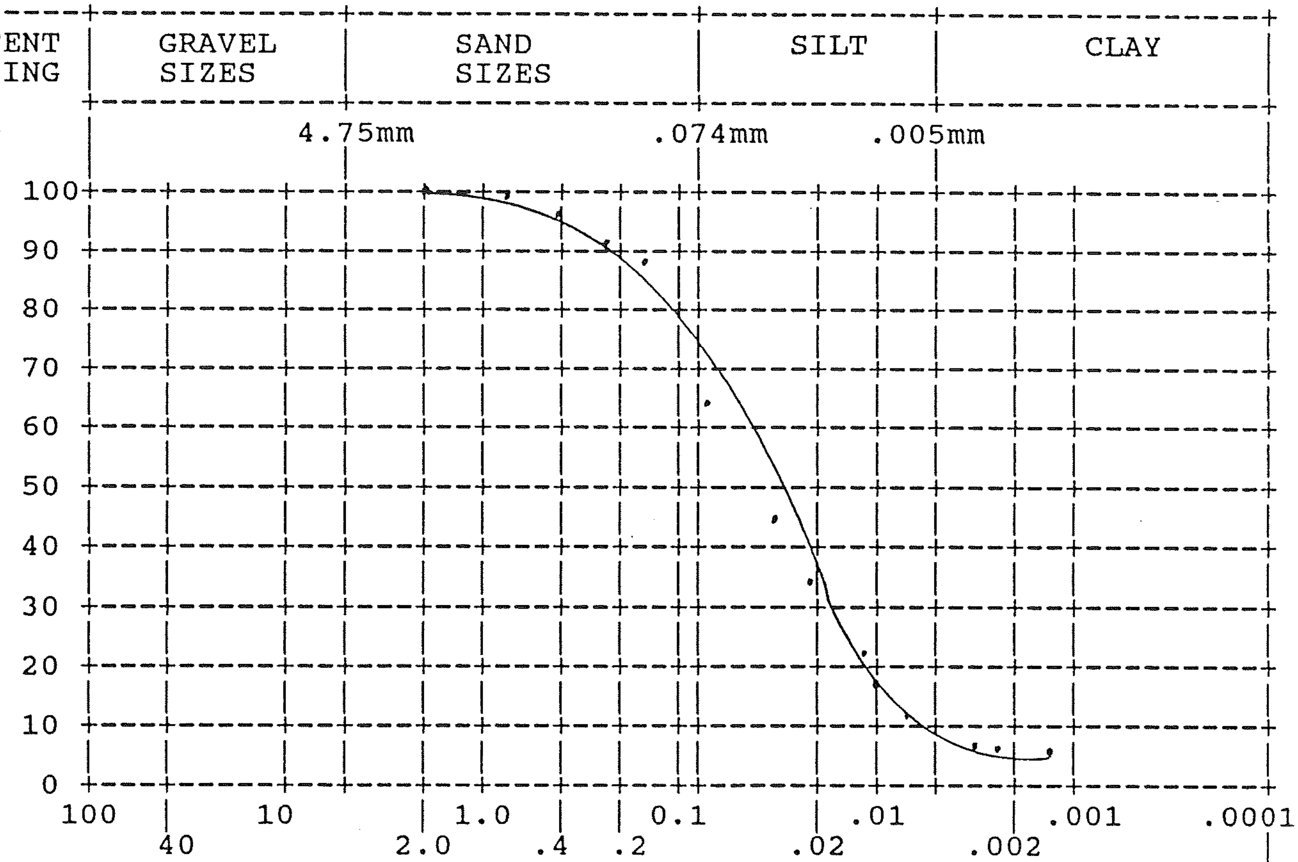
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-07 UP_DEPTH : 0.05 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	92
0.16	88
0.072	63.7
0.0333	45.2
0.0221	33.5
0.0132	23.0
0.0095	17.2
0.0068	12.3
0.0033	7.3
0.0025	7.0
0.0014	6.5



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(9)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

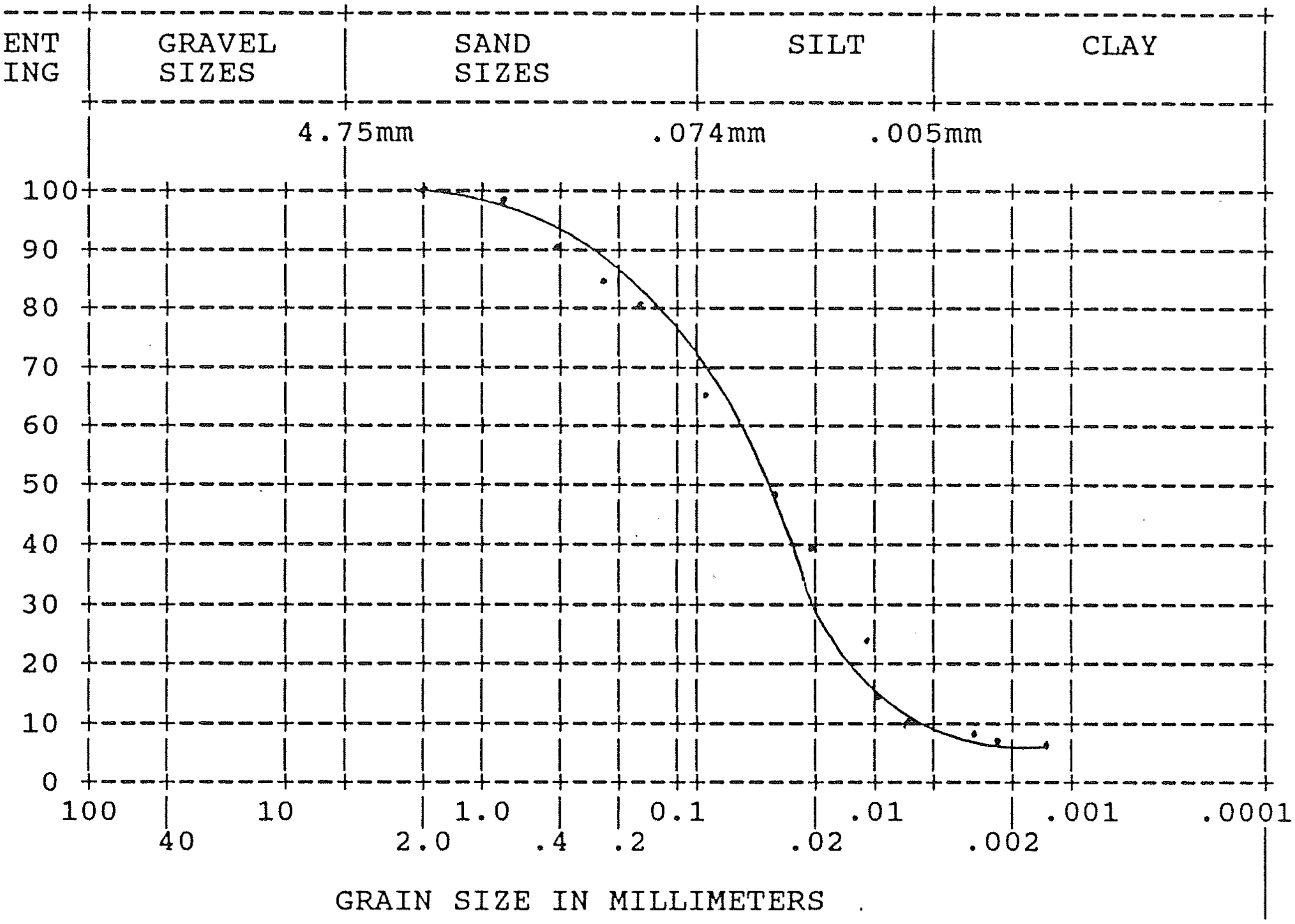
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.00 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	91
0.25	85
0.16	81
0.072	66.3
0.0326	48.1
0.0214	39.3
0.0131	24.4
0.0096	14.4
0.0068	11.2
0.0033	7.9
0.0025	7.4
0.0014	6.9



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(10)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

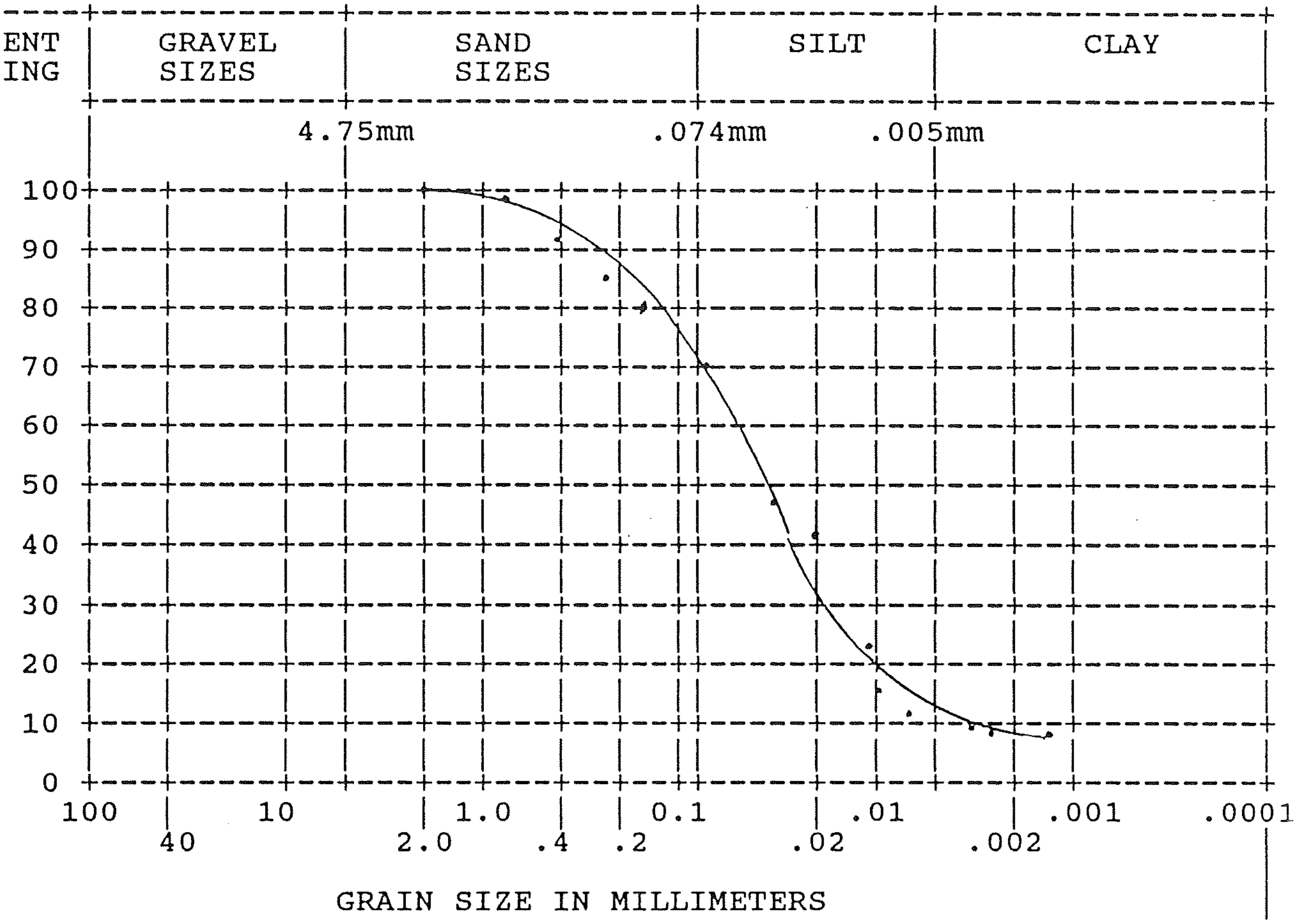
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91 DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.15 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	92
0.25	86
0.16	80
0.072	69.7
0.0330	47.2
0.0213	42.5
0.0132	22.9
0.0096	16.4
0.0068	12.2
0.0033	8.8
0.0026	8.3
0.0014	7.8



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(11)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

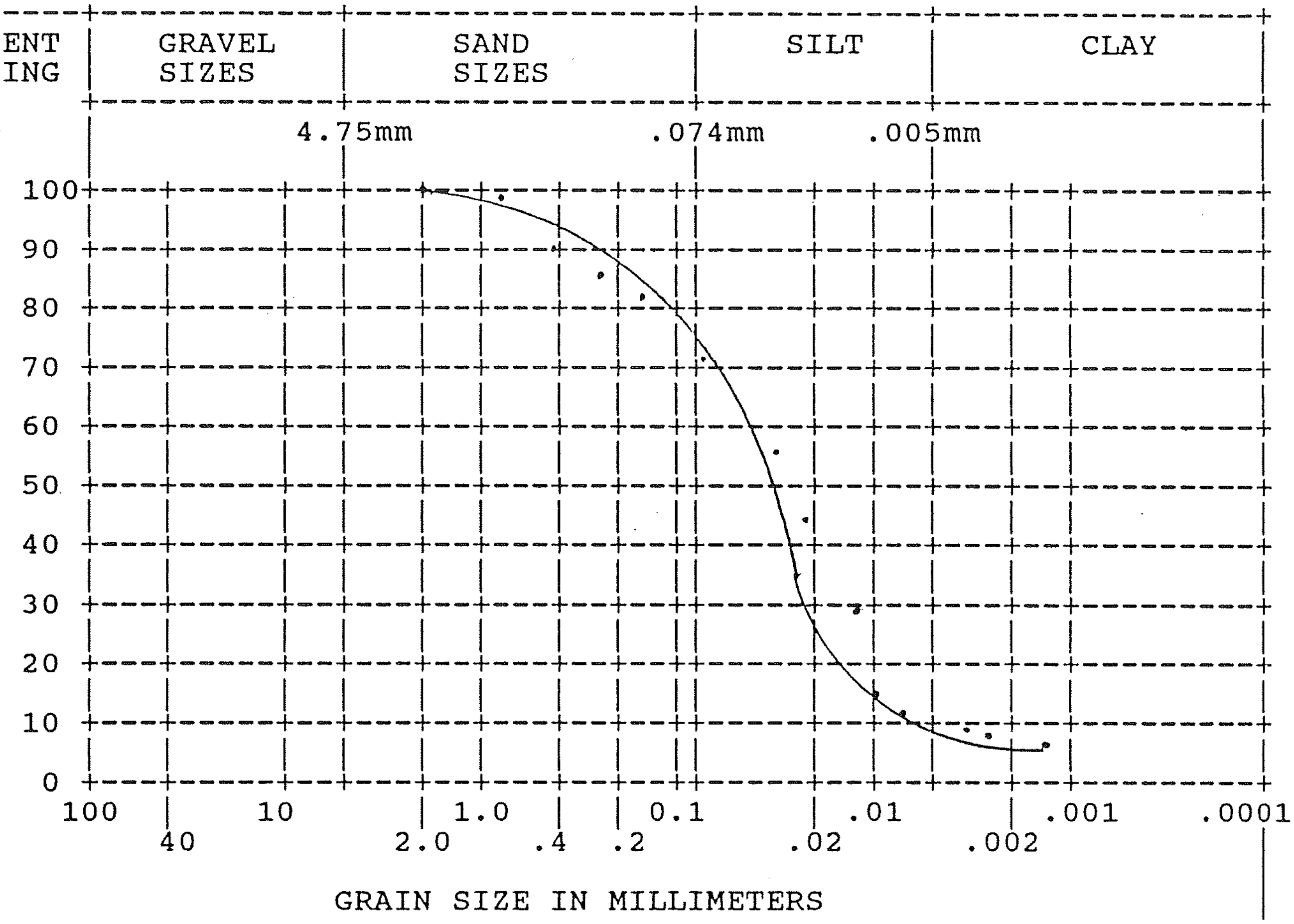
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.05 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	90
0.25	86
0.16	82
0.072	71.8
0.0321	55.6
0.0215	43.6
0.0132	28.9
0.0098	14.7
0.0070	11.5
0.0034	8.5
0.0026	7.8
0.0014	7.1



COMMENTS :

CHECKED BY : ________________________ CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(12)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

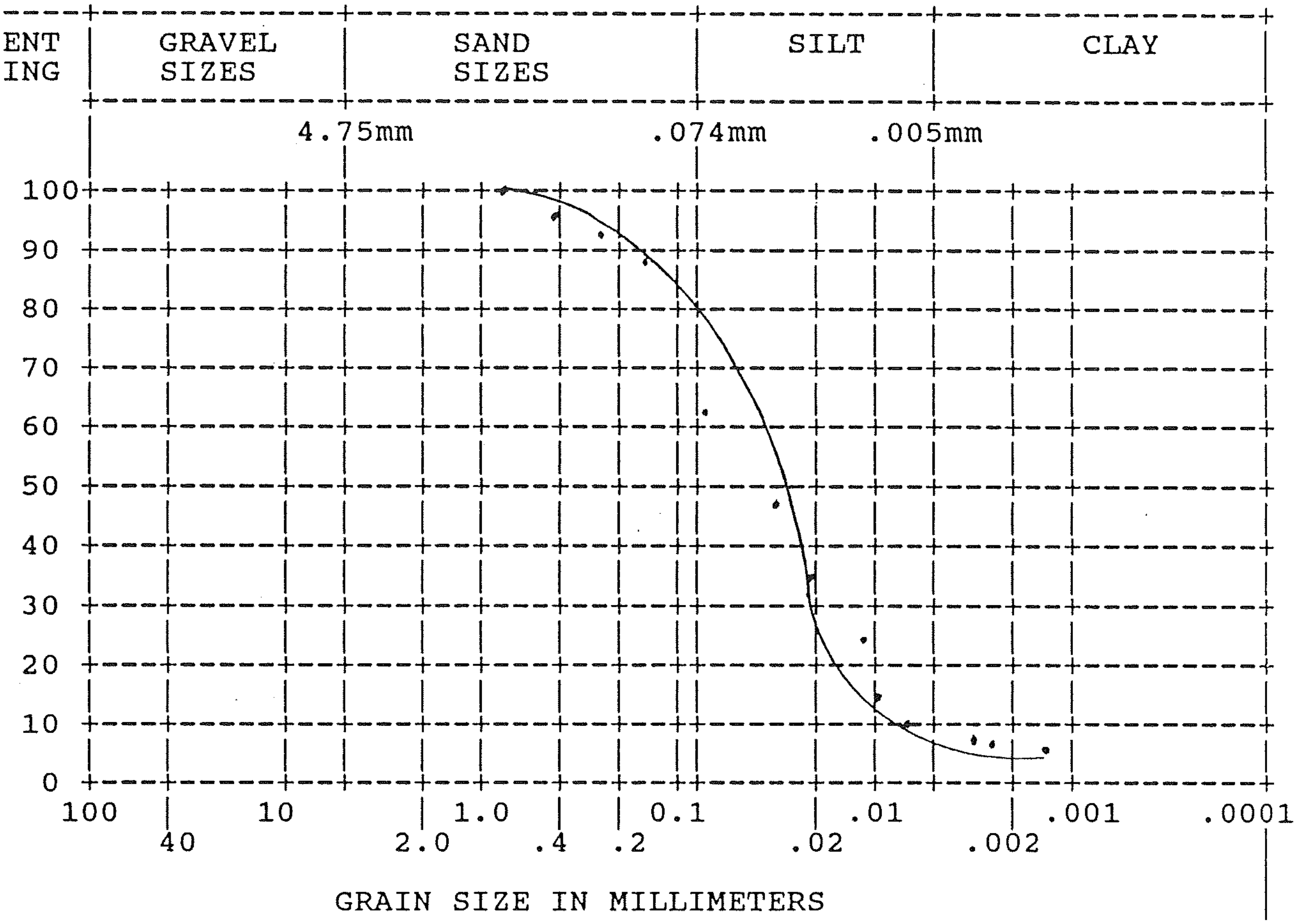
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-07 UP_DEPTH : 0.00 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	100
0.42	96
0.25	93
0.16	88
0.072	63.2
0.0325	46.5
0.0218	35.2
0.0133	23.6
0.0096	15.2
0.0069	10.3
0.0033	7.0
0.0026	6.6
0.0014	6.0



COMMENTS :

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CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(13)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

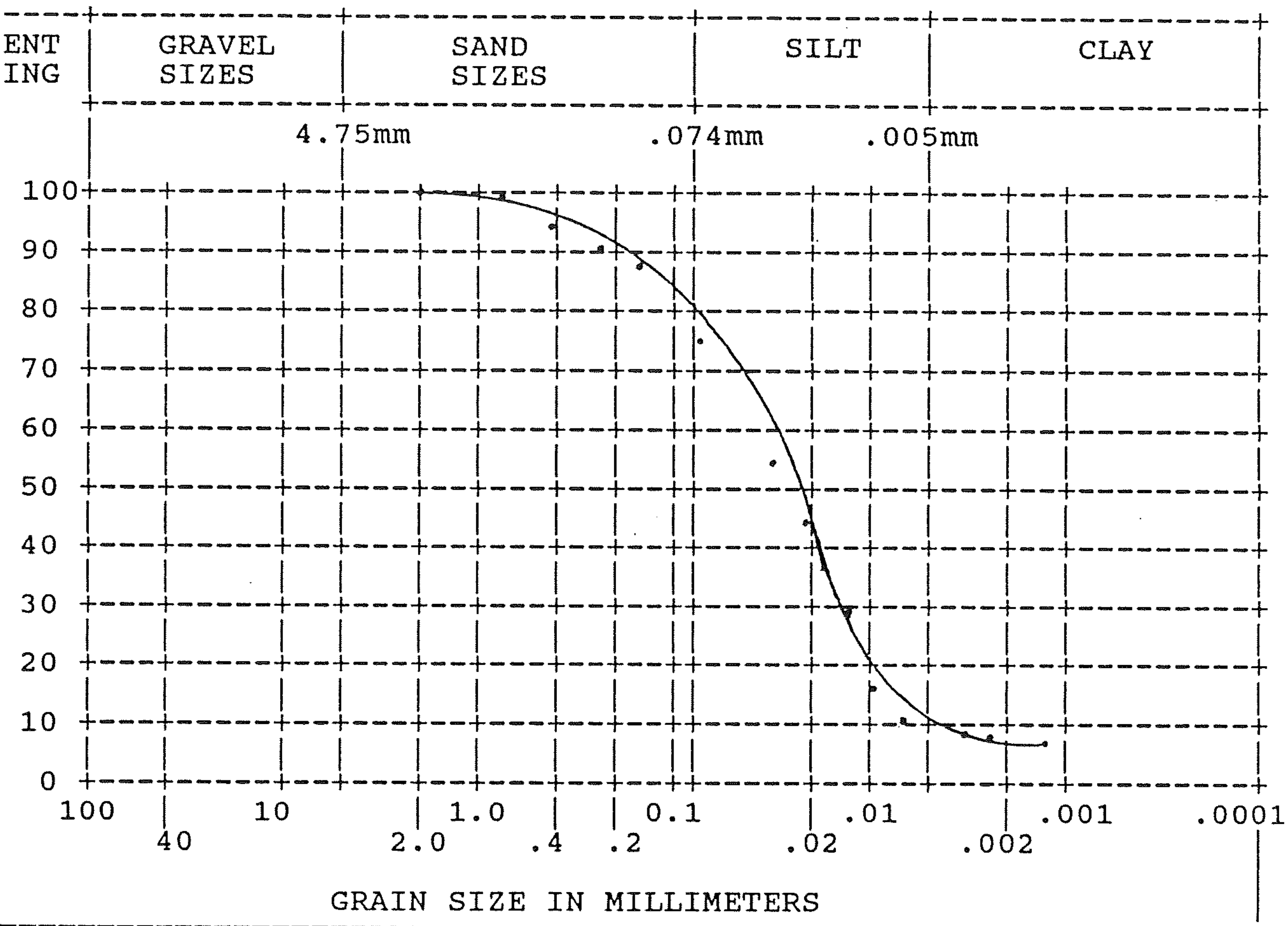
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01 UP_DEPTH : 0.10 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	91
0.16	88
0.072	75.4
0.0316	54.1
0.0209	44.2
0.0129	28.8
0.0095	16.4
0.0068	11.1
0.0033	7.7
0.0025	7.4
0.0014	6.9



COMMENTS :

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114)

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GRAIN SIZE ANALYSIS

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ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

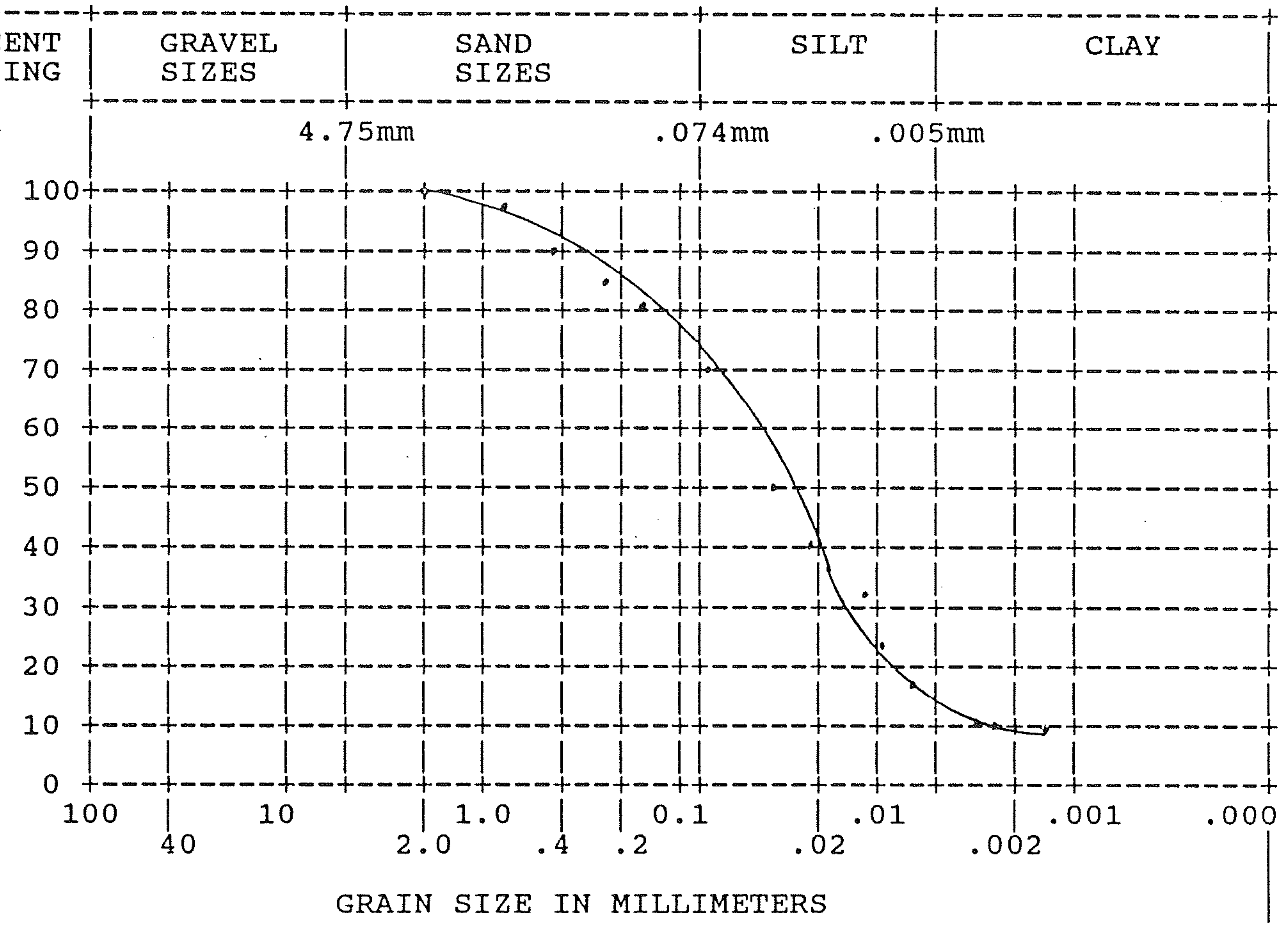
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-01   UP_DEPTH : 0.20   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	90
0.25	85
0.16	81
0.072	69.9
0.0337	49.7
0.0221	41.1
0.0130	33.3
0.0095	24.0
0.0068	17.1
0.0033	11.3
0.0026	10.6
0.0014	9.6



COMMENTS :

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GRAIN SIZE ANALYSIS

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BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

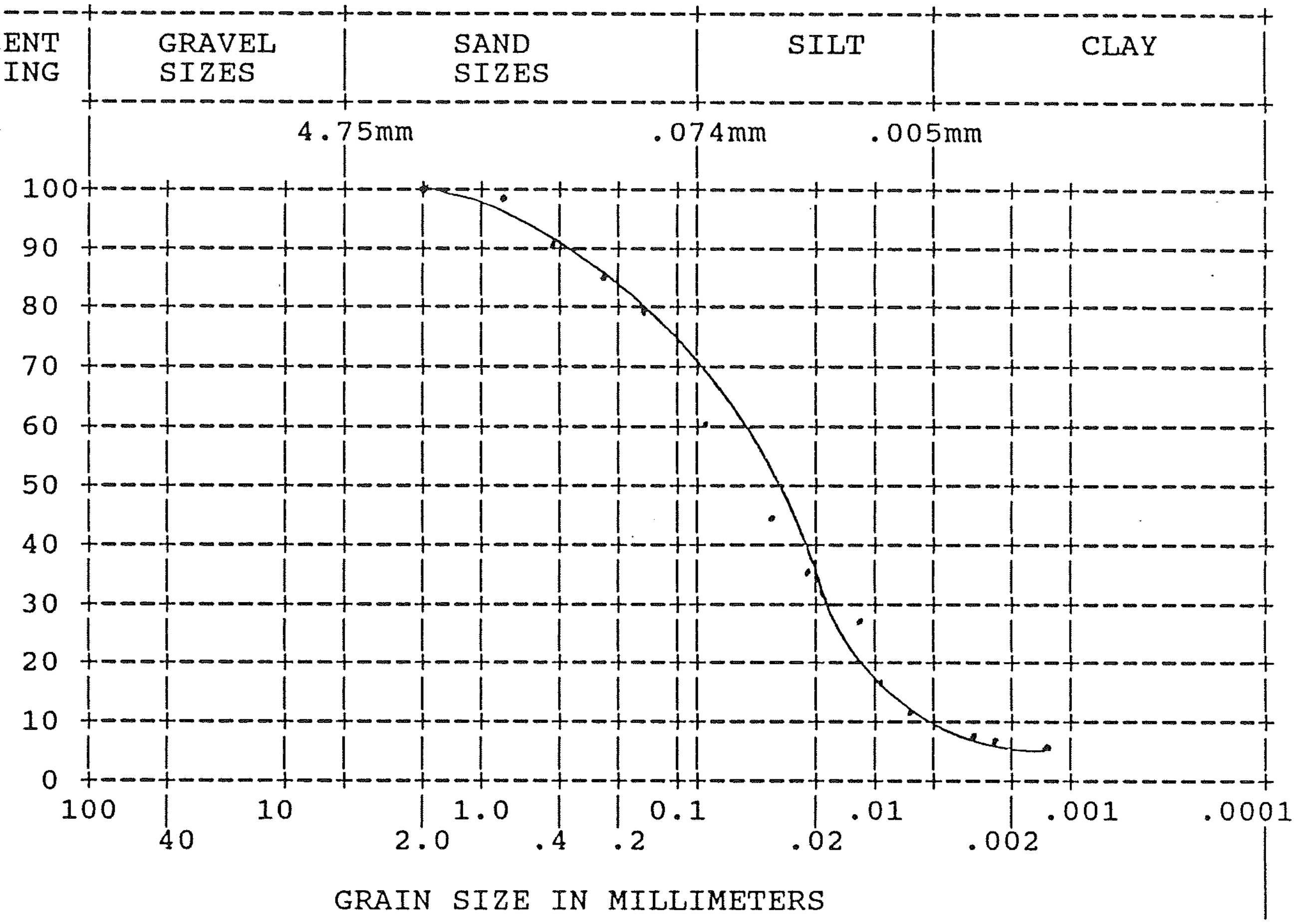
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.10 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	91
0.25	85
0.16	79
0.072	60.8
0.0332	44.4
0.0217	36.1
0.0130	27.2
0.0095	17.1
0.0068	11.6
0.0033	7.3
0.0025	6.8
0.0014	6.5



COMMENTS :

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CERTIFIED BY : ________________________

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116)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

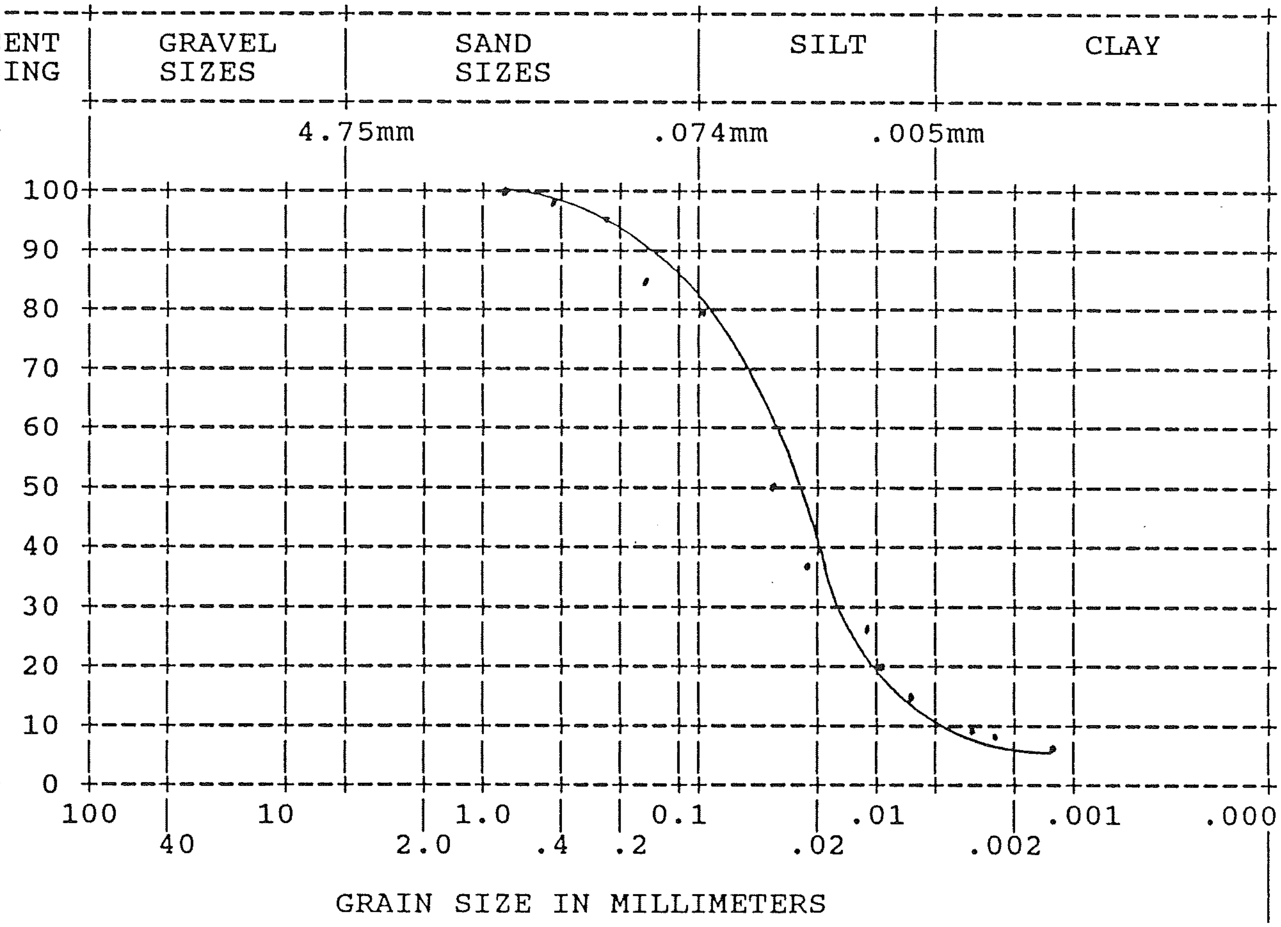
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-13 UP_DEPTH : 0.45 GS_INTER : 0.03

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	100
0.42	98
0.25	96
0.16	94
0.072	79.1
0.0326	50.0
0.0217	37.0
0.0130	26.6
0.0094	19.9
0.0068	15.0
0.0033	8.5
0.0025	7.2
0.0013	5.9



COMMENTS :

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GRAIN SIZE ANALYSIS

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BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

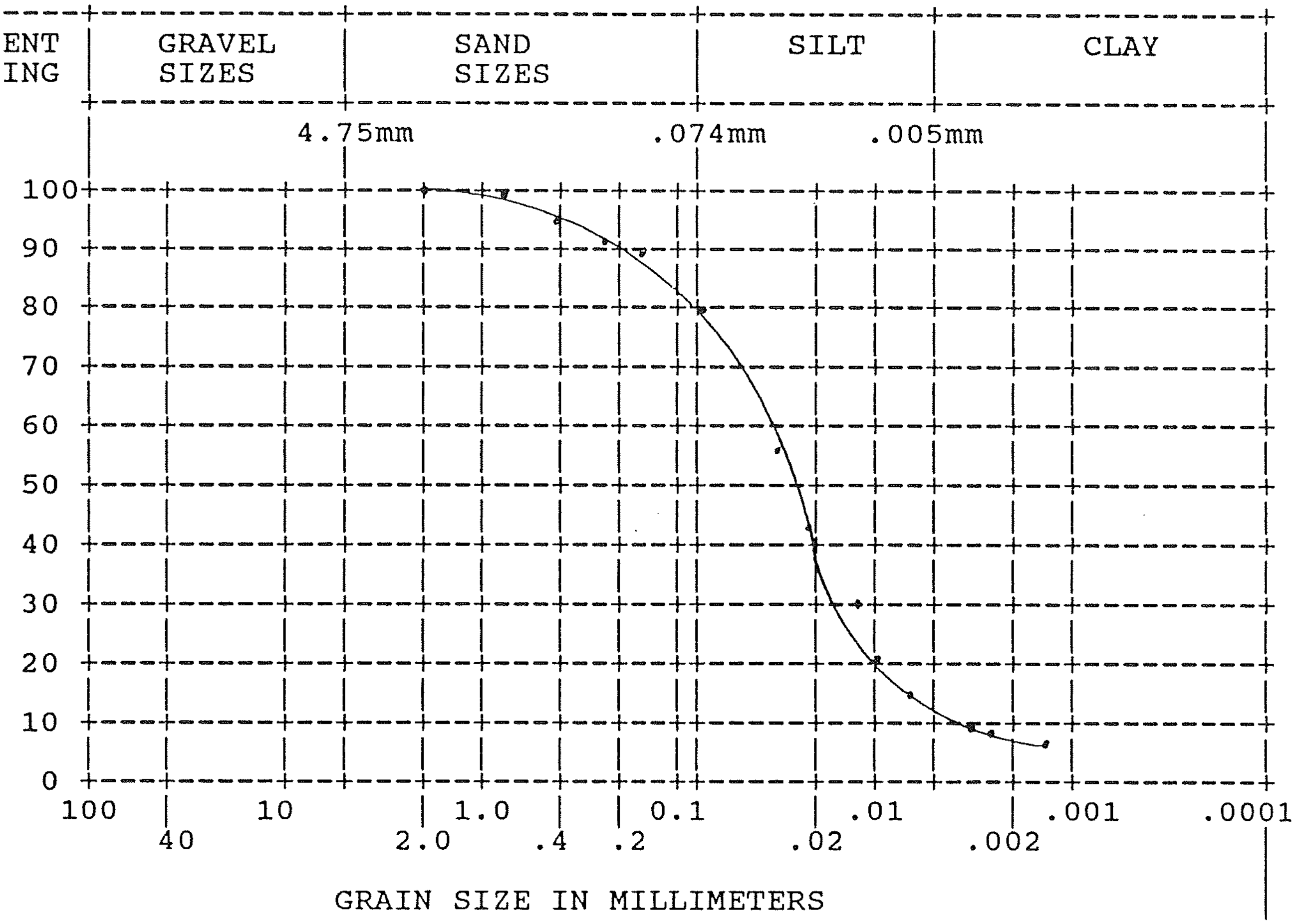
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18   UP_DEPTH : 0.25   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	92
0.16	89
0.072	79.2
0.0320	55.7
0.0215	43.3
0.0131	30.0
0.0096	21.3
0.0068	14.5
0.0033	9.2
0.0026	7.9
0.0014	6.7



COMMENTS :

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A.S.T.M. DESIGNATION D421,D422

(118)

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GRAIN SIZE ANALYSIS

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ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

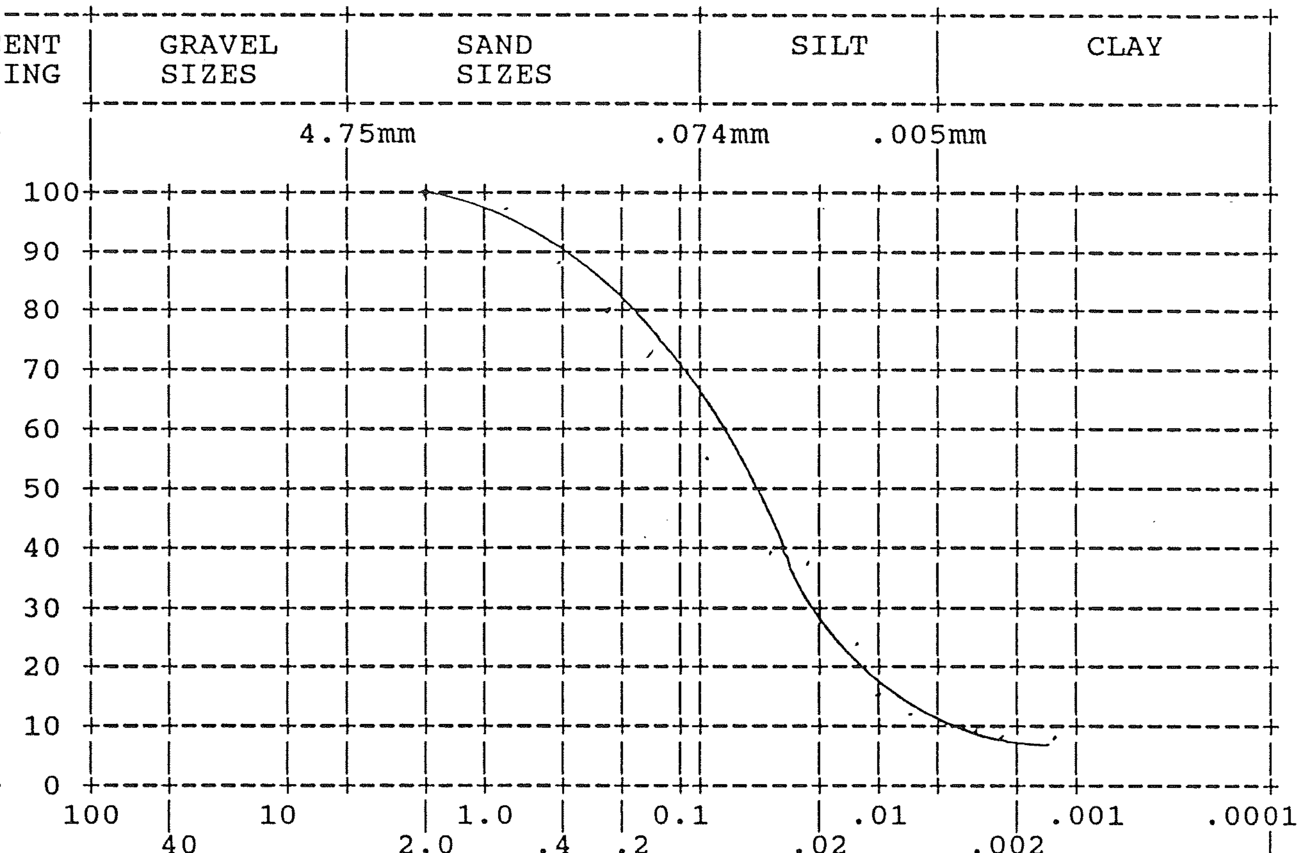
PROJECT : Geotechnical Particle Size

ROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18   UP_DEPTH : 0.00   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	88
0.25	80
0.16	73
0.072	55.7
0.0355	38.6
0.0226	36.9
0.0136	24.0
0.0099	15.6
0.0070	12.0
0.0034	8.6
0.0026	8.3
0.0014	7.8



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(14)

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GRAIN SIZE ANALYSIS

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ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

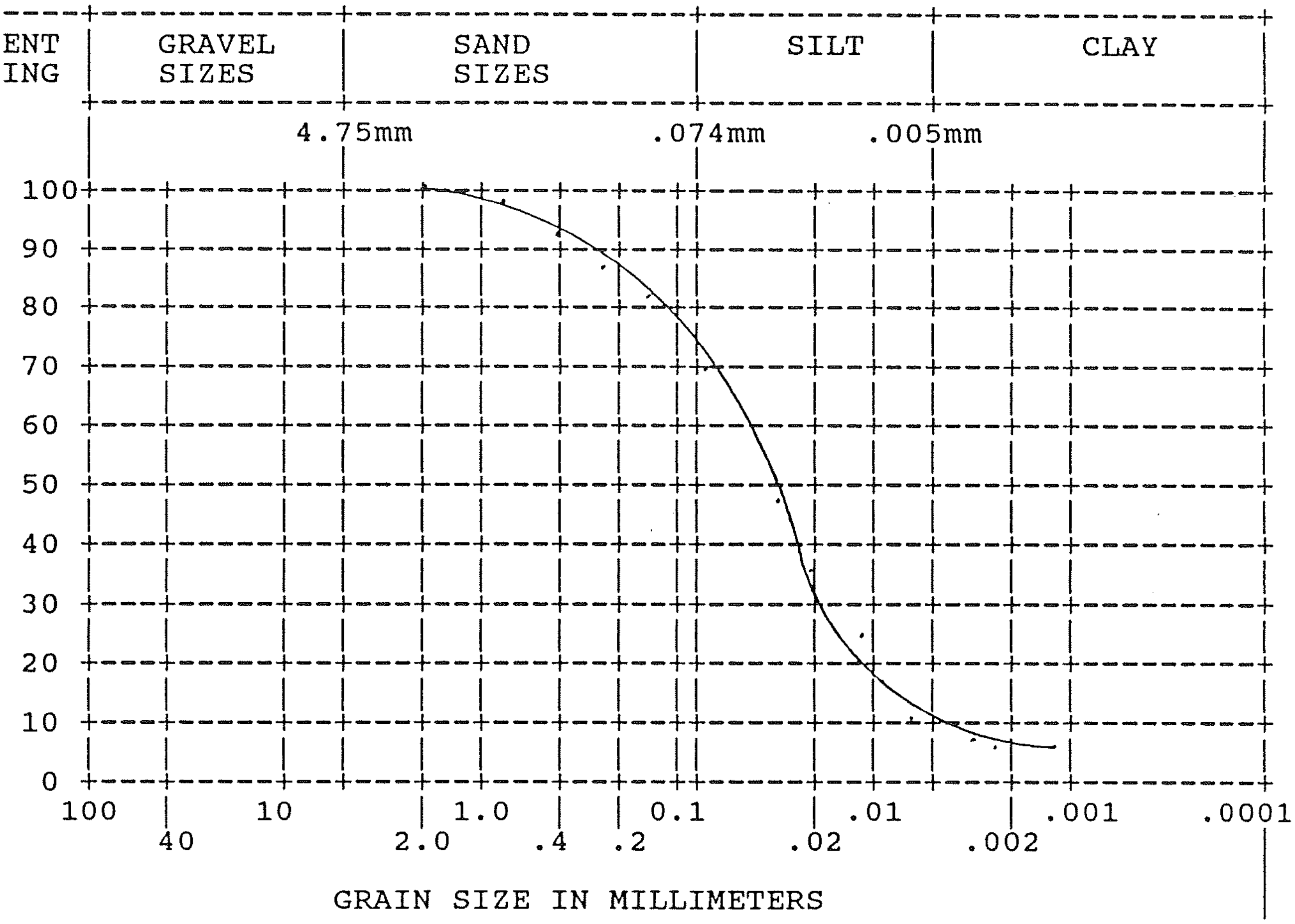
PROJECT : Geotechnical Particle Size

ROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.15 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	93
0.25	87
0.16	82
0.072	68.5
0.0316	46.8
0.0210	36.4
0.0128	25.4
0.0093	16.8
0.0067	10.8
0.0033	6.5
0.0025	6.0
0.0013	5.6



OMMENTS :

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CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(20)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

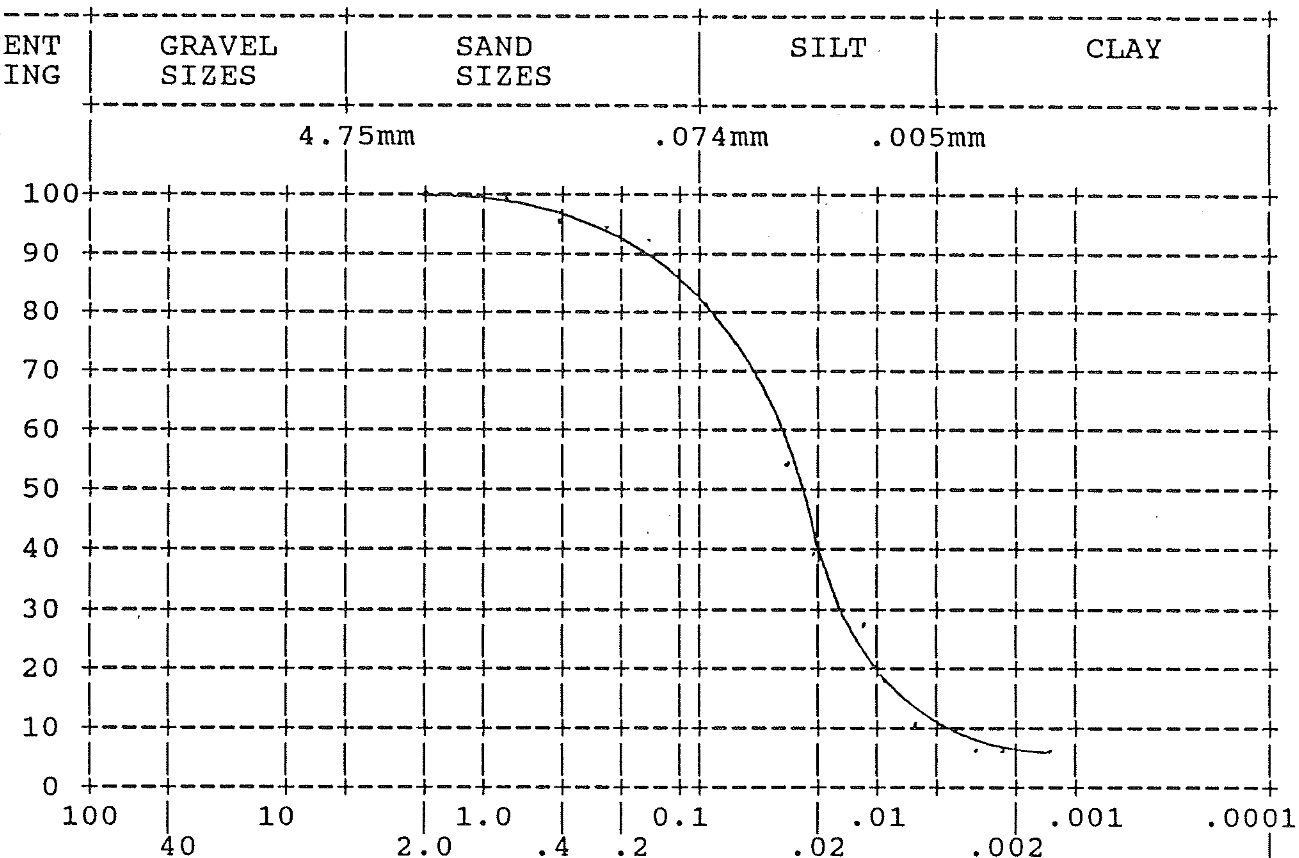
PROJECT : Geotechnical Particle Size

ROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-13   UP_DEPTH : 0.35   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	95
0.16	93
0.072	82.1
0.0300	54.2
0.0206	38.9
0.0125	26.6
0.0092	17.0
0.0066	10.9
0.0032	6.3
0.0024	6.3
0.0014	6.3



GRAIN SIZE IN MILLIMETERS

COMMENTS :

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GRAIN SIZE ANALYSIS

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BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

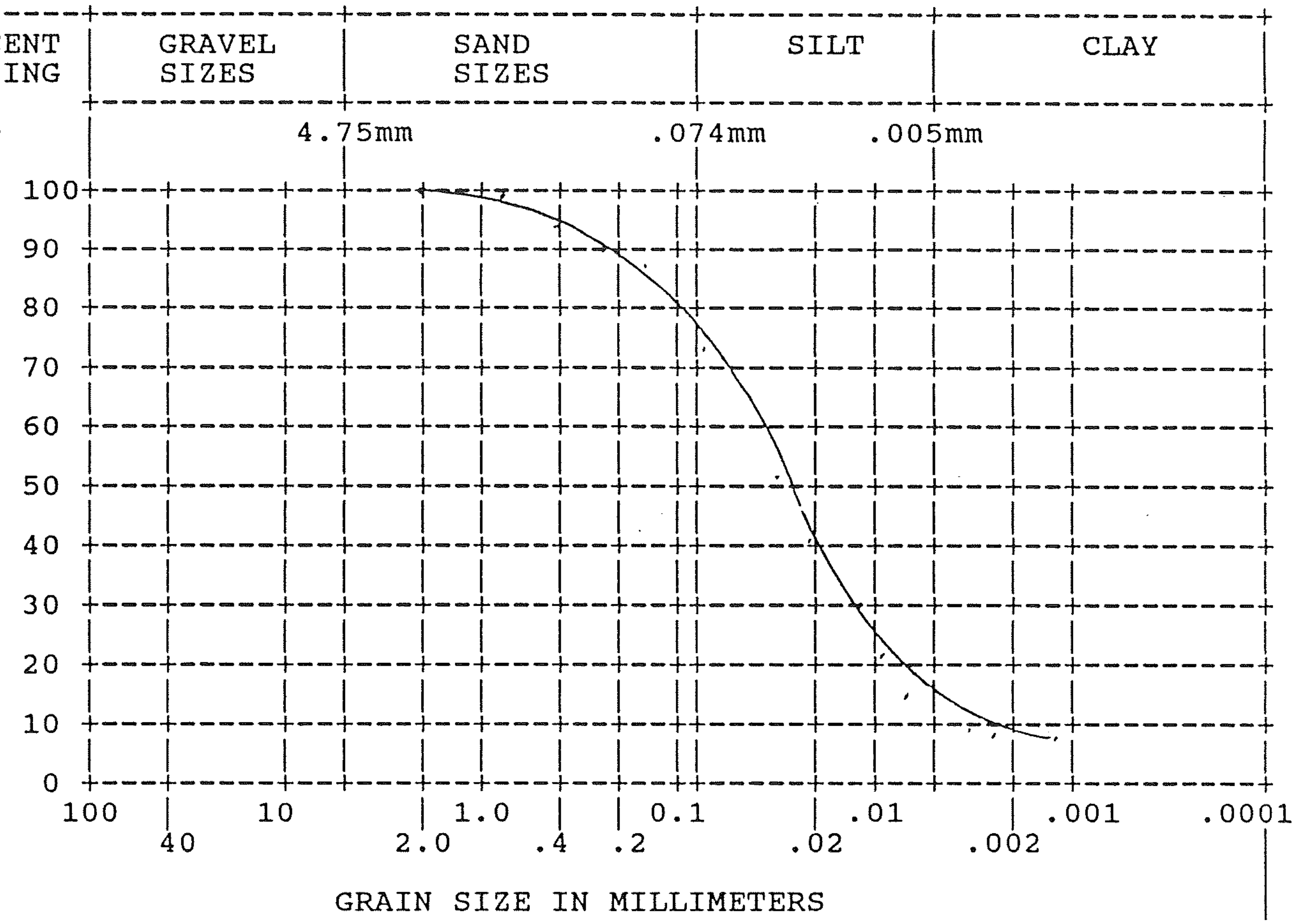
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.20 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	94
0.25	90
0.16	87
0.072	73.4
0.0324	51.5
0.0214	41.1
0.0129	30.2
0.0094	21.8
0.0068	15.3
0.0033	9.1
0.0025	8.0
0.0013	6.7



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

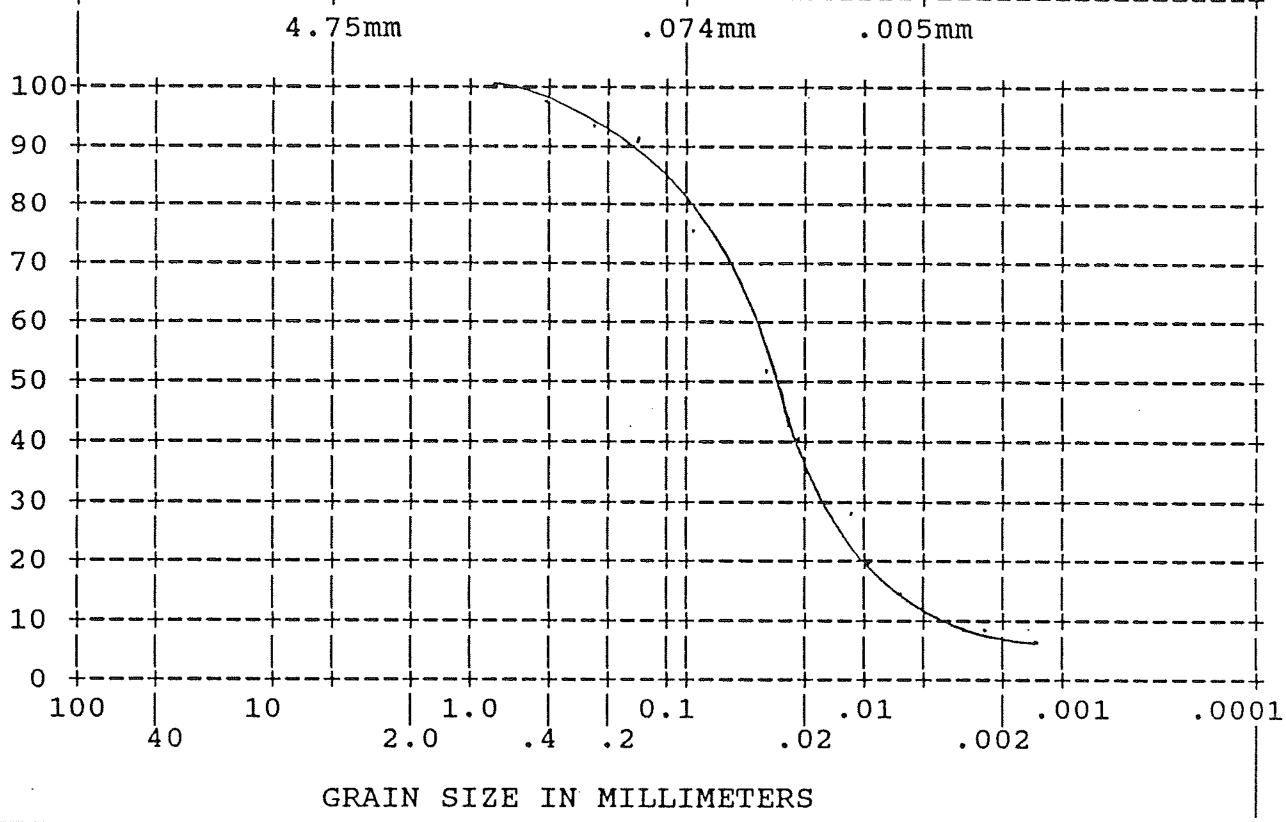
PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.40 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	100
0.42	97
0.25	94
0.16	91
0.072	75.9
0.0323	52.6
0.0215	40.3
0.0131	27.5
0.0096	19.8
0.0068	13.8
0.0033	8.1
0.0026	7.5
0.0014	6.1

GRAVEL SIZES	SAND SIZES	SILT	CLAY



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(?.3)

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GRAIN SIZE ANALYSIS

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ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

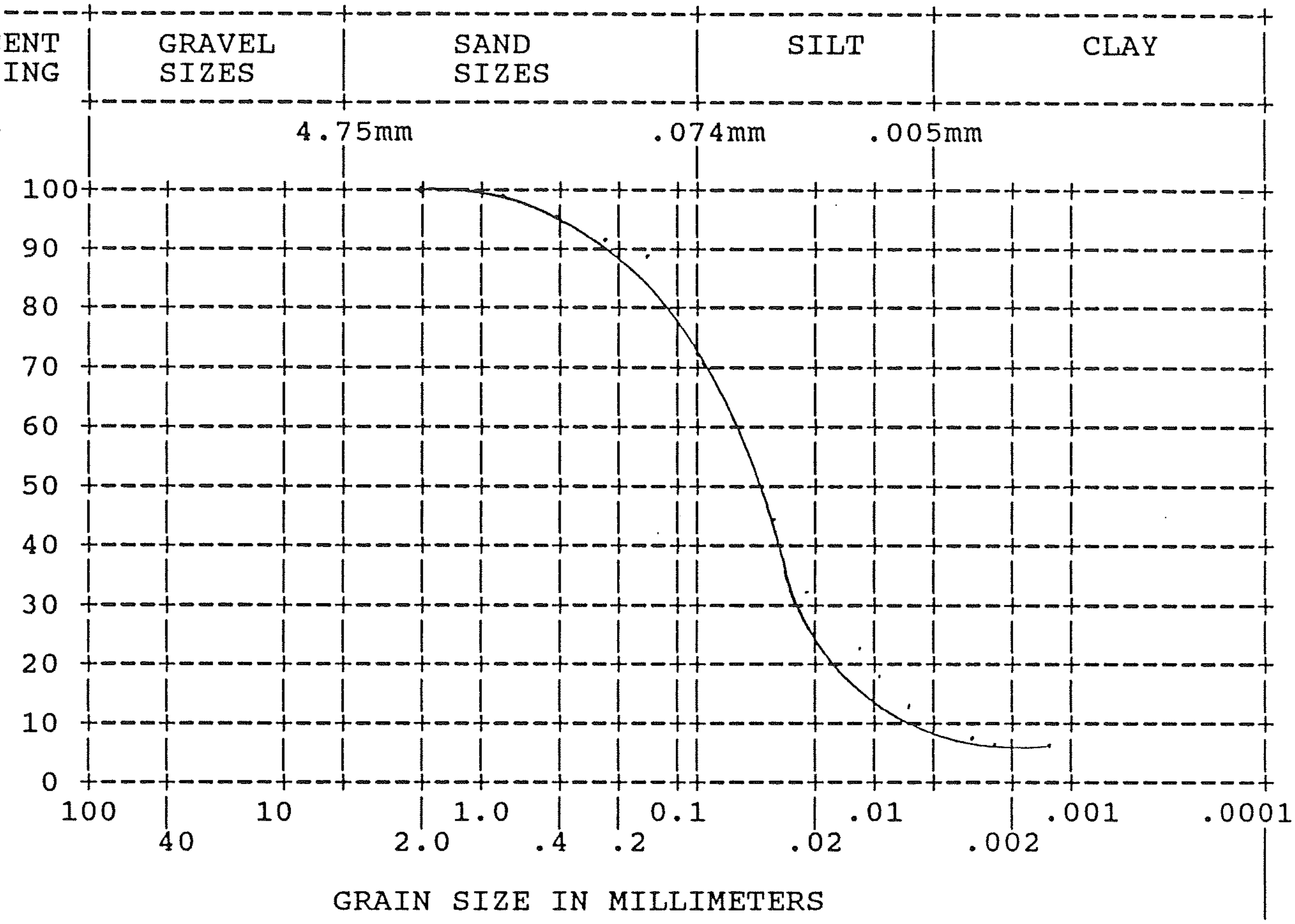
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.50 GS_INTER : 0.06

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	92
0.16	89
0.072	70.5
0.0326	44.5
0.0218	32.5
0.0131	22.6
0.0095	17.0
0.0068	12.6
0.0033	7.1
0.0026	6.4
0.0014	5.7



COMMENTS :

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A.S.T.M. DESIGNATION D421,D422

(24)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

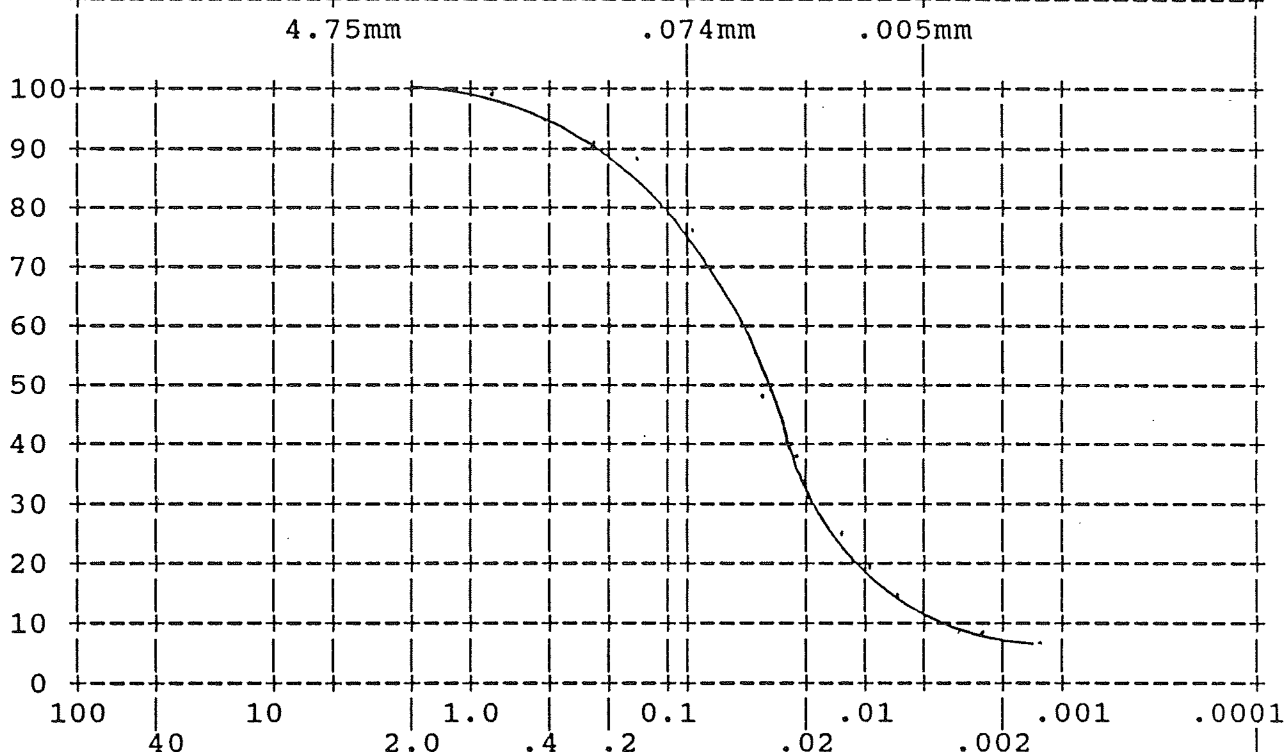
PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.35 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	91
0.16	88
0.072	75.9
0.0339	47.9
0.0225	36.9
0.0136	25.4
0.0097	18.7
0.0069	13.9
0.0034	8.4
0.0026	7.7
0.0014	6.4

GRAVEL SIZES	SAND SIZES	SILT	CLAY



GRAIN SIZE IN MILLIMETERS

COMMENTS :

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

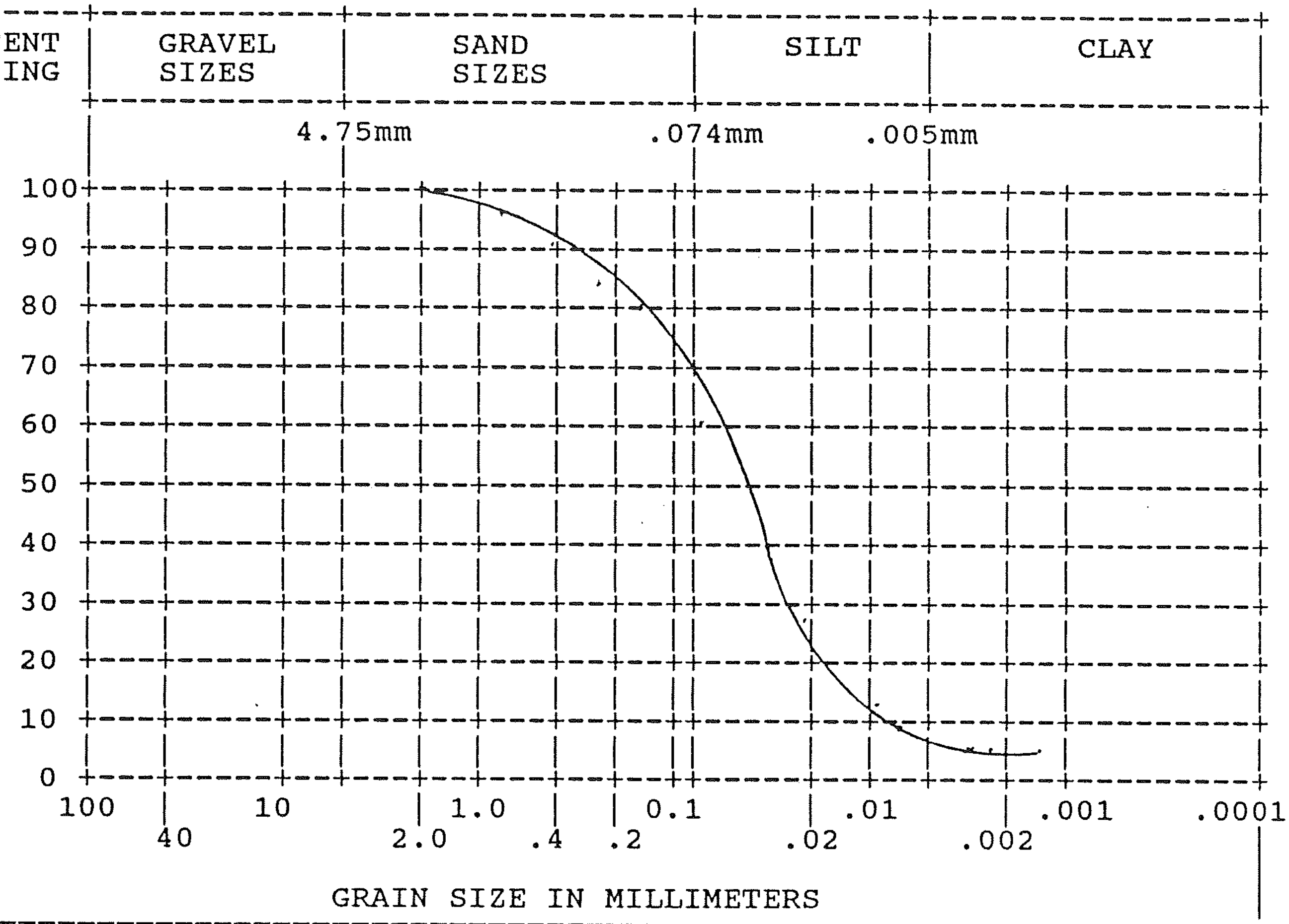
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-18 UP_DEPTH : 0.45 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	96
0.42	91
0.25	84
0.16	80
0.072	60.8
0.0328	36.8
0.0216	26.9
0.0129	18.2
0.0093	12.8
0.0065	9.2
0.0032	5.0
0.0025	5.0
0.0014	5.0



COMMENTS :

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CERTIFIED BY : ______________________

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 01/31/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

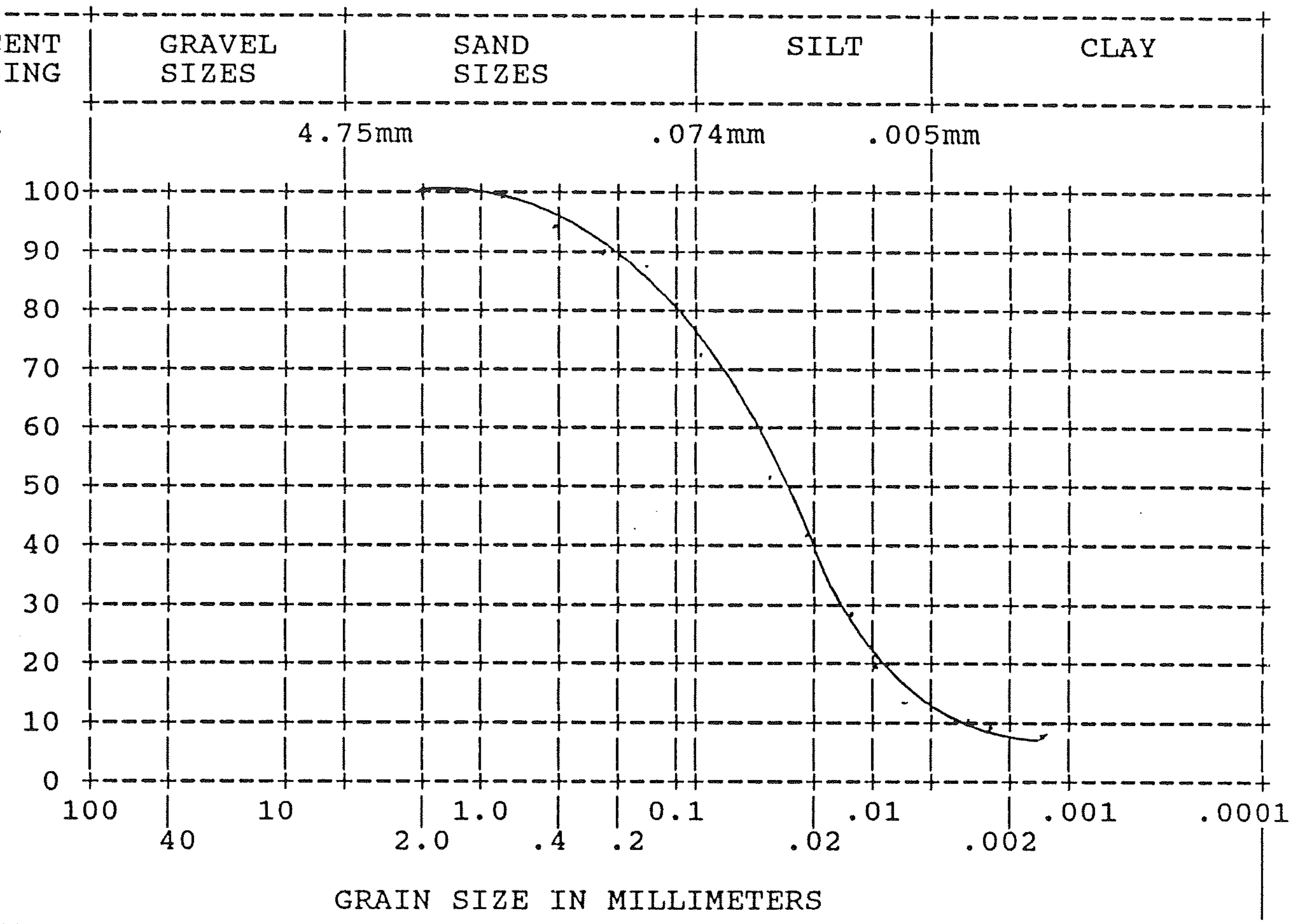
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 01/31/92

BH_CORE : GC-13 UP_DEPTH : 0.05 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	94
0.25	90
0.16	87
0.072	72.7
0.0335	52.3
0.0222	41.6
0.0135	28.4
0.0097	18.7
0.0069	13.0
0.0033	9.6
0.0026	8.5
0.0014	7.2



COMMENTS :

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

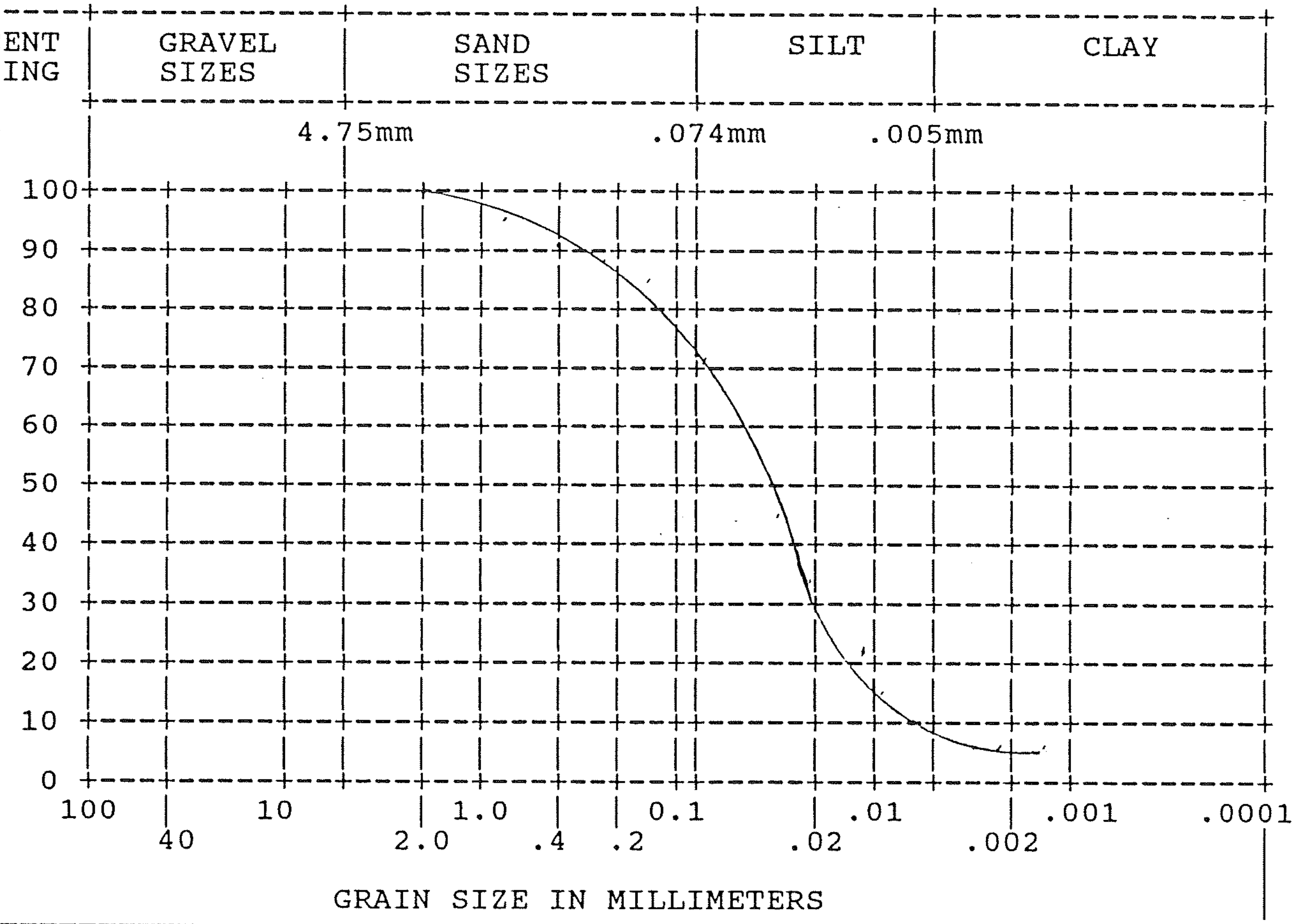
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/03/92

BH_CORE : GC-18 UP_DEPTH : 0.30 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	95
0.42	91
0.25	88
0.16	85
0.072	72.4
0.0310	45.1
0.0208	33.6
0.0126	21.7
0.0092	14.8
0.0065	10.1
0.0032	5.8
0.0024	5.8
0.0014	5.8



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(28)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

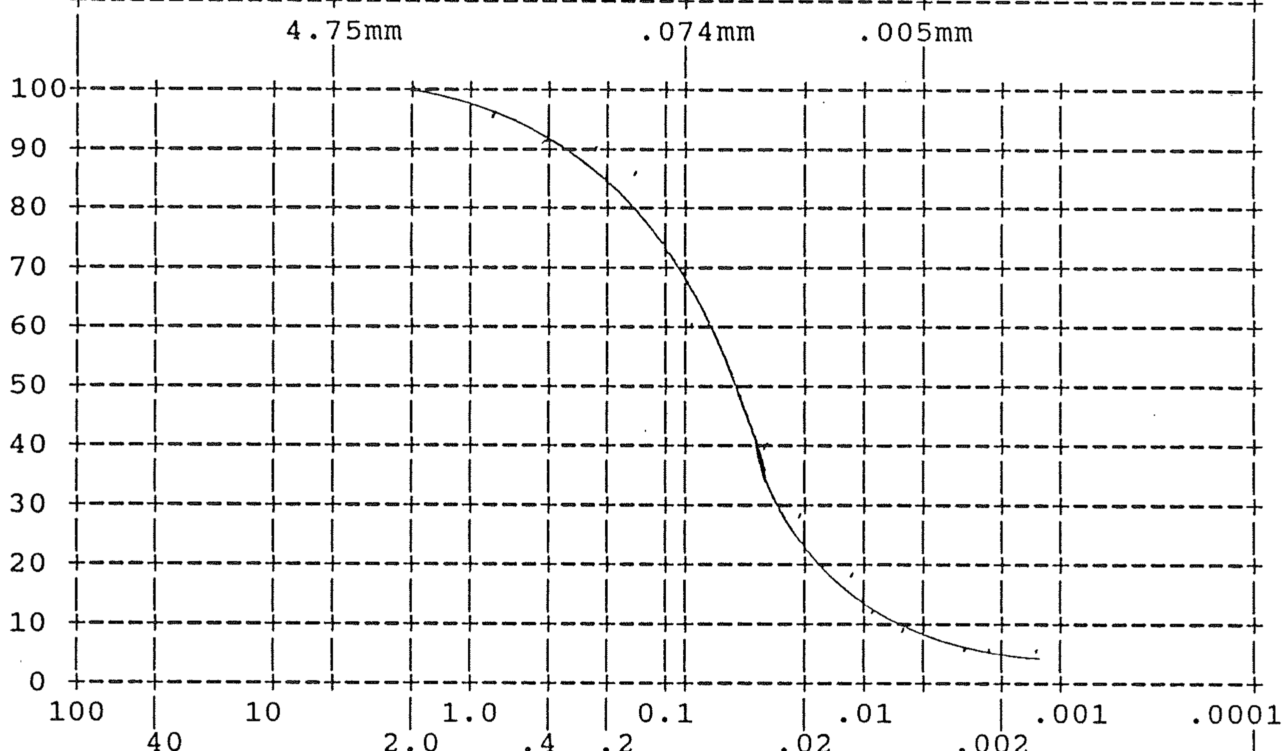
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/03/92

BH_CORE : GC-09A UP_DEPTH : 0.10 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	96
0.42	92
0.25	90
0.16	86
0.072	59.7
0.0320	39.7
0.0213	27.9
0.0127	17.5
0.0092	11.8
0.0066	8.6
0.0032	5.1
0.0024	5.1
0.0014	5.1



GRAIN SIZE IN MILLIMETERS

COMMENTS :

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GRAIN SIZE ANALYSIS

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B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

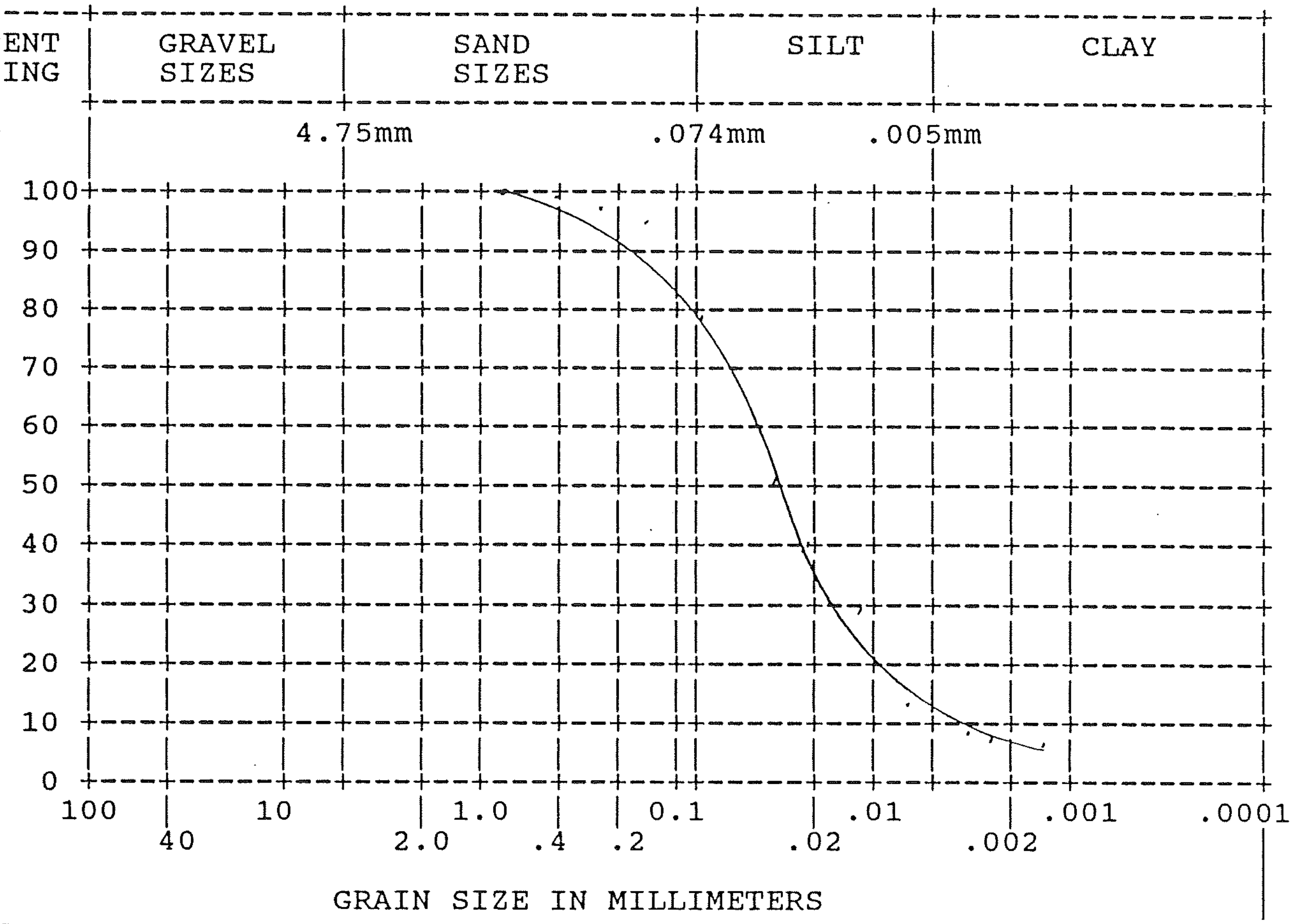
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

ROGRAM : MIR91 DATE TESTED : 02/03/92

BH_CORE : GC-13 UP_DEPTH : 0.40 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	100
0.42	99
0.25	97
0.16	95
0.072	78.4
0.0322	50.9
0.0214	39.8
0.0130	28.6
0.0096	19.9
0.0068	13.3
0.0034	8.0
0.0026	7.0
0.0014	6.1



OMMENTS :

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*                                        *
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GRAIN SIZE ANALYSIS

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B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

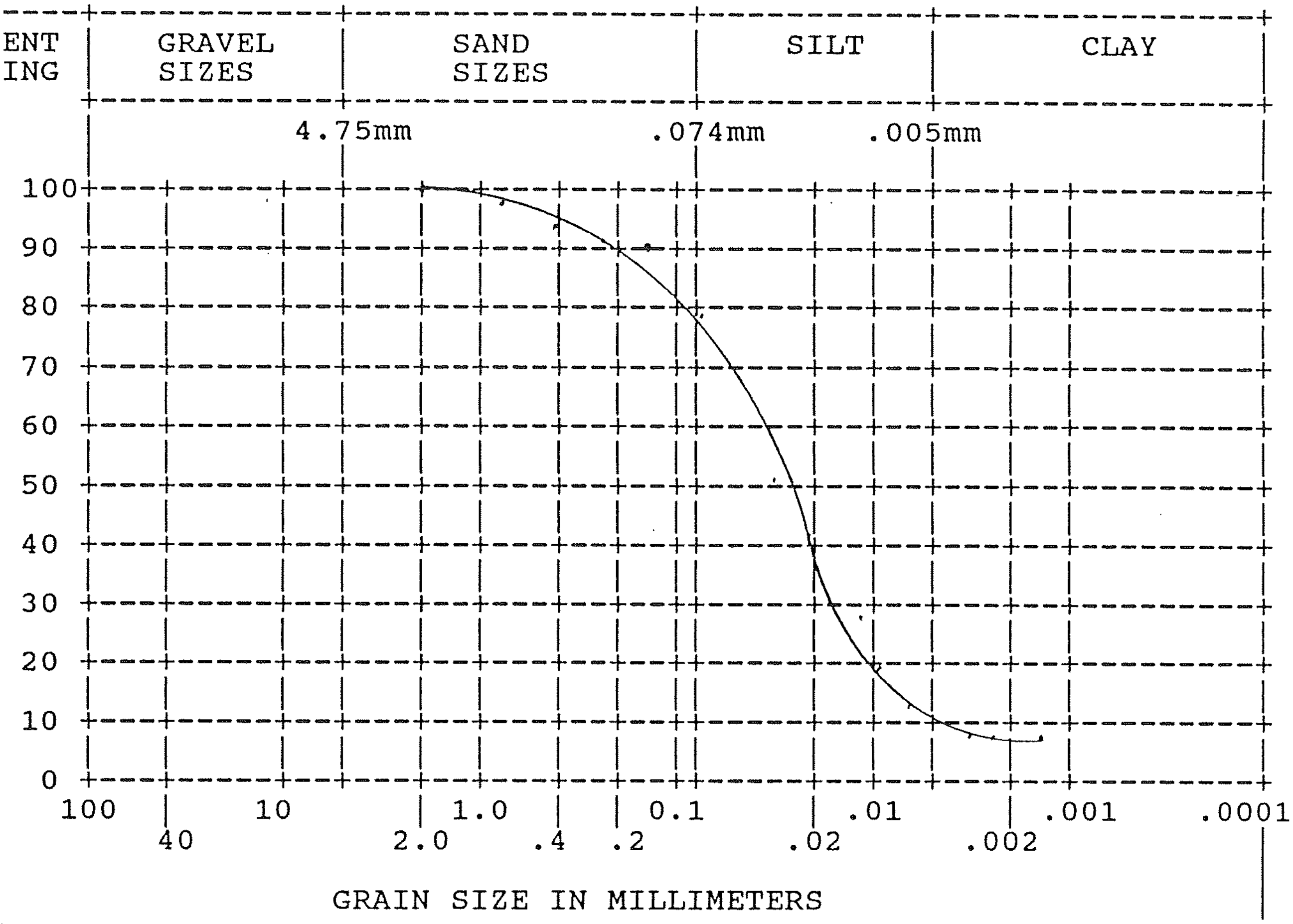
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/03/92

BH_CORE : GC-13 UP_DEPTH : 0.10 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	94
0.25	92
0.16	90
0.072	78.3
0.0318	50.7
0.0209	41.7
0.0128	26.9
0.0092	18.7
0.0065	12.7
0.0032	6.7
0.0024	6.7
0.0014	6.7



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31)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

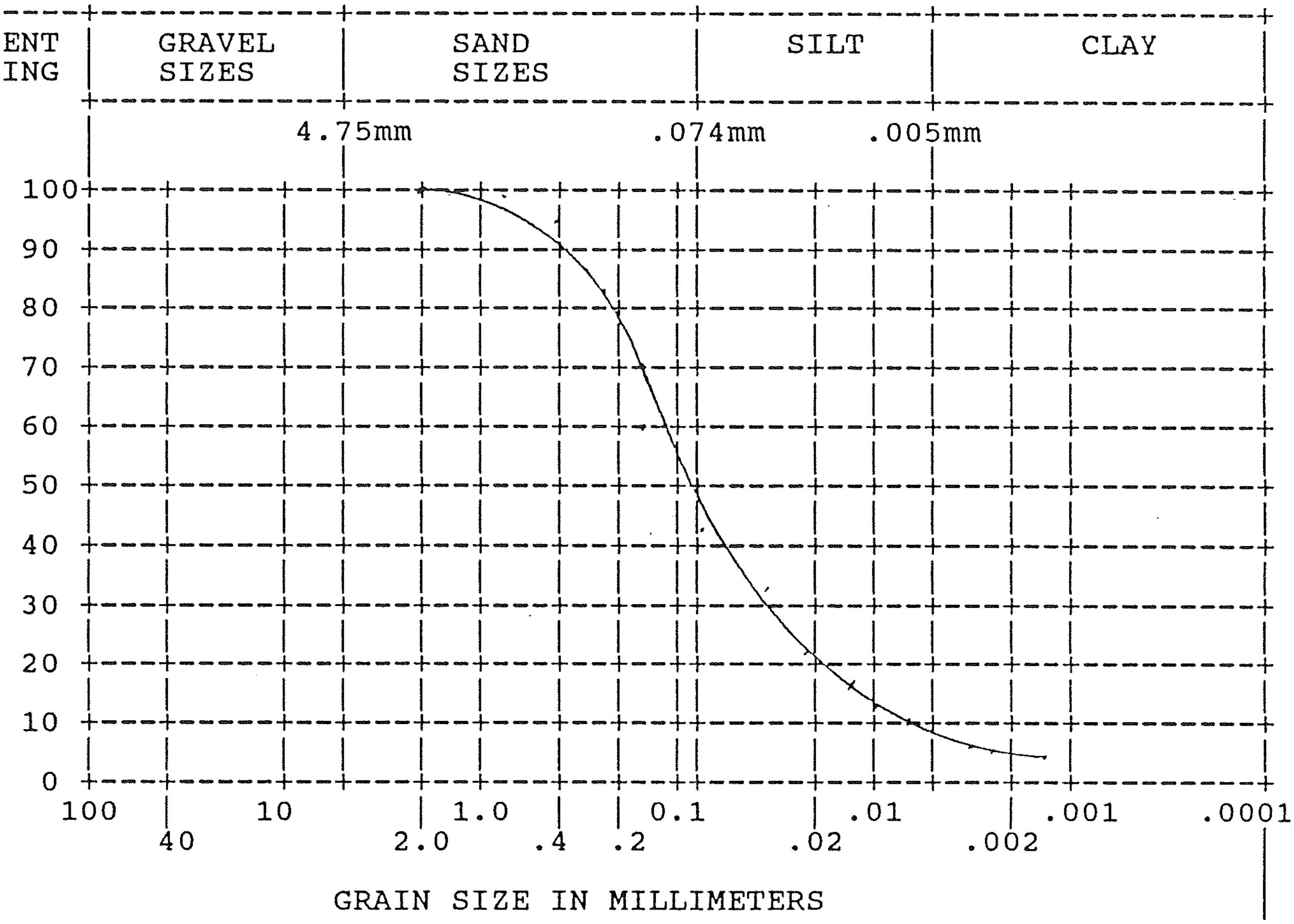
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

ROGRAM : MIR91 DATE TESTED : 02/03/92

BH_CORE : GC-09A UP_DEPTH : 0.20 GS_INTER : 0.03

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	83
0.16	60
0.072	42.9
0.0352	33.1
0.0232	21.9
0.0136	17.1
0.0098	12.9
0.0069	10.2
0.0033	6.2
0.0026	5.2
0.0014	4.4



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A.S.T.M. DESIGNATION D421,D422

(32)

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GRAIN SIZE ANALYSIS

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DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

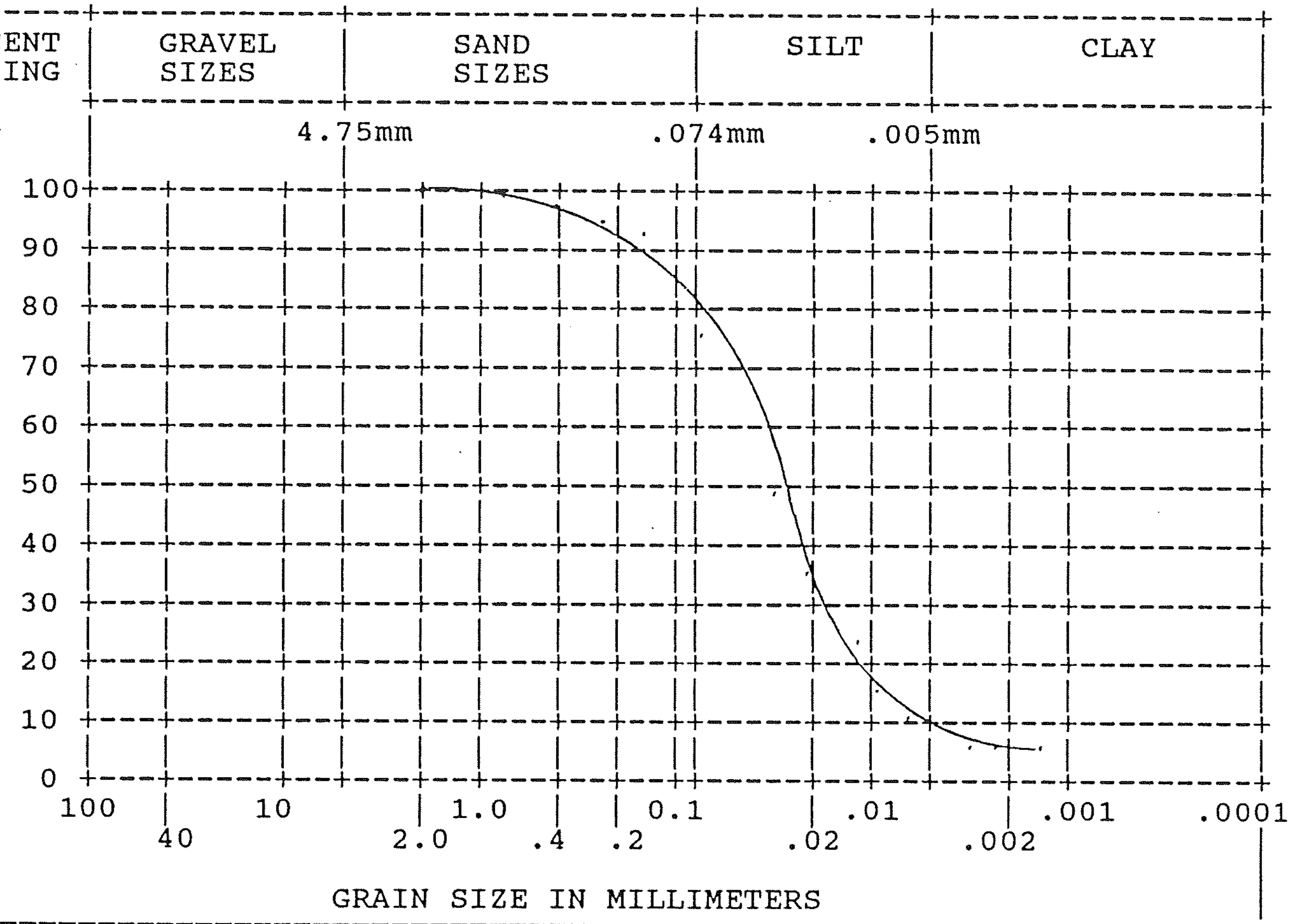
DATE TESTED : 02/04/92

BH_CORE : GC-13

UP_DEPTH : 0.20

GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	97
0.25	95
0.16	93
0.072	76.4
0.0317	48.7
0.0213	35.5
0.0129	23.6
0.0093	16.3
0.0066	10.8
0.0032	6.1
0.0024	6.1
0.0014	6.1



COMMENTS :

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CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(23)

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*                                     *
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*                                     *
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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

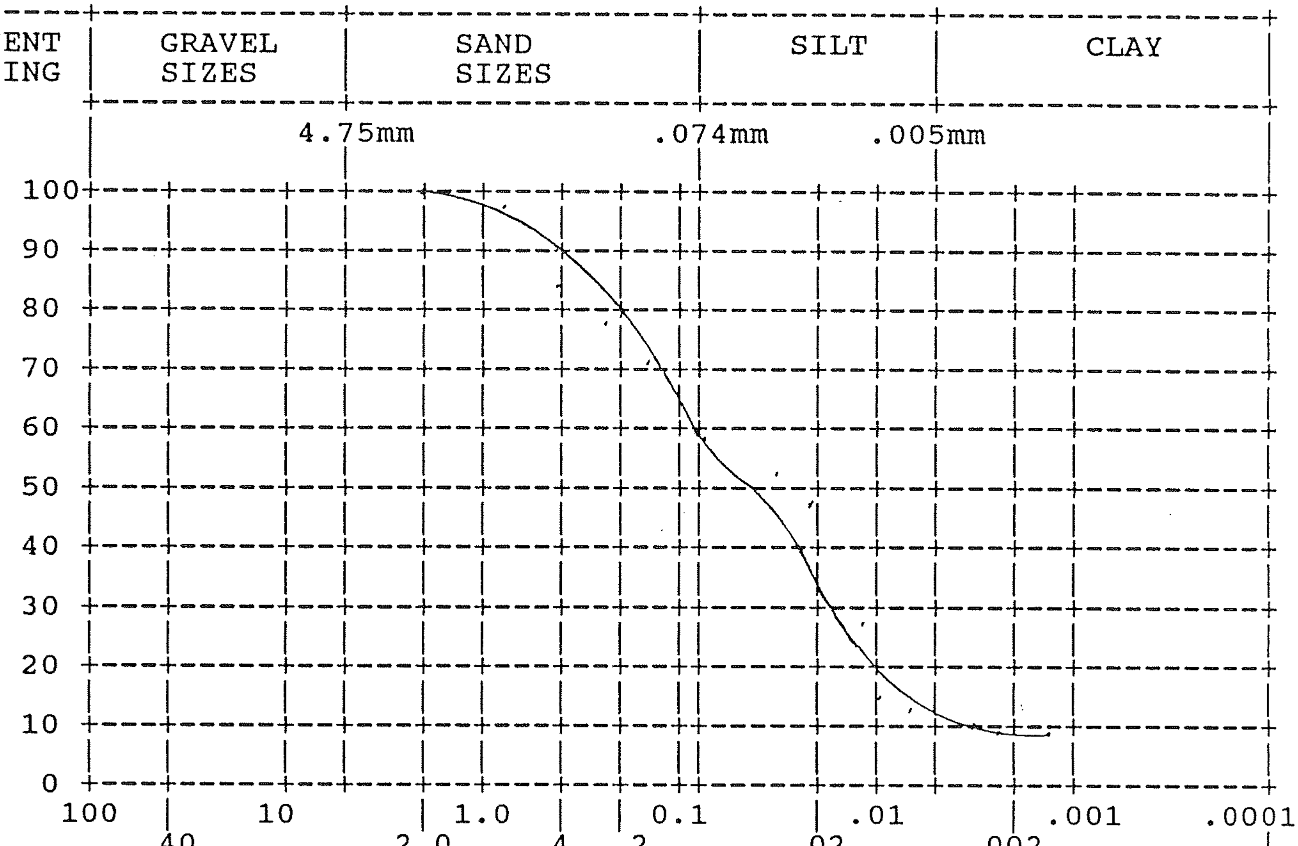
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-13   UP_DEPTH : 0.00   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	84
0.25	77
0.16	71
0.072	58.3
0.0326	53.0
0.0212	47.3
0.0133	26.9
0.0098	15.4
0.0069	12.7
0.0033	10.2
0.0025	9.4
0.0014	8.9



COMMENTS :

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A.S.T.M. DESIGNATION D421,D422

(24)

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

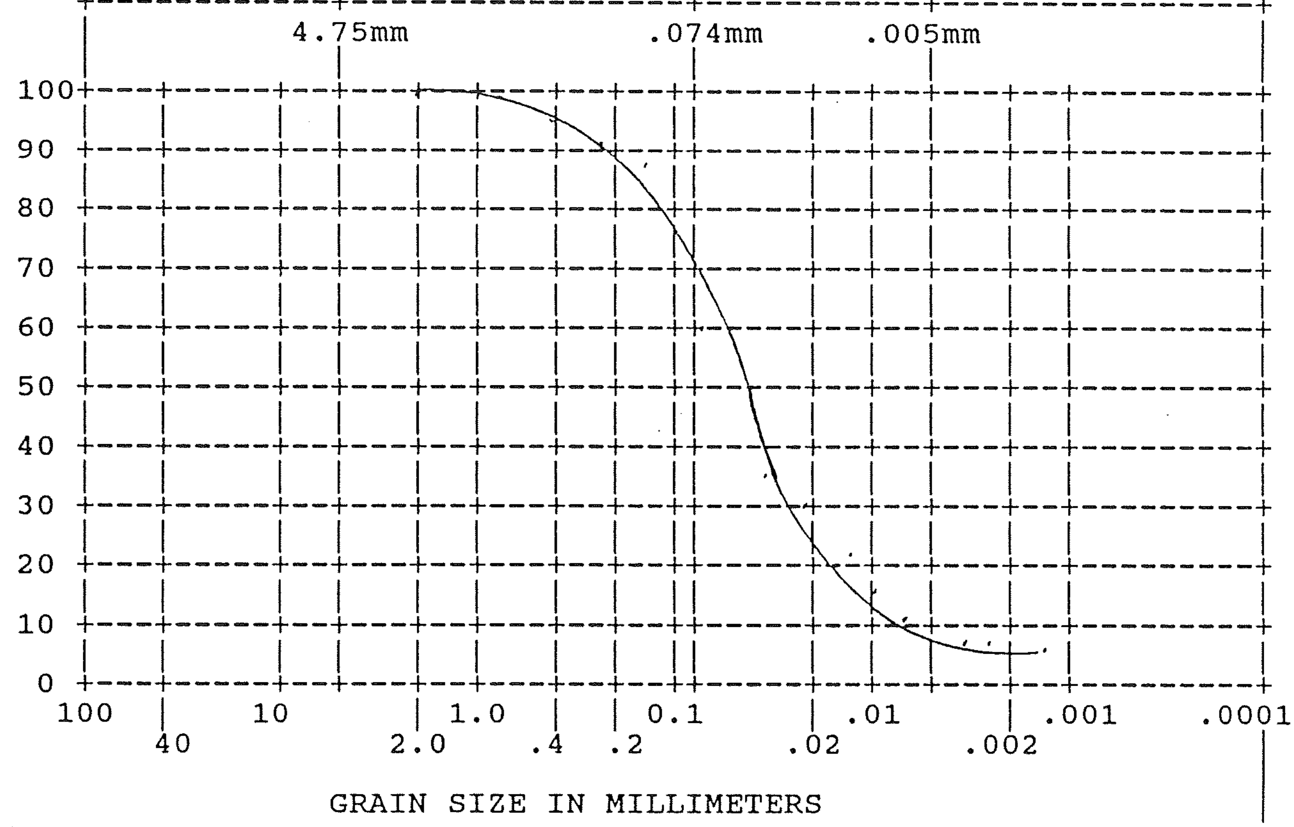
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-09B   UP_DEPTH : 0.05   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	91
0.16	87
0.072	60.0
0.0347	35.8
0.0226	29.9
0.0135	21.5
0.0097	15.8
0.0070	10.8
0.0034	7.2
0.0026	6.8
0.0014	6.3



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(35)

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GRAIN SIZE ANALYSIS

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B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

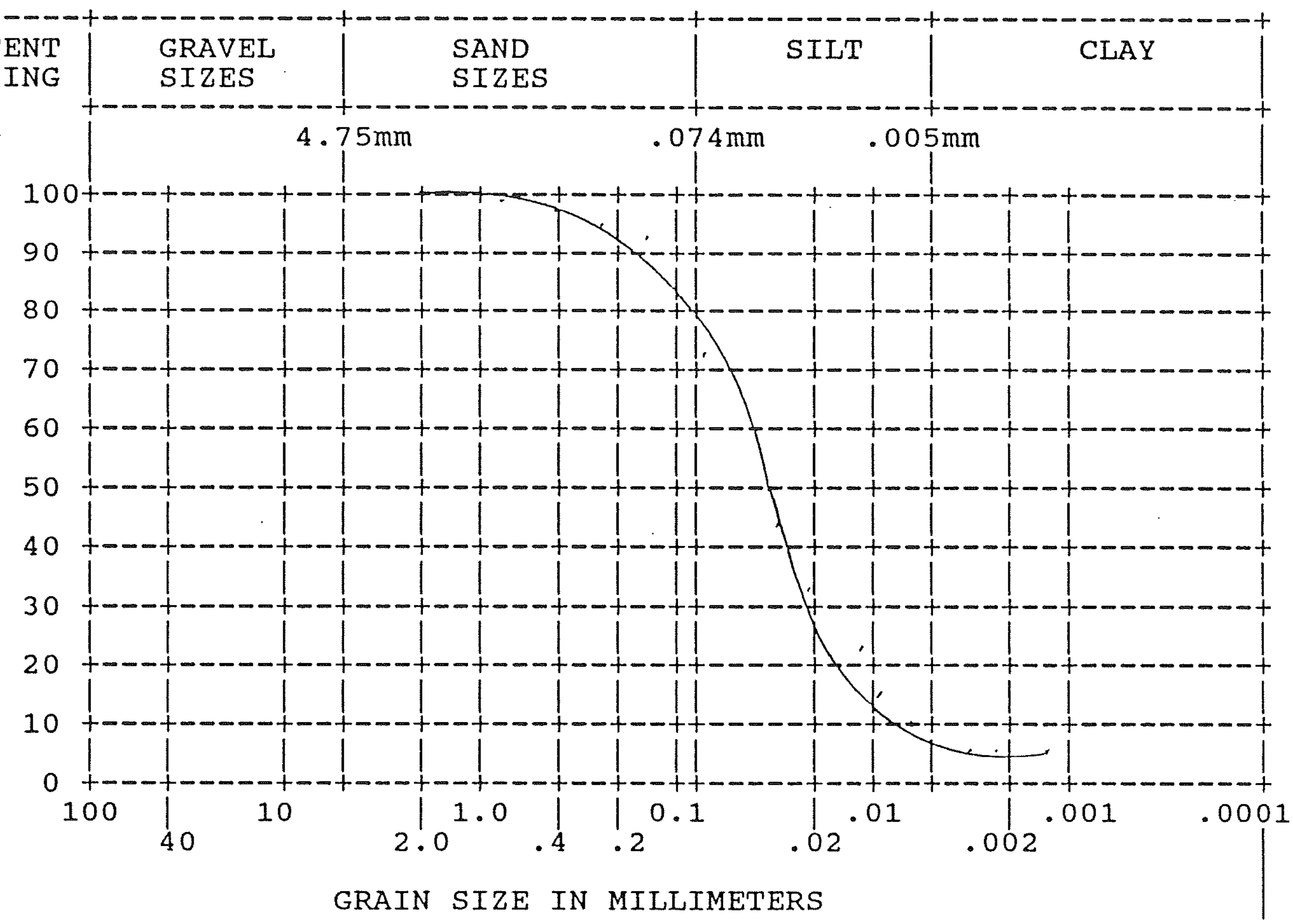
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-13 UP_DEPTH : 0.25 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	97
0.25	95
0.16	93
0.072	73.1
0.0318	44.3
0.0212	33.4
0.0128	23.3
0.0092	15.9
0.0066	10.4
0.0032	6.1
0.0024	6.1
0.0014	6.1



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

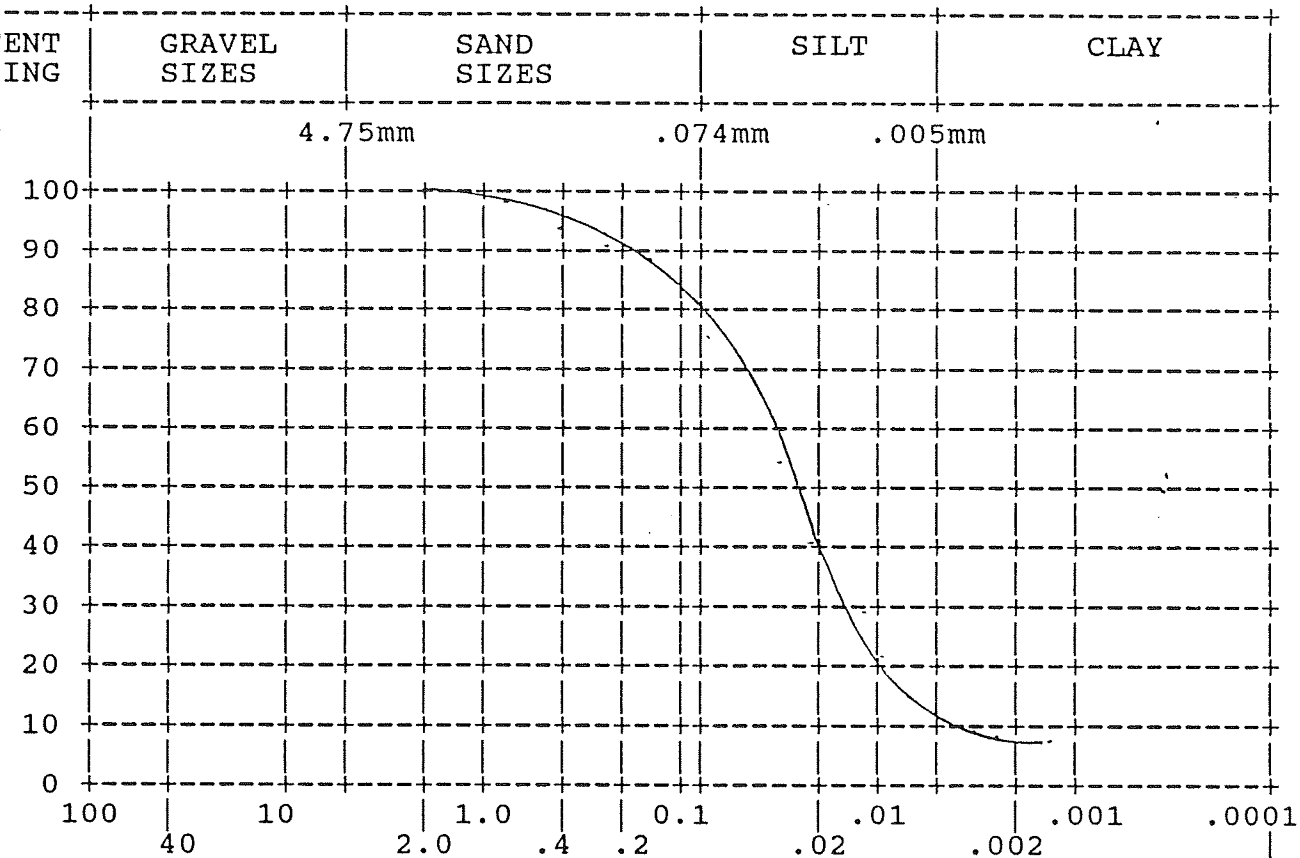
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

ROGRAM : MIR91   DATE TESTED : 02/04/92

BH_CORE : GC-13   UP_DEPTH : 0.15   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	94
0.25	91
0.16	88
0.072	75.4
0.0332	53.7
0.0222	40.8
0.0134	29.1
0.0096	21.6
0.0069	14.9
0.0033	9.2
0.0026	8.2
0.0014	7.2



COMMENTS :

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A.S.T.M. DESIGNATION D421,D422

(3)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

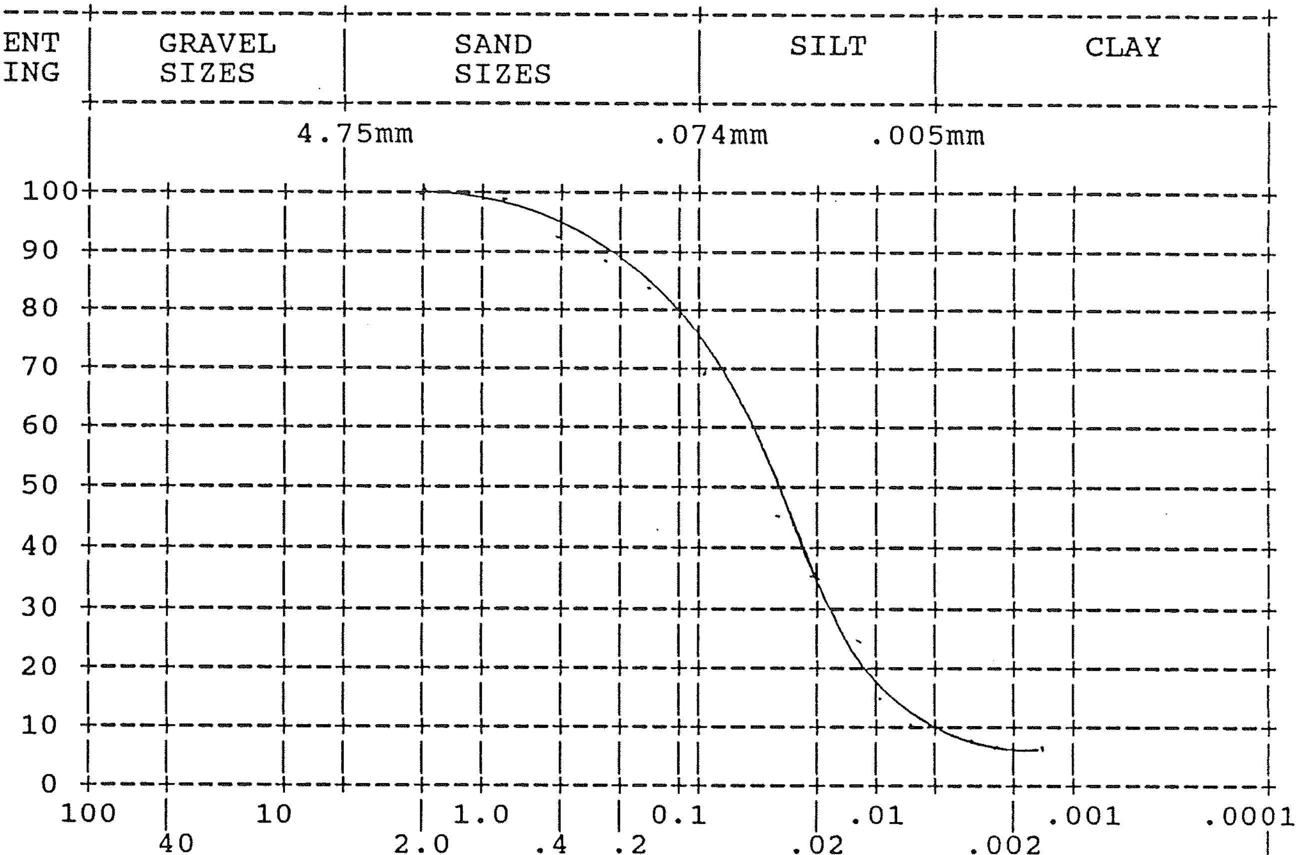
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-18 UP_DEPTH : 0.05 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	93
0.25	88
0.16	84
0.072	69.1
0.0320	45.9
0.0212	36.2
0.0128	24.8
0.0094	14.1
0.0068	9.7
0.0033	6.7
0.0025	6.4
0.0013	6.2



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ______________________

CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(3)

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Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

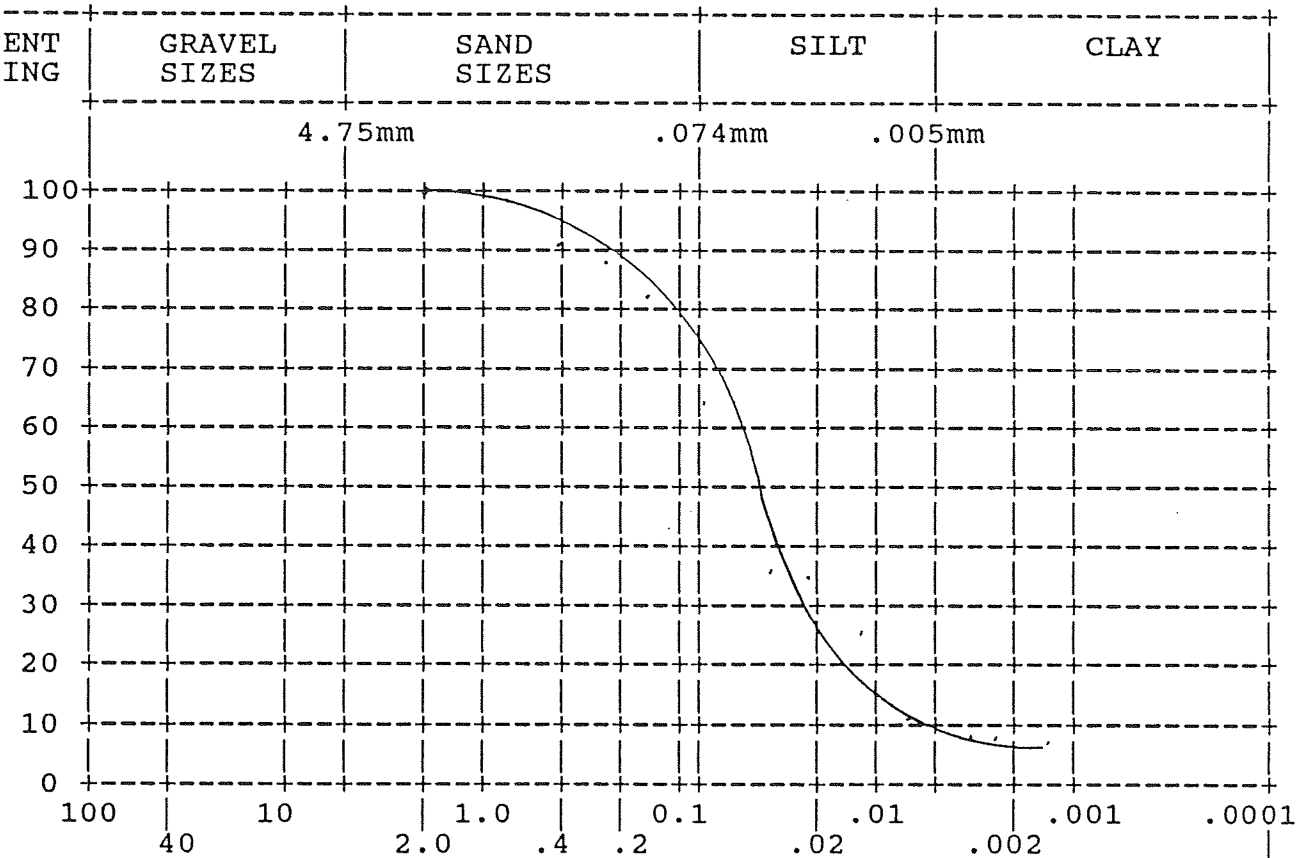
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-09B   UP_DEPTH : 0.00   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	91
0.25	87
0.16	83
0.072	64.1
0.0350	35.7
0.0222	35.0
0.0133	25.7
0.0098	15.4
0.0069	11.4
0.0034	8.3
0.0026	7.6
0.0014	6.6



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ________________________   CERTIFIED BY : ________________________

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Suite 116 , 900 Windmill Road
Dartmouth N.S. B3B 1P7 468-6486

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

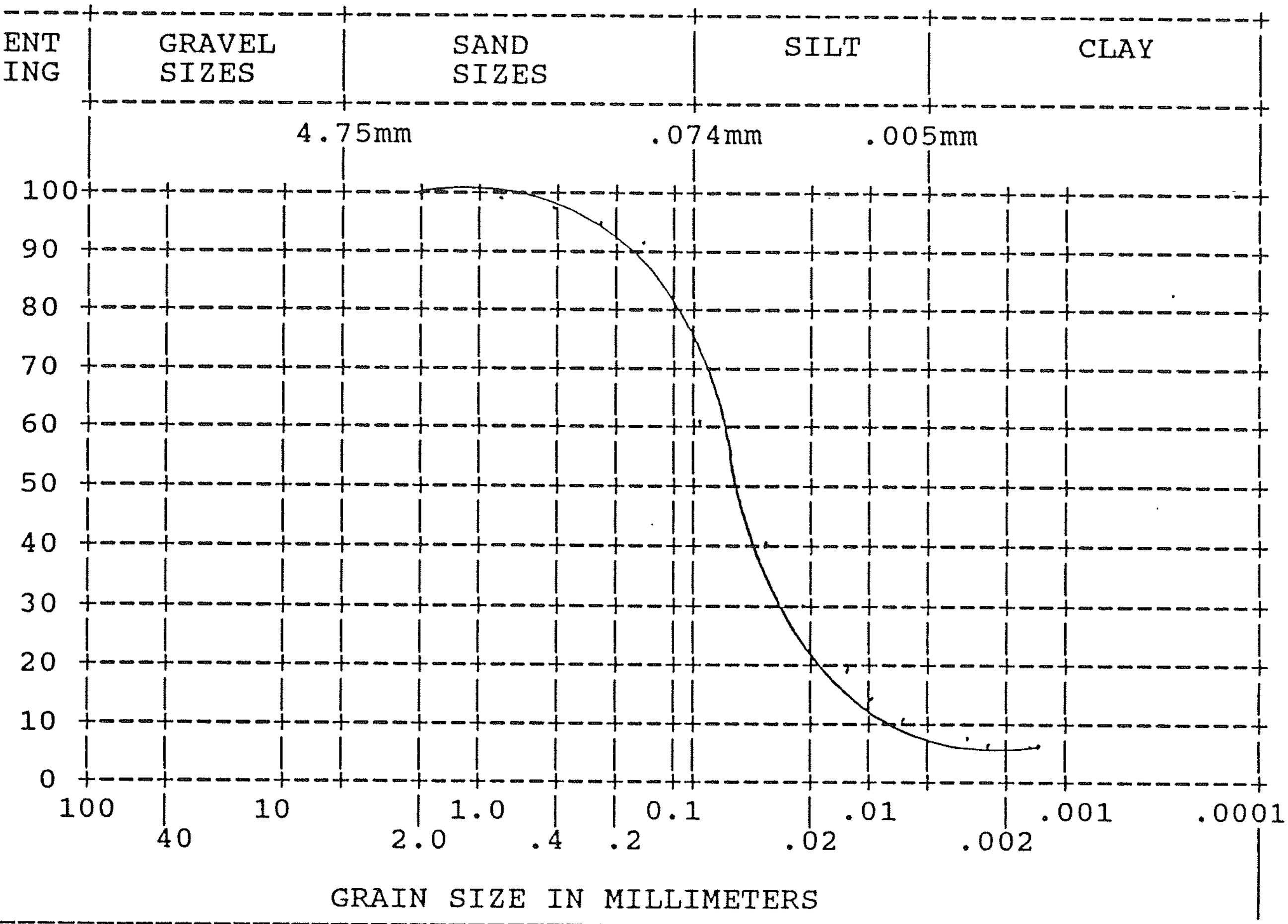
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-09B   UP_DEPTH : 0.10   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	97
0.25	95
0.16	92
0.072	61.2
0.0351	40.0
0.0231	30.0
0.0139	19.3
0.0098	14.4
0.0069	10.9
0.0033	6.7
0.0026	6.2
0.0014	5.9



COMMENTS :

CHECKED BY : ________________   CERTIFIED BY : ________________

A.S.T.M. DESIGNATION D421,D422

```
*****************************************
*                                       *
*   MARITIME  TESTING (1985)  LIMITED   *
*     Suite 116 , 900 Windmill Road     *
*   Dartmouth N.S. B3B 1P7 468-6486     *
*                                       *
*****************************************
```

GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

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BEDFORD INSTITUTE OF OCEANOGRAPHY
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DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

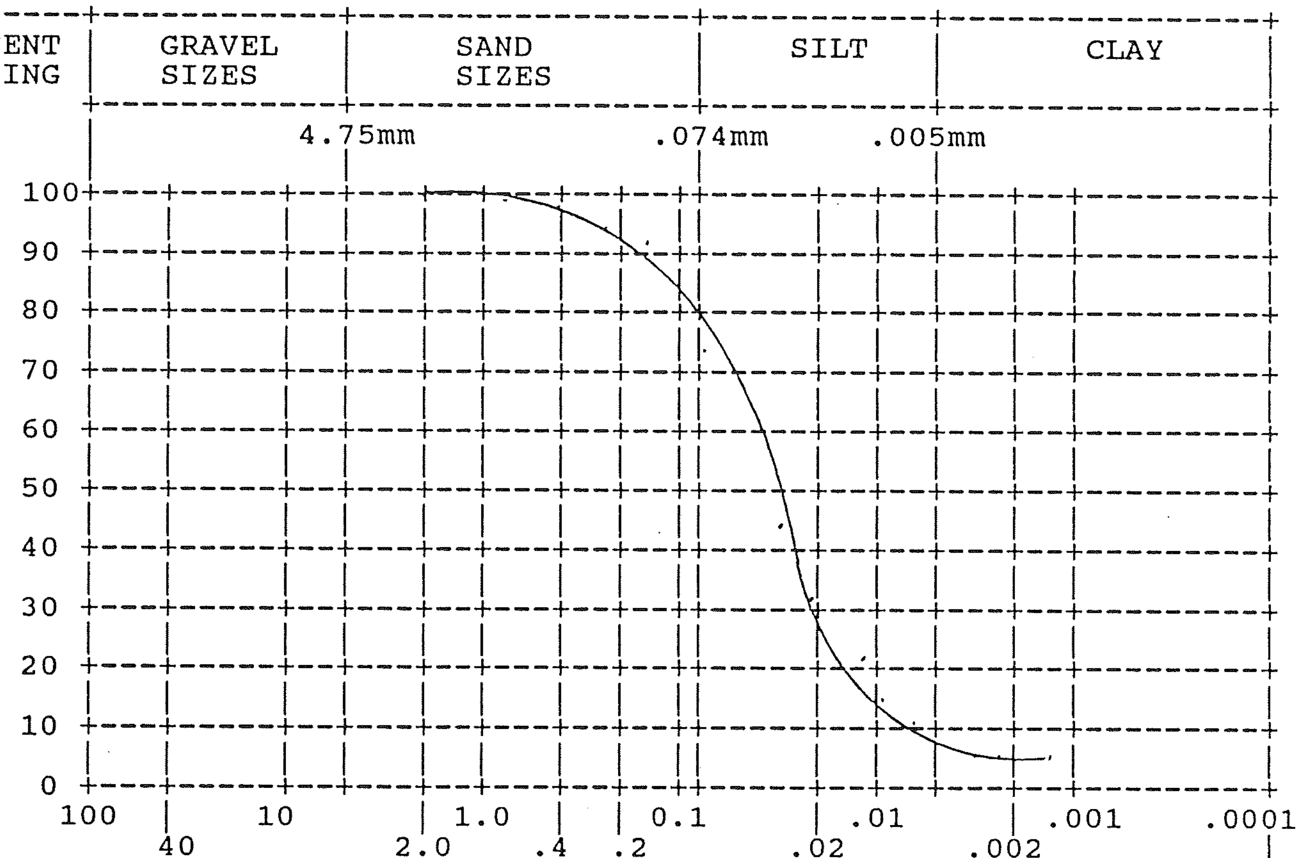
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/95

BH_CORE : GC-13   UP_DEPTH : 0.30   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	97
0.25	94
0.16	92
0.072	73.6
0.0319	43.8
0.0213	32.0
0.0128	21.5
0.0093	15.3
0.0066	11.1
0.0032	6.2
0.0024	6.2
0.0014	6.2



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ________________________   CERTIFIED BY : ________________________

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

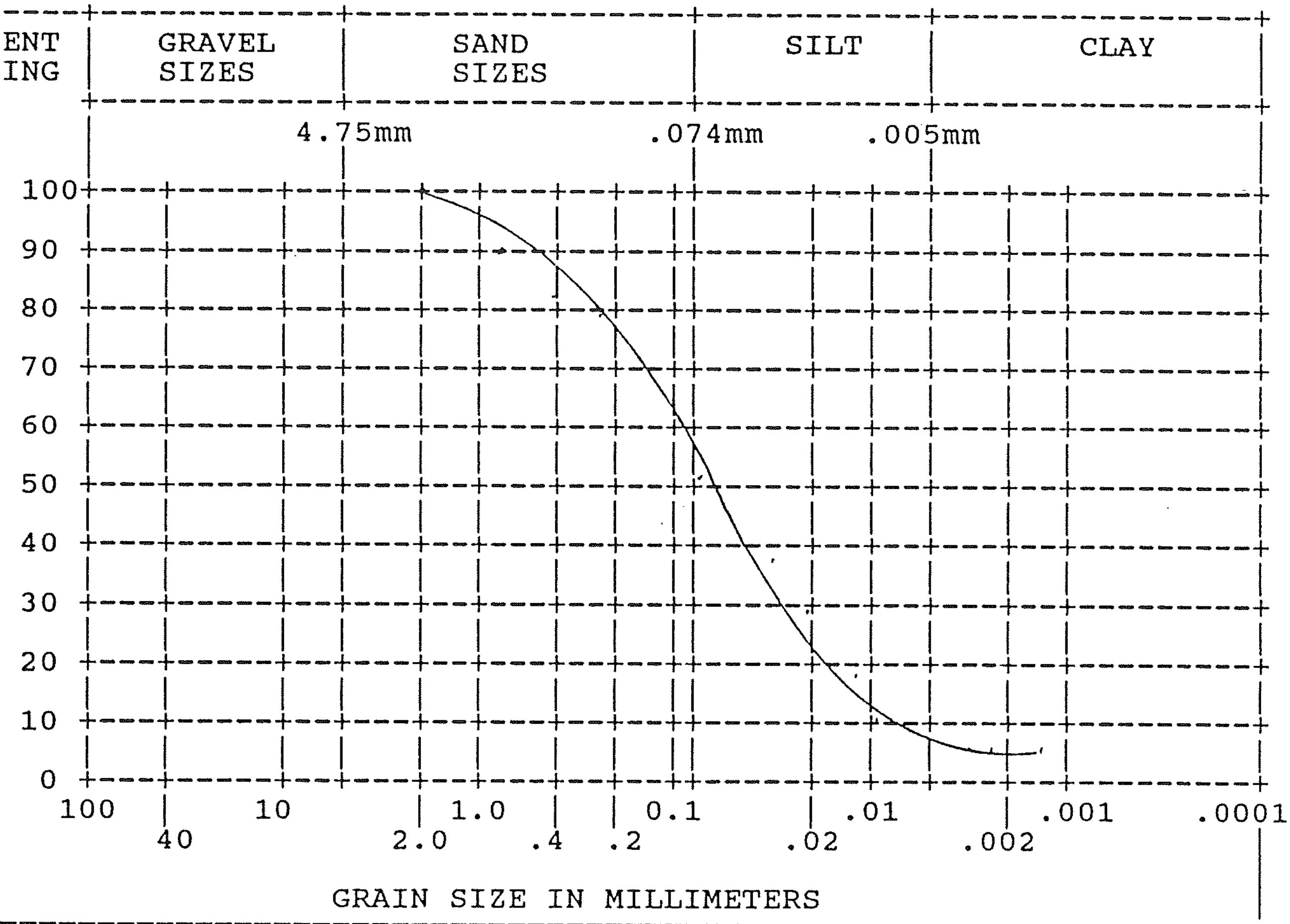
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

F OGRAM : MIR91 DATE TESTED : 02/04/92

BH_CORE : GC-09A UP_DEPTH : 0.05 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	90
0.42	83
0.25	79
0.16	75
0.072	52.0
0.0325	37.2
0.0213	28.8
0.0128	17.6
0.0092	10.9
0.0066	8.6
0.0032	5.8
0.0025	5.8
0.0014	5.8



OMMENTS :

HECKED BY : ________________________ CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

42

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

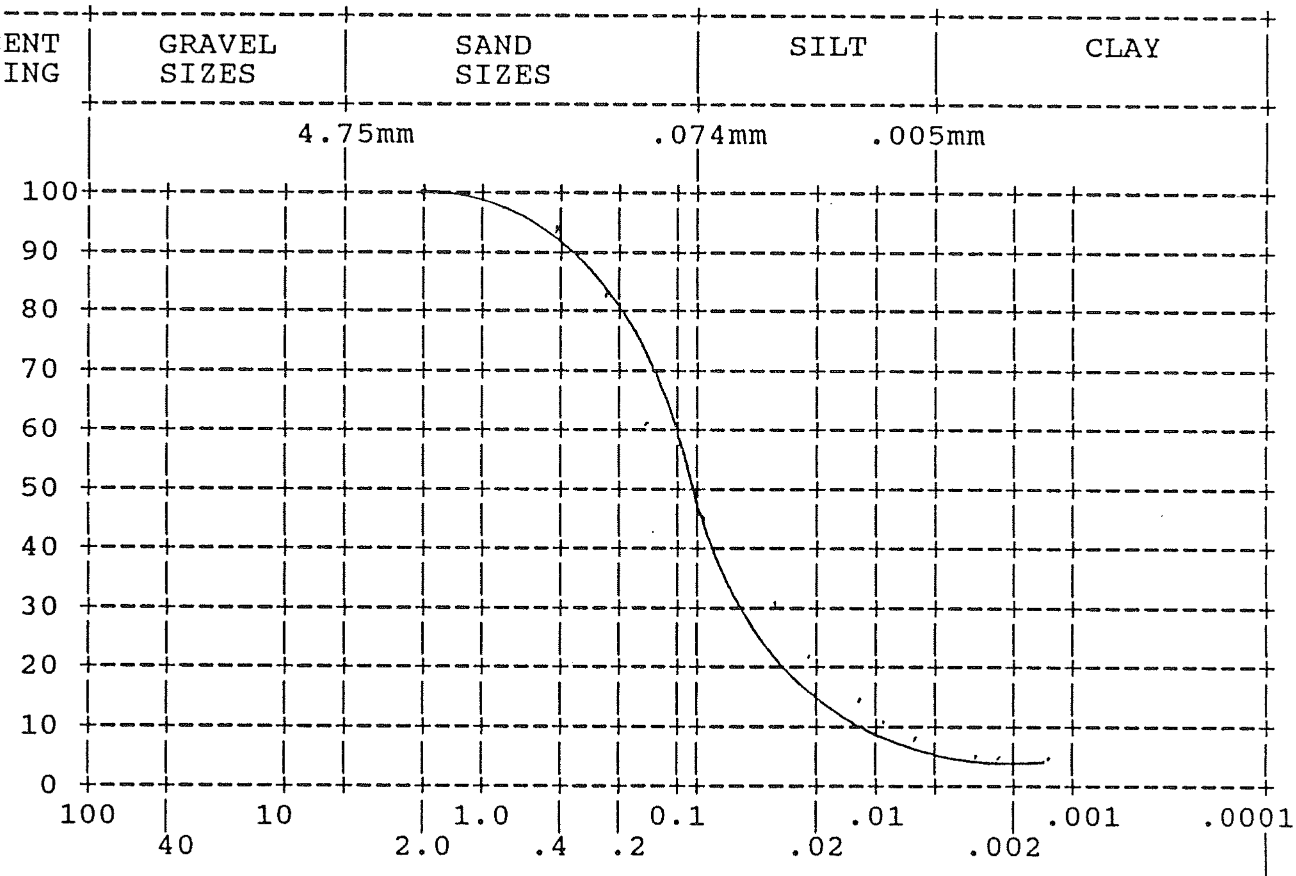
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-09B   UP_DEPTH : 0.15   GS_INTER : 0.07

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	94
0.25	83
0.16	61
0.072	45.1
0.0328	30.9
0.0216	22.1
0.0128	14.8
0.0092	10.6
0.0066	7.6
0.0032	4.5
0.0025	4.5
0.0014	4.5



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ______________________   CERTIFIED BY : ______________________

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

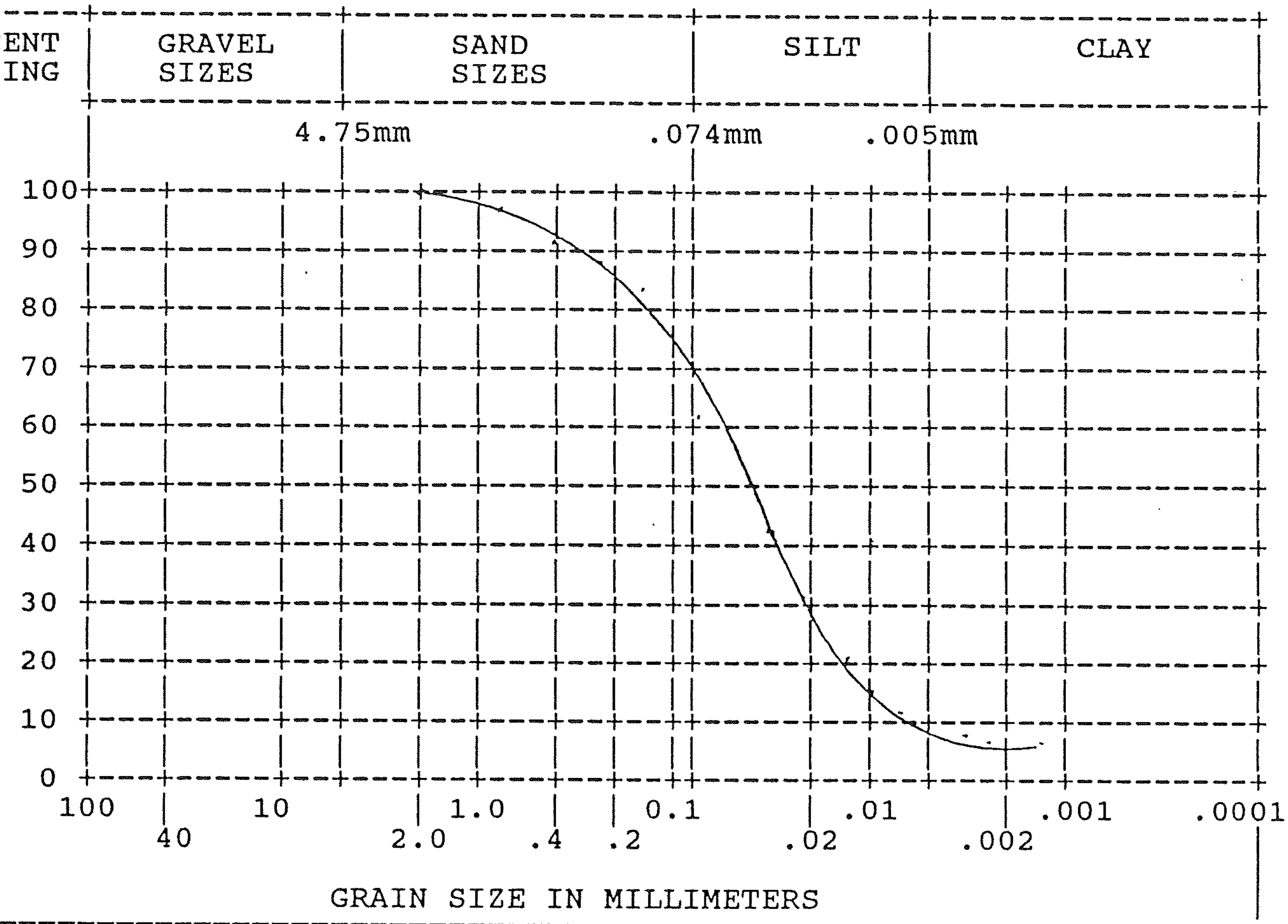
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : GC-09A UP_DEPTH : 0.15 GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	97
0.42	92
0.25	88
0.16	84
0.072	62.0
0.0344	42.7
0.0229	30.7
0.0137	21.1
0.0098	15.6
0.0070	11.5
0.0033	6.7
0.0026	6.2
0.0014	5.7



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

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GRAIN SIZE ANALYSIS

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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

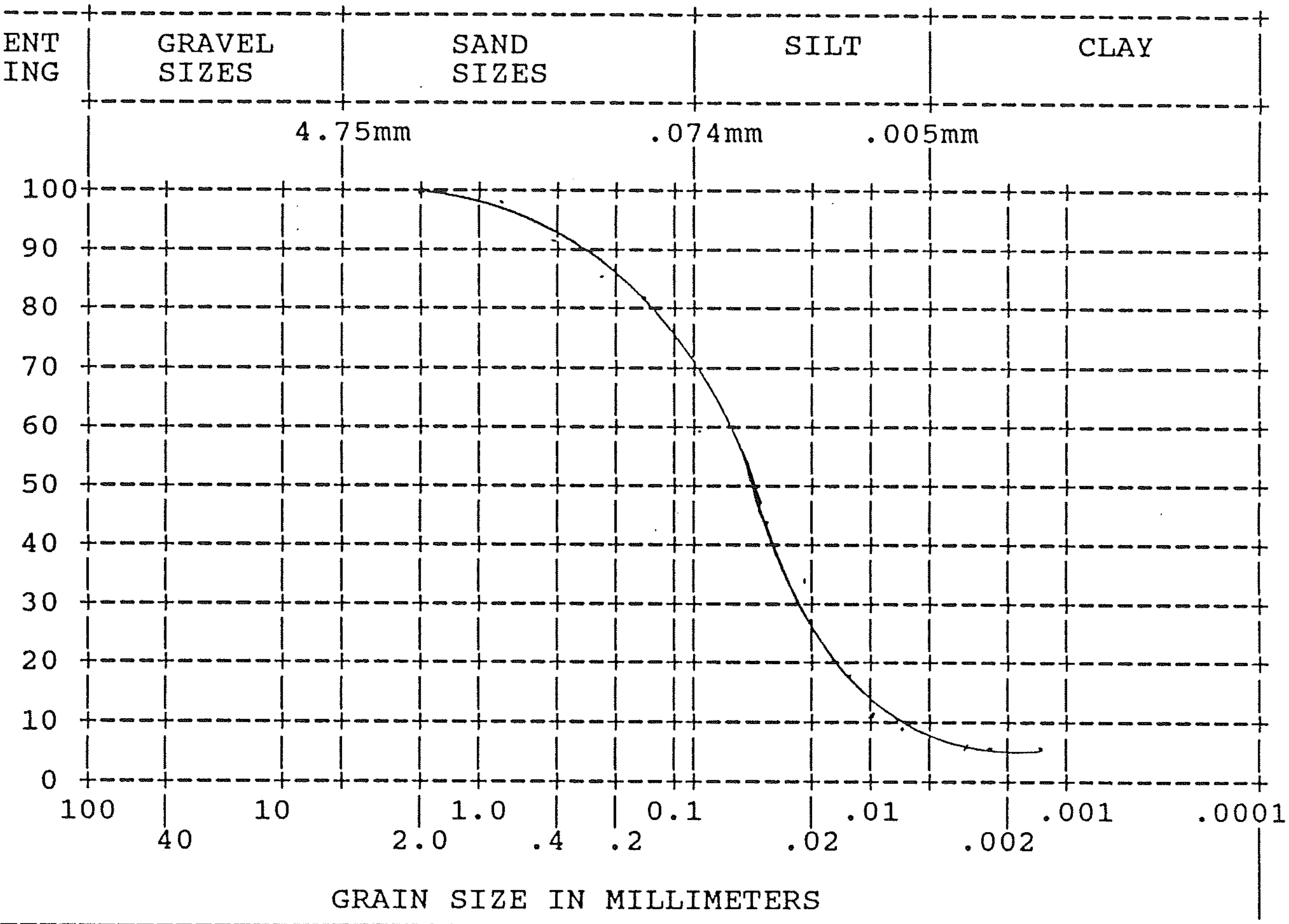
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : VV-09 UP_DEPTH : 0.00 GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	92
0.25	86
0.16	82
0.072	58.9
0.0339	44.1
0.0224	33.9
0.0138	17.3
0.0098	11.4
0.0069	8.7
0.0033	6.1
0.0025	6.1
0.0014	6.1



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

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BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

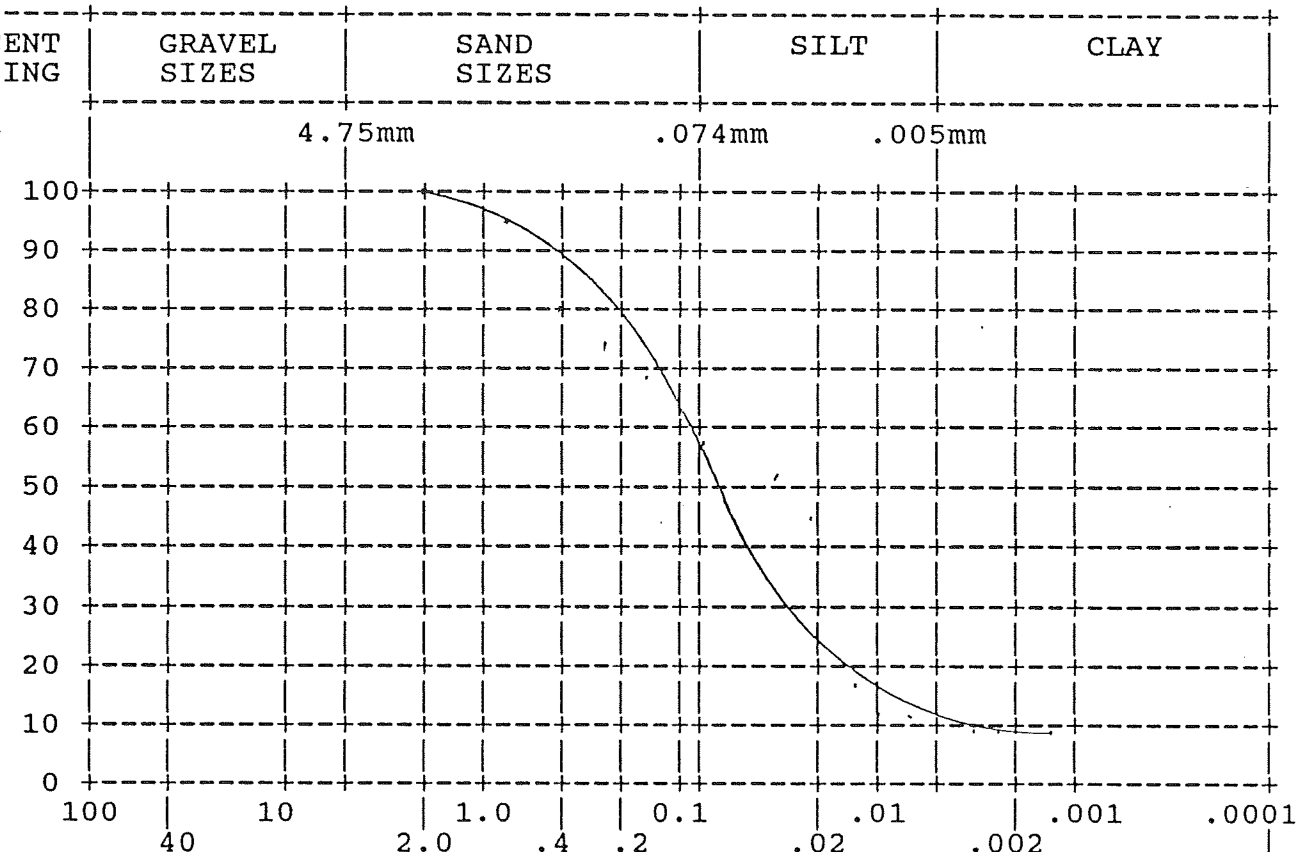
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91 DATE TESTED : 02/04/92

PH_CORE : VV-13 UP_DEPTH : 0.00 GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	94
0.42	80
0.25	74
0.16	68
0.072	56.7
0.0324	51.8
0.0211	45.3
0.0136	16.9
0.0098	12.4
0.0069	11.9
0.0033	9.2
0.0025	9.2
0.0014	9.2



GRAIN SIZE IN MILLIMETERS

COMMENTS :

CHECKED BY : ________________________ CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

149

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

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BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

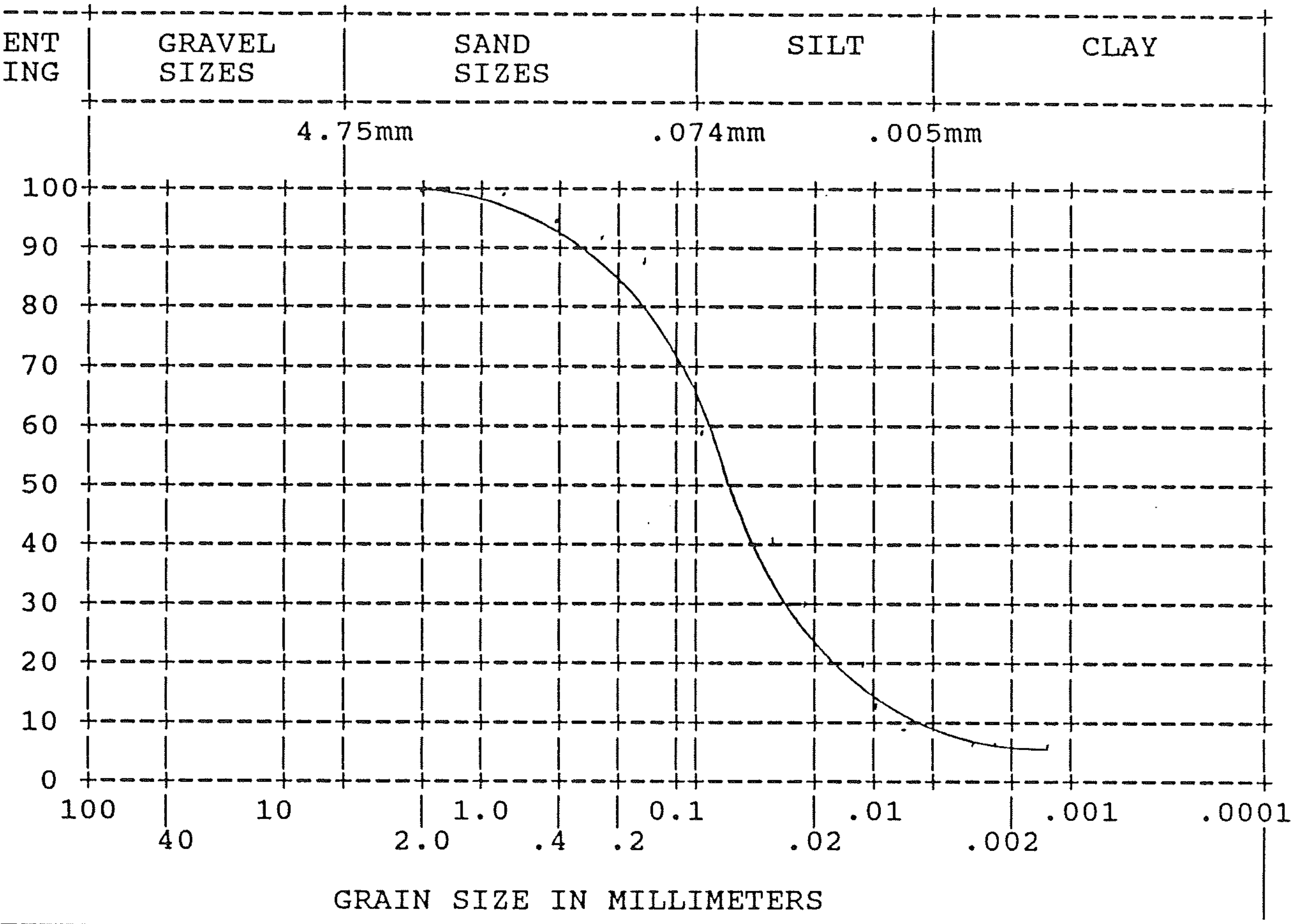
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

ROGRAM : MIR91 DATE TESTED : 02/04/92

PH_CORE : VV-10 UP_DEPTH : 0.00 GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	95
0.25	92
0.16	87
0.072	59.0
0.0340	40.5
0.0225	30.4
0.0134	19.6
0.0097	12.5
0.0070	8.7
0.0033	5.7
0.0025	5.7
0.0014	5.7



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

41)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

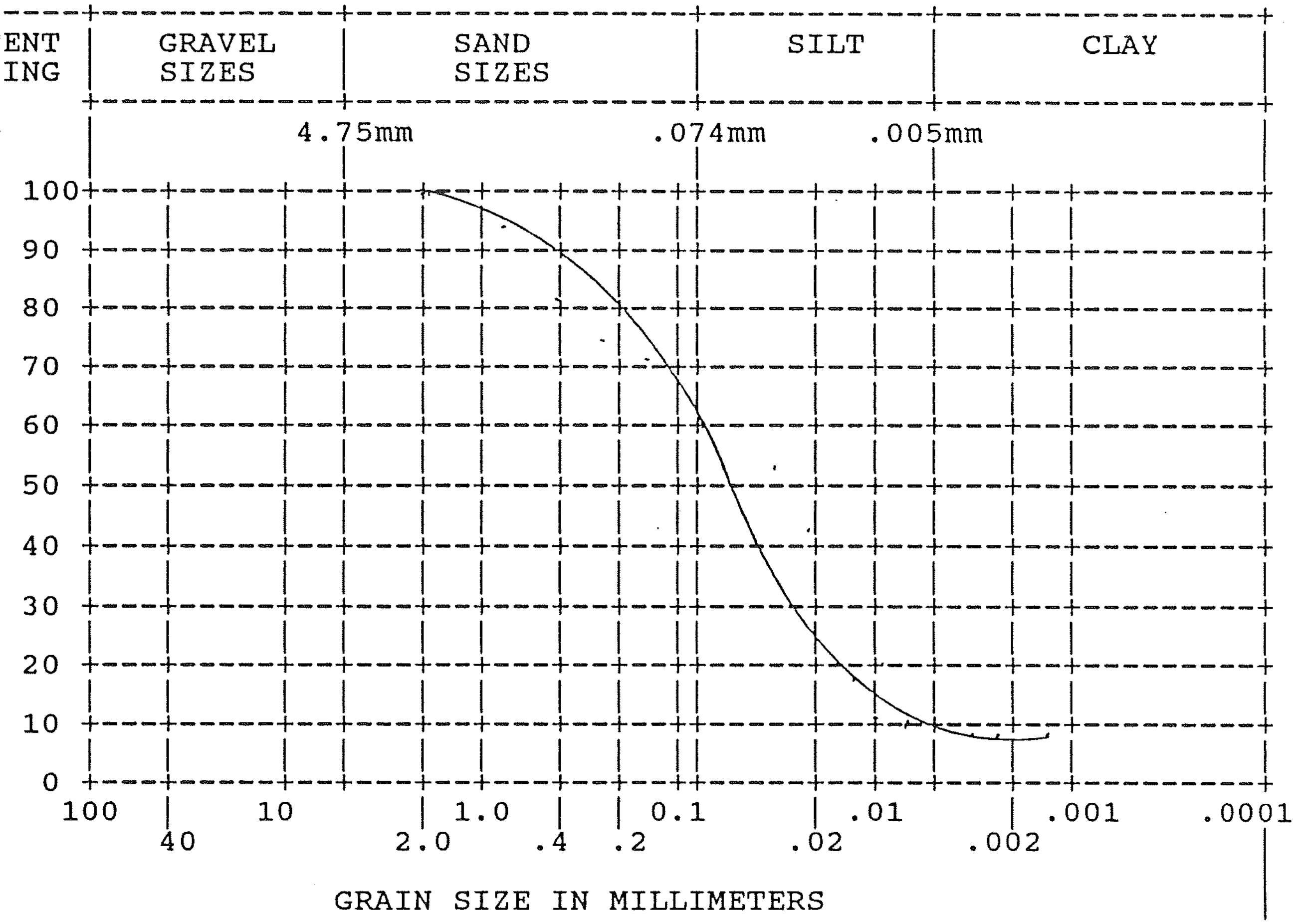
DATE TESTED : 02/04/92

BH_CORE : VV-18

UP_DEPTH : 0.00

GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	94
0.42	82
0.25	75
0.16	71
0.072	59.5
0.0325	52.6
0.0215	43.1
0.0138	17.2
0.0098	11.4
0.0069	9.9
0.0033	7.5
0.0025	7.5
0.0014	7.5



COMMENTS :

CHECKED BY : ______________________

CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

(40)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NAO0750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

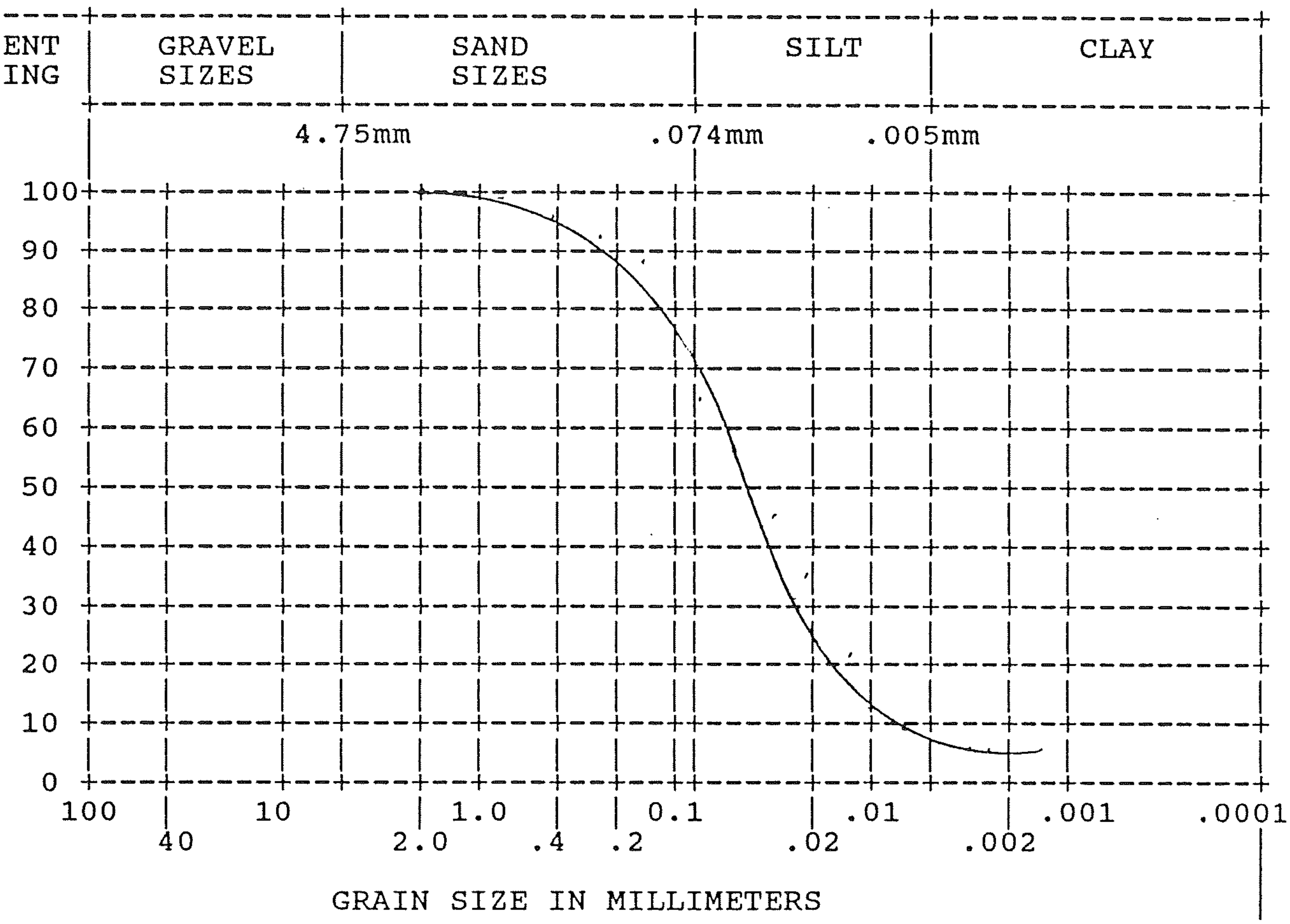
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : VV-07 UP_DEPTH : 0.00 GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	93
0.16	88
0.072	65.0
0.0331	45.8
0.0220	35.5
0.0135	22.0
0.0099	12.6
0.0070	9.1
0.0033	6.4
0.0026	6.1
0.0014	5.9



COMMENTS :

CHECKED BY : ______________________ CERTIFIED BY : ______________________

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(49)

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GRAIN SIZE ANALYSIS

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ENERGY MINES & RESOURCES
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P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

CONTRACT NO: OSC90-00315-(008)/A

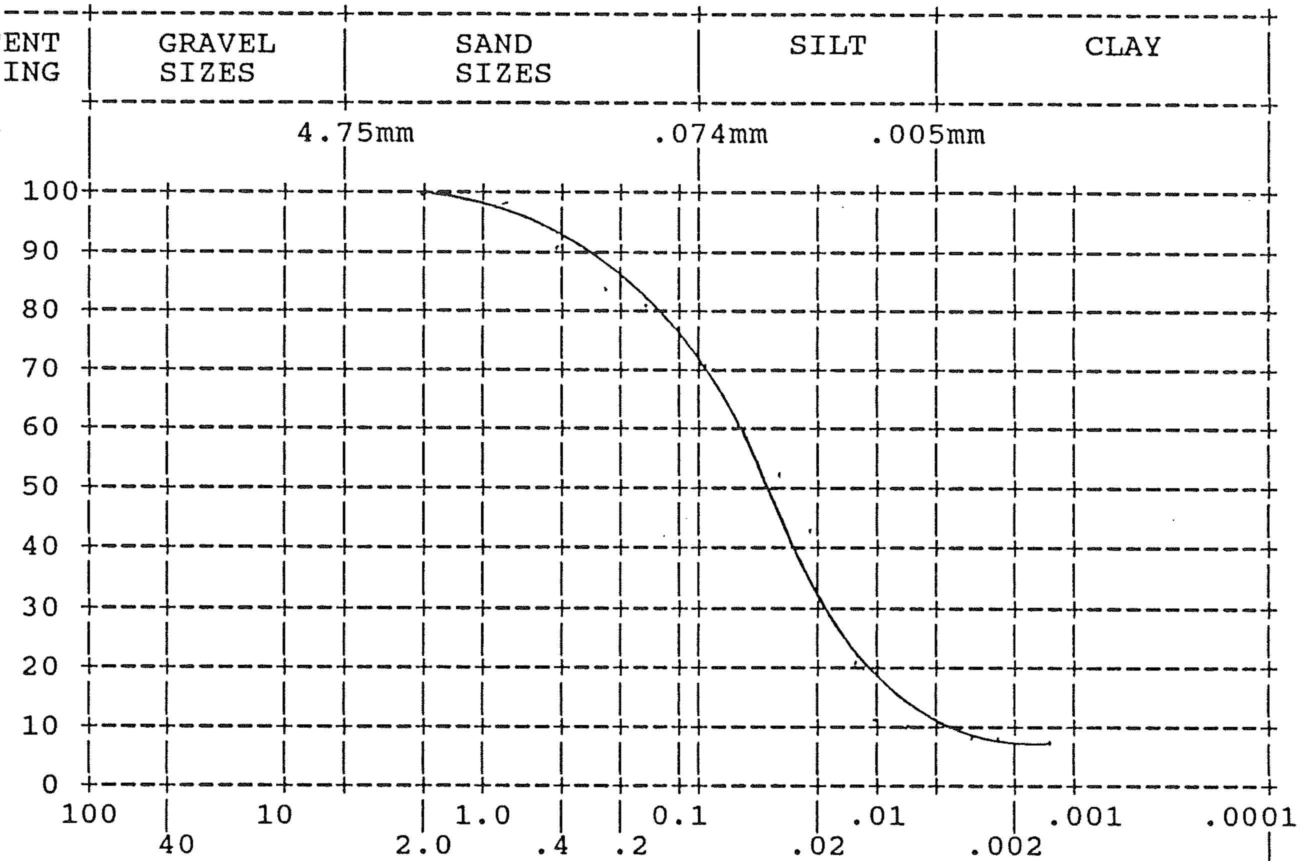
PROJECT : Geotechnical Particle Size

PROGRAM : MIR91

DATE TESTED : 02/04/92

BH_CORE : VV-01   UP_DEPTH : 0.00   GS_INTER : 0.10

SIEVE SIZE MM	PERCENT PASSING
5.0	100
9.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	98
0.42	91
0.25	84
0.16	81
0.072	71.2
0.0323	53.1
0.0215	42.5
0.0136	20.5
0.0098	12.2
0.0069	10.2
0.0033	8.3
0.0025	7.6
0.0014	7.1



COMMENTS :

CHECKED BY : ________________________

CERTIFIED BY : ________________________

A.S.T.M. DESIGNATION D421,D422

(2)

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GRAIN SIZE ANALYSIS

C.S.A. CERTIFIED LAB

ENERGY MINES & RESOURCES
BEDFORD INSTITUTE OF OCEANOGRAPHY
P.O. BOX 1006
DARTMOUTH, NOVA SCOTIA
B2Y A42

FILE : NA00750
DATE : 02/04/92

ATTN: BOB HARMES

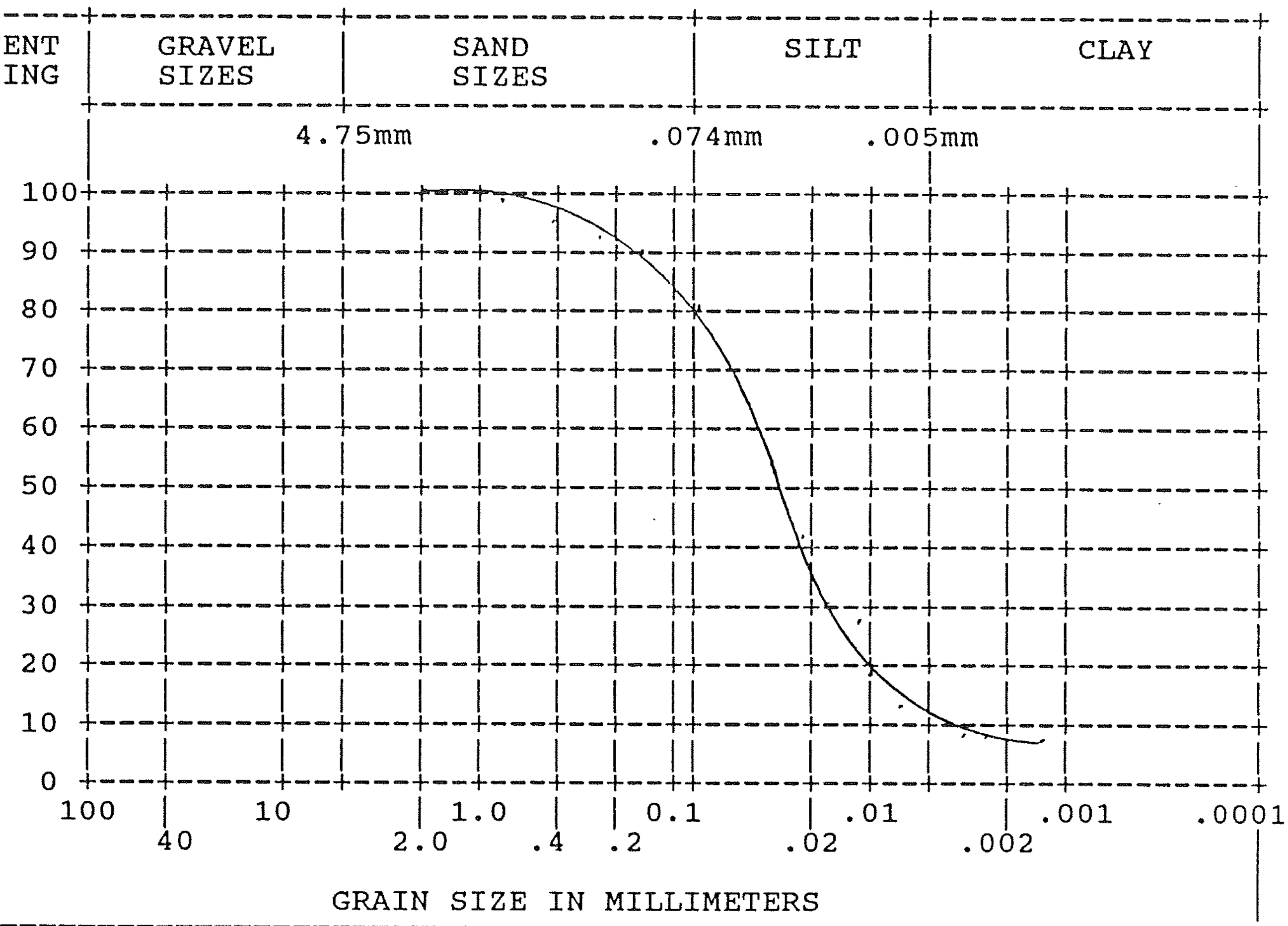
CONTRACT NO: OSC90-00315-(008)/A

PROJECT : Geotechnical Particle Size

PROGRAM : MIR91   DATE TESTED : 02/04/92

FI_CORE : GC-01   UP_DEPTH : 0.40   GS_INTER : 0.05

SIEVE SIZE MM	PERCENT PASSING
25.0	100
19.0	100
13.0	100
9.2	100
4.75	100
2.0	100
0.8	99
0.42	96
0.25	93
0.16	90
0.072	81.1
0.0325	54.2
0.0217	42.2
0.0133	27.2
0.0097	18.0
0.0070	12.7
0.0034	8.2
0.0026	7.5
0.0014	6.5



COMMENTS :

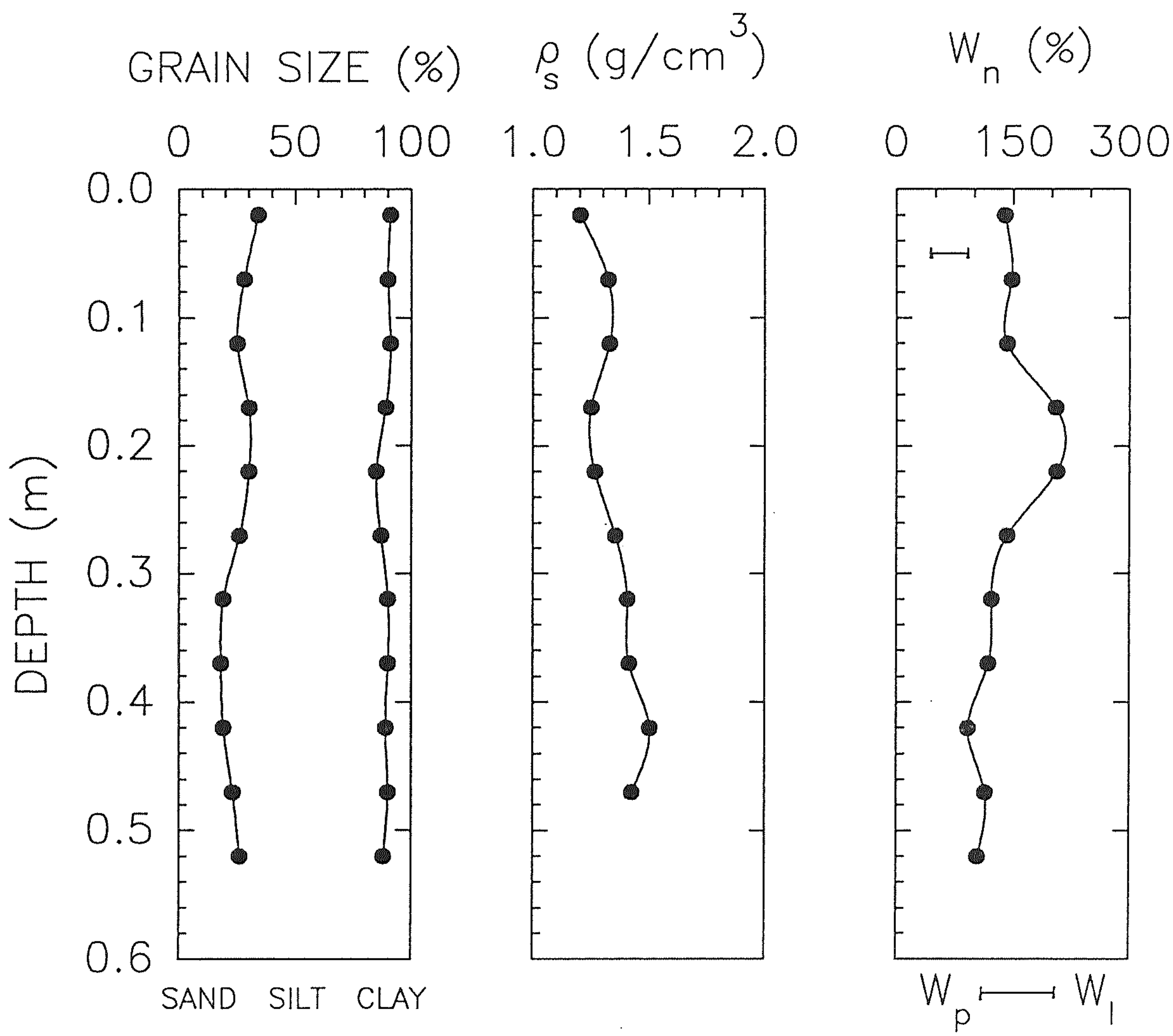
CHECKED BY : ______________________   CERTIFIED BY : ______________________

A.S.T.M. DESIGNATION D421,D422

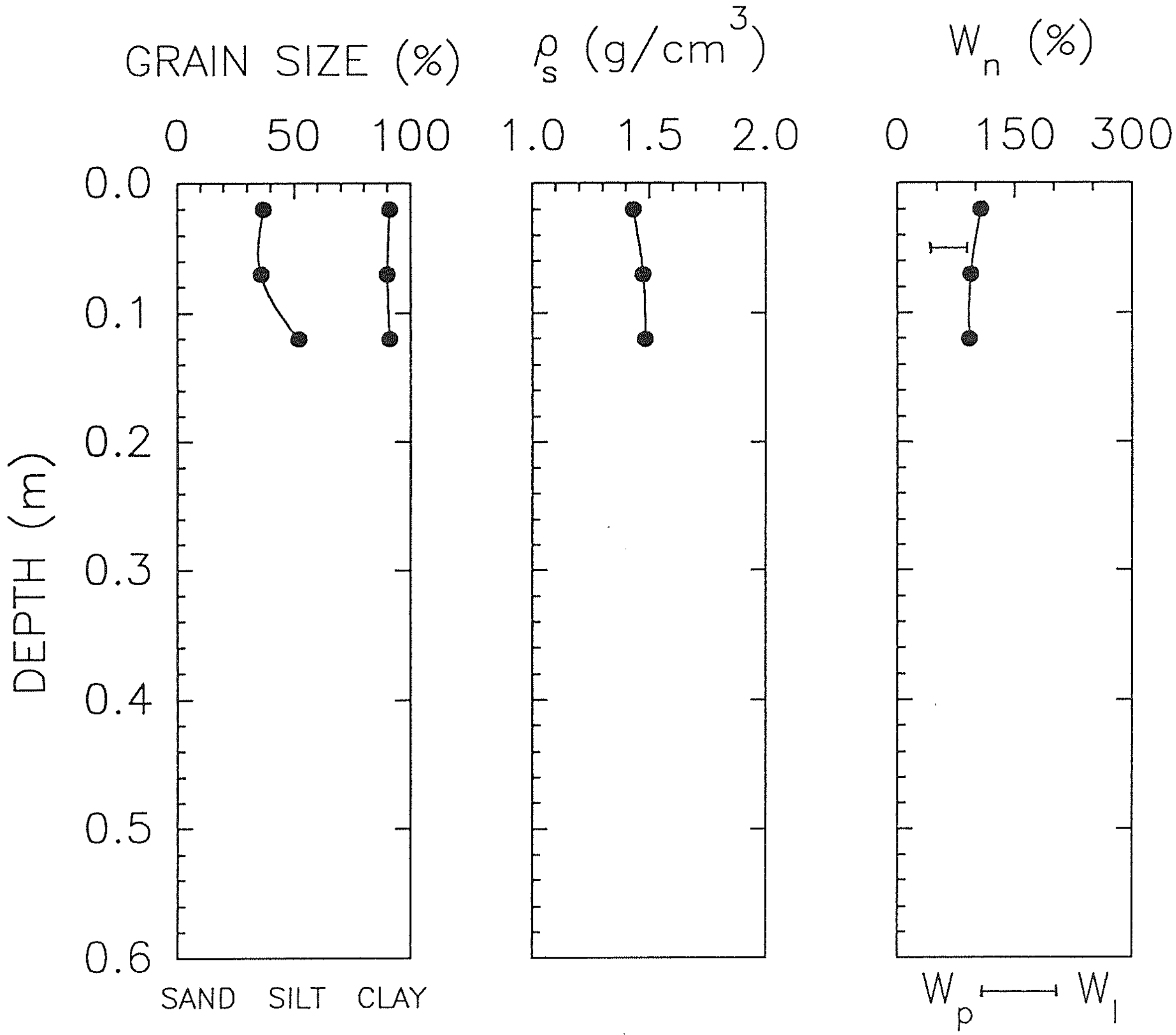
APPENDIX C

GRAPHICAL SUMMARTY OF SEDIMENT INDEX PROPERTIES

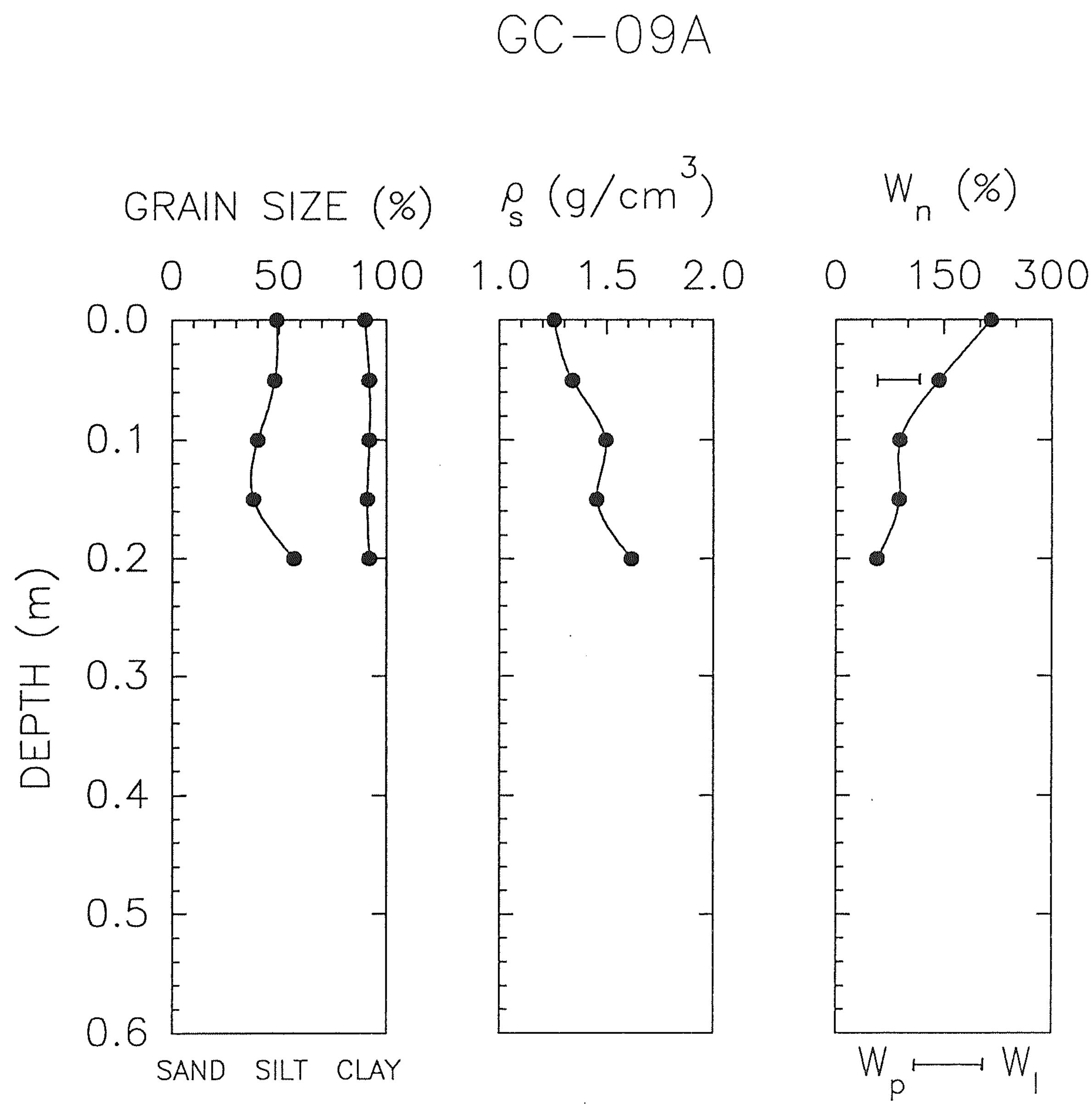
GC—01


GRAIN SIZE (%)
0
50
100
ρ_s (g/cm^3)
1.0
1.5
2.0
W_n (%)
0
150
300
DEPTH (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
SAND
SILT
CLAY
W_p
W_l

GC—07

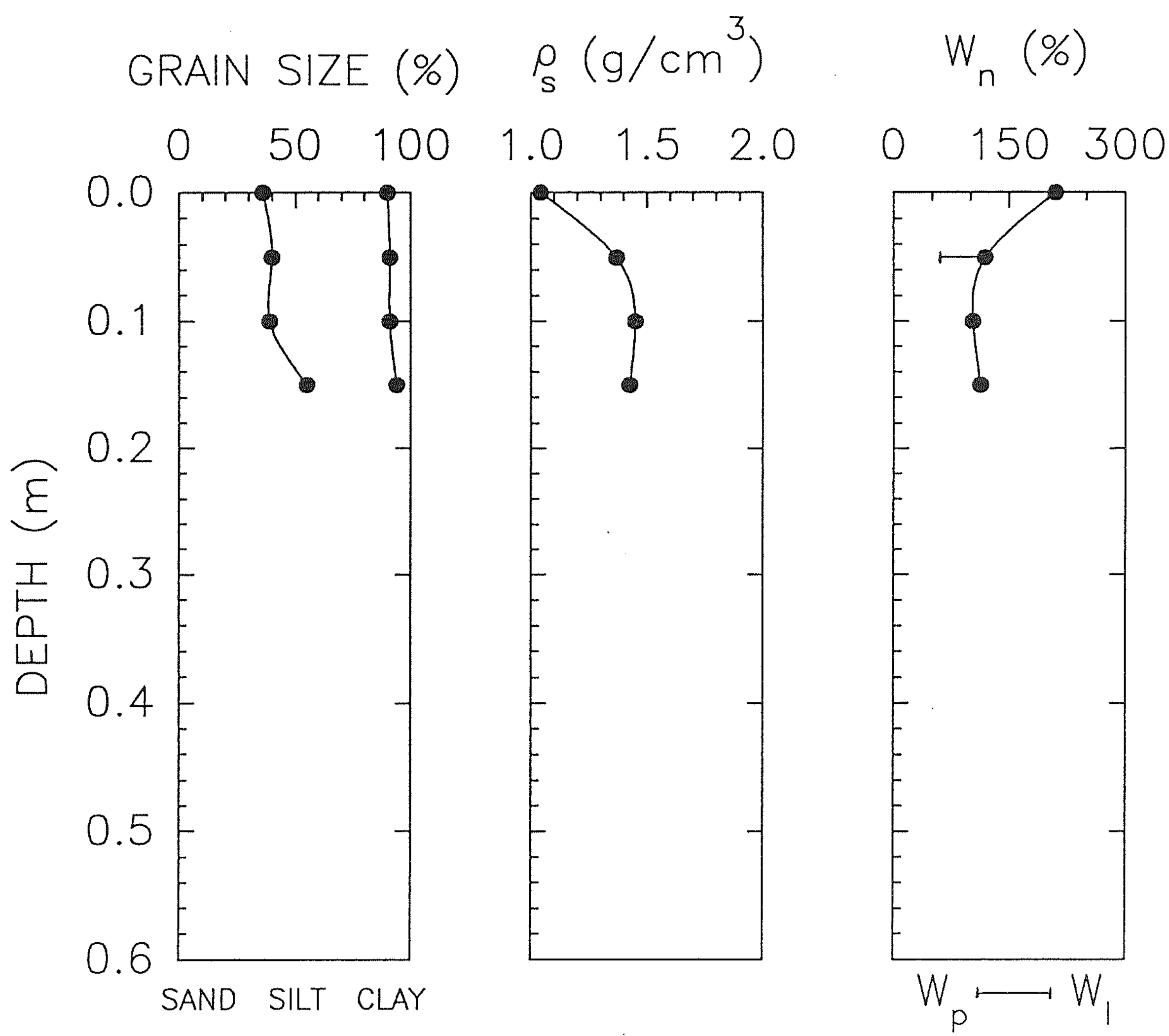


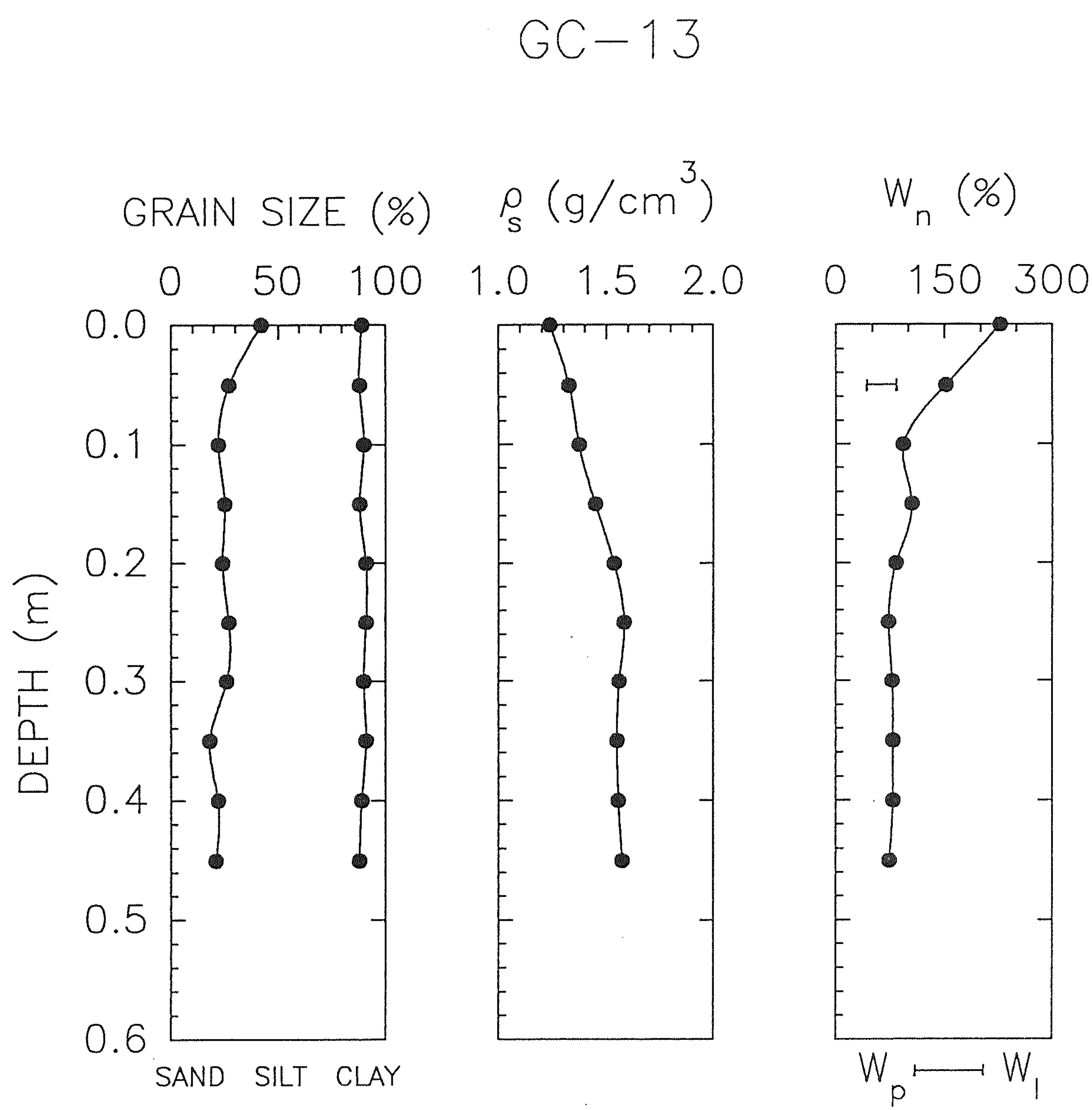
GRAIN SIZE (%)
0 50 100
ρ_s (g/cm^3)
1.0 1.5 2.0
W_n (%)
0 150 300
DEPTH (m)
0.0 0.1 0.2 0.3 0.4 0.5 0.6
SAND SILT CLAY
W_p — W_l

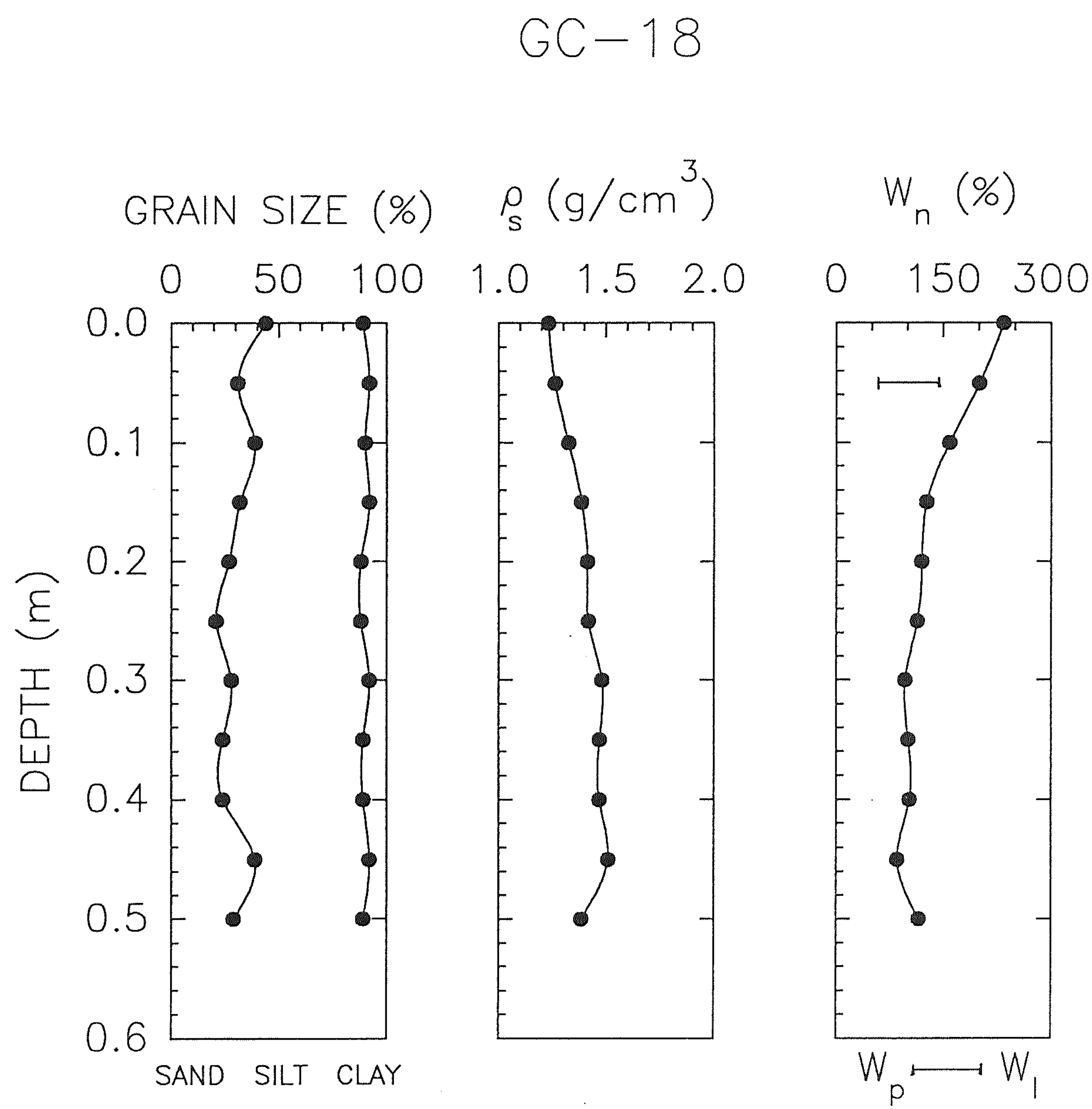


GC—09A
GRAIN SIZE (%)
0
50
100
ρ_s (g/cm^3)
1.0
1.5
2.0
W_n (%)
0
150
300
DEPTH (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
SAND
SILT
CLAY
W_p W_l

GC—09B


GRAIN SIZE (%)
ρs (g/cm3)
Wn (%)
0
50
100
1.0
1.5
2.0
0
150
300
DEPTH (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
SAND
SILT
CLAY
Wp
Wl


GC-13
GRAIN SIZE (%)
0
50
100
ρ_s (g/cm^3)
1.0
1.5
2.0
W_n (%)
0
150
300
DEPTH (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
SAND
SILT
CLAY
W_p ⊢—⊣ W_l


GC—18
GRAIN SIZE (%)
0
50
100
ρs (g/cm3)
1.0
1.5
2.0
Wn (%)
0
150
300
DEPTH (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
SAND
SILT
CLAY
Wp
Wl

APPENDIX D

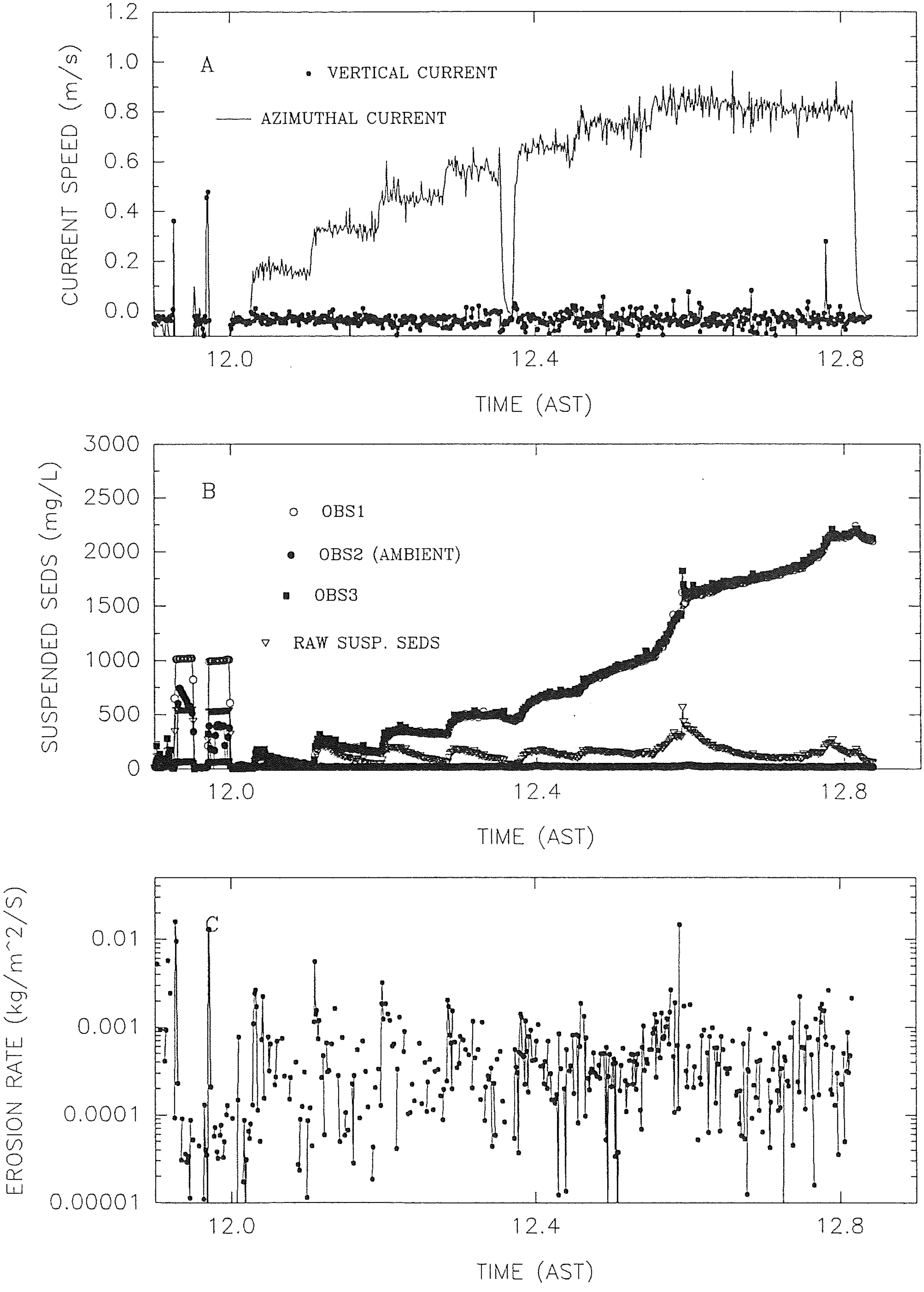
CORE PHOTOGRAPHS

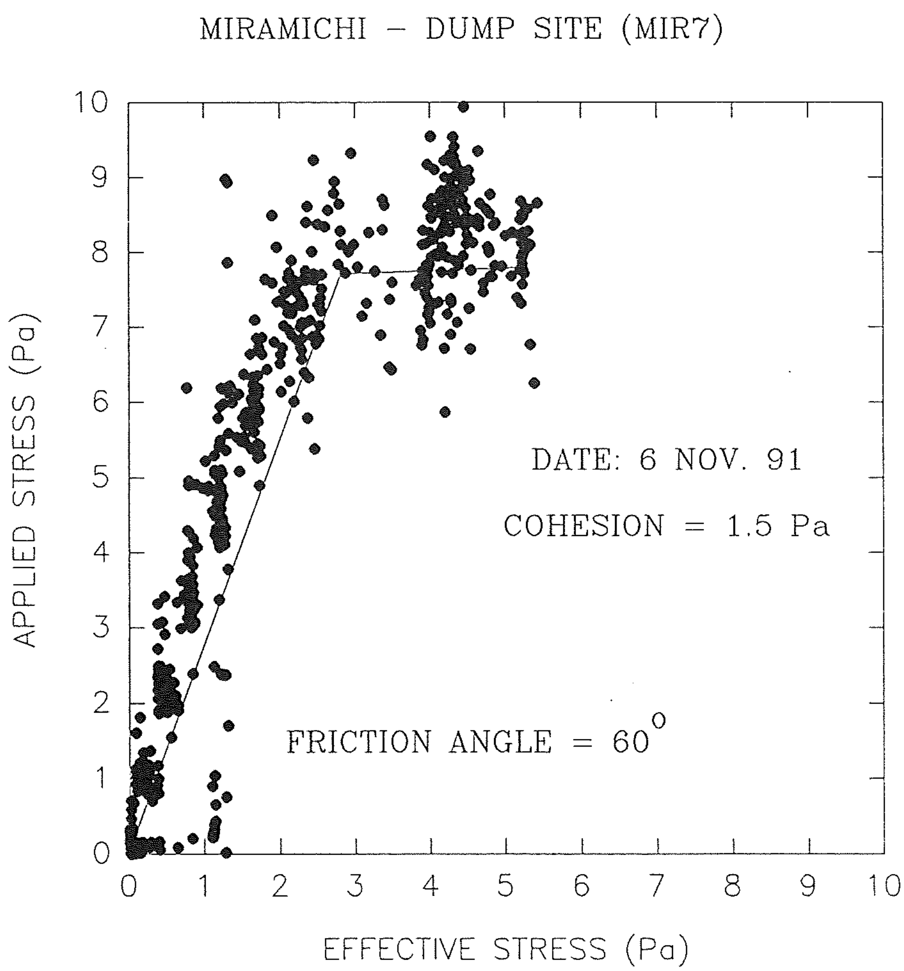
APPENDIX E

GRAPHICAL PRESENTATION OF SEA CAROUSEL RESULTS

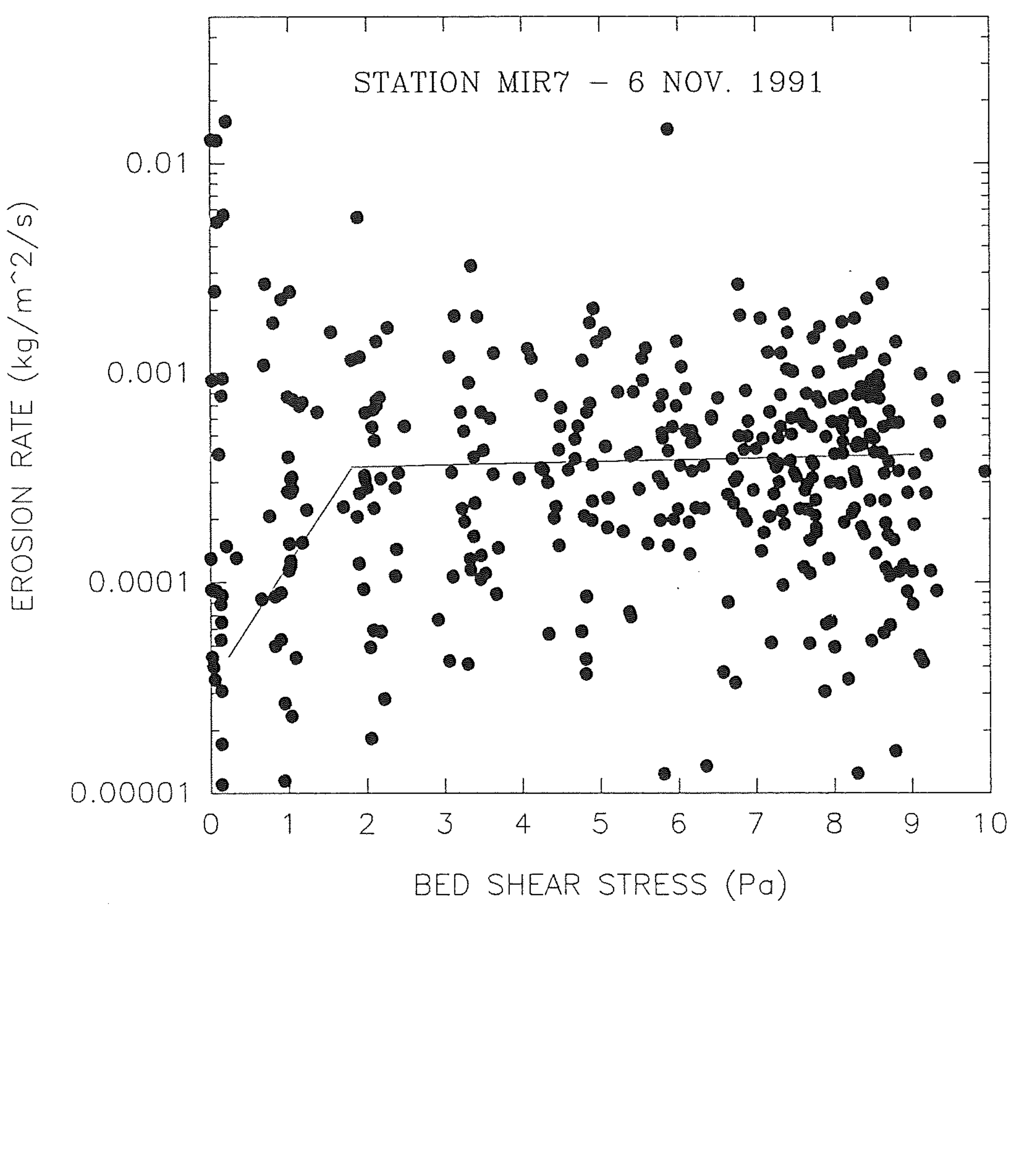
SEA CAROUSEL – MIRAMICHI DUMP SITE B (90)

STATION MIR7 – 6 Nov. 1991



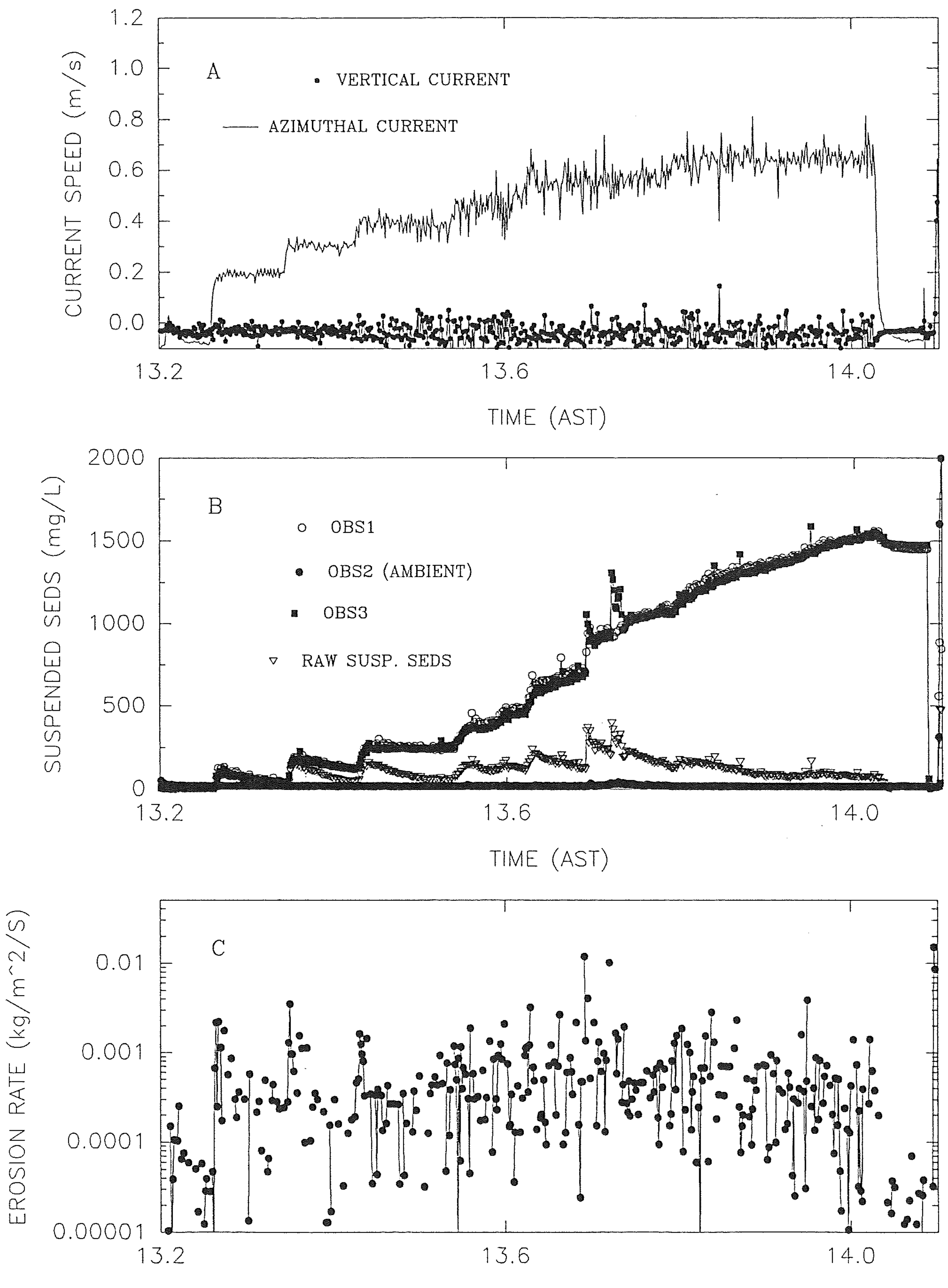

MIRAMICHI – DUMP SITE (MIR7)
DATE: 6 NOV. 91
COHESION = 1.5 Pa
FRICTION ANGLE = 60°
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
1
2
3
4
5
6
7
8
9
10

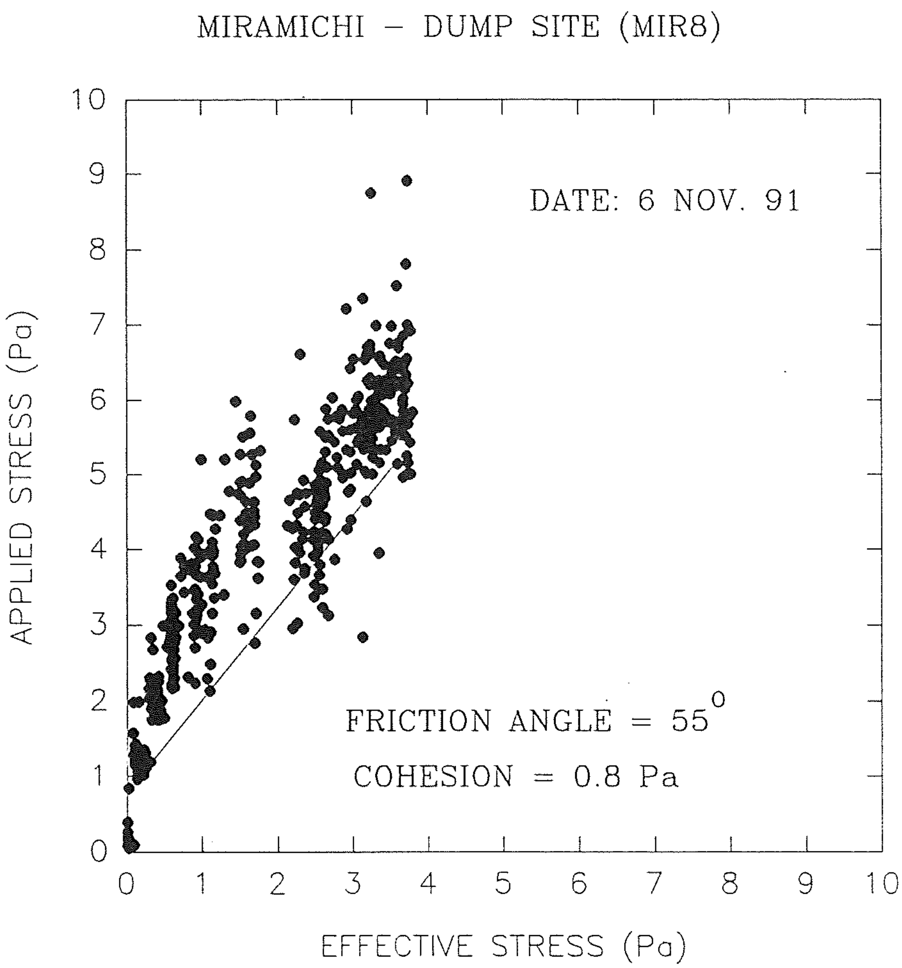
SEA CAROUSEL - MIRAMICHI - DUMP SITE (90)



SEA CAROUSEL – MIRAMICHI DUMP SITE B (90)

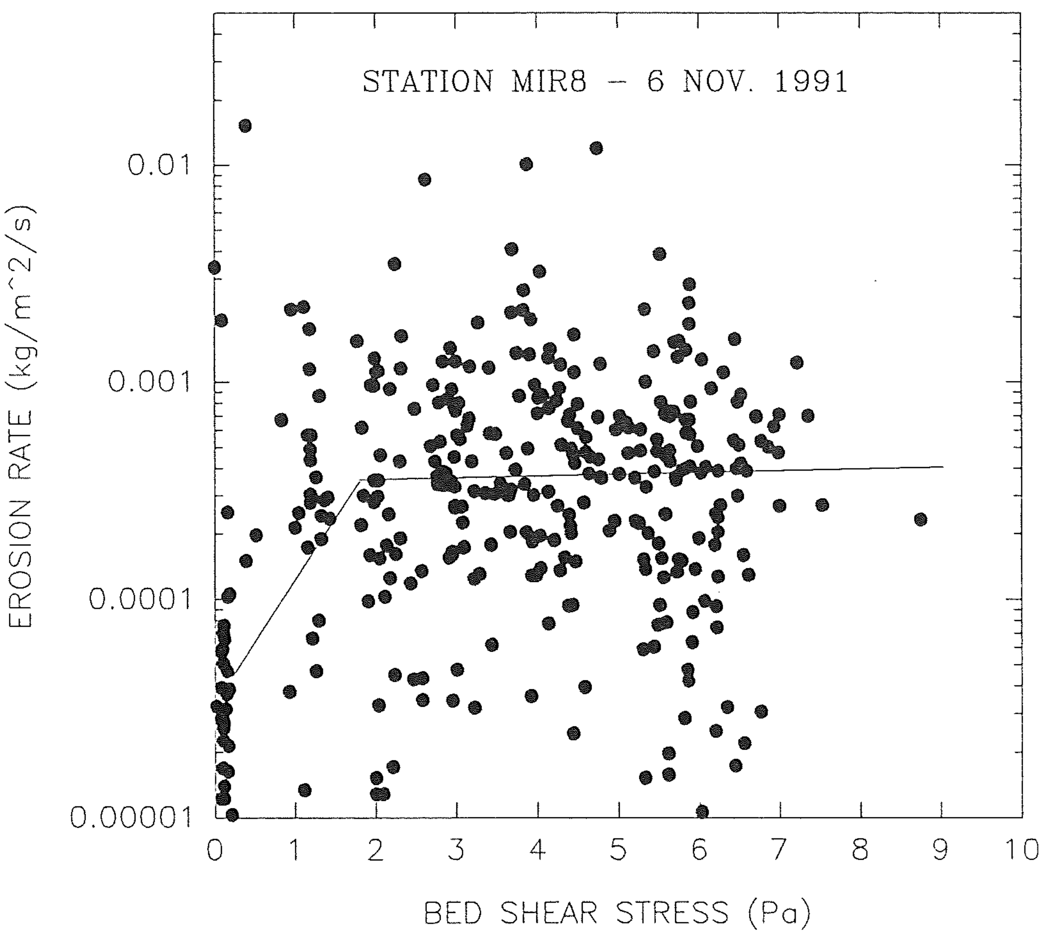
STATION MIR8 – 6 Nov. 1991





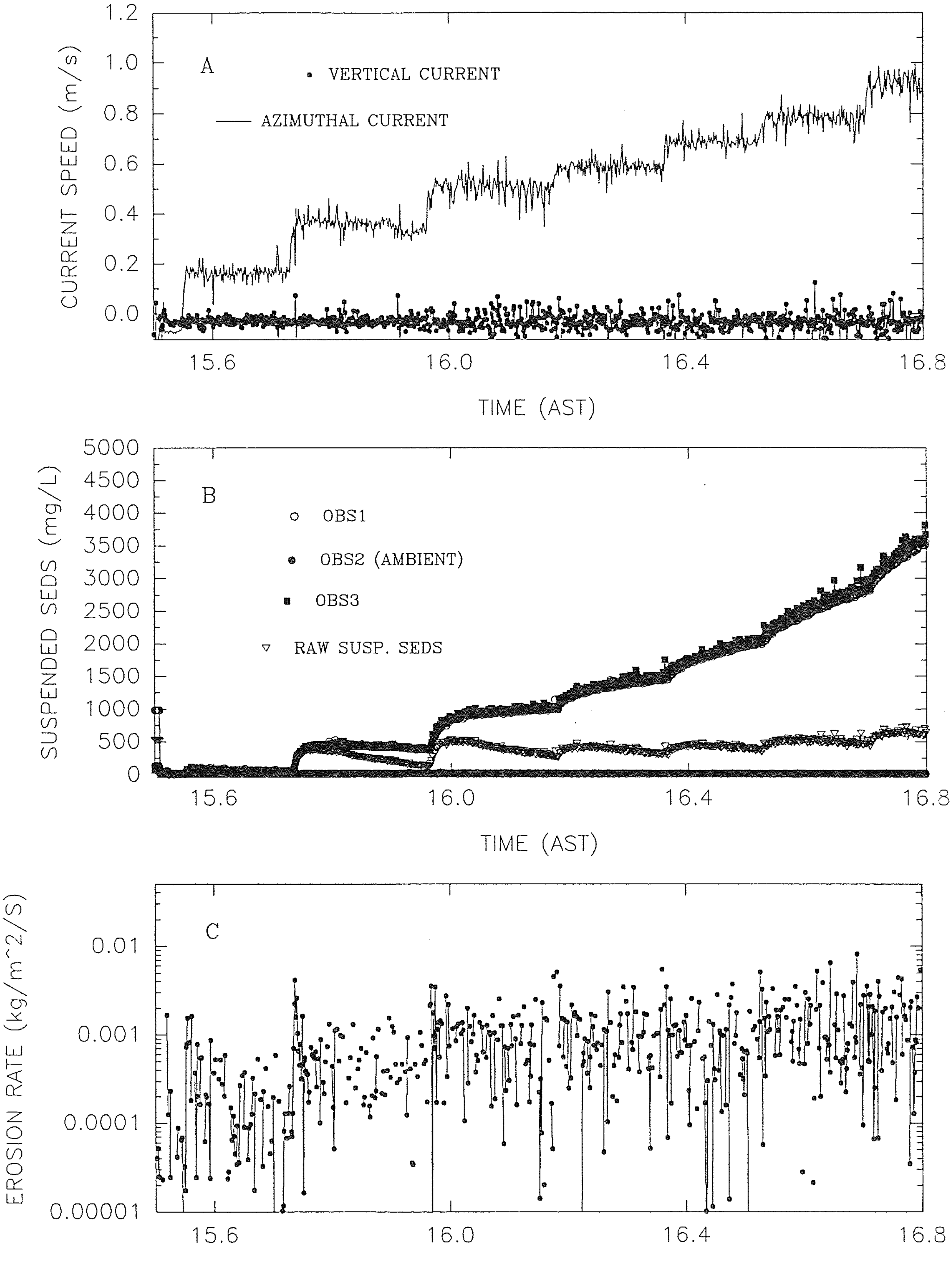
MIRAMICHI - DUMP SITE (MIR8)
DATE: 6 NOV. 91
FRICTION ANGLE = 55°
COHESION = 0.8 Pa
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
1
2
3
4
5
6
7
8
9
10

SEA CAROUSEL – MIRAMICHI – DUMP SITE (90)

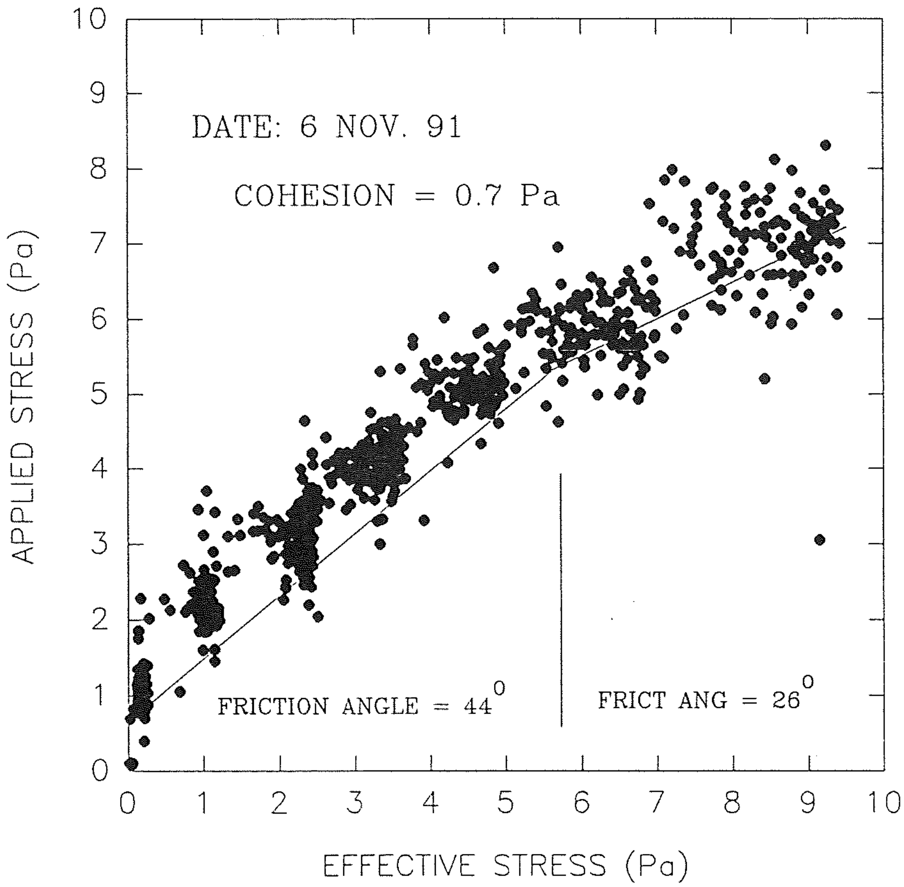


SEA CAROUSEL – MIRAMICHI DUMP SITE B (90)

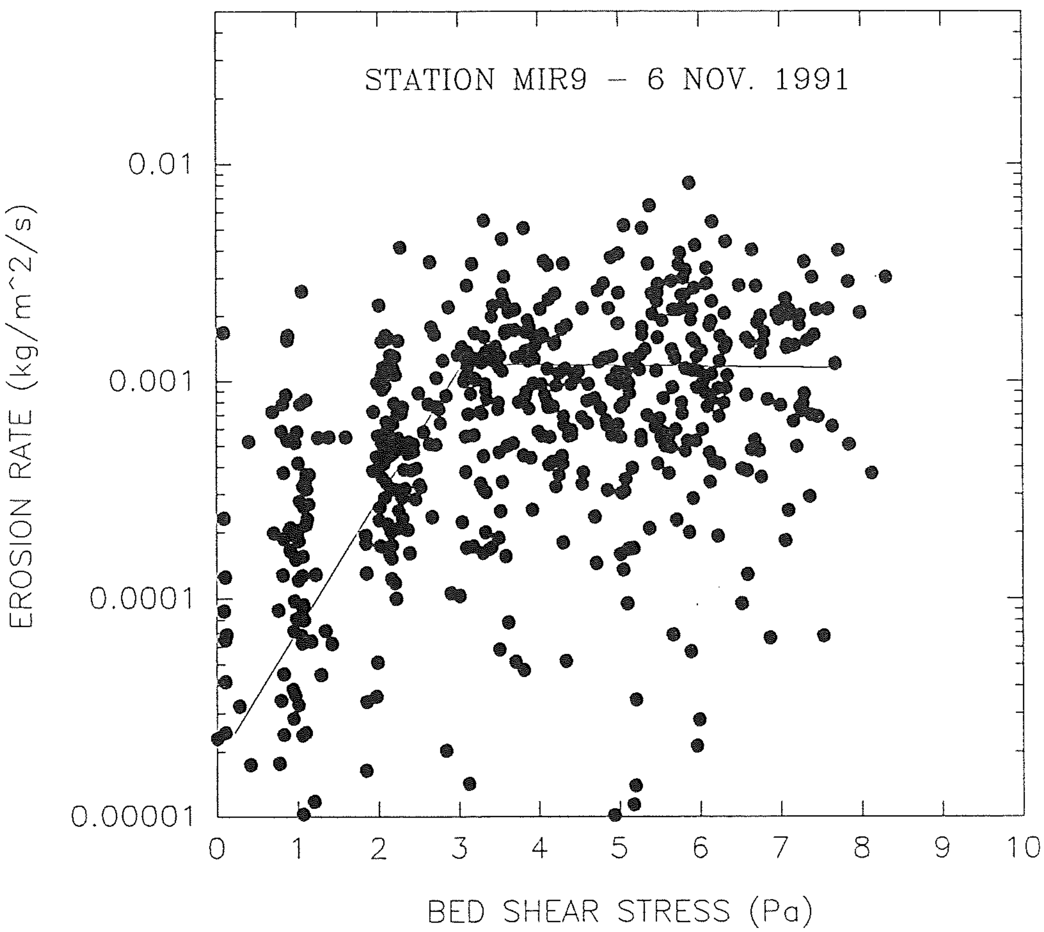
STATION MIR9 – 6 Nov. 1991



MIRAMICHI – DUMP SITE (MIR9)

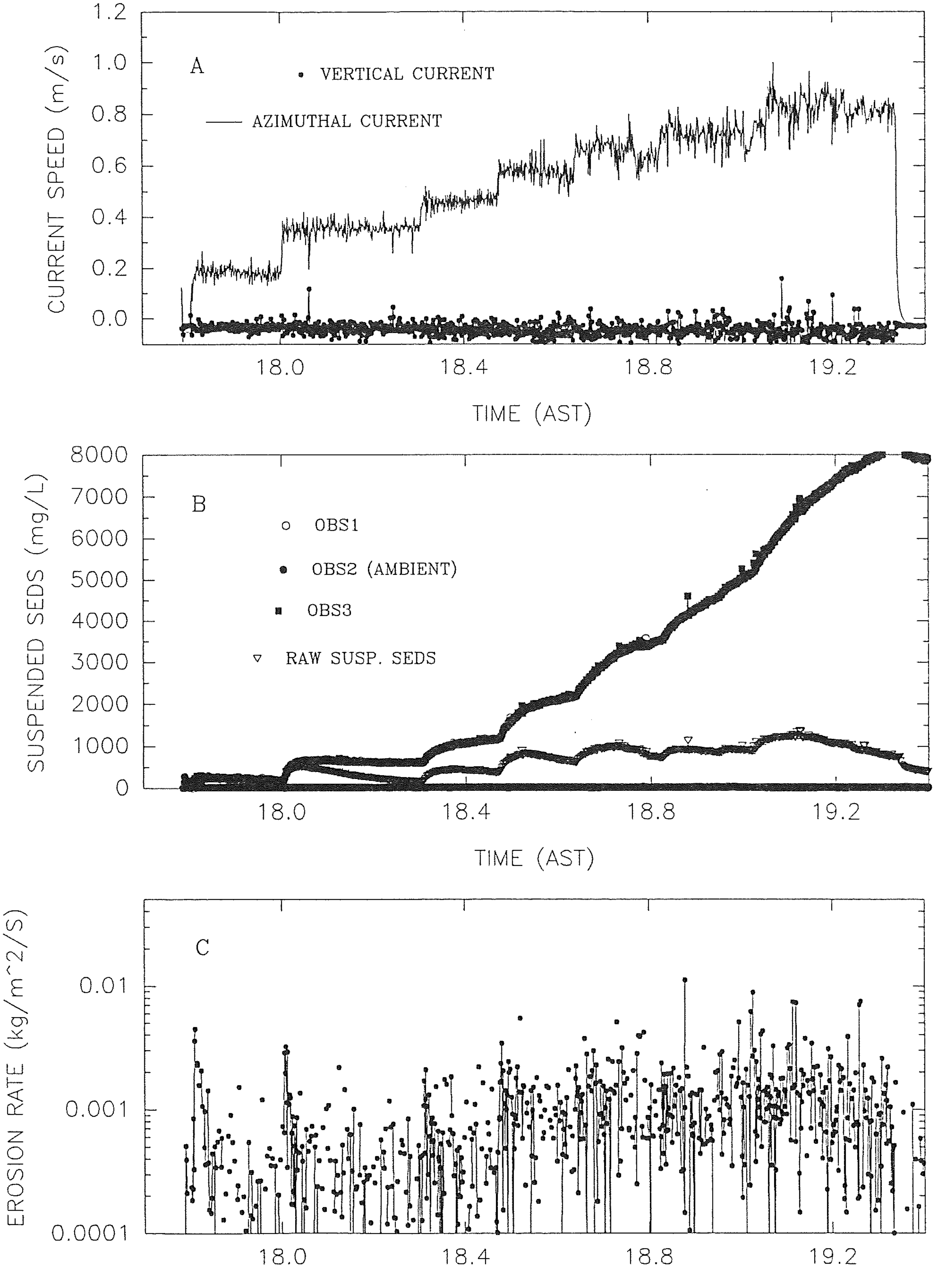


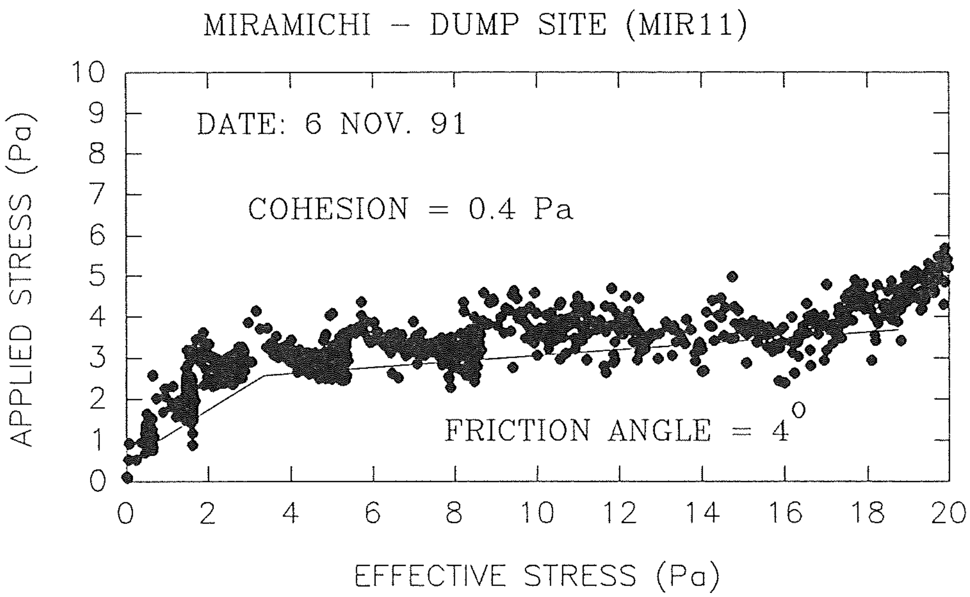
SEA CAROUSEL - MIRAMICHI - DUMP SITE (90)



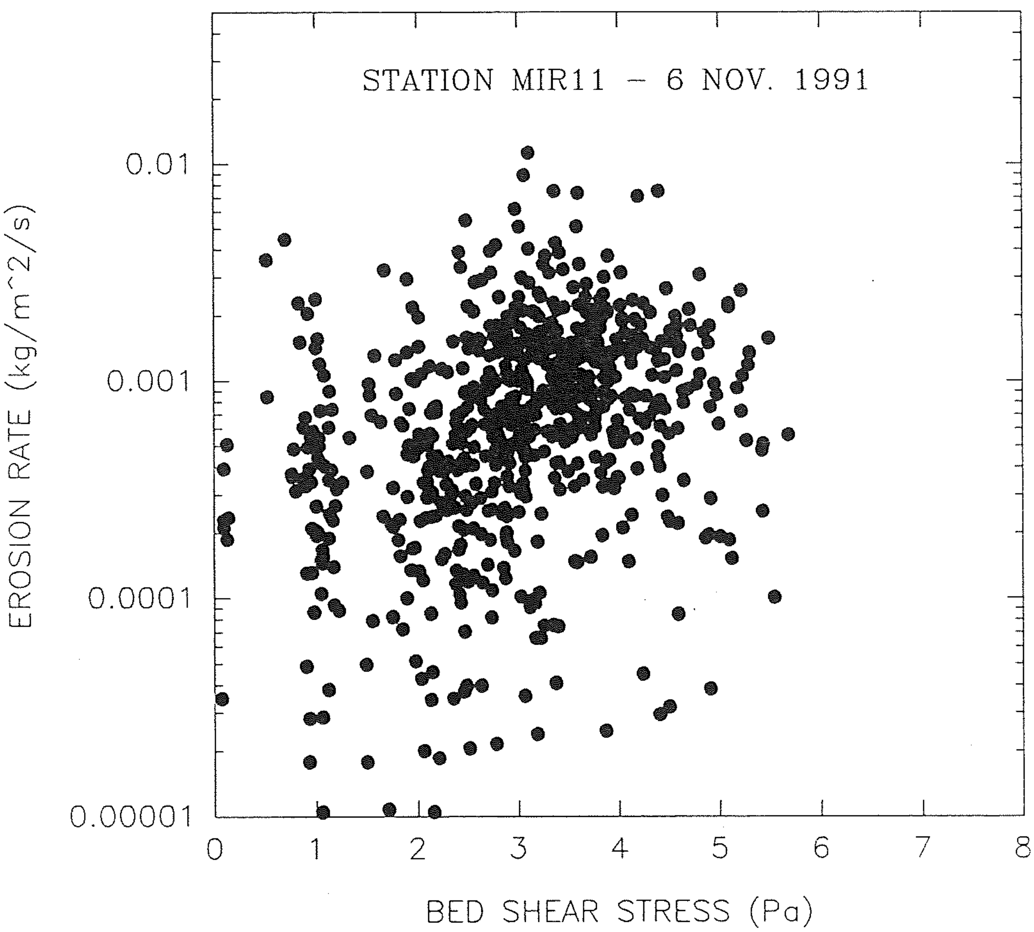
SEA CAROUSEL – MIRAMICHI DUMP SITE B (90)

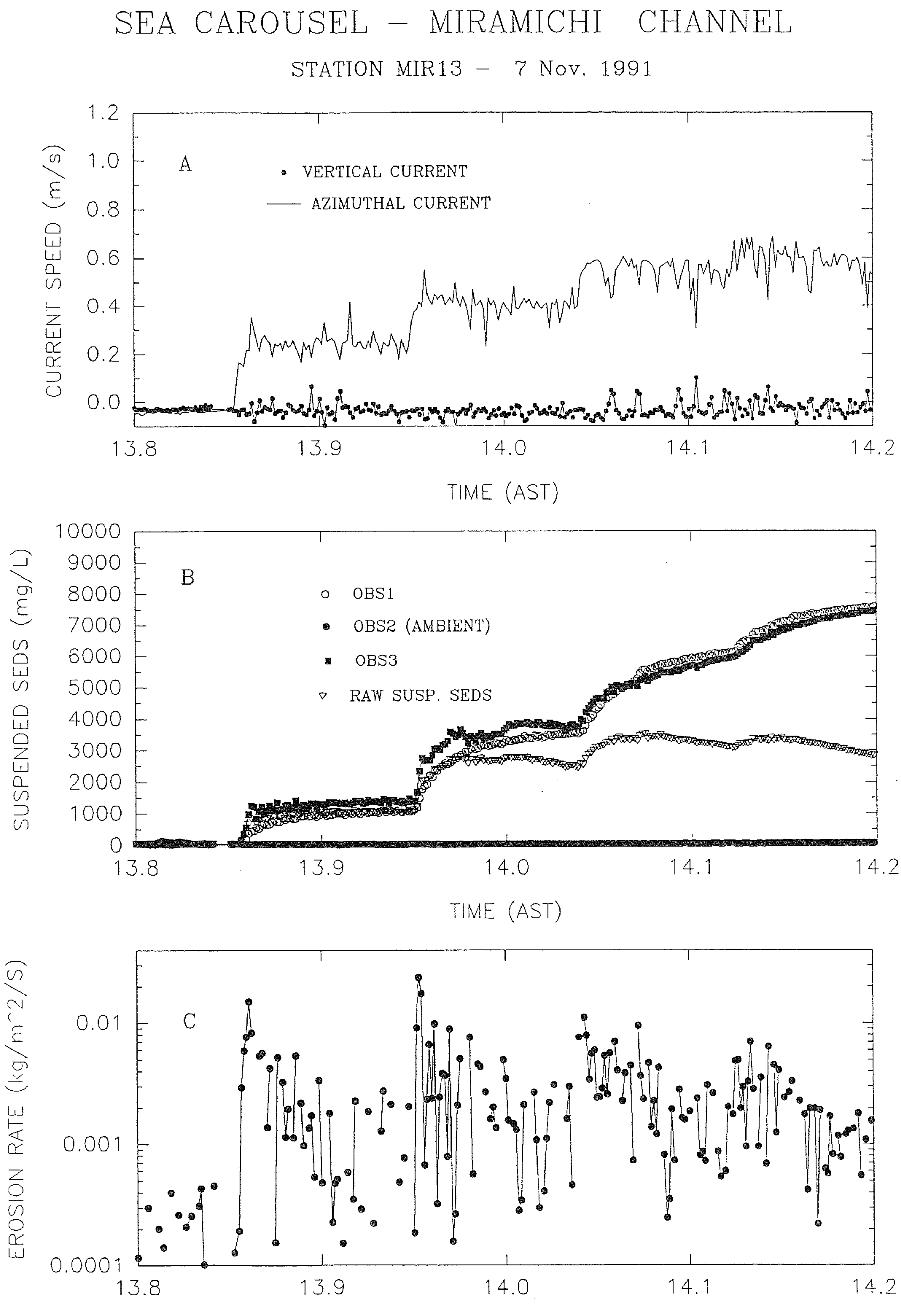
STATION MIR11 – 6 Nov. 1991

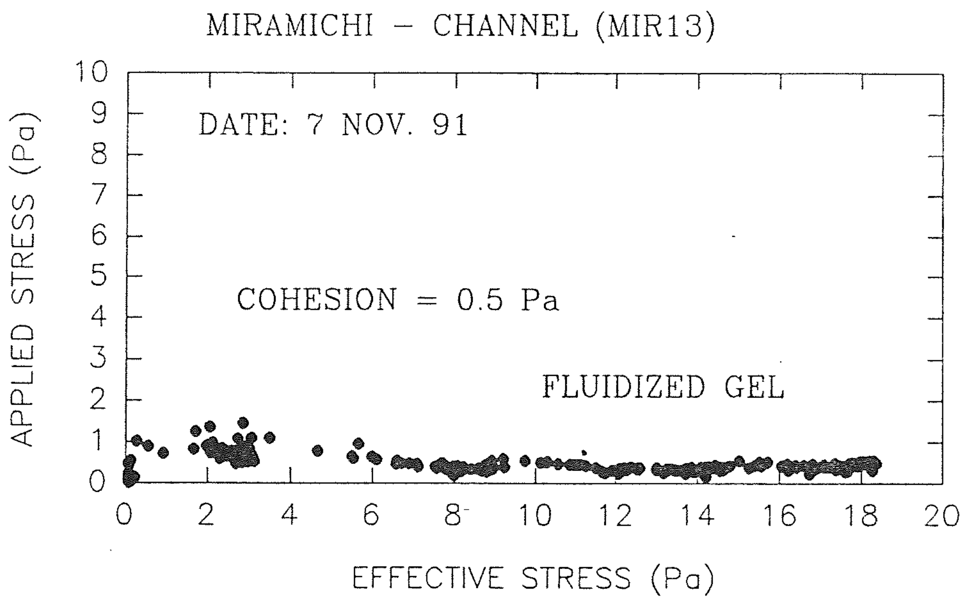


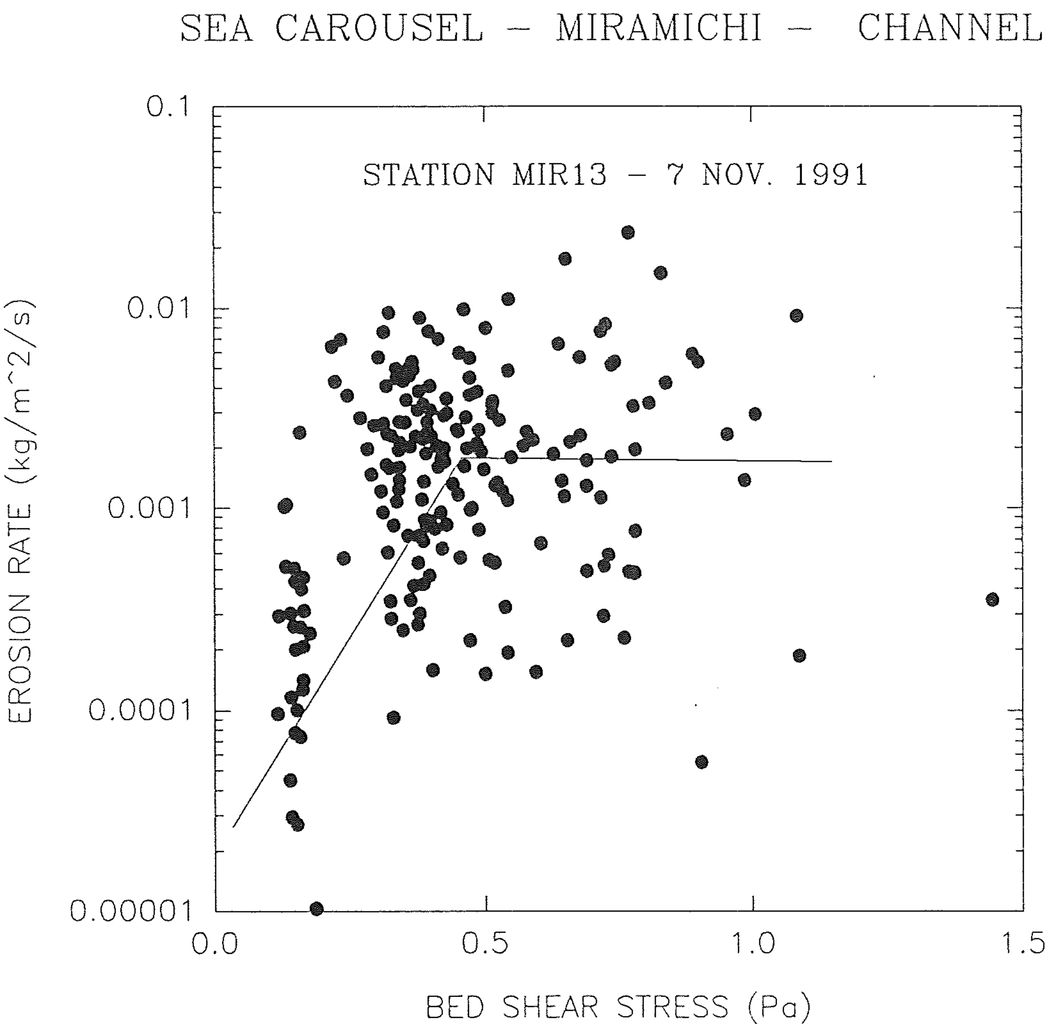

MIRAMICHI – DUMP SITE (MIR11)
DATE: 6 NOV. 91
COHESION = 0.4 Pa
FRICTION ANGLE = 4°
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20

SEA CAROUSEL – MIRAMICHI – DUMP SITE (90)



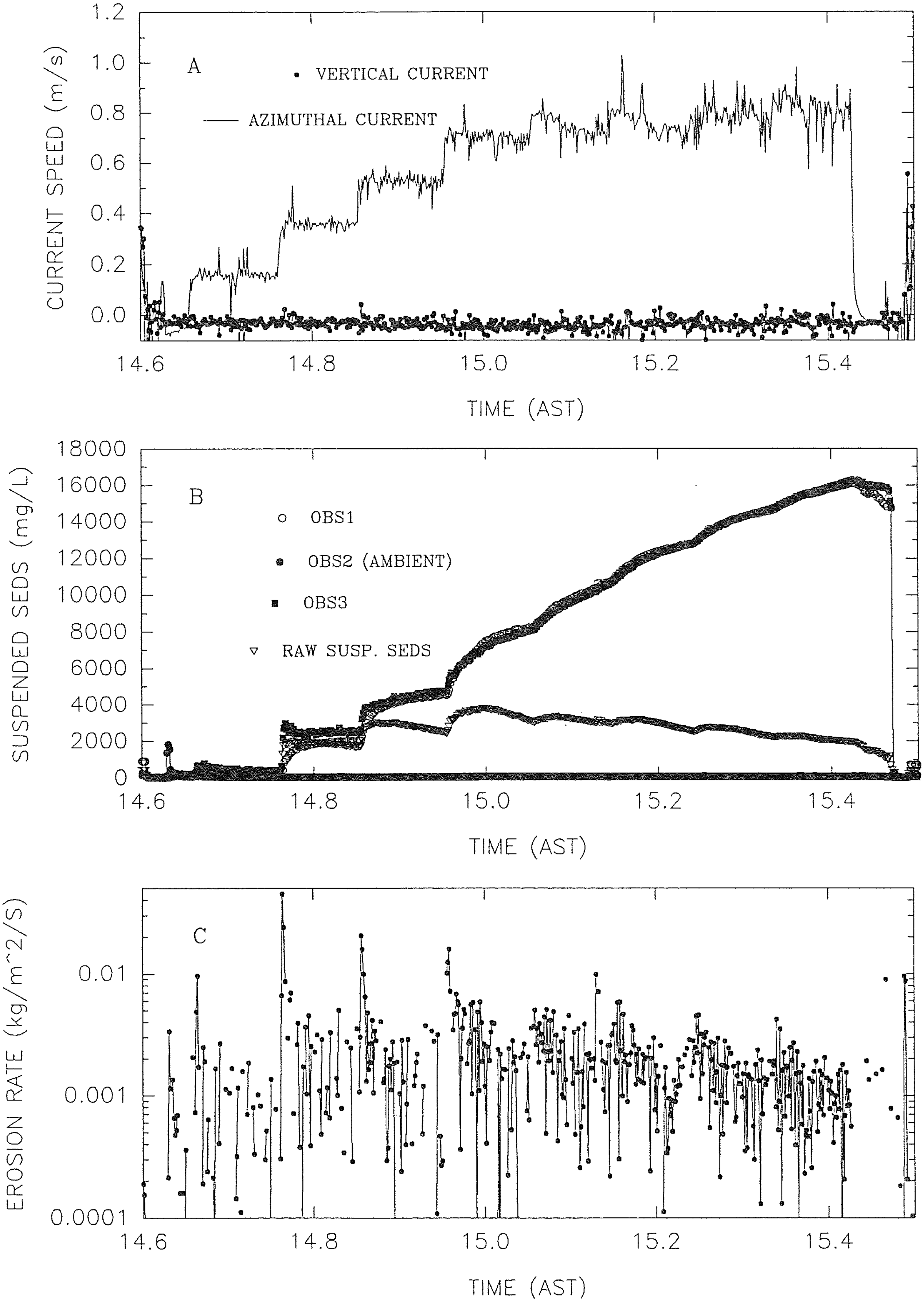

SEA CAROUSEL – MIRAMICHI CHANNEL
STATION MIR13 – 7 Nov. 1991
A
VERTICAL CURRENT
AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
13.8
13.9
14.0
14.1
14.2
TIME (AST)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
13.8
13.9
14.0
14.1
14.2
TIME (AST)
C
EROSION RATE (kg/m^2/S)
0.01
0.001
0.0001
13.8
13.9
14.0
14.1
14.2

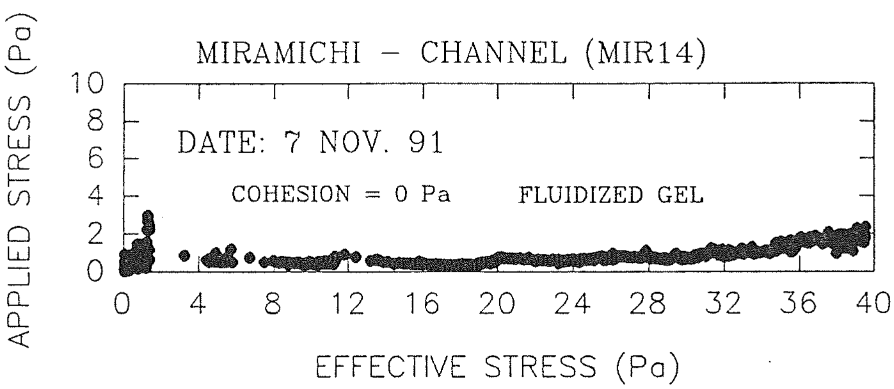

MIRAMICHI – CHANNEL (MIR13)
DATE: 7 NOV. 91
COHESION = 0.5 Pa
FLUIDIZED GEL
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20

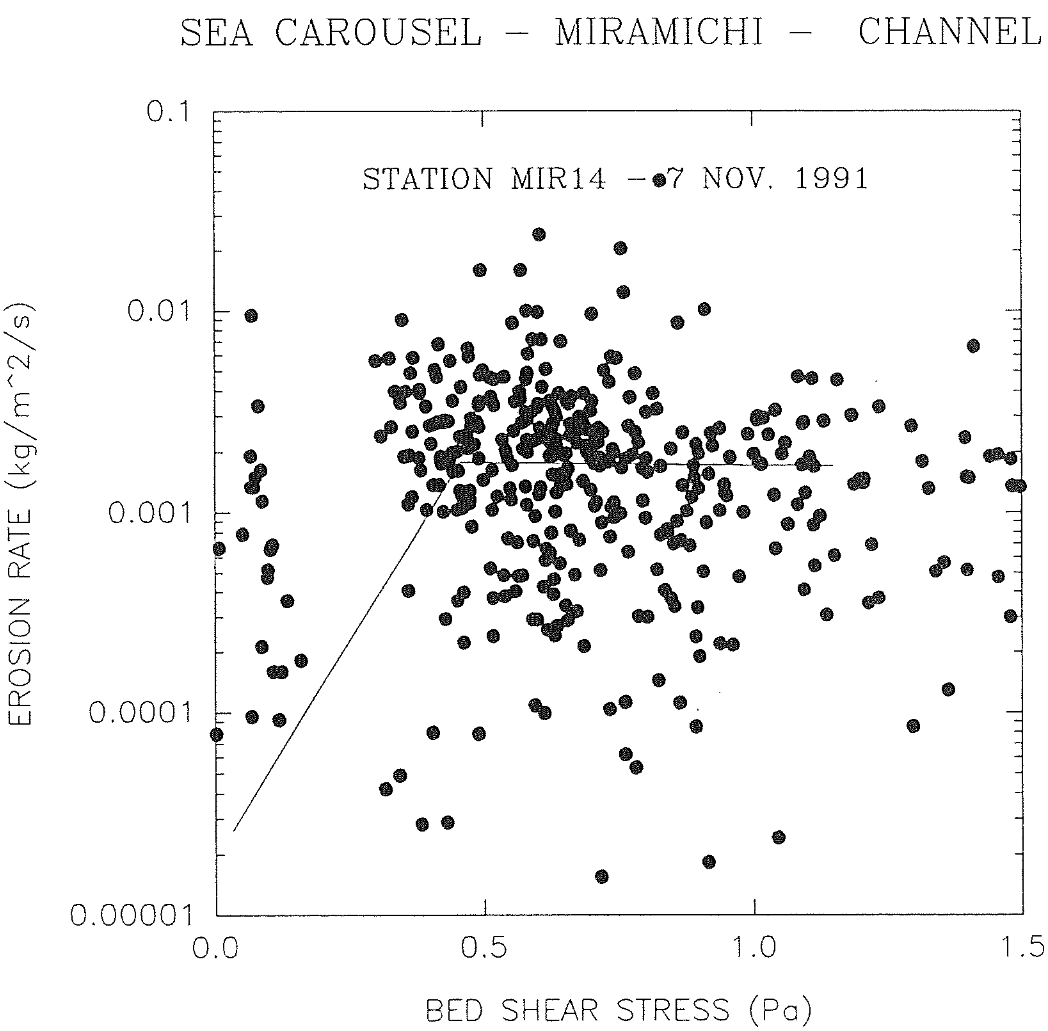

SEA CAROUSEL - MIRAMICHI - CHANNEL
STATION MIR13 - 7 NOV. 1991
EROSION RATE (kg/m^2/s)
0.1
0.01
0.001
0.0001
0.00001
0.0
0.5
1.0
1.5
BED SHEAR STRESS (Pa)

SEA CAROUSEL – MIRAMICHI NAVIGATION CHANNEL

STATION MIR14 – 7 Nov. 1991

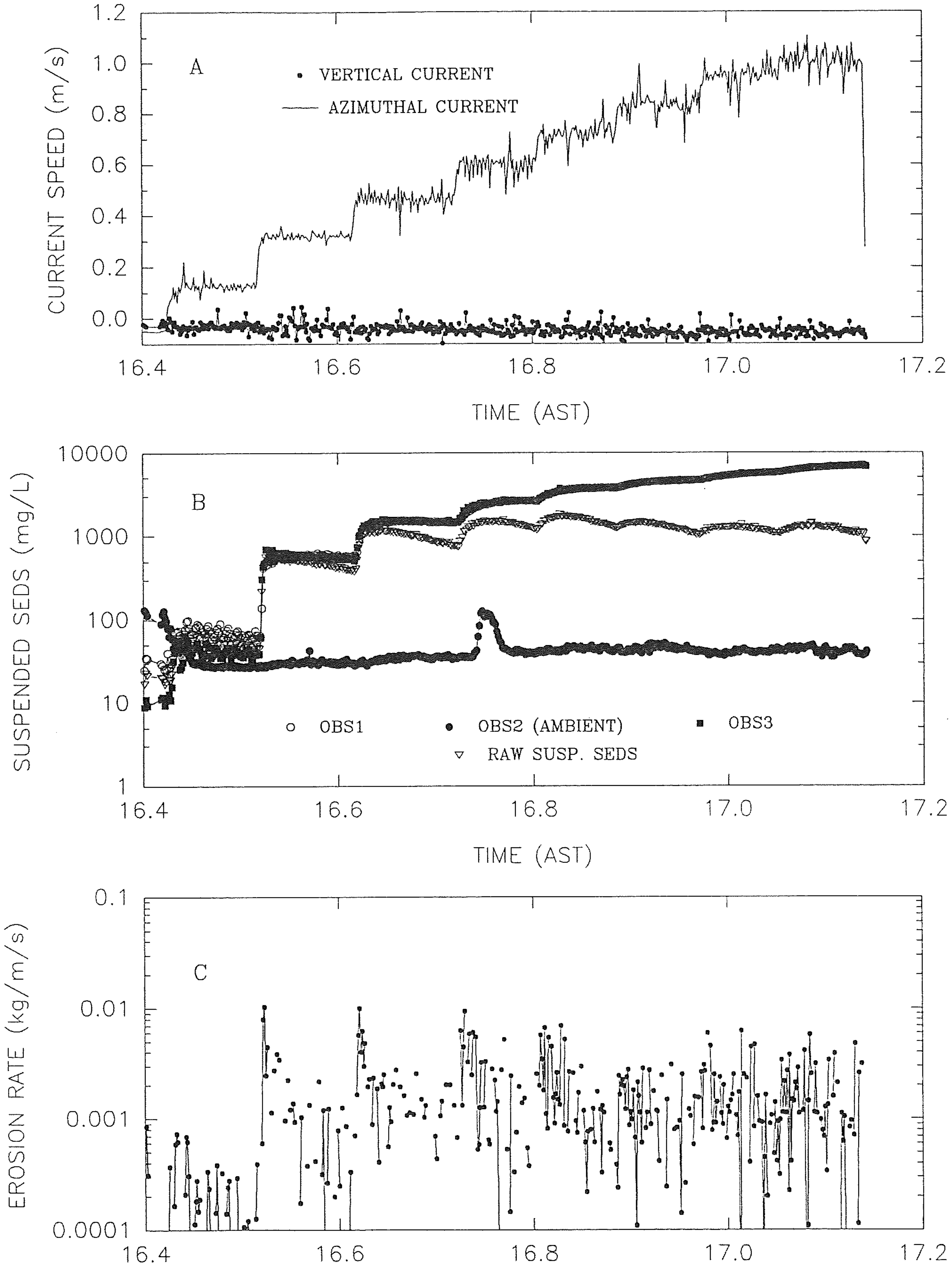


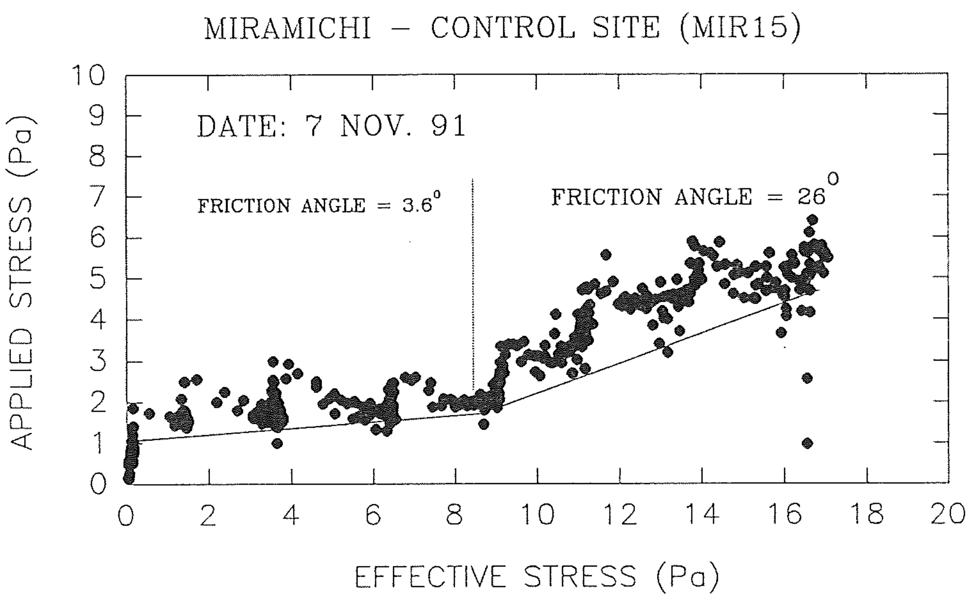

MIRAMICHI - CHANNEL (MIR14)
DATE: 7 NOV. 91
COHESION = 0 Pa
FLUIDIZED GEL
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
2
4
6
8
10
0
4
8
12
16
20
24
28
32
36
40

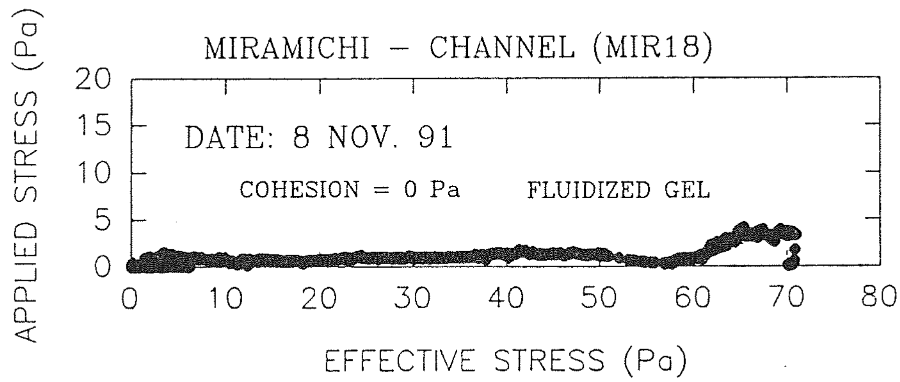

SEA CAROUSEL - MIRAMICHI - CHANNEL
STATION MIR14 - 7 NOV. 1991
EROSION RATE (kg/m^2/s)
BED SHEAR STRESS (Pa)
0.1
0.01
0.001
0.0001
0.00001
0.0
0.5
1.0
1.5

SEA CAROUSEL – MIRAMICHI CONTROL SITE

STATION MIR15 – 7 Nov. 1991

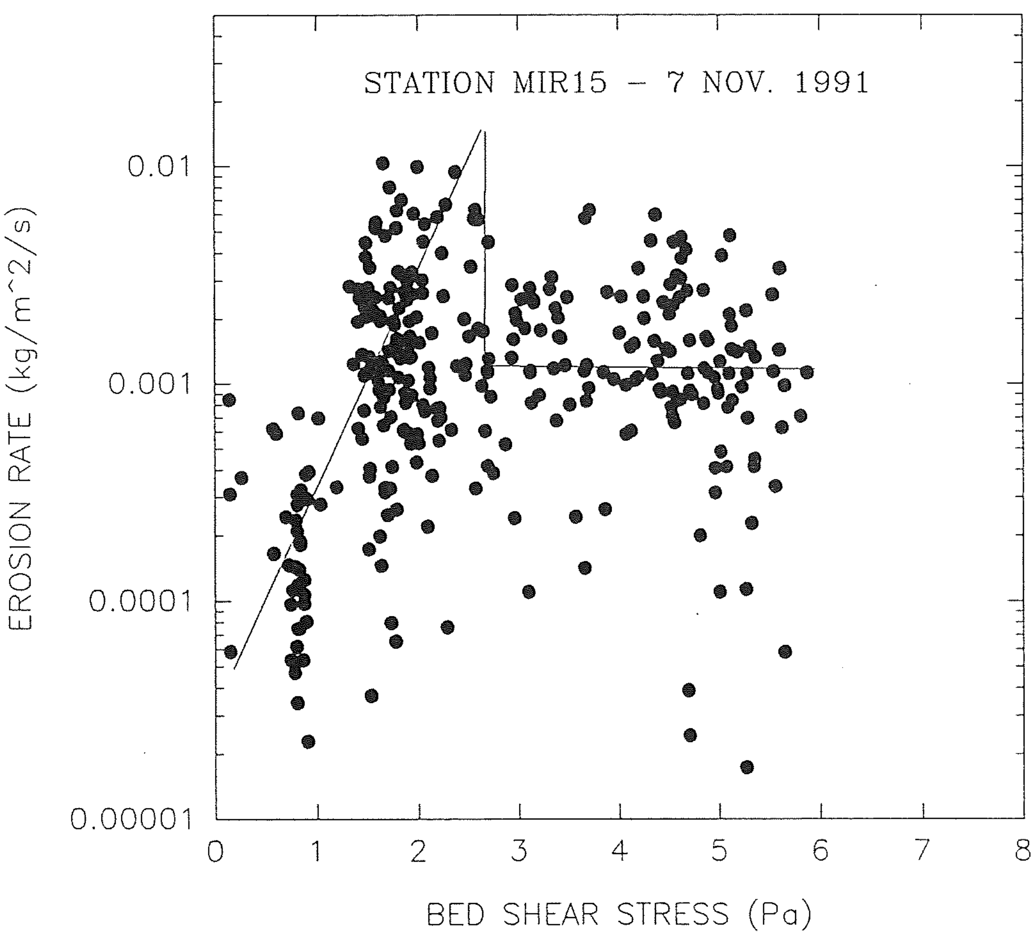



MIRAMICHI – CONTROL SITE (MIR15)
DATE: 7 NOV. 91
FRICTION ANGLE = 3.6°
FRICTION ANGLE = 26°
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20



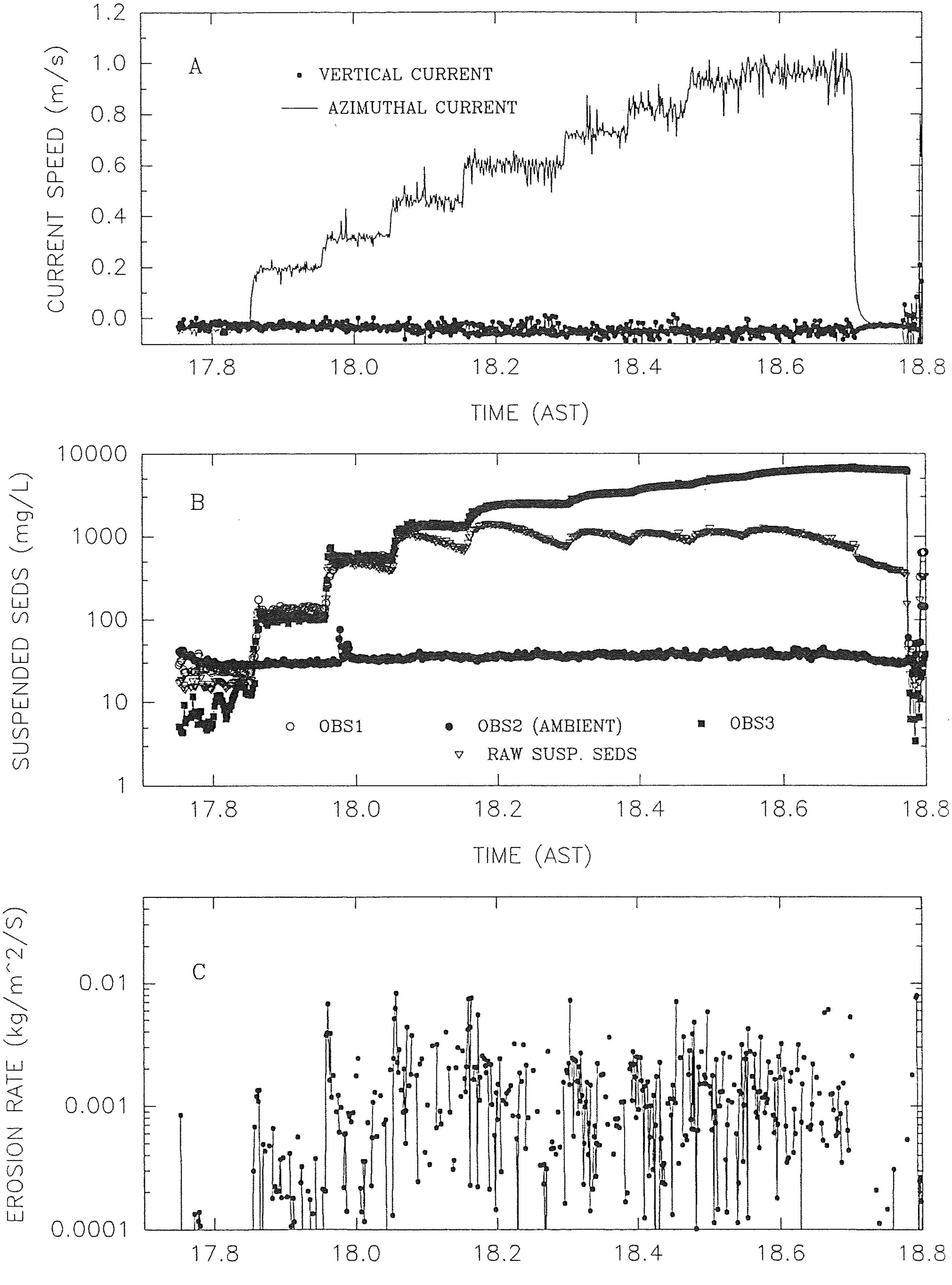
MIRAMICHI - CHANNEL (MIR18)
DATE: 8 NOV. 91
COHESION = 0 Pa
FLUIDIZED GEL
APPLIED STRESS (Pa)
20
15
10
5
0
0
10
20
30
40
50
60
70
80
EFFECTIVE STRESS (Pa)

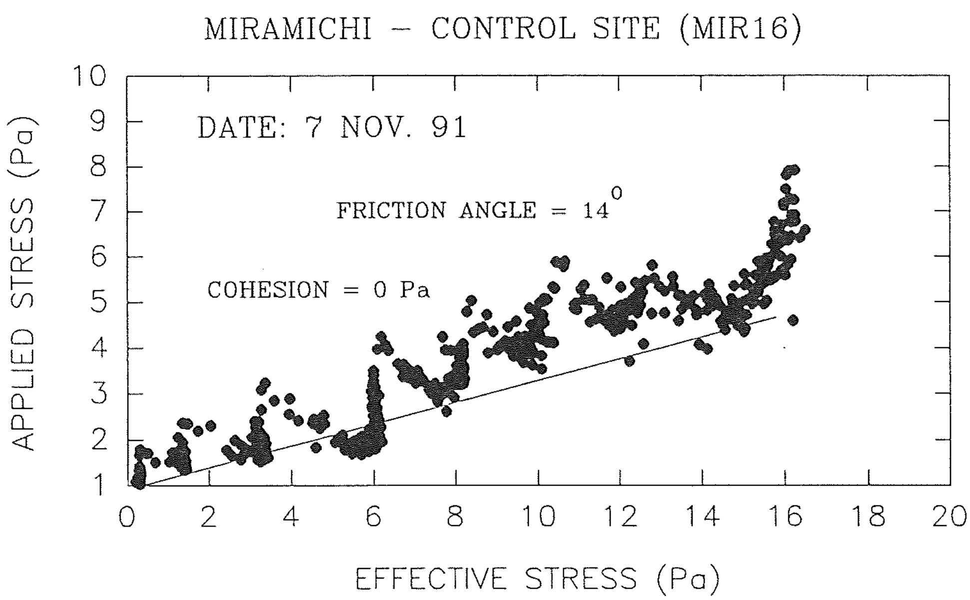
SEA CAROUSEL - MIRAMICHI - CONTROL SITE



SEA CAROUSEL – MIRAMICHI CONTROL SITE

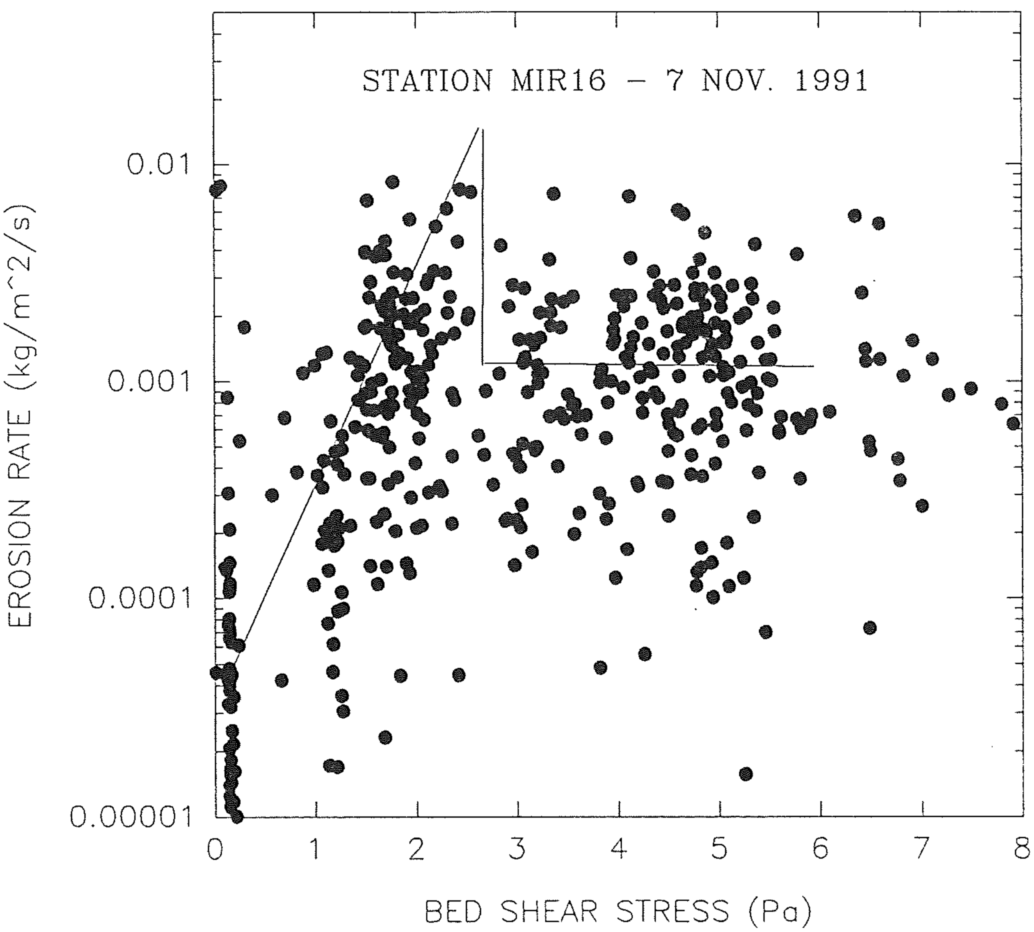
STATION MIR16 – 7 Nov. 1991





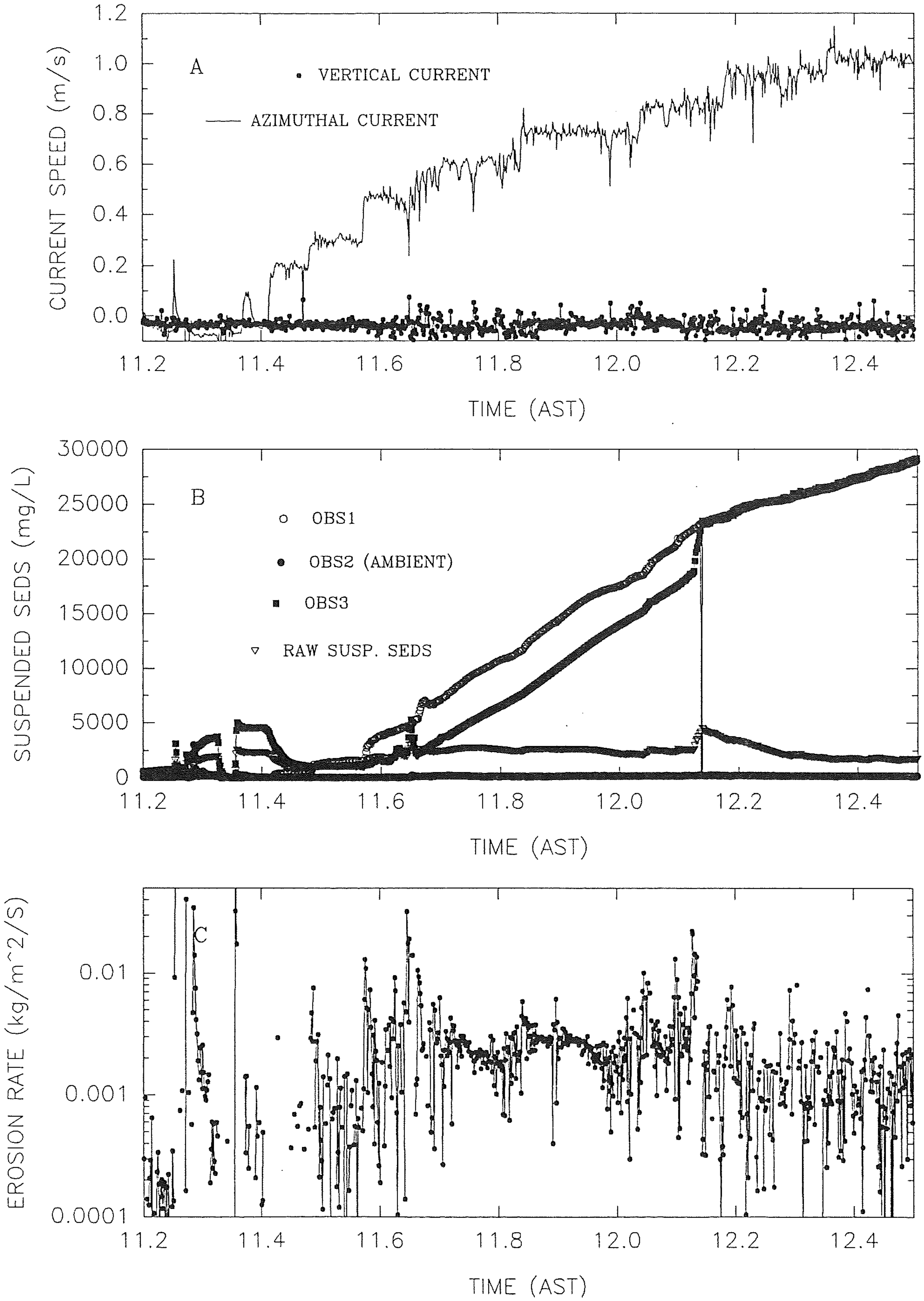
MIRAMICHI - CONTROL SITE (MIR16)
DATE: 7 NOV. 91
FRICTION ANGLE = 14°
COHESION = 0 Pa
APPLIED STRESS (Pa)
EFFECTIVE STRESS (Pa)
10
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20

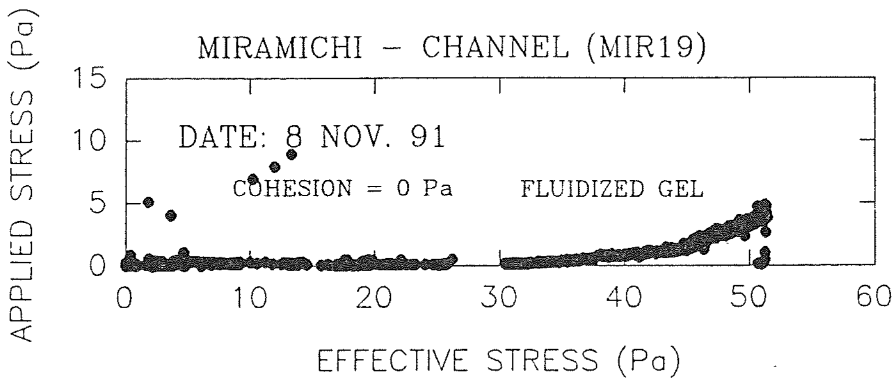
SEA CAROUSEL – MIRAMICHI – CONTROL SITE



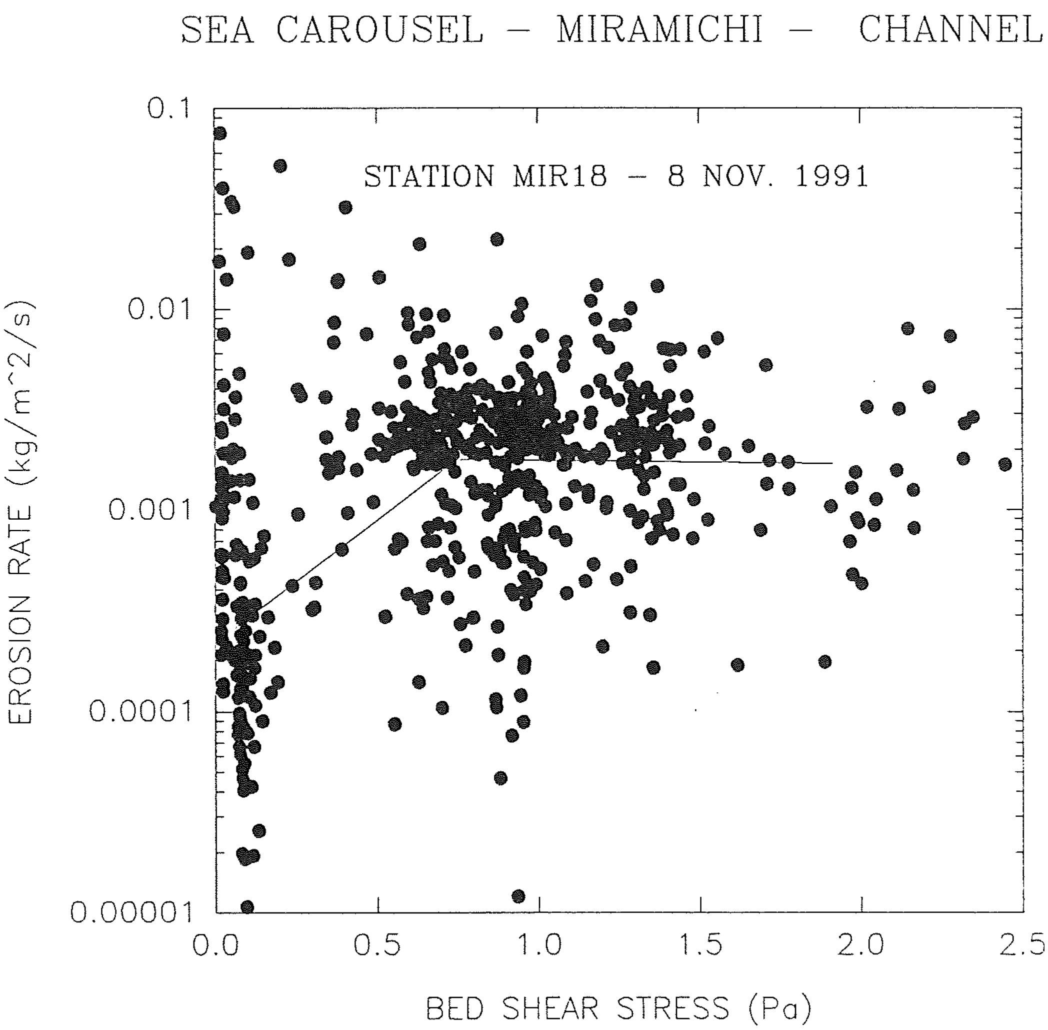
SEA CAROUSEL – MIRAMICHI NAVIGATION CHANNEL

STATION MIR18 – 8 Nov. 1991



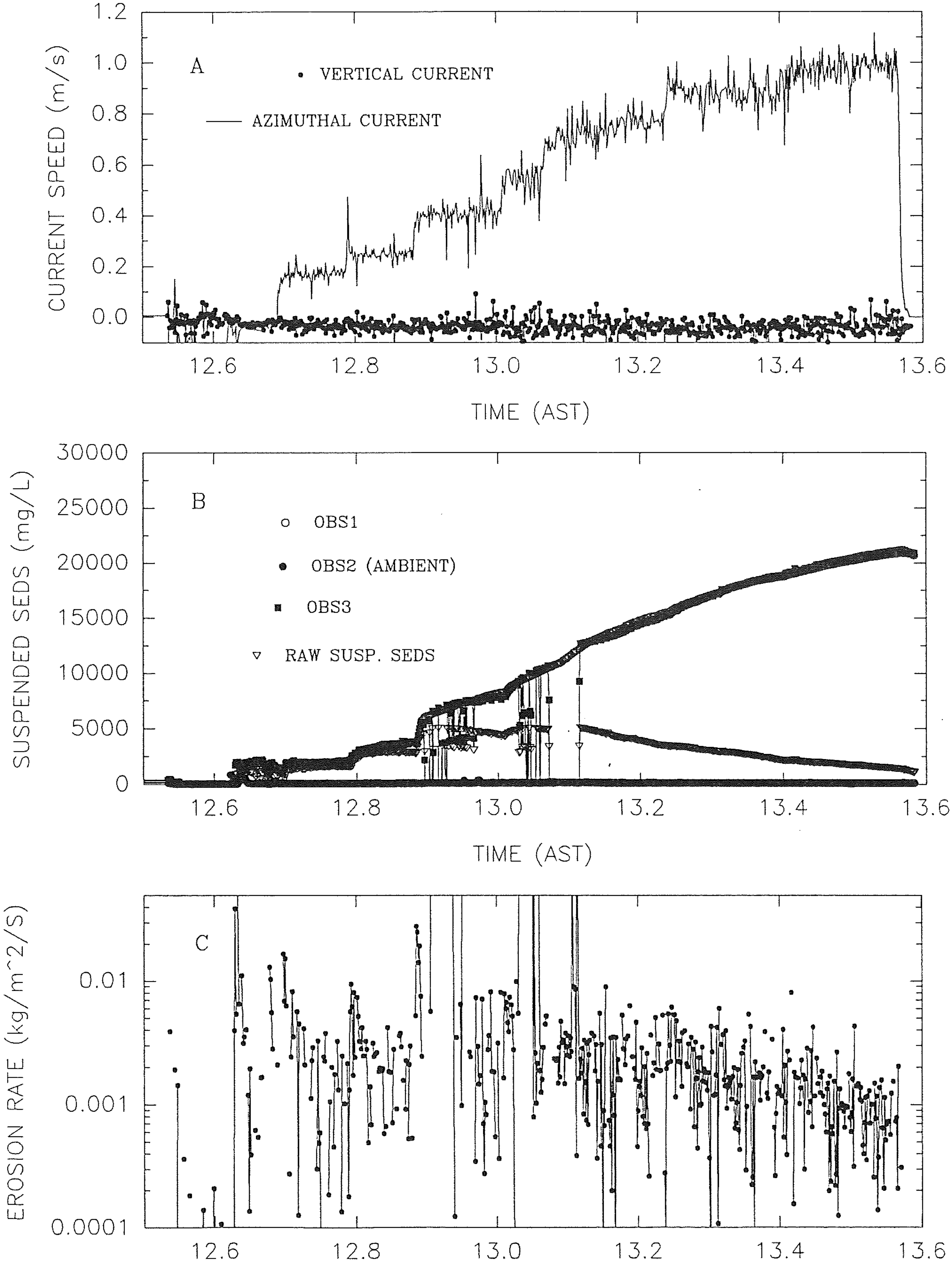


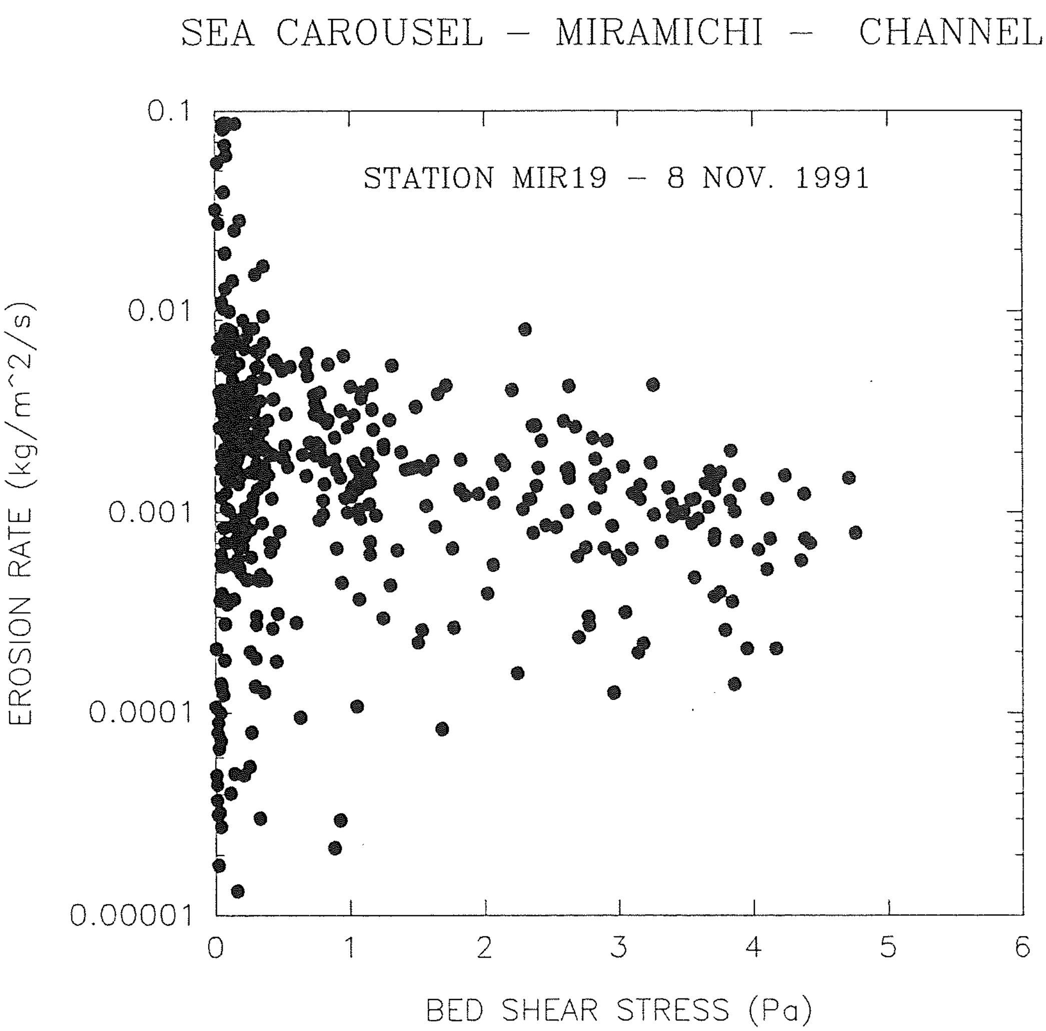
MIRAMICHI - CHANNEL (MIR19)
DATE: 8 NOV. 91
COHESION = 0 Pa
FLUIDIZED GEL
APPLIED STRESS (Pa)
15
10
5
0
0
10
20
30
40
50
60
EFFECTIVE STRESS (Pa)


SEA CAROUSEL - MIRAMICHI - CHANNEL
STATION MIR18 - 8 NOV. 1991
EROSION RATE (kg/m^2/s)
0.1
0.01
0.001
0.0001
0.00001
0.0
0.5
1.0
1.5
2.0
2.5
BED SHEAR STRESS (Pa)

SEA CAROUSEL – MIRAMICHI NAVIGATION CHANNEL

STATION MIR19 – 8 Nov. 1991




SEA CAROUSEL - MIRAMICHI - CHANNEL
STATION MIR19 - 8 NOV. 1991
EROSION RATE (kg/m^2/s)
0.1
0.01
0.001
0.0001
0.00001
0
1
2
3
4
5
6
BED SHEAR STRESS (Pa)

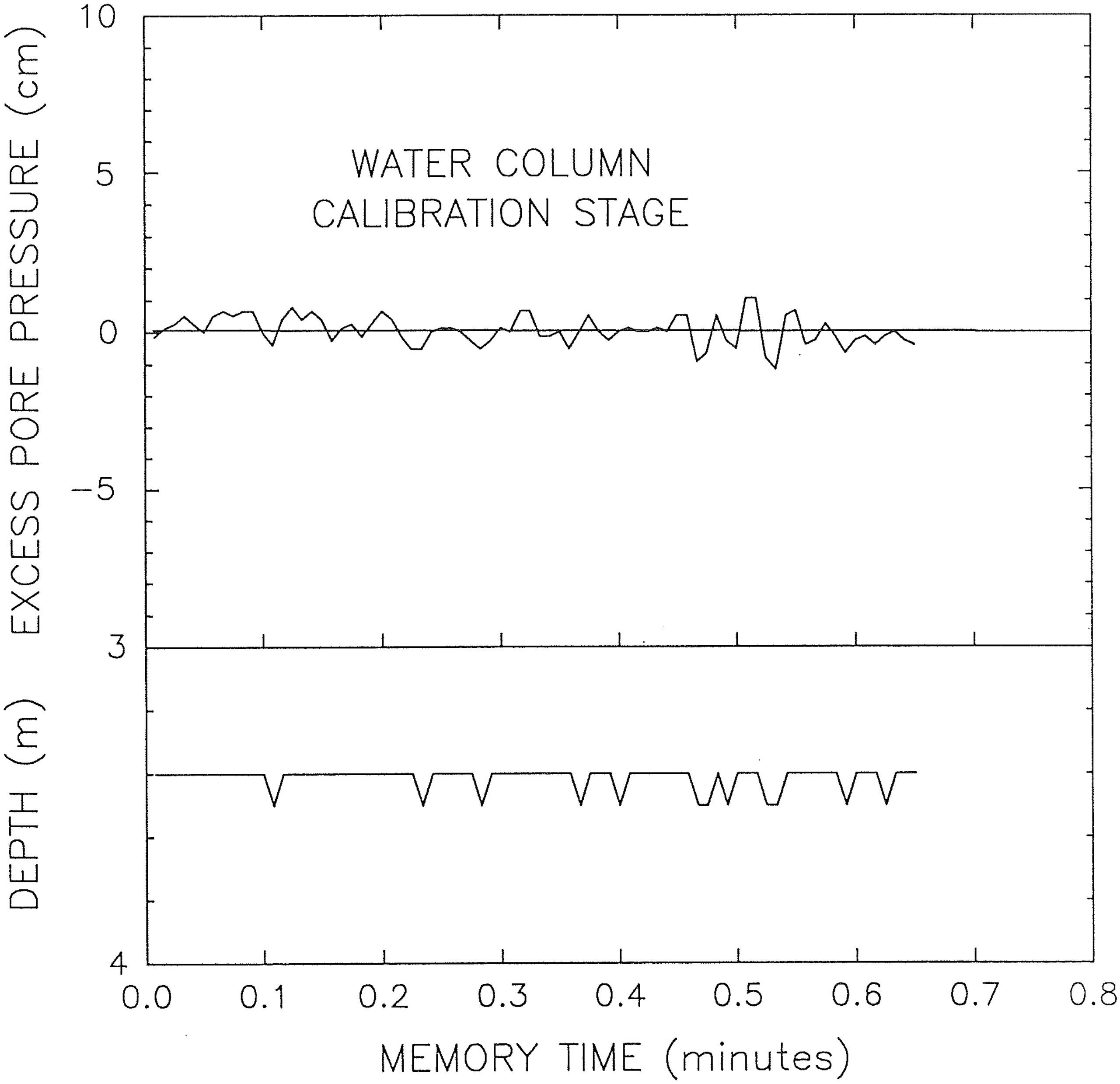
APPENDIX F

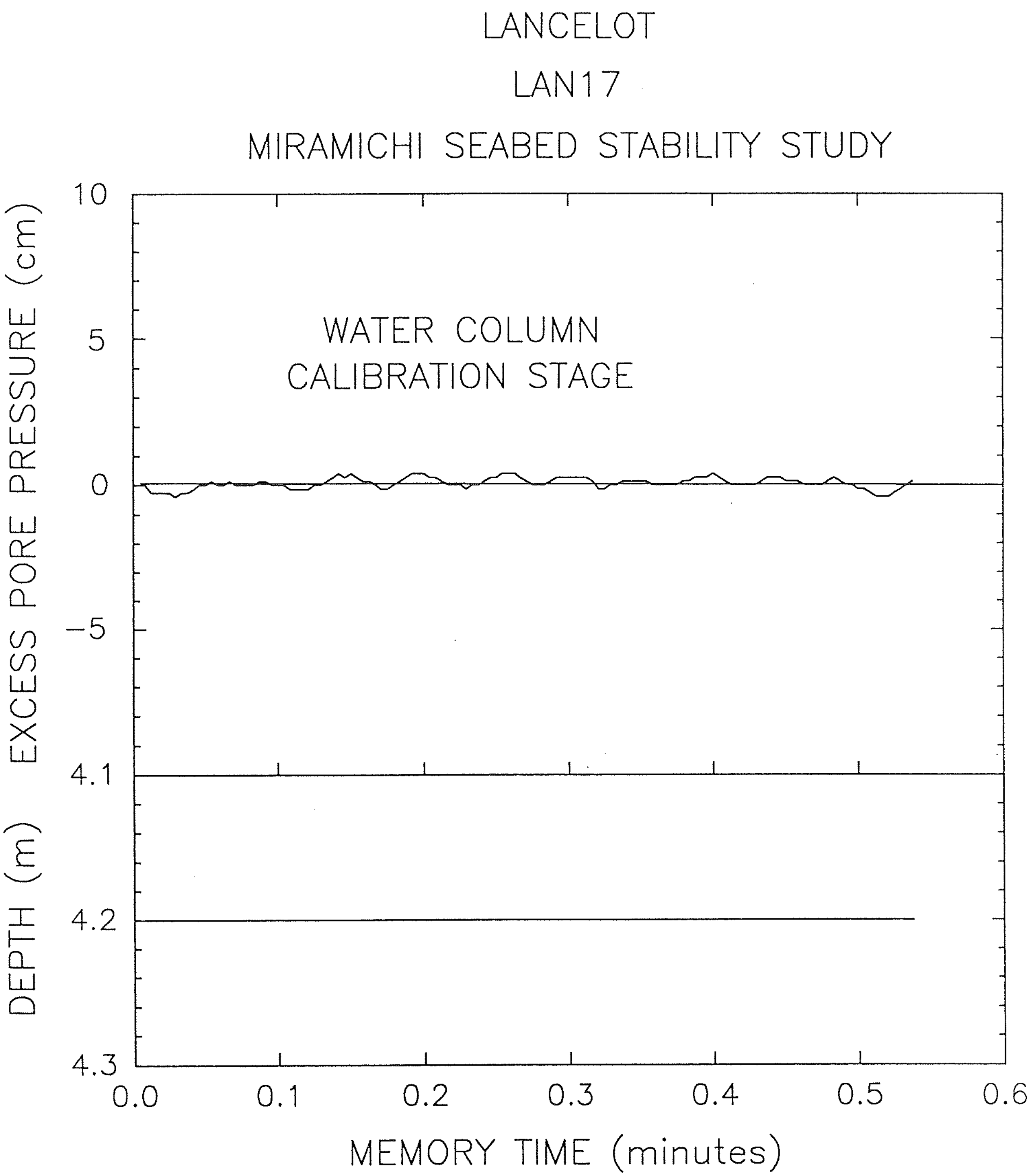
LANCELOT CALIBRATION AND PENETRATION RECORDS

LANCELOT

LAN15

MIRAMICHI SEABED STABILITY STUDY

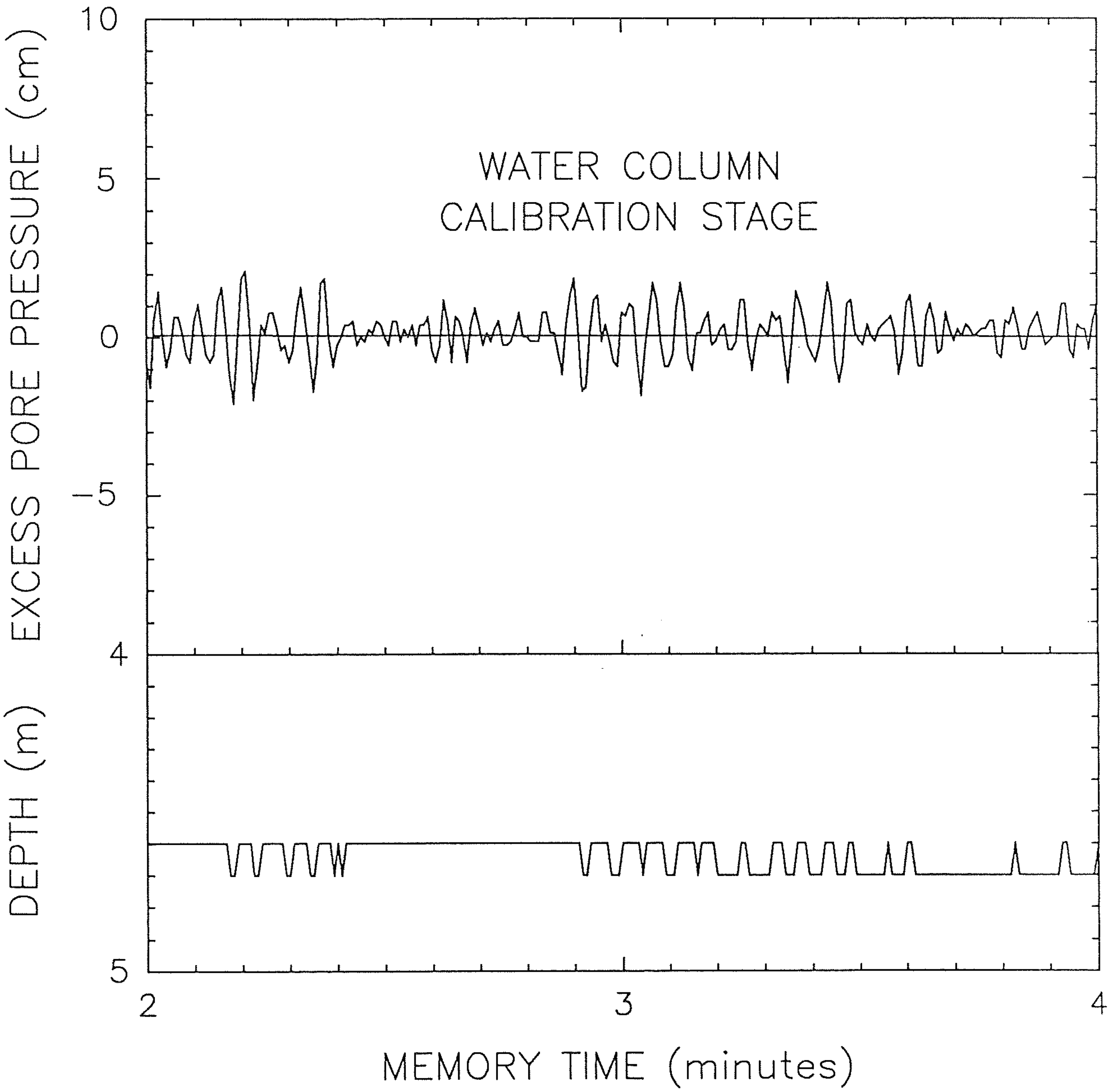


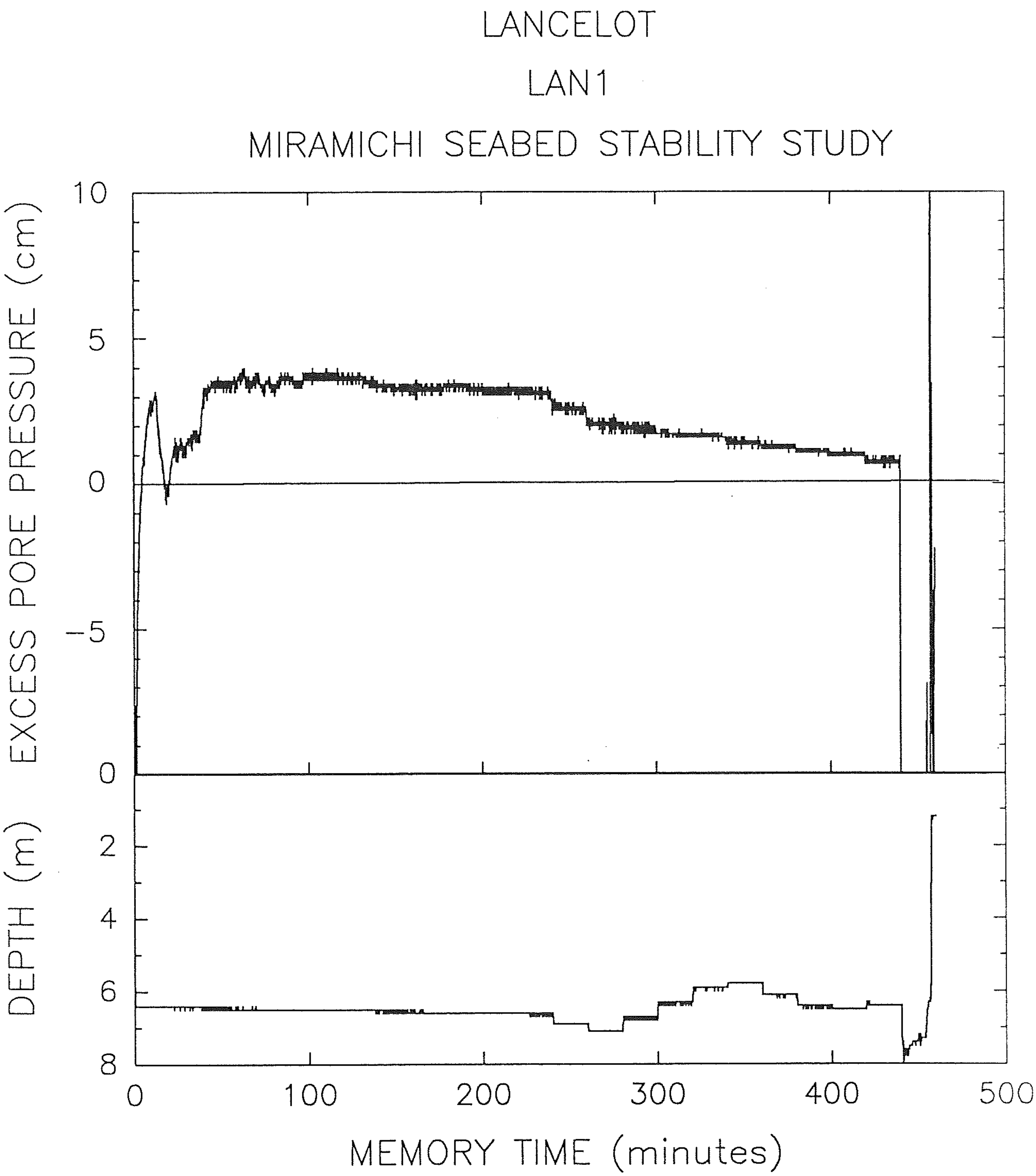

LANCELOT
LAN17
MIRAMICHI SEABED STABILITY STUDY
WATER COLUMN
CALIBRATION STAGE
EXCESS PORE PRESSURE (cm)
DEPTH (m)
10
5
0
-5
4.1
4.2
4.3
0.0
0.1
0.2
0.3
0.4
0.5
0.6
MEMORY TIME (minutes)

LANCELOT

LAN20

MIRAMICHI SEABED STABILITY STUDY

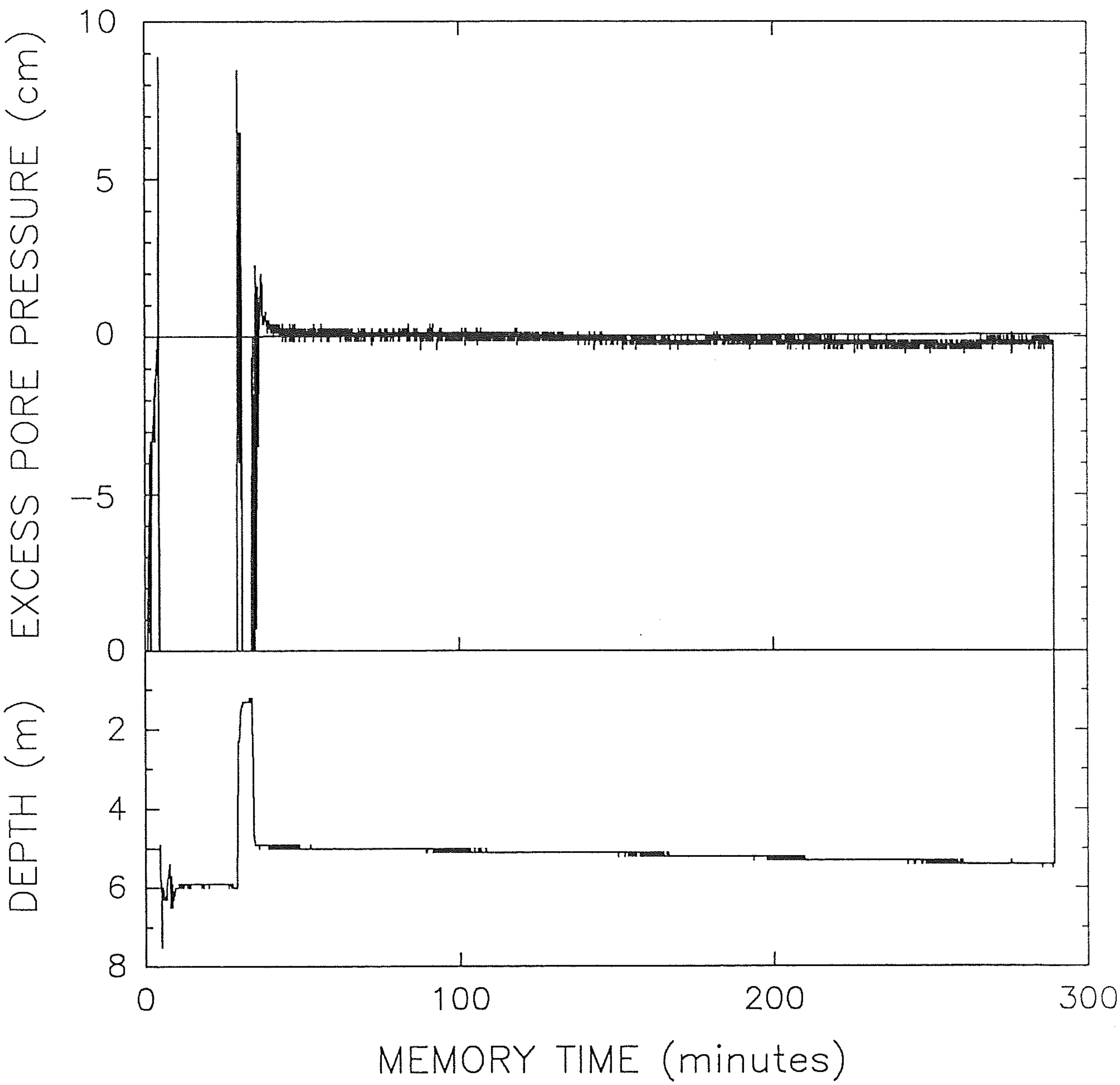


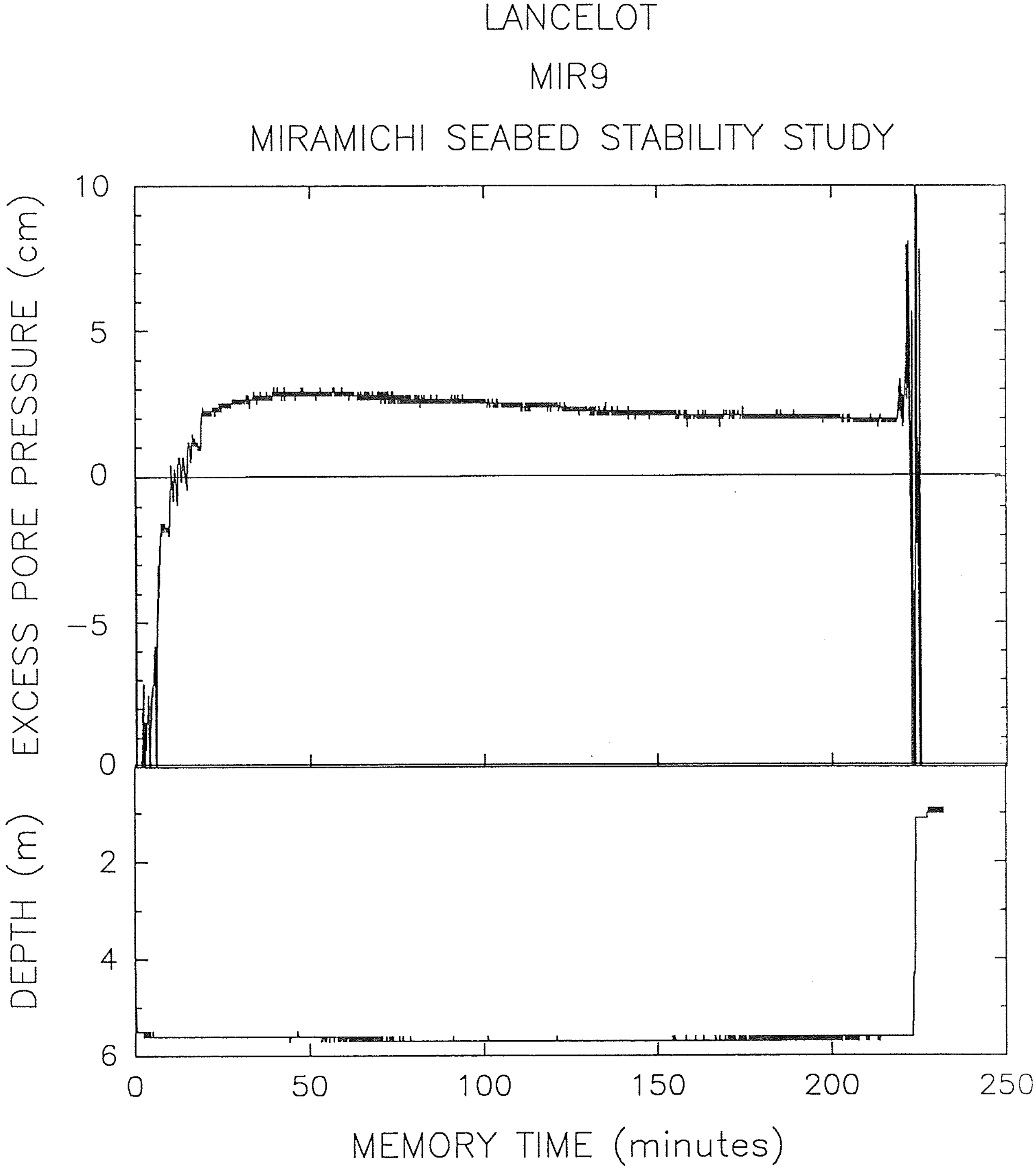

LANCELOT
LAN1
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
10
5
0
-5
0
DEPTH (m)
2
4
6
8
0
100
200
300
400
500
MEMORY TIME (minutes)

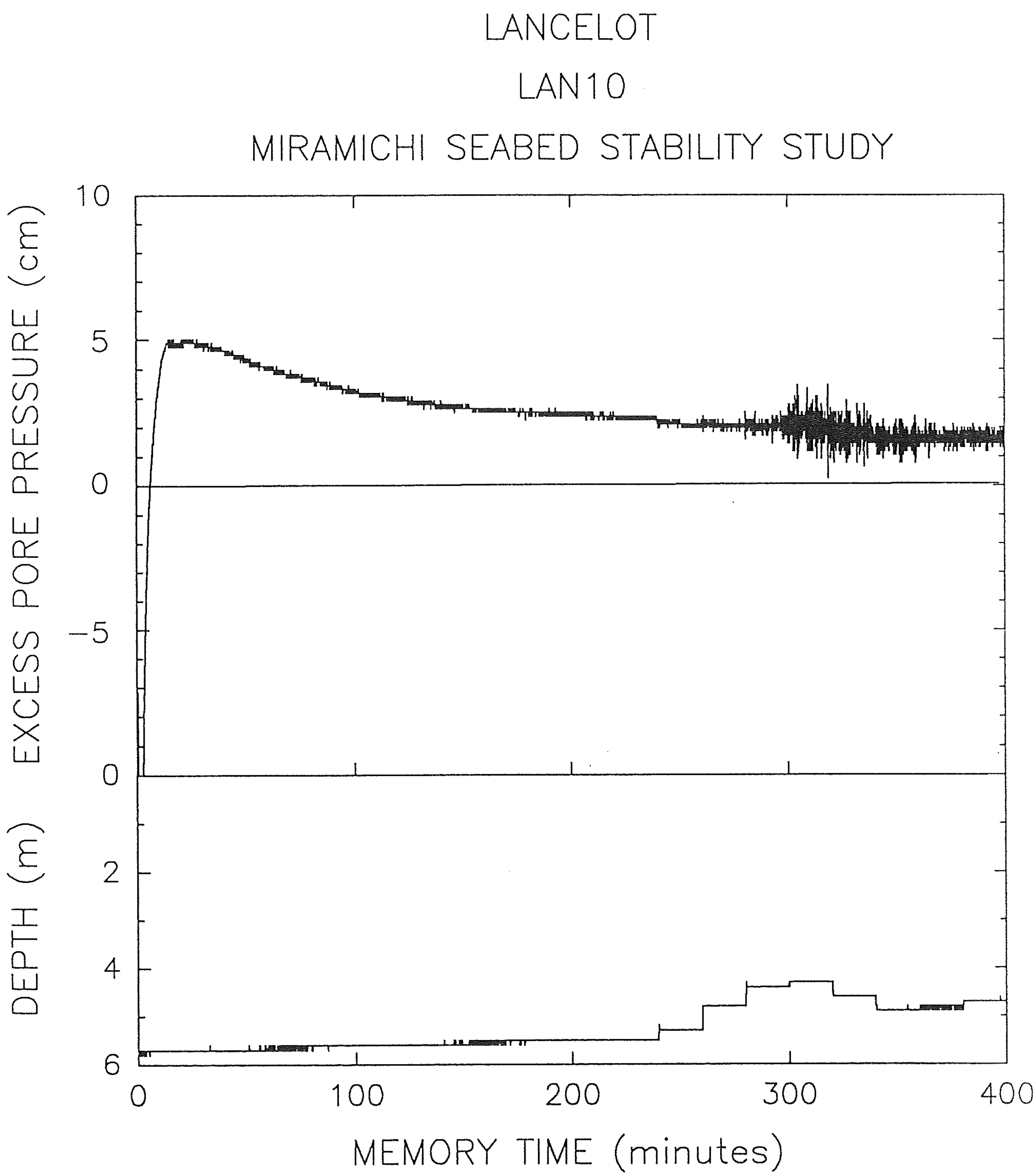
LANCELOT

LAN7

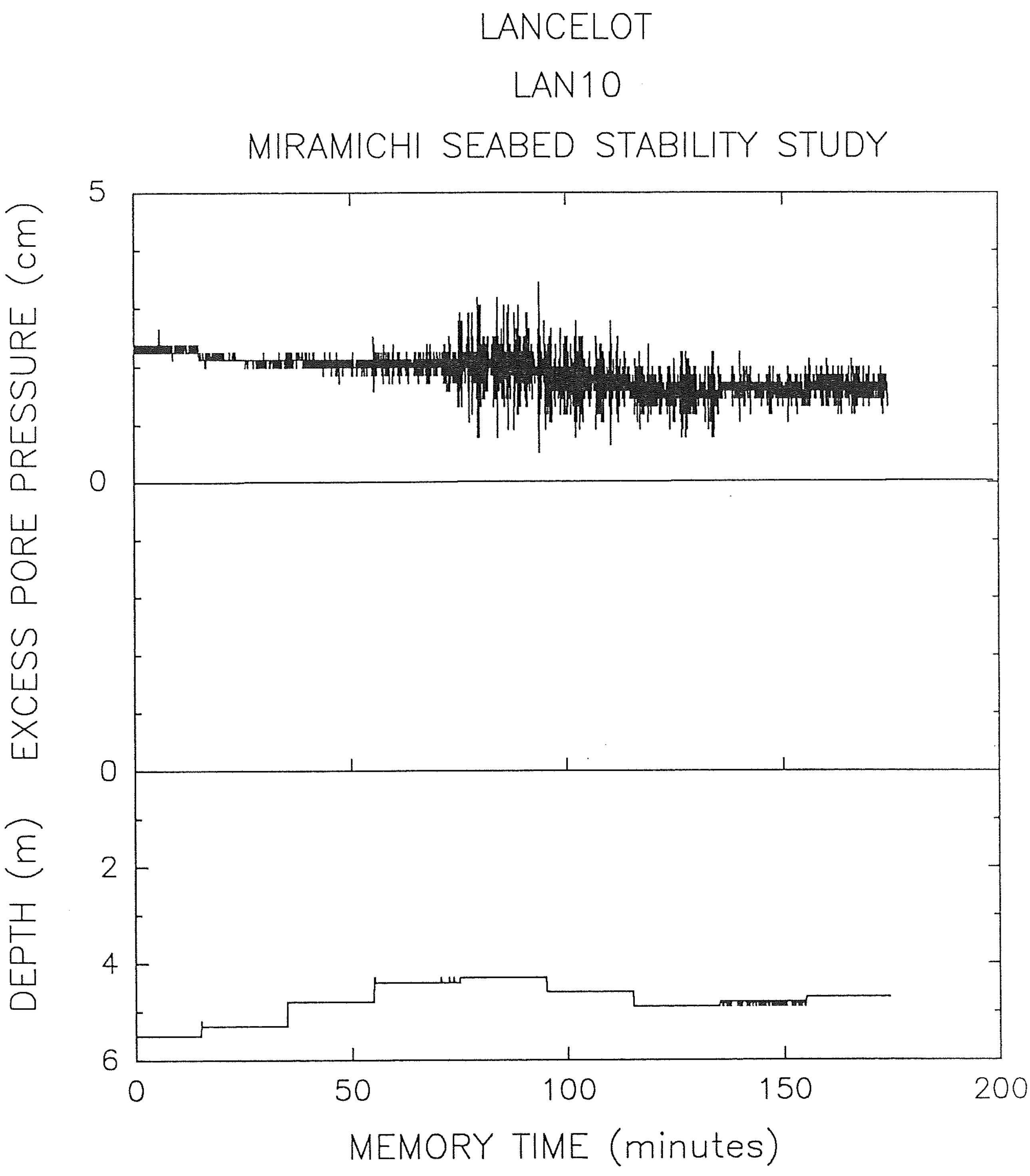
MIRAMICHI SEABED STABILITY STUDY




LANCELOT
MIR9
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
10
5
0
-5
DEPTH (m)
0
2
4
6
0
50
100
150
200
250
MEMORY TIME (minutes)



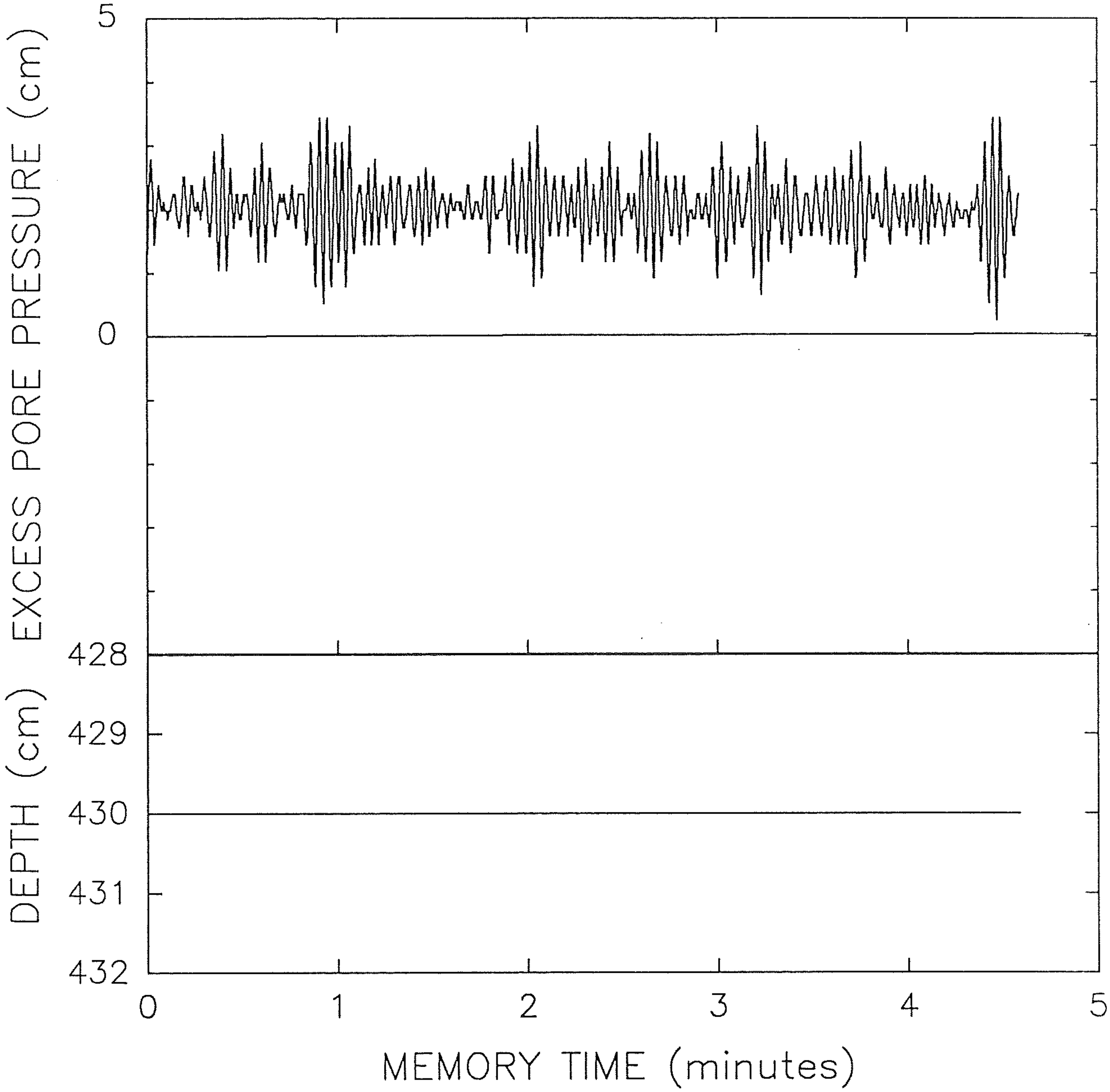
LANCELOT
LAN10
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
DEPTH (m)
MEMORY TIME (minutes)
10
5
0
-5
0
2
4
6
0
100
200
300
400

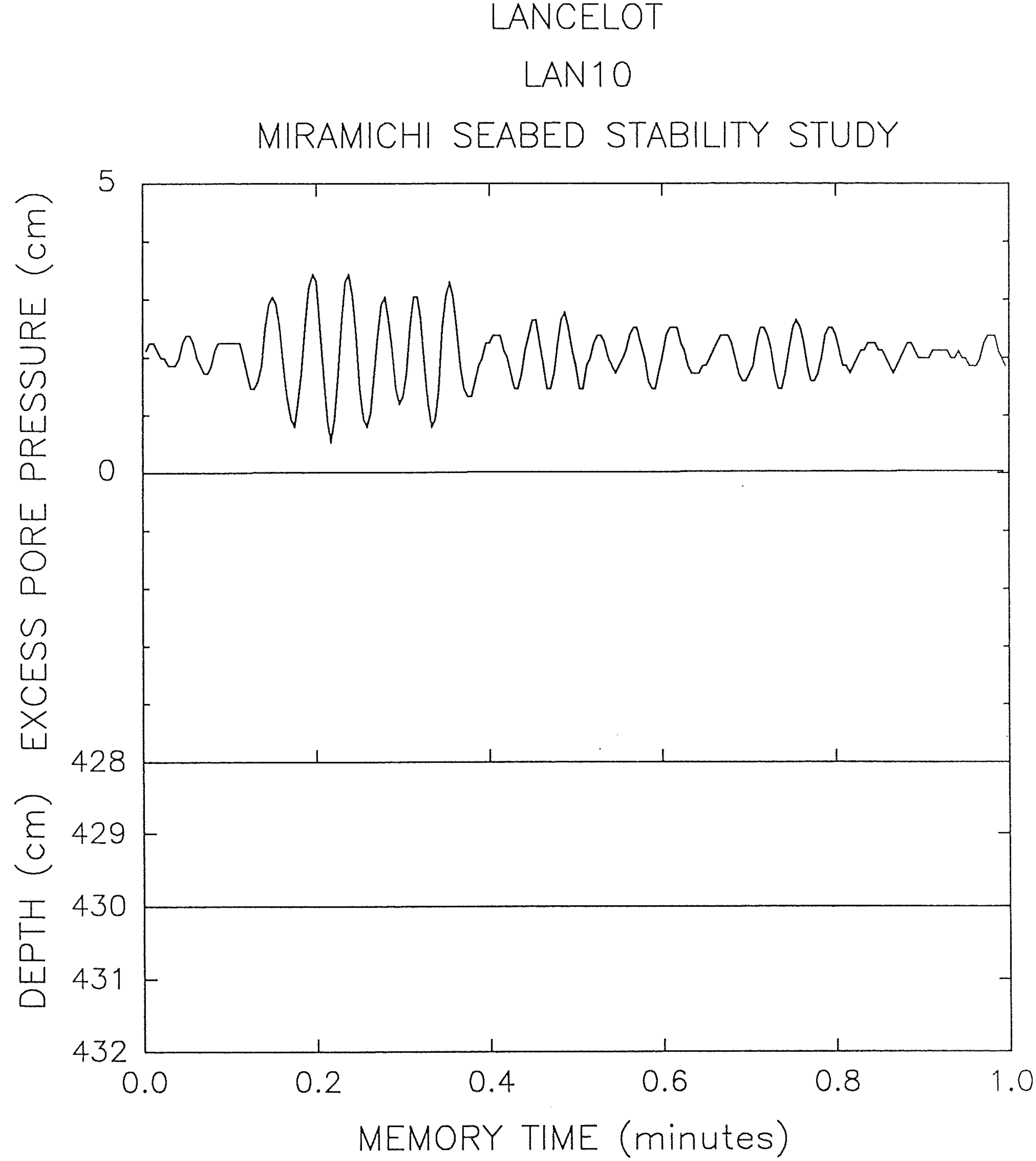

LANCELOT
LAN10
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
DEPTH (m)
MEMORY TIME (minutes)
5
0
0
2
4
6
0
50
100
150
200

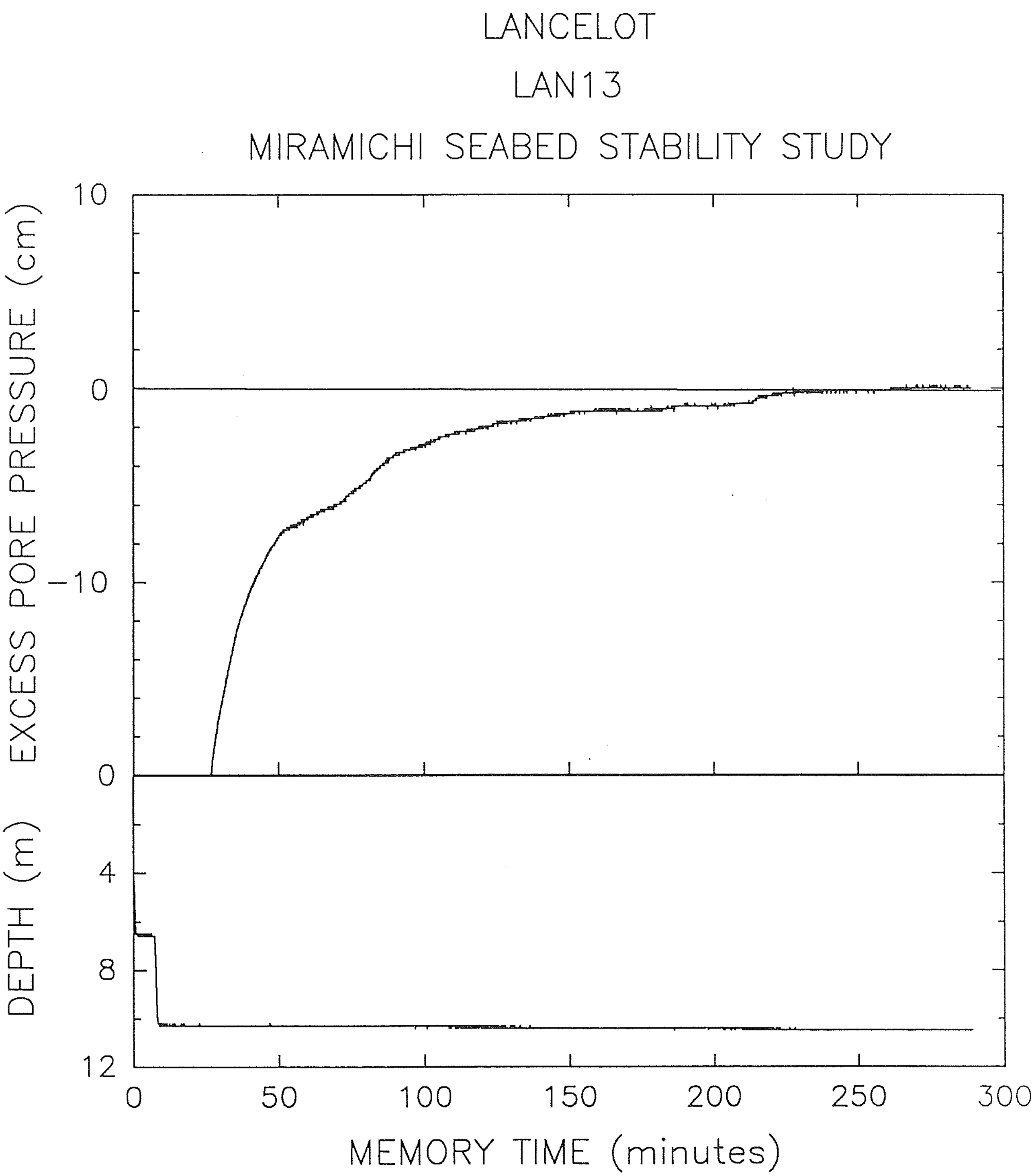
LANCELOT

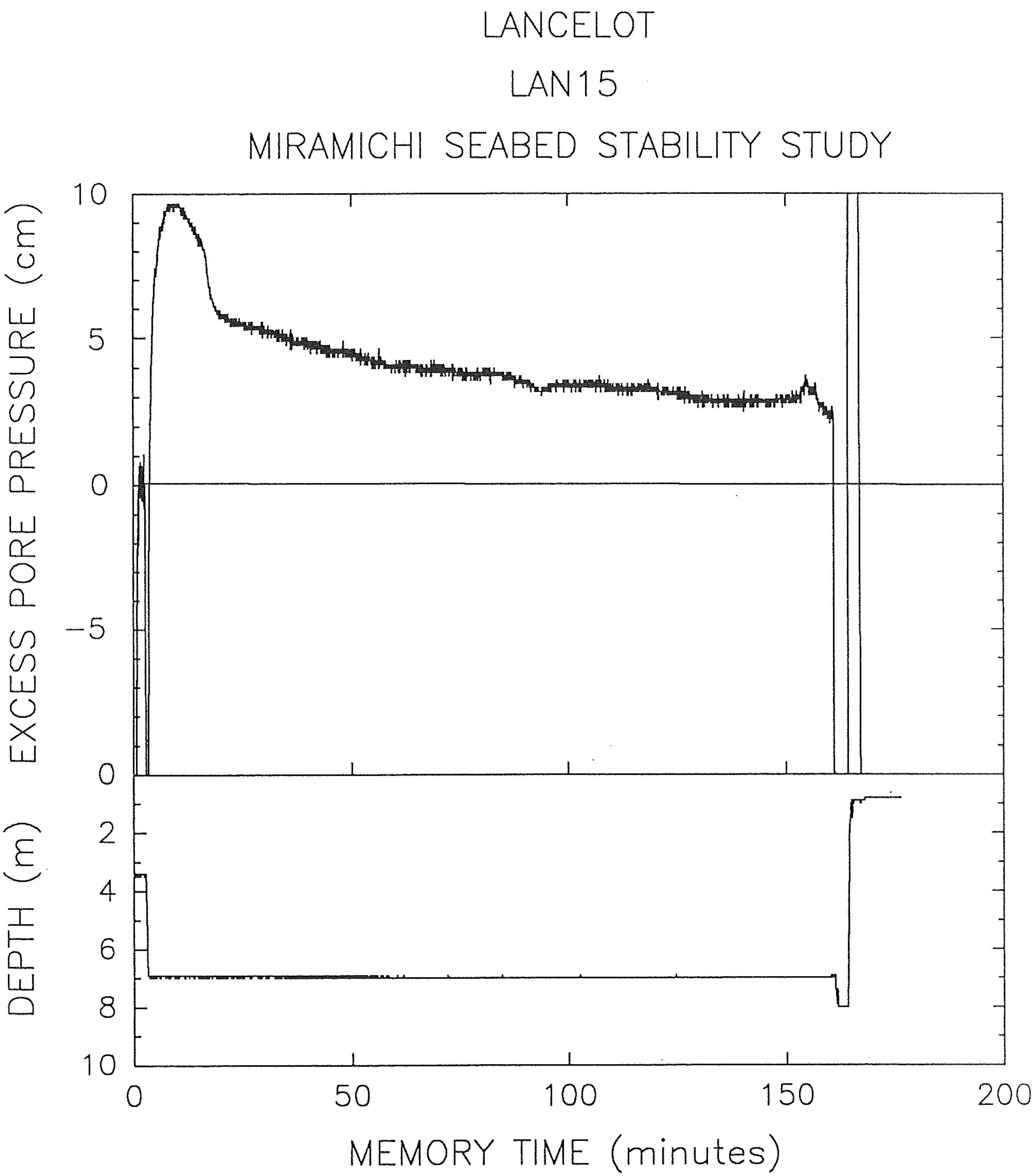
LAN10

MIRAMICHI SEABED STABILITY STUDY




LANCELOT
LAN10
MIRAMICHI SEABED STABILITY STUDY
5
0
EXCESS PORE PRESSURE (cm)
428
429
430
431
432
DEPTH (cm)
0.0
0.2
0.4
0.6
0.8
1.0
MEMORY TIME (minutes)


LANCELOT
LAN13
MIRAMICHI SEABED STABILITY STUDY
10
0
-10
0
EXCESS PORE PRESSURE (cm)
4
8
12
DEPTH (m)
0
50
100
150
200
250
300
MEMORY TIME (minutes)

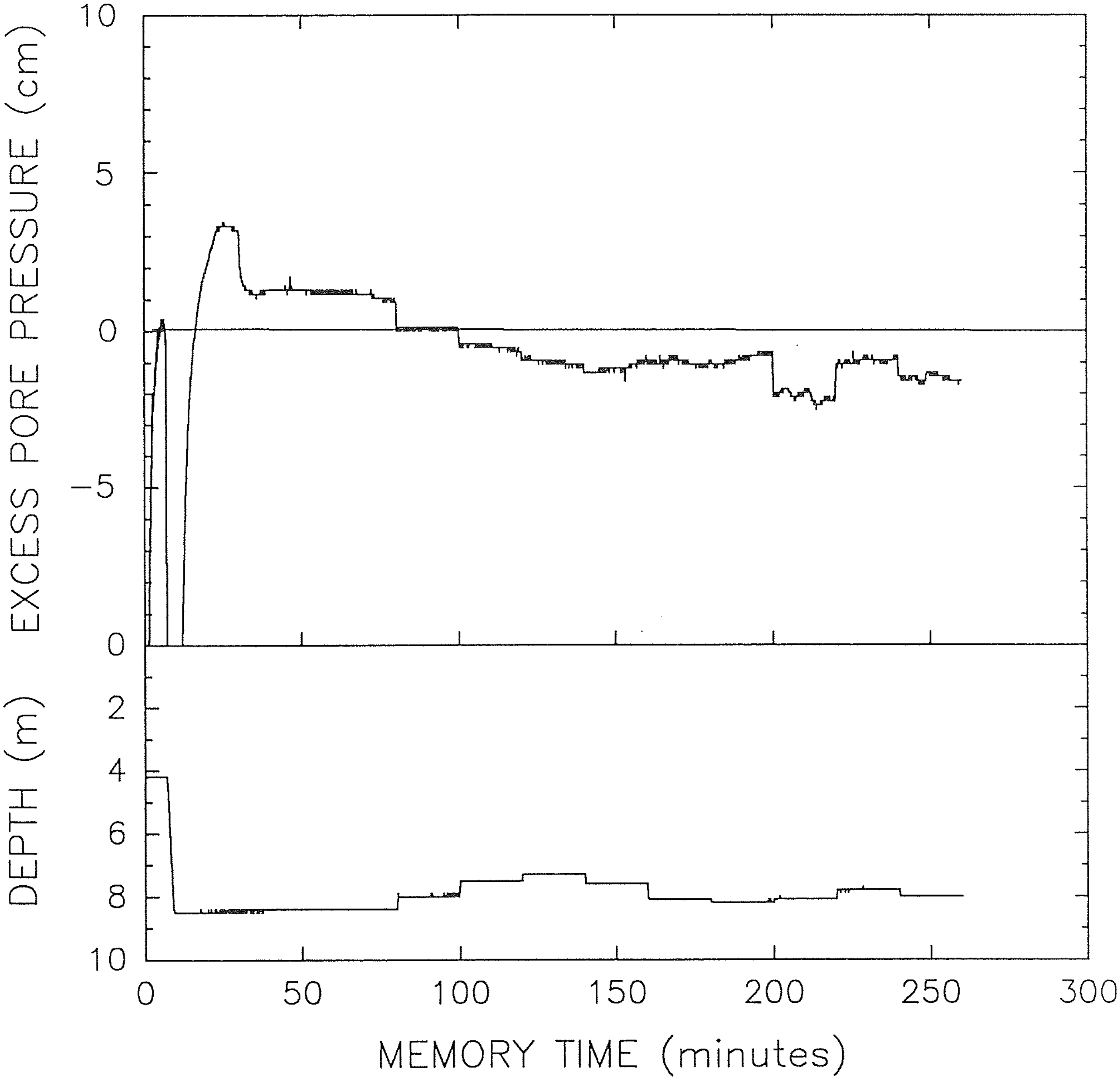


LANCELOT
LAN15
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
10
5
0
-5
0
DEPTH (m)
2
4
6
8
10
0
50
100
150
200
MEMORY TIME (minutes)

LANCELOT

LAN17

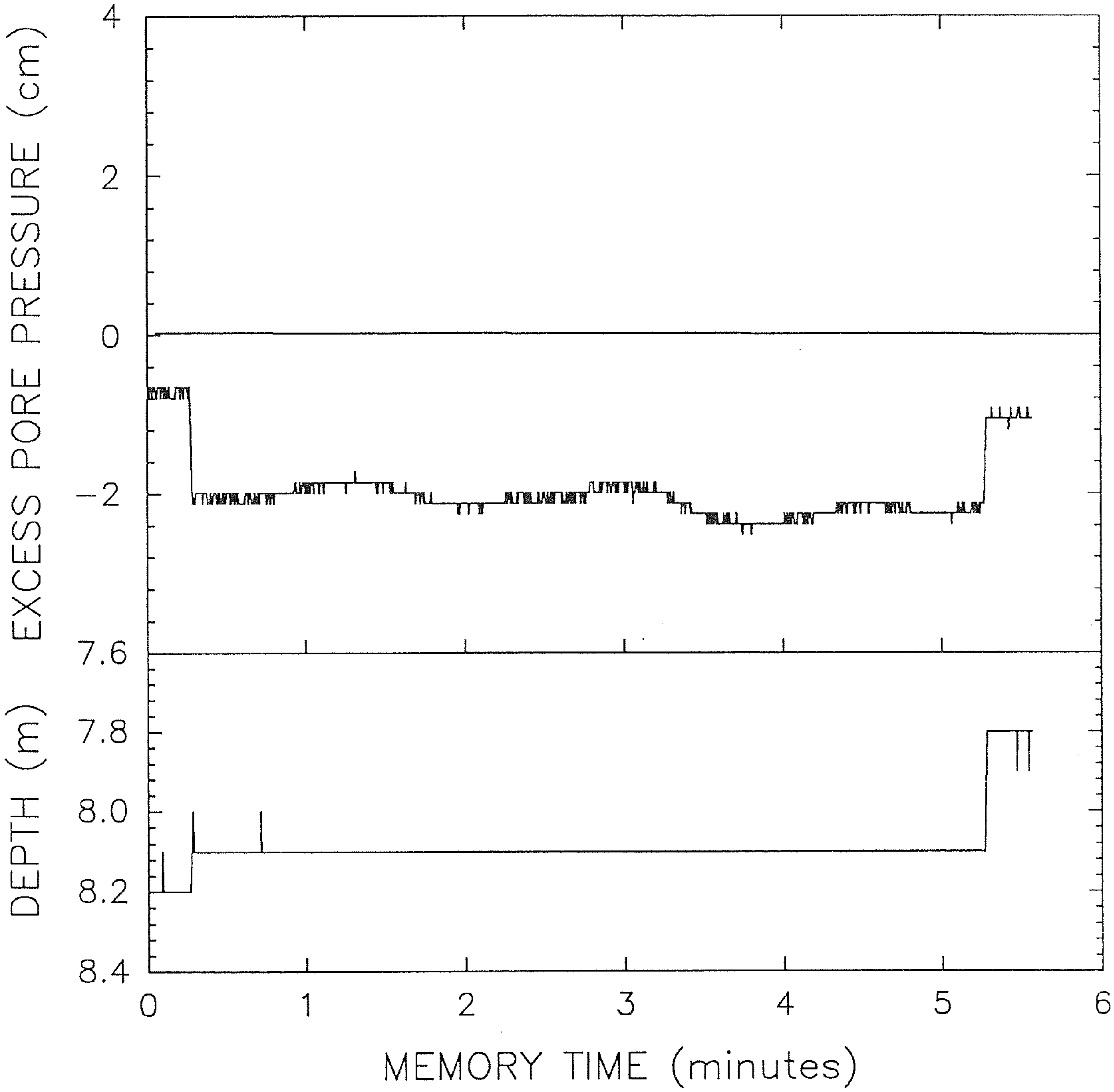
MIRAMICHI SEABED STABILITY STUDY

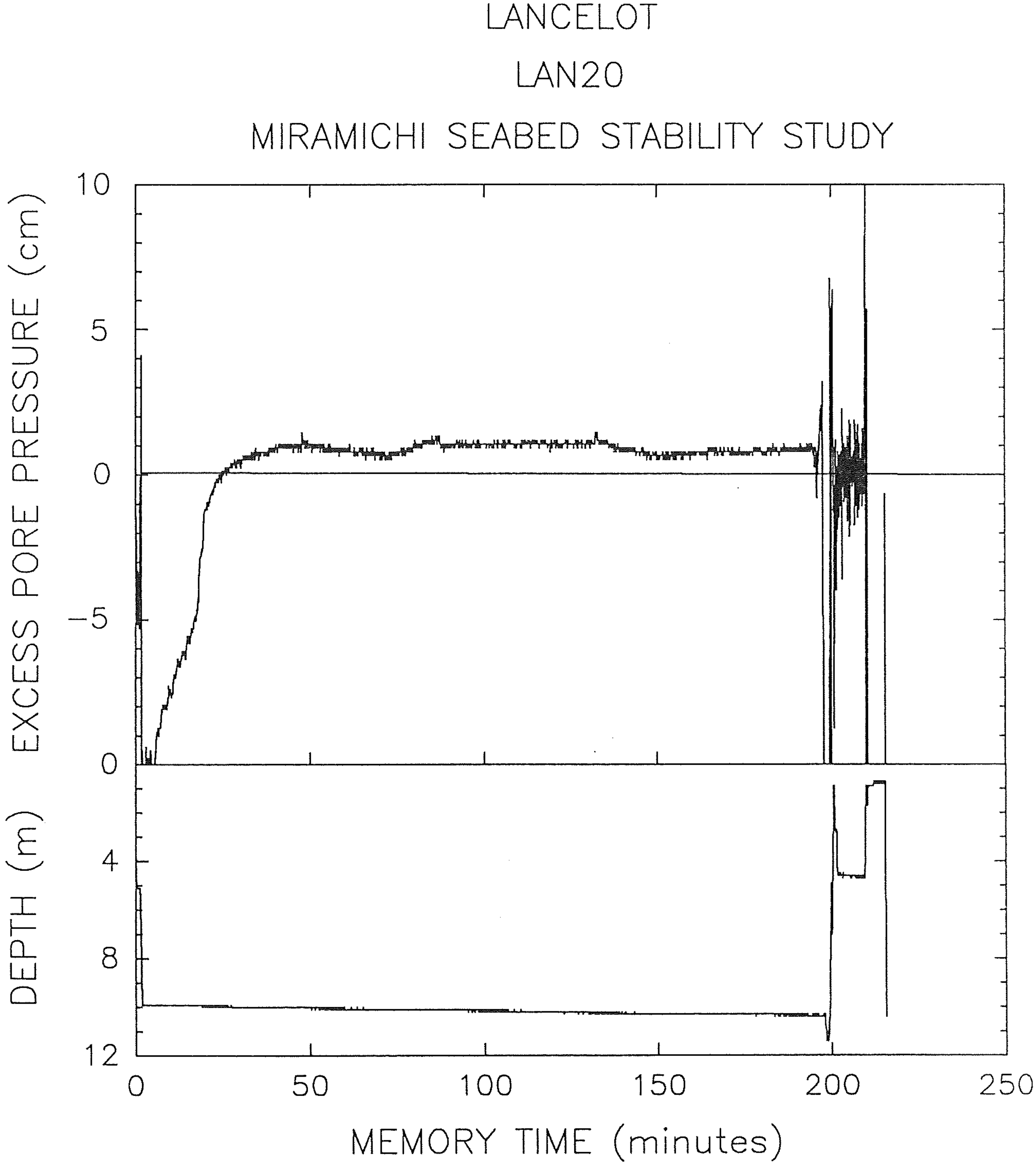


LANCELOT

LAN17

MIRAMICHI SEABED STABILITY STUDY

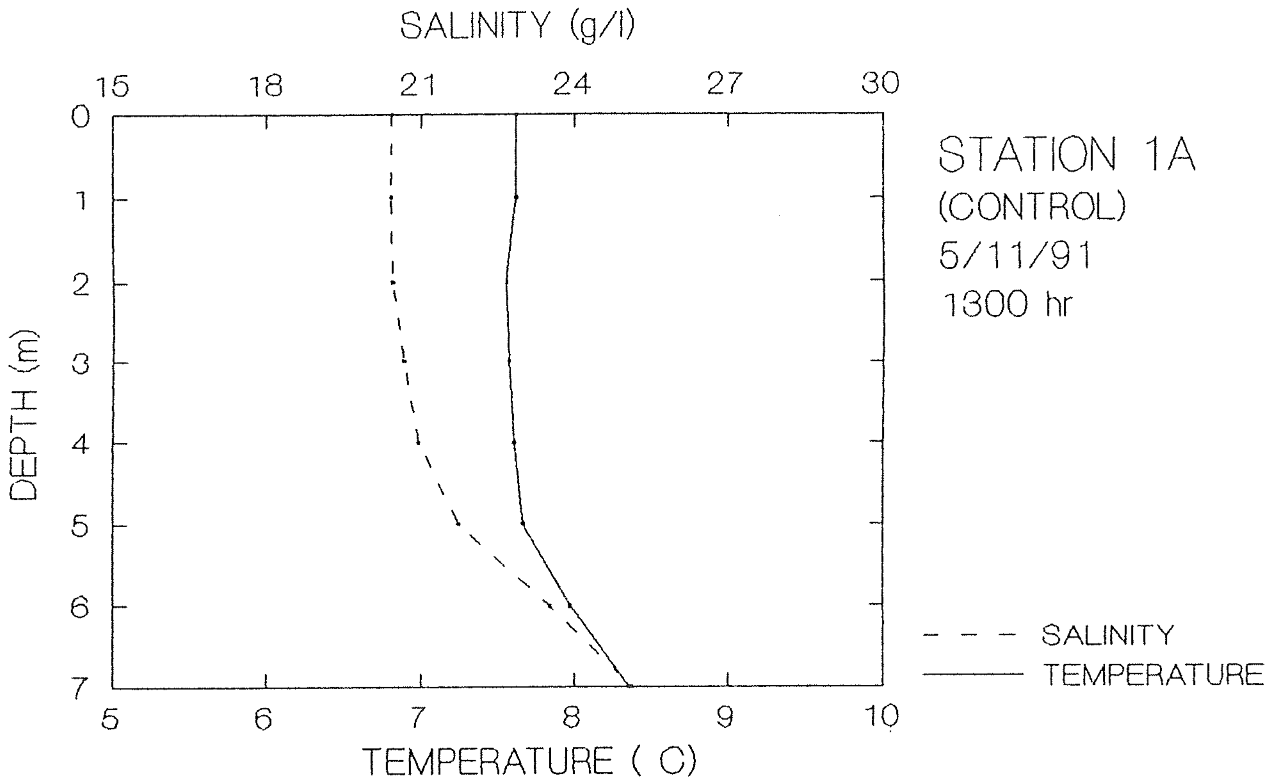


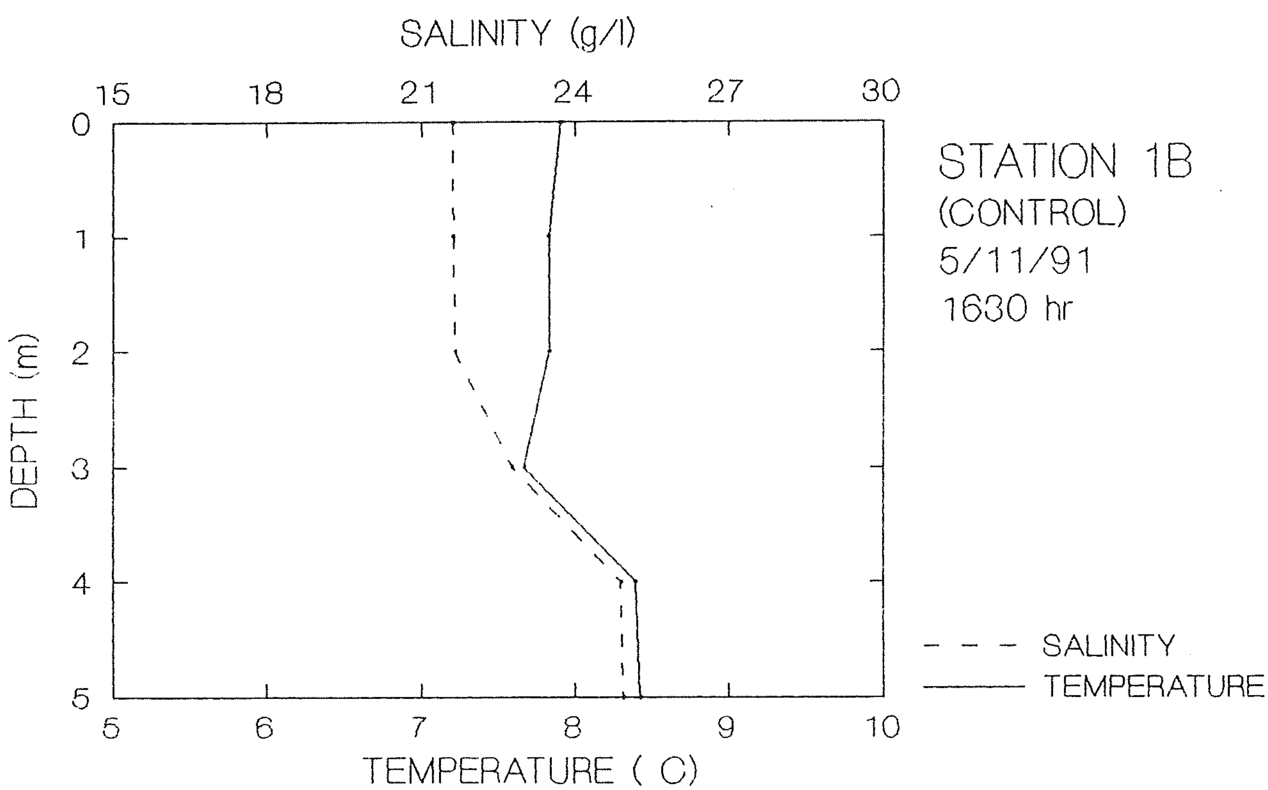


LANCELOT
LAN20
MIRAMICHI SEABED STABILITY STUDY
EXCESS PORE PRESSURE (cm)
DEPTH (m)
MEMORY TIME (minutes)
10
5
0
-5
0
4
8
12
0
50
100
150
200
250

APPENDIX G

SALINITY-TEMPERATURE PROFILES


SALINITY (g/l)
15
18
21
24
27
30
0
1
2
3
4
5
6
7
DEPTH (m)
5
6
7
8
9
10
TEMPERATURE (C)
STATION 1A
(CONTROL)
5/11/91
1300 hr
SALINITY
TEMPERATURE


SALINITY (g/l)
15
18
21
24
27
30
0
1
2
3
4
5
DEPTH (m)
5
6
7
8
9
10
TEMPERATURE (C)
STATION 1B
(CONTROL)
5/11/91
1630 hr
SALINITY
TEMPERATURE