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BEAUFORT SEA OCEAN DUMPSITE CHARACTERIZATION

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SUMMARY

The seabed at two potential Beaufort Sea dumpsites was characterized in late August 1986 by side-scan sonar coverage, bathymetry, sub-bottom profiling, surficial sediment particle size, surficial sediment trace metal and hydrocarbon content and infaunal benthic community species and density. Sampling was conducted during a one week cruise aboard the Fisheries and Oceans research ship "J.P. Tully". In addition, within each dumpsite, Otter trawls were carried out to qualitatively sample for epibenthos and bottom fish.

At each location, two grab samples were taken with a Smith-McIntyre grab (0.1 m^2 surface area bite). One was sieved for macrobenthos, the second sub-sampled for trace metals, hydrocarbon and particle size analyses. A total of 30 locations was sampled in and around each dumpsite. Sample locations were chosen randomly; 10 sites were within 1.5 km radius of the dumpsite centre; 20 sites between 1.5 and 3.0 km. Four separate trawls were carried out at Dumpsite B and five at Dumpsite A.

a) **Dumpsite A: (70°39'N; 135°50' W)**

The site area bathymetry dips gently toward the north-northwest at a slope of approximately 1 in 37 (1.55°). The contours are slightly concave in a north-northwest direction and the water depths range from 120 metres in the south-southeast to 300 metres at the north-northwestern edge of the study area. The seabed is smooth and regular with only very occasional and scattered features observed. With the limited sidescan coverage of the site, the features observed consisted of a single pock-mark feature (shallow gas venting) and numerous shallow trench features which are not associated with any known geological phenomena. These features were observed in a random distribution though normally parallel or sub-parallel to the contour orientation (possibly biased on the direction of survey).

Within the shallow subsurface sediments of the site area, the acoustic records showed a thick sequence of conformable soft marine sediments. These sediments range from 38 to 60 metres in thickness and are well banded in nature suggesting thin layers of silts and clays similar to the type of materials recovered in the grab sampling. The conformable sediments overly an acoustically homogeneous sediment body along an indistinct boundary. This boundary may be associated with a change in morphology or depositional environment of the slope materials, though the systems employed for this survey were unable to define this. The soft conformable subbottom

sediments showed some localized undulations or troughs and mounds in the order of 2 to 5 metres which appear to be conformable drape of the pelagic sediments onto deeper structural irregularities that were not clearly observed on the present acoustic records.

The upper 2 cm were predominantly clay size particles (overall mean 62.7% by weight) with less than 0.2% by weight of sand size or greater. Concentrations of metals and hydrocarbons in surface sediments were uniformly distributed within the dumpsite and as far as 3 km from the dumpsite centre except for Hg. Hg concentrations were higher and more variable in the dumpsite compared to the surrounding area (1.5 - 3.0 km). Mean metal concentrations were similar to those found at shallower locations and not significantly ($p \leq 0.05$) different from concentrations at Dumpsite B. Total PAH and alkane levels were about 20% higher than those at Dumpsite B.

A mean density of 3,474 animals/m^2 with a biomass of 22.83 g/m^2 was found on the basis of the analysis of the contents of 10 0.1 m^2 grabs. Polychaetes ~~at~~ were the dominant taxon accounting for almost 67% of the total number of organisms and 57.5% of the total biomass.

b) Dumpsite B: (69°40'N; 138°30'W)

The site area bathymetry dips gently toward the North at a slope of approximately 1 in 360 (0.16°). The contours are slightly concave in a northward direction and the water depths range from 137 metres in the southwest corner to 158 metres in the north central portion of the site. The seabed is smooth and regular with very occasional and scattered debris observed. Some of these debris appeared to be logs or branches that had become water logged after drifting to the region via the Mackenzie River; other features observed consisted of shallow depressions that are linear in shape and from 5 to 15 metres in length. These features are of unknown origin. Within the southeastern quadrant of the site area the seabed showed a patchy higher reflectivity pattern that had no particular orientation and was probably associated with biological concentrations of organisms as no indications of sedimentological grain size differences were noted from the grab sampling program conducted during the survey. The subseabed conditions showed a finely layered conformable soft sedimentary cover of at least 25 to 35 metres thickness over the entire site with no unusual features. Surficial sediments were composed primarily of fine silts and clays and the acoustic transparency of the 30 metre thick surficial sediments indicated that this was consistent to at least these depths. The finely banded surface sediments overlay a more irregular surface that was not clearly defined by the profiler data. These deeper sedimentary horizons most likely constitute similar sedimentary characteristics and type that have been structurally modified (to the acoustic records) by sediment loading and de-watering or de-gassification of these deeper materials. These material types were consistent to the limits of penetration of the acoustic system.

The upper 2 cm were a mixture of clay, silt and sand size particles (overall mean 50, 40 and 10% by weight respectively). Concentrations of metals and hydrocarbons in surface sediments were uniformly distributed within the dumpsite and as far as 3 km from the dumpsite centre. Mean metal concentrations were not significantly ($p < 0.05$) different than concentrations at Dumpsite A. Total PAH and alkane concentrations however were about 20% lower.

A mean density of 6,199 animals/m^2 with a biomass of 91.47 g/m^2 was found on the basis of the analysis of the contents of 10 0.1 m^2 grabs. Polychaetes were the dominant taxon accounting for 66.5% of the total number of organisms and 31% of the biomass. Bivalves were the dominant species in terms of biomass, contributing almost 45% of the total.

c) Number of Samples Required to Detect a One Standard Deviation Change in Contaminant Concentration

The required number of samples predicted by Hoff and Thomas (1986) for detecting a change of one standard deviation in contaminant concentrations at each dumpsite was tested using analysis of 20 samples of each contaminant. It was found that the numbers predicted were adequate for every contaminant.

d) Contaminant - Grain Size Relationship

The grain size-contaminant relationship established from the 1984 EPS data set from shallower depths was found to hold for total PAH, Cu, Zn, Ba and Hg. There was a significant ($p \leq 0.05$) difference between values predicted from the 1984 data and observed results for Cd, Cr, Ni, Pb and total n-alkanes. The differences are thought to be a result of laboratory bias and are not a result of a different contaminant/grain size relationship. It is suggested that some samples be saved and analyzed "blind" with any future samples from the dumpsites to allow a valid comparison with this data set.

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Arctic Laboratories Ltd.

Paul Erickson	- study management, supervision of trace metal analyses, field sampling
Blair Humphrey	- hydrocarbon analysis management
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Val Scott	- hydrocarbon analysis
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Gerrie Hosick	- word processing
Brenda Fraser	- drafting

LGL Limited

William Cross	- management of benthos sorting, identification and reporting
D. Thomson	- computer tabulation
Bill Griffiths	- fish

Earth and Ocean Research Ltd.

John Lewis	- side scan sonar and sub-bottom profiling

Quanta Trace Laboratories Ltd. - Ba and Cr digests and analysis

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Mark Gordon, EP Yellowknife, was the Scientific Authority; Glen Packman, EP Yellowknife organized and led the field program; Mark Gordon and Russell Shearer, EP Yellowknife, and Hal Nelson, EP Vancouver, took part in sampling and were responsible for ship-board processing of benthic infauna, epifauna and fish. Glen Packman critically reviewed the report.

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1. BACKGROUND AND STATEMENT OF OBJECTIVES

There are presently no common user Ocean Dumpsites in the Canadian Beaufort Sea. Environmental Protection, however, is evaluating two potential sites off the continental shelf (water depths > 100m) for dumping of inert solid wastes such as scrap metal. The purpose of this study was to physically and chemically characterize the sediments in the dumpsite areas, as well as to survey benthic infaunal and epifaunal populations, and to determine the presence/absence of demersal fish. At the same time, the sea bed features were to be characterized by side scan sonar and sub-bottom profile coverage in addition to detailed bathymetry.

Analysis of existing high quality Beaufort Sea sediment contaminant data has indicated a relationship with grain size which would allow predictions to be made of contaminant concentrations in terms of grain size properties. Based on these data, the optimum number of samples necessary to define changes in contaminant concentrations of one standard deviation was derived by Hoff and Thomas (1986). These data, however, are limited in distribution to depths of 20 m or less. It is desireable to know whether the grain-size/contaminant relationship derived from existing data is applicable to the dumpsites or if an alternate relationship exists. A well defined particle size-contaminant relationship will improve the predictive capability for environmental effects. Accordingly, this study had the additional objectives of testing the predictions of Hoff and Thomas (1986) for the required number of samples for each contaminant and the general applicability of the sediment-grain size/contaminant relationship derived from existing Beaufort Sea (<20 m) data to the dumpsite regions (>100 m).

Two potential dumpsites were identified: one in the Mackenzie Canyon at 69°40'N, 138°30'W, water depth 130 - 160 m; the second just off the edge of the shelf at 70°39'N, 135°50'W, water depth 120-300 m (see Figure 1.1). Eight days of ship time were available on the research vessel J.P. Tully to characterize the sediments and benthos in these two areas. The following sections outline the sampling strategy and methods for subsequent analysis and quality assurance.

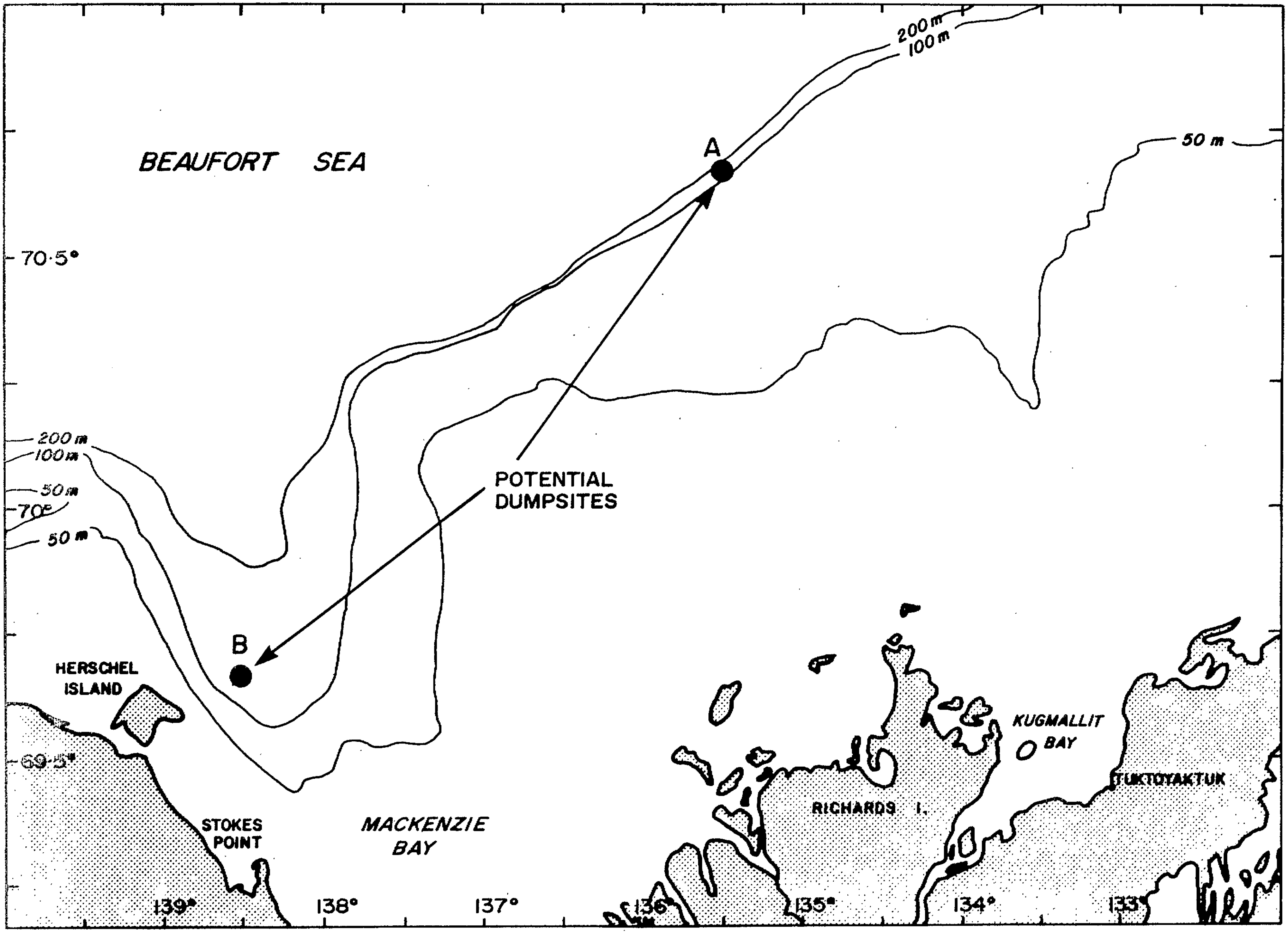

Figure 1.1 Potential Dumpsite Locations.

2. SAMPLING STRATEGY

2.1 Sampling Design

2.1.1 Trace Metals, Hydrocarbons and Grain Size

The sampling plan for chemical contaminants and grain size was based on the outline in Hoff and Thomas (1986, pages 82-87). Stratified random sampling was used with two strata. The inner stratum was a 1.5 km radius circle corresponding to the potential dumpsite. The outer stratum was the area from 1.5 -3 km from the dumpsite centre: data from this area will allow detection of changes which might occur outside the dumpsite itself.

The numbers of samples, n_i, needed to detect changes of one standard deviation in concentrations of contaminants based on data from shallower locations were given on p. 84 of Hoff and Thomas (1986). This is the number of samples predicted to be necessary to satisfy the first major objective of the sampling program, namely defining baseline conditions at an optimum level for future monitoring. A summary of the numbers required is given in Table 2.1. It was estimated that approximately 30 sediment samples could be obtained in a 24 hour working period under favourable conditions, thus allowing for at least a 50% oversampling.

It was shown on pages 86 and 87 of Hoff and Thomas (1986) that 16 samples analyzed for both percent clay and a contaminant would be sufficient to detect a difference of one standard deviation in the slope or the intercept of the regression of the contaminant on clay, assuming that the values calculated by Hoff and Thomas (1986) are the population (true) values for those statistics. It was thought that it would be sufficient to apply this test to 16 samples collected from both dumpsites rather than to 16 samples from each dumpsite on the assumption that the 100 -200 m depth environment at the dumpsites would be homogeneous in grain size distribution (and thus contaminant concentrations) relative to the approximately 20 m depth environment surveyed by EPS in 1984. However, if the sediment grain size proved to be very homogeneous it would not be possible to determine both the slope and the intercept at each site. A better strategy, therefore, would be to test the hypothesis for both dumpsites combined. In that case, it would be necessary to analyze 8 samples at each dump site for all contaminants and grain size fractions. Most of the n_i values needed to satisfy the first major objective (p. 84) are greater than 8. Thus, it would only be necessary to analyze a few more samples for Cr, Cu and Pb at each

Table 2.1.

Number of Samples (Ni) Required
for Chemical Constituent Analysis

	Metals								Total Alkane	Total PAH
	Cr	Ni	Cu	Zn	Cd	Pb	Ba	Hg		
σ^2	0.92	0.68	0.91	0.87	0.31	0.89	0.41	0.84	0.49	0.78
n_i	5	14	6	8	20	7	19	9	18	11
R.S.D.(%)	28	21	30	27	42	31	23	43	50	85

R.S.D. = Relative Standard Deviation

site to satisfy both major objectives. However, since 20 samples were to be analyzed for Cd at each dumpsite, it was decided to analyze this number of samples for all contaminants.

2.1.2 Benthos

Calculations of the required number of samples were based on those of Green (1979; pages 42-43), using the same assumptions; to detect a decrease of 50% in benthic density in each impact area (dumpsite) in contrast to no change in the control, with a 0.05 risk of making a type I error. In the absence of benthic data from the study area, the following data set extracted from Table 1 of Carey and Ruff (1977) was used. This data set consists of numbers of individuals in 0.1 m^2 Smith-McIntyre grab samples collected between 84 and 200 m depths at nine locations between Cape Halkett and Barter Island in the Alaskan Beaufort Sea:

445	214	324	171	460	122	328	321	97	525	152
250	237	166	194	96	182	99	201			

1. Mean (Z_1) and variance (S_z) of the above data set after log-transformation (ln (X + 1)) are 5.3624 and 0.2711, respectively. A Z_1 = 5.3624 value corresponds to $X_1 = e^{Z_1} - 1$ = 212.2, and Z_2 = 4.6739. This is a change of Z = -0.6885 in the impact area, which is the required level of detection. (The subscripts 1 and 2 refer to before and after impact respectively).

2. In a 2 x 2 factorial ANOVA with r replicates per area-by-time combination, the interaction is

$$F\,(1,4(r\text{-}s)df) = ((0.6885r)^2 \;/\; 4r)\;/\;0.2711$$
$$= 0.4371r*$$

* See Green (1979, page 43) for intermediate steps.

3. For values of

r =	2	4	6	8	9	10
$F_{.95}$ (1,4(r-1)df) =	7.71	4.75	4.35	4.20	4.15	4.11
0.4371r =	0.87	1.75	2.62	3.50	3.93	4.37

Therefore, r = 10 replicate grab samples were randomly allocated per area-by-times combination. A 50% oversampling, i.e. 15 replicate samples from each of the four sites at each time (i.e. before and after impact) would allow for a degree of unforeseen error (e.g. higher among-replicate variability than that in the data set used for the calculations above).

It was obvious from initial collections that a single grab contained sufficient numbers of organisms (> 100) for analysis. It was decided in the field, therefore, to collect single grab samples at all 30 sites sampled for grain size and chemistry. It was not possible to sample at a control location given the time constraints.

2.2 Field Procedures

At each location, two grab samples were taken with a Smith-McIntyre grab (0.1 m^2 surface area bite). The first grab at each site was sieved for macrobenthos, the second sub-sampled for trace metal, hydrocarbon and particle size analyses. A total of 30 locations were sampled within each dumpsite. Sample locations were chosen randomly; 10 sites were within a 1.5 km radius of the dumpsite centre; 20 sites were between 1.5 and 3.0 km of the dumpsite centre. The sites were chosen in the following manner. Each area was divided into 100 equal parts as shown in Figure 2.1 and numbered from 1 - 25 in the inner stratum and from 1 - 75 in the outer. Sites were chosen using a standard random numbers table. Station locations are shown in Figures 2.2 and 2.3. Bathymetry within the dumpsites is shown in Figures 2.4 and 2.5. In addition, at dumpsite A, three locations were sampled in triplicate (Stations 1 -24, 1-14, and 1-1) for sediment chemistry and particle size, and triplicate subsamples were taken from one grab at each of these sites as part of field quality control. Nine sites on a line from Dumpsite A to Tuktoyaktuk were sampled for sediment chemistry and particle size on the return trip to Tuktoyaktuk. A list of all stations and depths is given in Appendix E. An inventory of samples and their location is given in Table 2.2.

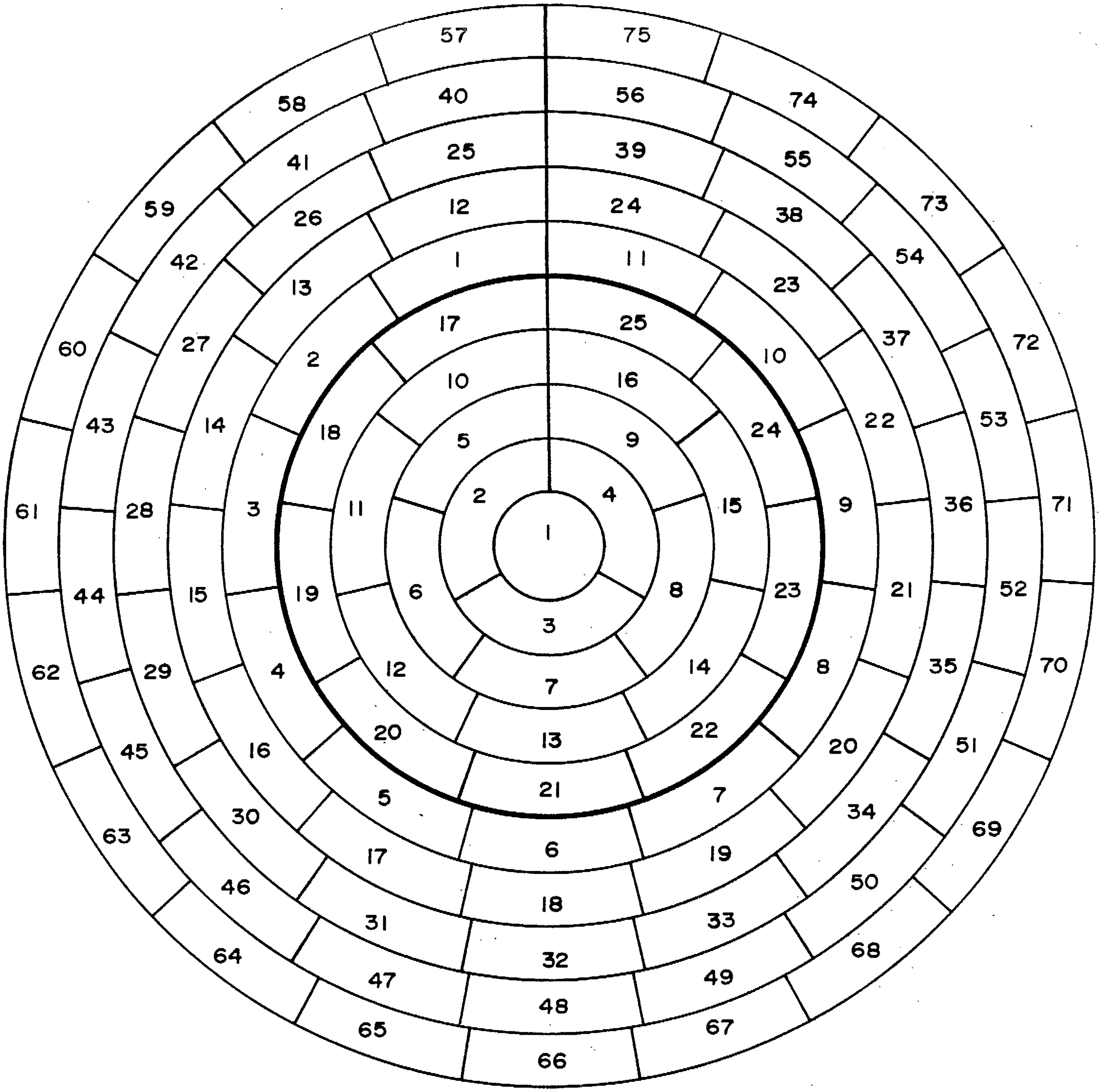

Figure 2.1 Division of dumpsites into stations of equal area for random selection of sampling sites.

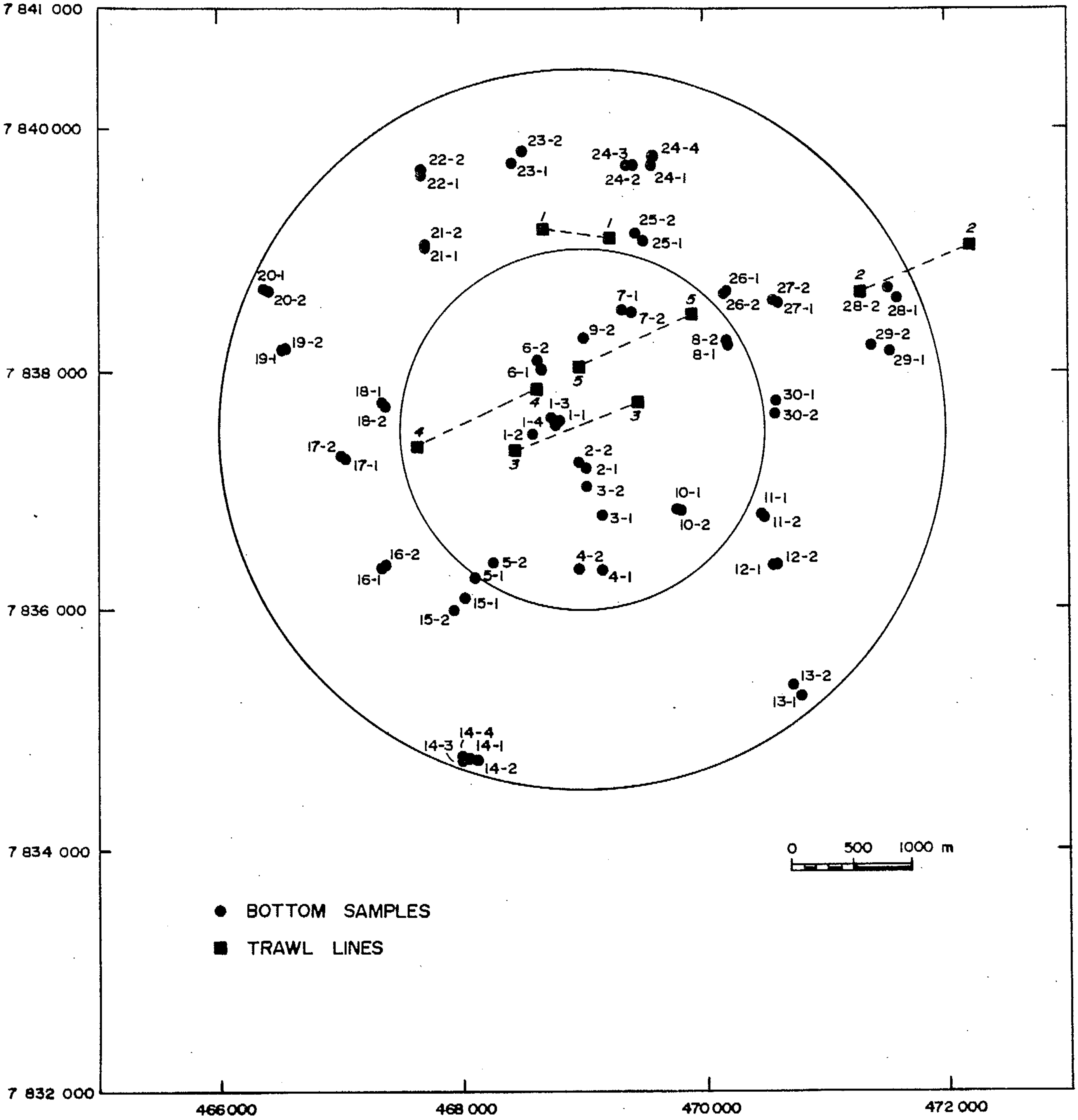

Figure 2.2 Station locations and trawl lines, Dumpsite A. ($70^{o}38$'N; $135^{o}50.5$'W). Bottom sample locations are by station number and grab number (e.g. 16-1; Station 16, 1st grab).

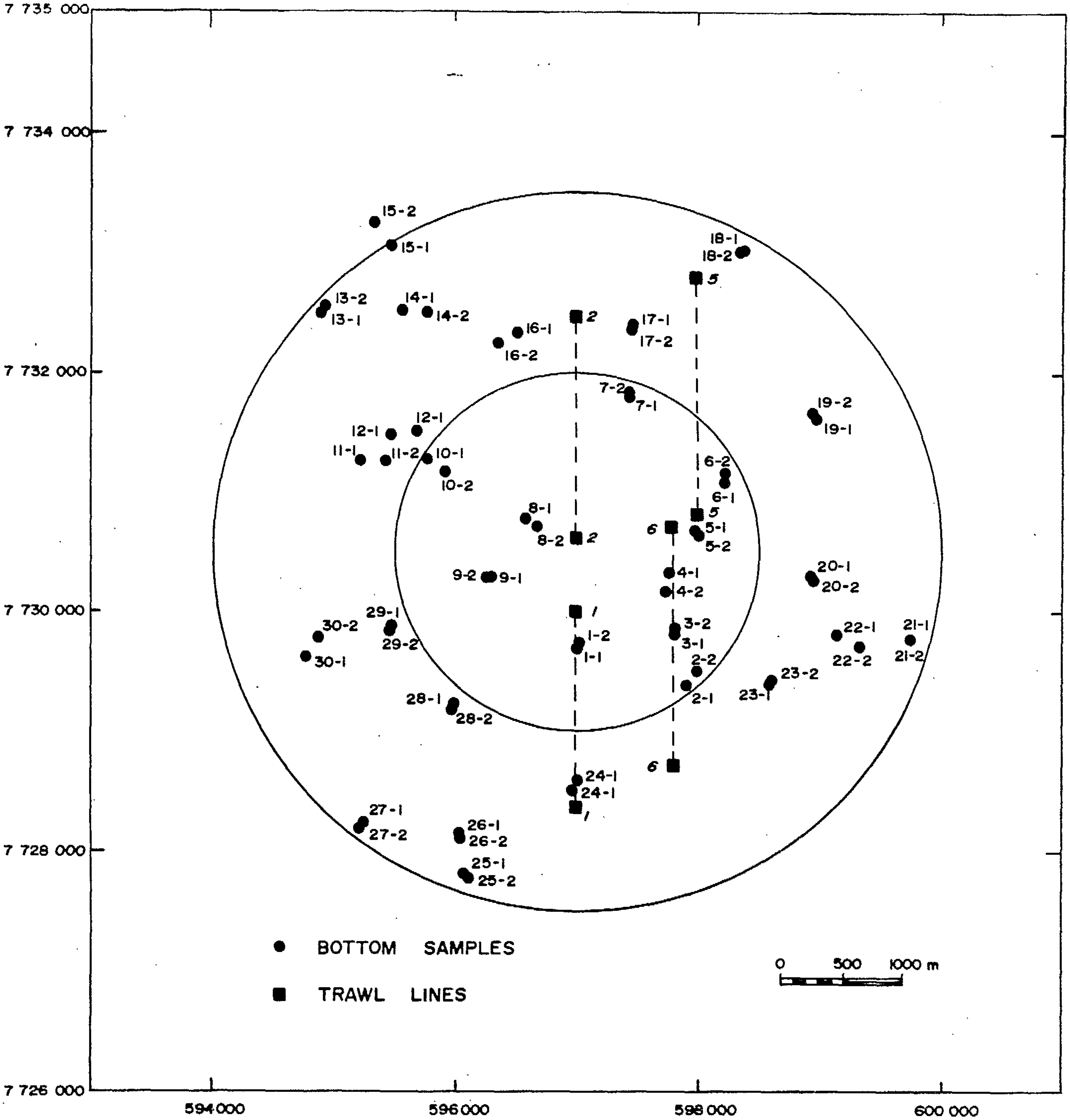

Figure 2.3 Station locations and trawl lines, Dumpsite B (69°40'N; 138°30'W). Bottom sample locations are by station number and grab number (e.g. 16-1; Station 16, 1st grab).

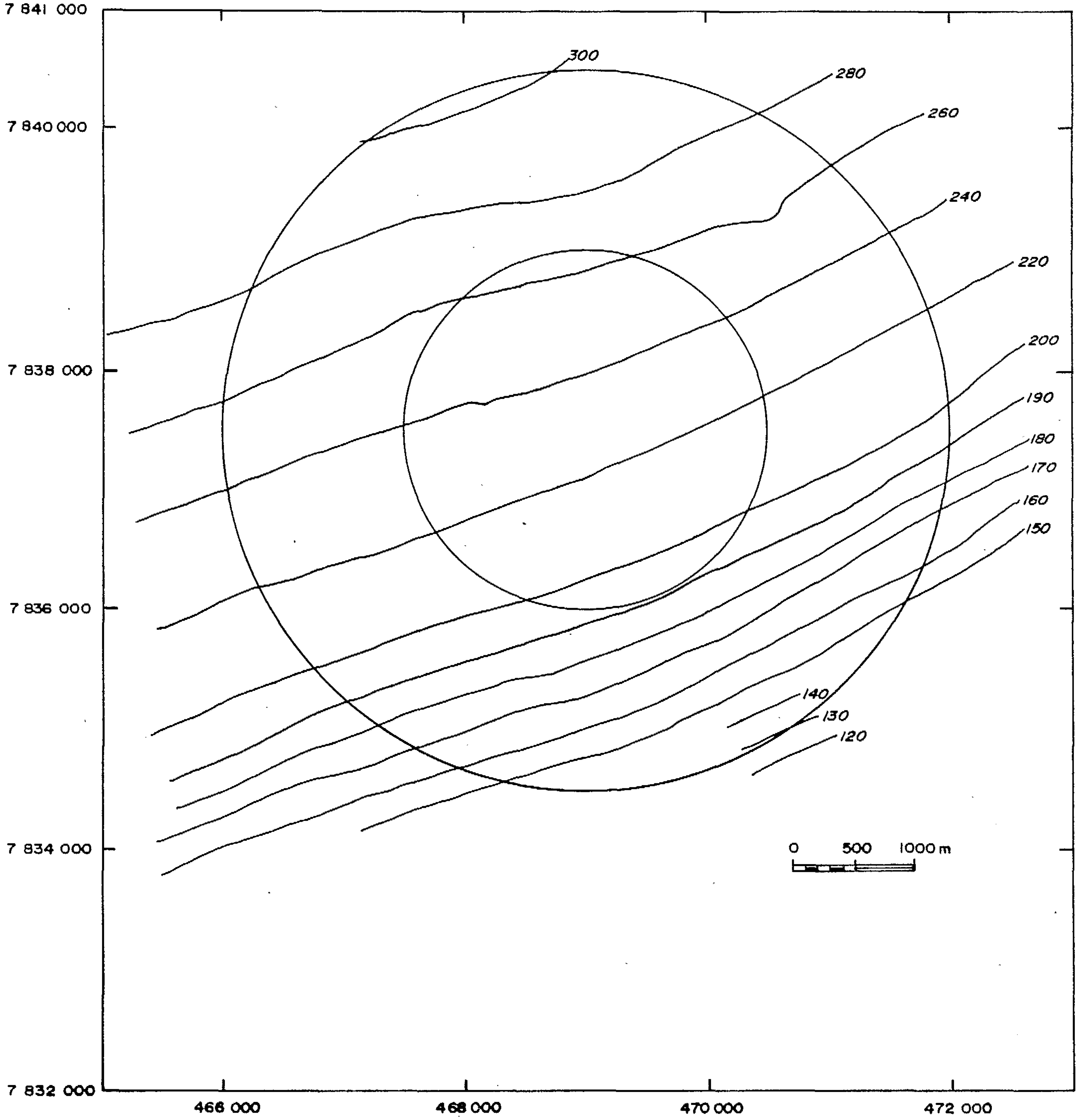

Figure 2.4 Bottom bathymetry, Dumpsite "A" (contours in metres).

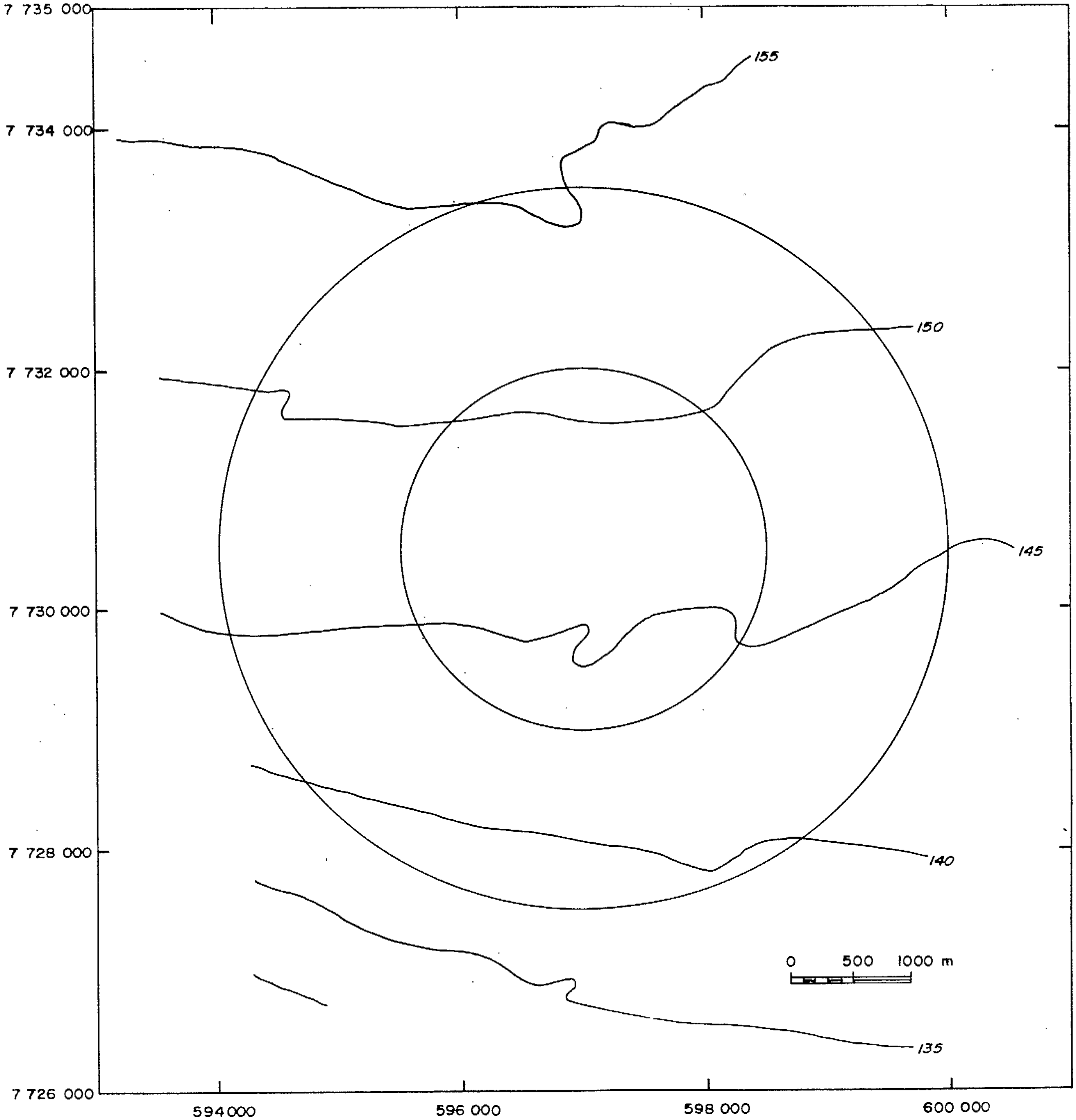

Figure 2.5 Bottom bathymetry, Dumpsite "B"
(contours in metres)

Table 2.2

Inventory of Samples Collected

Sample Type	Number	Storage Container/Conditions	Sample Location
Sediment hydrocarbons	81	glass jars; teflon cap liners; frozen	Arctic Laboratories Limited Sidney, B.C.
Sediment trace metals	81	8 oz "Whirlpak" bags; frozen	Arctic Laboratories Limited Sidney, B.C.
Sediment particle size	81	8 oz "Whirlpak" bags; frozen	Arctic Laboratories Limited Sidney, B.C.
Benthos: from grab samples	60 (samples in 63 jars)	500 mL polyethylene jars; 5% formalin. Original formalin has been replaced by LGL.	LGL, King City, Ontario
Fish (from trawls)	All fish from each trawl were saved: (< 10 individuals per trawl)	plastic jars: in 10% formalin	LGL, Sidney, B.C.
Invertebrates from trawls	A number of individuals of all species were saved as well as a fraction of the total catch from each trawl	plastic buckets; 500 mL polyethylene jars; samples stored originally in 10% formalin in seawater.	LGL, King City, Ontario

2.2.1 Sediment Chemical Contaminants and Particle Size

Immediately after retrieval of the grab, surface water was carefully removed by siphoning (leaving fines undisturbed). If the water was extremely murky, the fines were allowed to settle or another grab was taken. The appearance of the grab was noted (general characteristics, presence of any large objects, benthos, etc.). Subsamples were skimmed from the upper 1 - 2 cm of the sediment through the top of the grab. Samples were taken in the order: hydrocarbons; trace metals; particle size. A plastic scoop was used for metals and particle size, and a solvent-cleaned stainless steel scoop for hydrocarbons. Sediment was stored in plastic "Whirl Pak" bags for metals and particle size, and in cleaned glass jars (Section 3) for hydrocarbons. All samples were frozen for storage and returned to Sidney, B.C. aboard the Tully.

2.2.2 Infauna

When each grab sample arrived on deck, the condition of the substrate surface was noted and excess water was siphoned off in some cases. The grab contents were then transferred to a plastic tub and the volume of the grab was measured to the nearest litre. The samples were then rinsed through a 0.5 mm mesh screen with running seawater, and preserved in labelled plastic jars with 5% formalin (2% formaldehyde): 95% seawater.

2.2.3 Epibenthos and Demersal Fish

At each site, four samples of epibenthic invertebrates and demersal fish were collected using a 4.8 m Otter trawl with 2.5 cm mesh; a 0.63 cm mesh cod end was used only on the first trawl. Trawls were deployed for 20 - 35 minutes at speeds of 1.2 - 3.5 knots over a distance of 1 - 2 km. Approximate travel lines are shown in Figures 2.2 and 2.3.

All fish collected were preserved in 5% formalin (2% formaldehyde): 95% seawater and returned to the laboratory for analysis. Invertebrates collected in trawls were processed on deck, and representative specimens were returned to the laboratory for analysis. Deck processing consisted of (1) subsampling large samples using a large plastic tray, shovel and bucket, (2) sorting the sample or subsample into categories of organisms that were grossly similar, (3) counting the number of organisms in each category, (4) preserving (as above) a small number of individuals from the categories sorted from each trawl, and (5) discarding the remainder of the samples overboard. This method resulted in relatively good estimates of relative abundance for large, easily distinguished species (e.g., starfish). For the majority of taxa, however, species were not separated in the field. In cases where the groupings sorted in the field contained more than one species, and it was not possible to back-calculate the number which each represented in the original group, the taxa were reported as unidentified.

2.2.4 Side Scan Sonar, Sub-Bottom Profiling and Bathymetry

Side scan sonar and sub-bottom profile surveys were done at both sites by Mr. John Lewis of Earth and Ocean Research Ltd. Sounding data were collected by the Canadian Hydrographic Service under the direction of Chief Hydrographer Mike Woods. Details of the methods and equipment used are given in Appendices A and B.

2.2.5 Positioning

Positioning at Dumpsite A utilized an ARGO DM54 medium range system operated in the range/range mode. Confirmation of positions was provided using the Global Positioning System. Estimated positioning accuracy was ± 20 m.

A Trisponder 542 operated in the range/range mode was used for positioning at Dumpsite B. Estimated positioning accuracy was ± 25 m.

3. LABORATORY ANALYSES

3.1 Trace Metal Analyses

Total Ni, Pb, Cu, Cd, and Zn concentrations were determined by atomic absorption spectrometry after samples had been completely dissolved by wet acid (oxidative) digestion in Teflon bombs. For Ba and Cr, a fusion method was used for digestion as certain mineral phases of Ba and Cr are resistant to the wet acid digestion. A hot acid digest in glass bottles was used to liberate mercury. Twenty samples from each site were analyzed (8 from the inner stratum; 12 from the outer).

3.1.1 Pretreatment

Each frozen sediment sample was homogenized by kneading the contents of the "Whirl-Pak" bags. A subsample was withdrawn (~20 g) and air dried at 40°C, then disaggregated by grinding with an agate mortar and pestle, and screened with a nylon sieve (200 mesh, 73 μm) to remove any coarse particles. Particle size analysis of sediments from both dumpsites indicated that >95% of sediment was < 73 μm. The fine fraction was weighed again. About 5 g dry weight was required for all metal analysis.

3.1.2 Digestion

a) Cu, Cd, Pb, Zn, Ni

The method of digestion was essentially that of Rantala and Loring (1975).

Approximately 0.5 g of dry, sieved sediment was weighed into acid-cleaned Teflon bombs and wetted with 1 mL of aqua regia and 6 mL of HF (all acids Baker Analysed Trace Metal Grade). The bombs were sealed and heated at 100°C for at least one hour. Bombs were cooled to room temperature and the contents washed into acid-cleaned and Milli-Q water-rinsed polyethylene bottles containing 5.6 g boric acid and 20 mL Milli-Q water. The sample solutions were thoroughly shaken and brought to 50 g total weight with Milli-Q water. Samples were allowed to settle and only the clear supernatant was analyzed.

b) Ba and Cr

Barium, in some mineral forms, is incompletely dissolved by the wet acid digest. Therefore, sediments were also digested by a fusion method using lithium metaborate (Owens and Gladney, 1976) under subcontract to Quanta Trace Laboratories Ltd. in Vancouver. Chromium was also determined from this digest. Approximately 0.5 g of dried sieved sediment (Section 3.1.1) were fused with $Li_2B_4O_7$ in $LiNO_3$ with dissolution of the melt in nitric acid.

c) Hg

The procedure, modified from Hatch and Ott (1968), consisted of oxidizing the sample by digesting it with a mixture of concentrated nitric and sulphuric acids. About 500 mg of dried ground sediment were accurately weighed into a 500 mL Pyrex glass BOD bottle. The sediment was wetted and washed to the bottom with a few mL of tap water. Fifteen mL of concentrated HNO3/H2SO4 solution (1:2, both Baker "suitable for Hg analysis grade") were added and the bottle placed unstoppered in a water bath at 80^{o}C for 2 hours. The bottle was then cooled to room temperature and tap water was added to give a total volume of about 500 mL. The bottle was then stoppered until analysis.

3.1.3 Instrumental Quantification

a) Cu, Cd, Pb, Zn, Cr, Ni, Ba

Zinc was determined in the sample digests by flame atomic absorption using an acetylene/air flame. Graphite furnace atomic absorption was used to determine Cd, Cu, Ni and Pb. Sample digest solutions were analysed in triplicate. Standard calibration solutions (having the same acid matrix as the samples) were used to relate sample absorbance to concentration. It was necessary to dilute samples by factors of up to 20 for Cu and Pb analyses.

The instruments used were a Perkin Elmer 703 with an HGA 500 or a Perkin Elmer 2380 in the flame mode. Samples were delivered to the graphite furnace with an AS-1 autosampler. Pyrolytic coated graphite tubes were used for all analyses.

b) Hg

Mercury in sample digests was determined by cold vapour atomic absorption (CVAA). The diluted sample was divided into 2 equal portions. Just before analysis, 10 mL of a 10% (w/v) stannous chloride solution were added to the 250 mL samples (a solution containing 10% (w/v) stannous chloride and 20% (v/v) sulphuric acid was prepared in tap water and purged with nitrogen for 4-6 hours to remove traces of mercury). The diffuser was immediately inserted, the sample shaken for 30 seconds, let stand for 30 seconds and purged with N_2 gas at a flow rate of 0.4 L/min for approximately one minute through a 30 cm path length cell of a Laboratory Data Control U.V. monitor. The peak absorbance of mercury at 253.7 nm is proportional to its concentration. Peak heights from two 250-ml aliquots were averaged for each sample.

The instrument settings were:

U.V. Monitor (Laboratory Data Control, Riviera Beach, Florida -
30 cm path length cell)

Range - 0.02 Absorbance

Recorder (Fisher Recordall - Series 5000)
Range - 1 mv Full Scale (25 cm)
Chart Speed - 5 cm/minute

Nitrogen Gas (Grade G) Flow Rate - 0.4 L/minute

The system was purged between samples using tap water. The 6 cm (length) x 2 cm (diameter) polyethylene drying tube was re-packed with fresh ACS grade magnesium perchlorate after analysis of approximately 30 aliquots. Glass wool was used at each end of the drying tube to prevent $Mg(ClO_4)_2$ from entering the U.V. gas cell.

The recorder span factor (ng Hg/mm peak height) was determined by spiking each 3-5 aliquots of 250 mL of tap water, containing 5 mL nitric acid/dichromate solution, with 5 ng Hg. Three to five aliquots were analyzed and a mean factor derived. Standard spiked samples were analysed before every run (approximately 9 samples).

c) Ba and Cr

These elements were determined under subcontract using inductively coupled argon plasma spectrometry (ICAP) by Quanta Trace Laboratories Ltd. in Vancouver. A Spectrometrix SMI Model 3B ICAP was used coupled to a PDP 11/24 mini-computer.

3.2 Hydrocarbons

3.2.1 Rationale for GC/FID and GC/MS Analytical Methods

A cost-effective strategy in many monitoring studies is to screen samples with a low cost method for compounds of interest before committing to more expensive analyses. For hydrocarbons, two screening methods have been used; a total hydrocarbon analysis by infra-red spectrophotometry (IR) and an aromatic hydrocarbon analysis by UV/fluorescence. These methods could represent a considerable savings over a GC method if equivalent data are obtained. However, it was believed that neither method was suitable for this study due to the nature and background levels of hydrocarbons in Beaufort Sea sediments.

Reported sediment concentrations of total saturated hydrocarbons range from 18.4 to 163.6 $\mu g \cdot g^{-1}$ (Wong et al., 1976) and 1.3 to 80.3 $\mu g \cdot g^{-1}$ (Thomas et al., 1982). The concentration range for polycyclic aromatic hydrocarbons (PAHs) is also large (e.g., 68 to 1856 $\mu g \cdot g^{-1}$) (Erickson et al., 1983). For a sensitive characterization of the impact area, the analytical method must accurately quantify background hydrocarbons over these entire concentration ranges. The general screening techniques are unable to do this and also lack standard material for calibration, thereby introducing serious uncertainty in the results.

Consequently, alkane determinations were carried out by GC/FID. This is a sensitive and relatively rapid instrumental method which, with the aid of internal standard quantification methods, provides accurate and sensitive total alkane analyses. Individual PAHs listed in Table 3.1 were analysed by GC/MS with selected ion monitoring (SIM) and isotope dilution internal standard quantification.

The base digestion/partition extraction method used is based upon our standard method and this type of extraction has been found to give high accuracy and reproducibility (Wong and Williams, 1980). Kuderna-Danish tube evaporators were

Table 3.1

List of PAHs Analysed

Naphthalene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benz (a) anthracene
Chrysene
Benzo (e) pyrene
Perylene
Benzo (b) fluoranthene
Benzo (k) fluoranthene
Benzo (a) pyrene
Dibenz (ah) anthracene
Benzo (ghi) perylene
Indeno (1,2,3cd) pyrene

used throughout to avoid losses of the more volatile components, as this method has been found to quantitatively recover alkanes down to n-octane.

3.2.2 Moisture/Dry Weight Determination

A subsample (approximately 5 g) of homogenized sediment was weighed into a tared glass Petri dish and air-dried at 80°C to constant weight. The percent moisture detemined was used to convert hydrocarbon analysis results from a wet weight to a dry weight basis.

3.2.3 Analyses

a) Materials

Solvents were pesticide grade, distilled in glass (hexane, pentane, acetone, methanol, isopropanol and dichloromethane, supplied by BDH Omnisolv).

Distilled water and potassium hydroxide solutions were extracted with hexane before use. Anhydrous sodium sulfate (BDH Chemicals) was cleaned by heating at 350oC overnight. Silica gel (BDH, 60-120 mesh) was heated for 10 hours at 350oC, cooled, deactivated with 5% (by weight) of glass-distilled water and allowed to stand at least 24 hours before use. The silica gel was slurry packed in pentane into a 13 cm x 1.0 cm column, covered with a 1-cm layer of anhydrous sodium sulfate and flushed with ~25 mL of pentane.

Glassware and metal items were washed with laboratory detergent, rinsed with distilled water and heated at 350oC overnight. Non-heatable and plastic items were solvent rinsed (acetone and dichloromethane) before use.

Internal standards (hexadecylbenzene, Aldrich; perdeuterated n-decane, hexatriacontane, m-xylene, naphthalene, fluorene, phenanthrene, pyrene, chrysene, perylene, benzo(k)fluoranthene, dibenzo(ah)anthracene, benzo (ghi)perylene and indeno(1,2,3cd)pyrene; Merck, Sharp and Dohme) were used as received. Polycylic aromatic hydrocarbons (naphthalene, fluorene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, perylene, benzo(e)pyrene, benzo(a)pyrene, phenanthrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, benzo(ghi)perylene, indeno(1,2,3cd)pyrene) were obtained from Sigma Chemical, Aldrich and Eastman Chemicals.

b) Sample Containers and Storage

Sediment samples were stored in pre-cleaned 250 mL glass jars with teflon-lined screw-on lids. The glass jars were cleaned by washing with laboratory detergent, rinsing with distilled water and heating at 350°C before use. The teflon liners were rinsed in chromic acid and then in solvent (acetone and dichloromethane) before use.

c) Hydrocarbon Extraction Procedures

The procedure used in the determination of hydrocarbons in sediments is an adaptation of the method of Cretney et al. (1980). A sample of sediment (20 - 30 g) was placed in a 500 mL round bottom flask to which was added 100 mL of MeOH, 8 ml of KOH (50% by weight), boiling stones and 1.0 mL of internal standards. The flask was refluxed for 1 hr, then 100 mL of distilled water was added and refluxed for a further 30 min. The flask was cooled and the solution carefully decanted into a 1 L separatory funnel. The reflux flask was rinsed with pentane (4 x 25 mL) and pentane rinses were added to the funnel. After each rinse, the flask was placed in an ultrasound to release pentane trapped in sediment, which also was added to the funnel. The MeOH/pentane solution was shaken and separated. The aqueous phase was extracted with two additional portions of pentane (2 x 100 mL). The combined pentane extracts were washed with distilled water (3 x 100 mL) and then dried over anhydrous sodium sulphate. The dried extract was decanted into a Kuderna-Danish flask to which 1 mL of iso-octane was added, and then the extract was concentrated to ~1 mL in a 50°C water bath. The concentrated extract was then transferred to centrifuge tubes for fractionation by silica gel liquid chromatography. The alkane fraction was eluted with 25 mL of pentane and the PAH fraction with 40 mL of dichloromethane. Each fraction was then reduced in volume to ~1 mL in a Kuderna-Danish concentrator and transferred to centrifuge tubes for GC/FID and GC/MS analysis. The alkane fractions were analysed by capillary GC/FID for total alkanes and the aromatic fractions were analysed by GC/MS for individual PAHs.

d) Instrumental Analysis

Alkane Fraction

Alkane fractions were analysed using a Hewlett-Packard 5830/40A gas chromatograph with flame ionisation detection (FID) operated with the following instrumental conditions.

Column:	30 m x 0.25 mm, BP-5 bonded phase silica column (S.G.E.); giving 90,000 effective theoretical plates (for nC-13)
Carrier:	Hydrogen at 16 p.s.i., column flow 1 mL min^{-1}
Injector Temperature:	250°C
Detector Temperature:	300°C
Detector Flows:	H_2 30 mL min^{-1}, air 240 mL min^{-1}, and N_2 (make-up) 30 mL min^{-1}

All injections made in the splitless mode for 1.0 min.

Temperature Program:	Sample injected at 50°C, held for 1.0 min; column oven heated at 10° min^{-1} to 300°C and held for 5 min.

Calibration of the GC/FID system to alkanes and internal standards was by daily injection of a response calibration standard containing fourteen even carbon number n-alkanes (nC10 to nC36, 20 ng each) and the internal standards.

Compound identities were assigned on the basis of the relative retention time of the GC peak maximum.

A procedural blank was carried through the analysis for each batch of 6 to 10 samples.

Quantification was by automated integration of resolved peak areas in the boiling range of n-dedecane to n-octatriacontane. Sediment concentrations of total alkanes are provided on a $\mu g \cdot g^{-1}$ dry weight basis.

Aromatic Fraction

Aromatic fractions were analysed on a Finnigan 9500/3200 gas chromatograph/mass spectrometer (GC/MS), with a Finnigan 6100 data system using the following conditions:

Column:	30 m x 0.25 mm BP-1 bonded phase fused silica column (S.G.E.)
Carrier Gas:	helium
Injector Flow Rate:	60 mL min-1
Injector Pressure:	17 p.s.i.
Column Flow:	40 cm s-1
Split Ratio:	40:1 (approximately)
Injector Temperature:	260 ^{o}C
Injection Sequence:	splitless injection at room temperature, splitting resumed at 1 minute, 100^{o} C at 2 minutes and 10^{o} min-1 at 4.5 minutes to 280^{o} C and hold for 10 minutes. 0.5 μL injections.
Mass Spectrometer:	electron impact source
Source Emission	0.50 mA
Electron Energy:	40 eV
Operating Pressure:	1 x 10-^{5} torr
Multiplier Voltage:	2400 V (gain > 106)
Data Acquisition:	data acquired in the "selected ion monitor" mode with one scan/sec; four ions per scan in five clusters of four ions per run. Data archived on magnetic tape.

The GC provides separation power of 50,000 effective theoretical plates (for nC-16) and the following compounds were resolved (10% of baseline or better, with peak maxima separated by a minimum of three MS scans) as determined by analysis of authentic standards:

phenanthrene/anthracene;
benz(a)anthracene/chrysene;
benzo(e)pyrene/benzo(a)pyrene/perylene;

The mass spectrometer was tuned daily for optimal mass resolution and sensitivity to selected ions from perfluorobutylamine (FC43) with baseline resolution at 219, 264 and 502. The data system was mass calibrated daily and the calibration confirmed by comparison to an acquired spectrum of FC43. The centres of the 219 and 264 fragment peaks were required to be within 0.2 amu, otherwise the spectrometer was retuned and the data system recalibrated. The mass spectrometer resolution and ion transmission was periodically evaluated by injection of 100 ng of decafluorotriphenylphosphine. Using the ion abundance criteria of the US EPA (Eichelberger et al., 1975) for acceptable performance, it is required that the 442^+ ion be 40% or more of the base peak (198).

Calibration of the GC/MS system to PAH and internal standards was by twice-daily injection of a response calibration standard containing approximately 10 ng of each PAH and the perdeuterated internal standards. The relative response of each PAH with respect to the appropriate internal standard must be constant within 10% over each working day for acceptance of data acquired on that day.

Compound identities were assigned on the basis of the relative retention time of the GC peak maximum in the characteristic ion mass chromatogram, with the relative retention time required to be within 0.004 ± 0.002 RRT units of the expected relative retention time as determined on that day using the calibration standard.

A procedural blank was carried through the analysis for each batch of 6 to 10 samples.

Quantification was by manually-controlled area integration of the mass chromatogram.

A linearity check of the GC/MS response using three standards with concentrations ranging from ten times to one thousand times the detection limit indicated that the response was essentially linear within experimental error under the conditions used.

The method was verified by analysis of standard reference materials and intercalibration samples.

3.3 Particle Size Analysis

Particle size analyses were done by wet-sieving to separate the sand/gravel fractions from clay/silt (63 µm, 4 phi, 230 mesh). The clay/silt content (at 1.0 phi intervals) was determined by standard sedimentation procedures using hydrometer tests (ASTM D422). Sample preparation was as per the procedures outlined in Walton (1978). Sieving and hydrometer tests were done under subcontract to Thurber Consultants in Victoria. For comparative purposes, 8 samples chosen at random were analyzed by an alternate sedimentation method. Thurber Consultants utilized a Micrometrics Sedigraph 5000D at the Pacific Geoscience Centre in Victoria, B.C. Samples were freeze dried (~ 1 g) then resuspended in 50 mL of a 0.5% sodium hexametaphosphate solution. The solution was placed in an ultra-sonic bath for 30 minutes prior to Sedigraph analyses.

3.4 Quality Control/Quality Assurance

3.4.1 Trace Metals

Accuracy of the methods was estimated by the analysis of marine reference sediments MESS-1 and BCSS-1 produced by the National Research Council. Reference materials were digested with each set of sediment digests and the results used to assess the accuracy of the digest and subsequent analysis.

Results for each element are presented in Table 3.2. For all metals, mean results were within the quoted 95% tolerance limits of the certified means.

All samples gave results which were above the quantitation limits of the methods. Blanks for all (except Hg) metals were below detection. An estimate of the detection limit was made by extrapolation of a calibration curve for each element to zero absorbance and calculating the spread in the intercept using the variation in the absorbance of the standards. Three times the calculated concentration from the variation in the intercept was taken as the detection limit (DL); the quantitation limit (QL) was defined as 10 times this value. For Hg, the DL and QL were defined as 3 and 10 times the standard deviation of the blank respectively.

A measure of the precision of the methods was obtained from the relative standard deviation of the reference material analyses (Table 3.2) and by running blind replicates on one sample from each site. These were samples that are run without the analyst knowing the identity of the sample: results for blind replicate analyses

Table 3.2.

Analysis of Reference Materials for Trace Metals, Trace Metal Blanks and Detection Limits
(values in μg/g)

Metal	MESS-1 Certified*	MESS-1 Found $x \pm s_b(n)$	BCSS-1 Certified*	BCSS-1 Found $x \pm sb(n)$	Blank[a,b] $x \pm sb(n)$	Detection Limit 3sb	Quantification Limit 10 sb
Cu	25.1 ± 3.8	24.2 ± 0.8 (3)	18.5 ± 2.7	19.6 ± 1.4 (6)	0.06 ± 0.03	0.09	0.3
Cd	0.59 ± 0.10	0.59 ± 0.05 (3)	0.25 ± 0.04	0.22 ± 0.06 (6)	0.02 ± 0.006	0.018	0.06
Pb	34.0 ± 6.1	32.7 ± 5.4 (3)	22.7 ± 3.4	24.0 ± 1.7 (6)	0.2 ± 0.03	0.09	0.3
Zn	191 ± 17	176 ± 11 (3)	119 ± 12	114 ± 9 (6)	2 ± 1	3	10
Ni	29.5 ± 2.7	28.0 ± 1.5 (3)	55.3 ± 3.6	52.7 ± 3.1 (6)	2 ± 1	3	10
Cr	71 ± 11	67 ± 5 (3)	123 ± 14	134 ± 18 (5)	3 ± 2	6	20
Ba	270[c]	293 ± 12 (4)	330[c]	319 ± 21 (8)	5 ± 4	12	40
Hg	0.171 ± 0.014	0.185 ± 0.014 (3)	0.129 ± 0.012	0.131 ± 0.012 (n=10)	0.006 ± 0.003	0.009	0.030

* concentrations are ± 95% tolerance limits

a) blank calculated on the basis of 50 g of digest and 0.5 g sample size except Ba and Cr: for these metals 0.2 g of sample in 200 mL solution.

b) blanks below detection except for Hg: blank given is intercept for 0 absorbance from calibration curve; S_B = variation in intercept.

c) not certified

NA - not analyzed

are given in Table 3.3. The blind replicates indicate that the variability of replicates from the mean was the same as, or slightly greater than, that obtained for reference materials.

3.4.2 Hydrocarbons

Procedural blank determinations are presented in Table 3.4 for alkanes and Table 3.5 for PAHs. These data are used to determine limits of detection (LOD) and quantification (LOQ) for the alkanes and PAHs of interest. The calculated LODs and LOQs are presented in Tables 3.4 and 3.5 (3 and 10 times the standard deviation of the blank, respectively).

Results of blind duplicate analyses of alkanes and aromatics in several of the sediment samples are presented in Tables 3.6 and 3.7. Relative differences between duplicates (presented in Tables 3.6 and 3.7) indicate the precision of the alkane and aromatic determinations. The alkane results show more variability than the aromatic results, likely due to the natural presence of alkanes in the environment and the limited number of alkane internal standards used in the anlaysis. The number of alkane internal standards is limited by the complexity of the chromatogram of the alkane fraction of the extract.

Comparison of PAH analysis results for an interlaboratory comparison sediment sample (Duwamish Sediment - NOAA) are presented in Table 3.8 and indicate that Seakem results are in agreement with those obtained by other laboratories.

To estimate the contributions to analytical variability from the various stages of collection and analysis, a series of replicate analyses were conducted on sediments from three sampling sites. The replication scheme includes triplicate GC/FID and GC/MS determinations on sediment extracts, triplicate extractions on individual sediment samples, analysis of triplicate samples from individual grabs and analysis of sediments from 3 grabs from each of three sites. The results of these analyses are presented in Tables 3.9 through 3.11 and summarized in Table 3.14. These data, which indicate that there is variability at every step of the sampling and analysis procedure, are useful for defining the significance of statistical comparisons between samples and for distinguishing sampling variability from analytical variability. The data in Tables 3.9 and 3.11 indicate that the alkane analysis results have a relative standard deviation (RSD) of approximately 20% while the PAH results show a RSD of approximately 10%. The data in Tables 3.12 through 3.14 indicate

Table 3.3

Blind Replicate Trace Metal Analyses
(μg/g))

Sample	Cu	Cd	Pb	Zn	Ni	Hg	Cr	Ba
1-3	28.6	0.13	21.3	132	41.0	0.463	128	820
	34.8	0.13	23.7	138	47.7	0.398	102	870
	35.6	0.13	24.5	137	4.29	0.484	106	920
	34.7	0.13	24.5	139	43.1	0.339	143	820
	33.3	0.14	23.9	145	43.1	0.324	168	850
X	33.4	0.13	23.6	138	44.5	0.401	129	856
S.D.	2.8	0.01	1.3	5	3.1	0.072	27	42
%	8.4	7.6	5.6	3.6	7.0	18.0	21	4.9
2-2	31.5	0.23	20.1	115	32.3	0.259	121	880
	31.1	0.10	21.9	128	37.5	0.302	118	870
	31.1	0.09	22.1	128	43.6	0.262	141	800
	30.6	0.10	22.8	120	37.5	0.242	150	840
	29.9	0.12	22.4	129	36.7	0.294	177	850
X	30.8	0.13	21.9	124	37.5	0.272	142	848
S.D.	0.6	0.06	1.0	6	4.0	0.025	24	31
%	2.0	44.6	4.8	5.0	10.7	9.2	16.9	3.7

TABLE 3.4 Alkanes in Sediments: Procedural Blanks and Method Detection Limits (ng.g-1 dry weight)

Run Number	701	691	668	663	656	1156	646					***15 g sample***	
DUMPSITE SEDIMENTS								MEAN	STD	DET	QUANT	DET	QUANT
COMPOUND													
nC-12	<21	<31	<33	<24	<16	<49	<22	<25	6.4	<19	<58	<1.3	<3.8
nC-13	<21	<31	<32	<23	<15	<50	<21	<24	6.5	<20	<59	<1.3	<3.9
FARNESANE	<20	<30	<31	<22	<15	<51	<20	<23	6.3	<19	<56	<1.3	<3.8
nC-14	<20	<30	<31	<22	<15	<51	<20	<23	6.3	<19	<56	<1.3	<3.8
TRIMETHYL nC-13	<20	<30	<31	<22	<15	<51	<20	<23	6.3	<19	<56	<1.3	<3.8
nC-15	<20	<31	<31	<22	<15	<51	<20	<23	6.5	<19	<58	<1.3	<3.9
nC-16	<19	<32	<31	<22	<16	<50	<20	<23	6.6	<20	<60	<1.3	<4.0
NORPRISTANE	<19	<32	<31	<22	<16	<50	<20	<23	6.6	<20	<60	<1.3	<4.0
nC-17	<20	<34	<34	<24	<17	<53	<21	<25	7.3	<22	<66	<1.5	<4.4
PRISTANE	<20	<34	<34	<24	<17	<53	<21	<25	7.3	<22	<66	<1.5	<4.4
nC-18	<21	<36	<36	<26	<19	<57	<22	<27	7.6	<23	<68	<1.5	<4.5
PHYTANE	<21	<36	<36	<26	<19	<57	<22	<27	7.6	<23	<68	<1.5	<4.5
nC-19	<22	<38	<38	<27	<20	<64	<24	<27	8.0	<24	<72	<1.6	<4.8
nC-20	<23	<40	<40	<28	<21	<74	<26	<30	8.4	<25	<75	<1.7	<5.0
nC-21	<25	<41	<42	<30	<21	<75	<27	<31	8.6	<26	<78	<1.7	<5.2
nC-22	<26	<43	<44	<31	<22	<77	<28	<32	9.1	<27	<82	<1.8	<5.5
nC-23	<28	<45	<46	<33	<23	<80	<29	<34	9.5	<28	<85	<1.9	<5.7
nC-24	<29	<47	<48	<35	<25	<82	<31	<36	9.6	<29	<86	<1.9	<5.8
nC-25	<30	<48	<49	<36	<25	<82	<31	<37	9.9	<30	<89	<2.0	<6.0
nC-26	<31	<49	<51	<37	<26	<81	<31	<38	10	<31	<93	<2.1	<6.2
nC-27	<32	<51	<53	<39	<28	<80	<32	<39	10	<32	<95	<2.1	<6.3
nC-28	<34	<52	<56	<41	<29	<79	<32	<41	11	<33	<100	<2.2	<6.7
nC-29	<70	<53	<58	<43	<30	<77	<32	<48	16	<47	<140	<3.1	<9.3
nC-30	<36	<54	<59	<45	<31	<75	<32	<43	12	<35	<110	<2.4	<7.1
nC-31	<38	<56	<61	<46	<32	<72	<32	<44	12	<37	<110	<2.5	<7.4
nC-32	<39	<57	<63	<48	<33	<67	<32	<45	13	<39	<120	<2.6	<7.7
nC-33	<41	<60	<66	<50	<34	<64	<32	<47	14	<42	<130	<2.8	<8.4
nC-34	<43	<62	<69	<52	<36	<60	<33	<49	14	<43	<130	<2.9	<8.6
nC-35	<46	<65	<74	<56	<38	<57	<34	<52	16	<47	<140	<3.1	<9.4
nC-36	<49	<70	<79	<60	<40	<53	<34	<55	18	<52	<160	<3.5	<11
SUM	<780	<1200	<1200	<900	<630	<1700	<700	<900					

Limit of Detection defined as 3 times the standard deviation of the mean blank.

Limit of Quantification defined as 9 times the standard deviation of the mean blank.

TABLE 3.5 PAH in Sediments: Procedural Blanks and Method Detection Limits (ng/g dry weights) ***15 g sample***

HYDROCARBON ANALYSES
DUMPSITE SEDIMENTS

COMPOUND	641	616	609	600	628	639	1147	MEAN	STD	DET	QUANT	DET	QUANT
NAPHTHALENE	<12	4.4	<3.4	8.1	8.0	13	<130	<8.2	3.9	<12	<35	<.78	<2.3
FLUORENE	1.4	1.2	3.3	2.9	4.5	4.1	<1.4	<2.9	1.4	<4.2	<13	<.28	<.84
PHENANTHRENE	1.3	1.0	2.2	2.7	2.4	11	9.1	3.4	3.8	11	34	.76	2.3
ANTHRACENE	.59	.39	1.0	1.7	<2.1	1.8	<2.5	<1.3	.7	<2.1	<6.3	<.14	<.42
FLUORANTHENE	.49	<.46	1.4	1.6	<.34	3.7	<2.1	<1.3	1.3	<3.9	<12	<.26	<.78
PYRENE	1.5	1.4	1.9	2.4	<.34	6.1	<1.9	<2.3	2.0	<6.0	<18	<.40	<1.2
BENZ[a]ANTHRACENE	<.53	1.6	<1.1	8.3	5.6	5.2	16	<3.7	3.1	<9.3	<28	<.62	<1.9
CHRYSENE	2.2	2.1	<1.0	<2.1	<4.9	2.3	7.4	<2.4	1.3	<3.9	<12	<.26	<.78
BENZOFLUORANTHENES	3.0	5.0	5.3	7.0	<5.5	4.9	14	<5.1	1.3	<3.9	<12	<.26	<.78
BENZO[e]PYRENE	<.56	2.9	2.4	<2.1	<5.8	<2.5	<4.4	<2.7	1.7	<5.1	<15	<.34	<1.0
BENZO[a]PYRENE	<.60	2.6	1.7	<2.5	<7.1	<3.1	<5.3	<2.9	2.2	<6.6	<20	<.44	<1.3
PERYLENE	3.8	4.4	4.8	5.7	<6.9	<3.1	<4.7	<2.8	1.4	<4.2	<13	<.28	<.84
BENZO[g,h,i]PERYLENE	3.6	<1.5	<2.4	3.6	<6.3	<4.3	<4.9	<3.6	1.7	<5.1	<15	<.34	<1.0
DIBENZ[a,h]ANTHRACENE	7.2	<1.5	<2.4	5.4	<6.7	<4.9	<5.8	<4.7	2.3	<6.9	<21	<.46	<1.4
INDENO[1,2,3c,d]PYRENE	0	<.7	<.8	<.1	<2.2	<2.0	<4.9	<2.0	1.0	<2.9	<8.6	<.19	<.57
SUM	<39	<31	<35	<56	<69	<72	<210	<50					

Limit of detection defined as 3 times the standard deviation of the mean blank.

Limit of Quantification defined as 9 times the standard deviation of the mean blank.

TABLE 3.6 Blind Replicate Analyses of Alkanes in Sediments (concentrations in ng/g dry weight)

Sample No.	1-06			1-25			2-12			1-04		
Run No.	RUN 1	RUN 2	RSD	RUN 1	RUN 2	RSD	RUN 1	RUN 2	RSD	RUN 1	RUN 2	RSD
	¦---ng per g---¦			¦---ng per g---¦			¦---ng per g---¦			¦---ng per g---¦		
nC-12	350	370	.04	470	170	.66	330	130	.61	270	490	.41
nC-13	490	430	.09	660	230	.68	390	210	.42	360	490	.22
FARNESANE	200	150	.20	160	60	.64	89	58	.30	77	250	.75
nC-14	580	450	.18	570	180	.74	330	180	.42	240	630	.63
TRIMETHYL nC-13	430	250	.37	380	120	.74	210	110	.44	120	420	.79
nC-15	590	540	.06	600	220	.66	380	230	.35	240	670	.67
nC-16	620	200	.72	430	130	.76	290	150	.45	210	790	.82
NORPRISTANE	490	180	.65	190	82	.56	130	75	.38	70	310	.89
nC-17	710	400	.39	430	220	.46	380	210	.41	180	560	.73
PRISTANE	630	340	.42	420	160	.63	300	160	.43	150	450	.71
nC-18	620	230	.65	270	150	.40	260	150	.38	130	390	.71
PHYTANE	420	180	.57	190	96	.46	170	95	.40	73	390	.97
nC-19	490	220	.54	200	130	.30	250	110	.55	110	280	.62
nC-20	480	190	.61	160	150	.05	270	120	.54	82	210	.63
nC-21	520	190	.66	200	140	.25	270	120	.54	75	140	.43
nC-22	280	160	.39	150	120	.16	230	120	.44	60	100	.35
nC-23	390	240	.34	230	200	.10	330	210	.31	80	140	.39
nC-24	280	190	.27	150	140	.05	190	150	.17	57	84	.27
nC-25	420	330	.17	270	230	.11	340	300	.09	83	130	.31
nC-26	200	180	.07	<31	120	.85	140	140	0	47	84	.40
nC-27	460	480	.03	390	300	.18	430	490	.09	120	220	.42
nC-28	140	170	.14	<40	81	.49	110	120	.06	38	73	.45
nC-29	460	600	.19	470	330	.25	480	690	.25	140	350	.61
nC-30	96	120	.16	<49	69	.24	74	89	.13	26	59	.55
nC-31	340	490	.26	310	270	.10	450	590	.19	87	240	.66
nC-32	74	100	.21	<58	74	.17	65	83	.17	37	44	.12
nC-33	<15	180	1.2	<64	96	.28	110	190	.38	29	85	.69
nC-34	<15	48	.74	<70	17	.86	15	<25	.35	<22	<31	.24
nC-35	<16	<34	.51	<78	<17	.91	<8.1	<28	.79	<23	<28	.14
nC-36	<17	<37	.52	<87	<19	.91	<8.7	<31	.78	<25	<31	.15
SUM	8600	6500		6000	3800		6100	4800		2700	6300	

Sample No.	1-16			2-24			1-28		
Run No.	RUN 1	RUN 2	RSD	RUN 1	RUN 2	RSD	RUN 1	RUN 2	RSD
	¦---ng per g---¦			¦---ng per g---¦					
nC-12	380	230	.35	300	270	.07	240	130	.42
nC-13	510	340	.28	380	310	.14	340	220	.30
FARNESANE	120	160	.20	90	110	.14	140	150	.05
nC-14	420	330	.17	300	330	.07	500	370	.21
TRIMETHYL nC-13	280	140	.47	160	170	.04	340	260	.19
nC-15	460	330	.23	270	320	.12	620	500	.15
nC-16	370	280	.20	230	270	.11	610	590	.02
NORPRISTANE	150	110	.22	80	110	.23	250	220	.09
nC-17	380	260	.27	190	260	.22	340	210	.33
PRISTANE	350	260	.21	180	220	.14	630	450	.24
nC-18	240	130	.42	110	150	.22	290	380	.19
PHYTANE	170	96	.39	83	110	.20	480	460	.03
nC-19	230	130	.39	100	150	.28	620	690	.08
nC-20	190	110	.38	93	160	.38	370	260	.25
nC-21	190	140	.21	82	140	.37	310	430	.23
nC-22	140	94	.28	60	110	.42	210	240	.09
nC-23	190	140	.21	95	200	.50	260	280	.05
nC-24	130	110	.12	58	120	.49	180	220	.14
nC-25	210	170	.15	110	260	.57	24	23	1.3
nC-26	99	88	.08	42	97	.56	330	360	.06
nC-27	210	270	.18	160	400	.61	160	150	.05
nC-28	58	87	.28	36	91	.61	570	470	.14
nC-29	170	470	.66	200	550	.66	160	200	.16
nC-30	37	<88	.58	25	61	.59	510	490	.03
nC-31	110	290	.64	160	510	.74	120	180	.28
nC-32	31	<110	.79	19	<51	.65	500	450	.07
nC-33	<11	<120	1.18	<11	140	1.2	81	92	.09
nC-34	<12	<130	1.18	<11	<59	.97	190	150	.17
nC-35	<12	<140	1.19	<12	<65	.97	51	33	.30
nC-36	<13	<160	1.20	<12	<72	1.0	56	<31	.41
SUM	4800	4000		3000	4900		7600	7100	

TABLE 3.7 **Blind Duplicate Analyses of Aromatics in Sediments Concentrations in ng.g-1 Dry Weight**

Sample I.D.	1-06			2-12			1-01B1			1-14C3			1-17		
REPLICATE NO.	1	2	RSD	1	2	RSD	1	2	RSD	1	2	RSD	1	2	RSD
NAPHTHALENE	35	35	0	24	24	0	40	36	.07	36	40	.07	30	36	.13
FLUORENE	18	18	0	12	14	.11	20	19	.04	16	15	.05	15	16	.05
PHENANTHRENE	100	95	.04	60	67	.08	110	100	.07	76	90	.12	86	100	.11
ANTHRACENE	3.4	2.4	.24	2.3	1.5	.30	3.6	3	.13	1.8	2.5	.23	2.0	3.0	.28
FLUORANTHENE	16	16	0	14	9.7	.26	21	15	.24	17	20	.11	12	3.3	.80
PYRENE	26	31	.12	22	20	.07	42	30	.24	30	33	.07	24	5.6	.88
BENZ(a)ANTHRACENE	12	11	.06	5.5	9	.34	11	9.8	.08	9.0	10	.07	8.4	10	.12
CHRYSENE	91	62	.27	36	39	.06	85	65	.19	50	73	.26	55	79	.25
BENZOFLUORANTHENES	57	57	0	30	34	.09	70	46	.29	49	58	.12	49	51	.03
BENZO(e)PYRENE	74	74	0	38	41	.05	91	65	.24	67	91	.21	67	73	.06
BENZO(a)PYRENE	14	14	0	6.7	7.4	.07	14	11	.17	13	14	.05	11	11	0
PERYLENE	200	180	.07	130	140	.05	240	160	.28	170	200	.11	150	170	.09
BENZO(g,h,i,)PERYLENE	78	79	.01	39	76	.46	95	65	.27	63	93	.27	64	82	.17
DIBENZ(a,h,)ANTHRACENE	8.8	21	.58	15	19	.17	18	16	.08	13	13	0	16	14	.09
INDENO(1,2,3c,d)PYRENE	8.7	5.8	.28	1.7	6.5	.83	8.8	4.1	.52	5.8	10	.38	4.1	9.0	.53
SUM	740	700		440	510		870	640		620	760		590	660	

Sample I.D.	2-03			2-10			1-28		
REPLICATE NO.	1	2	RSD	1	2	RSD	1	2	RSD
NAPHTHALENE	22	26	.12	24	31	.18	47	42	.08
FLUORENE	13	14	.05	16	16	0	17	17	0
PHENANTHRENE	66	62	.04	75	69	.06	85	85	0
ANTHRACENE	1.8	1.8	0	2.1	2.9	.23	4.0	3.7	.06
FLUORANTHENE	9.7	13	.21	12	14	.47	21	20	.03
PYRENE	19	23	.13	23	24	.03	32	32	0
BENZ(a)ANTHRACENE	6.1	6.7	.07	8.5	8.6	.01	14	14	0
CHRYSENE	37	37	0	47	48	.02	61	55	.07
BENZOFLUORANTHENES	24	35	.26	44	41	.05	57	55	.03
BENZO(e)PYRENE	29	49	.36	58	57	.01	77	77	0
BENZO(a)PYRENE	5.8	9.0	.31	10	10	0	19	19	0
PERYLENE	98	160	.34	180	160	.08	200	200	0
BENZO(g,h,i,)PERYLENE	31	37	.12	63	52	.14	71	74	.03
DIBENZ(a,h,)ANTHRACENE	7.1	<.90	1.10	21	<3.1	1.1	15	12	.16
INDENO(1,2,3c,d)PYRENE	3.0	4.9	.34	2.1	13	1.0	9.0	9.9	.07
SUM	370	480		590	550		730	720	

Table 3.8

Intercalibration Results, Duwamish Sediment
Concentrations in ng.g-1 dry weight

	Seakem Results	NOAA	Intercal
Naphthalene	310	62	51
Fluorene	210	110	110
Phenanthrene	1200	675	728
Anthracene	370	270	290
Fluoranthene	2000	1700	1700
Pyrene	1700	1400	1400
Benz(a)anthracene	820	580	890
Chrysene	1300	1000	1100
Benzofluoranthenes	1700		
Benzo(e)pyrene	650	560	820
Benzo(a)pyrene	820	620	840
Perylene	380	270	460
Benzo(g,h,i)perylene	460		
Dibenz(a,h)anthracene	170		
Indeno(1,2,3c,d)pyrene (Corr)	230		

TABLE 3.9 **Replicate GC/FID Determinations of Alkane Concentrations in Sediment Extracts**

Sample I.D.	EXTRACT 1-24C3-A					EXTRACT 1-14C1-A					EXTRACT 1-01B2-A				
Replicate No.	1	2	3	RSD	MEAN	1	2	3	RSD	MEAN	1	2	3	RSD	MEAN
NC12	280	220	200	.18	230	880	840	610	.19	780	560	460	450	.12	490
NC13	370	280	260	.19	300	1000	1000	770	.14	920	700	570	560	.13	610
FARNESANE	60	59	70	.10	63	380	240	210	.33	280	130	110	160	.19	130
NC14	310	240	230	.17	260	930	880	660	.17	820	610	500	530	.10	550
TRIMETH 13	170	150	150	.07	160	640	510	390	.24	510	360	310	330	.08	330
NC15	350	270	270	.16	300	940	860	660	.18	820	690	570	610	.10	620
NC16	330	280	270	.11	300	990	610	460	.40	690	600	500	510	.10	540
NORPRIS	120	90	99	.15	100	390	220	180	.42	260	220	180	210	.10	200
NC17	310	260	260	.10	280	590	470	400	.20	490	560	420	480	.14	490
PRISTANE	260	210	210	.13	230	640	450	340	.32	480	430	380	380	.07	400
NC18	230	180	180	.15	200	430	230	190	.45	280	290	240	270	.09	270
PHYTANE	130	120	130	.05	130	340	150	130	.56	210	190	160	200	.11	180
NC19	210	220	190	.07	210	520	180	210	.62	300	190	170	230	.16	200
NC20	200	210	170	.11	190	220	130	160	.27	170	220	180	190	.11	200
NC21	190	180	220	.11	200	170	140	190	.15	170	170	150	160	.06	160
NC22	130	160	220	.27	170	130	120	140	.08	130	110	130	130	.09	120
NC23	190	220	310	.26	240	170	160	190	.09	170	200	220	20	.75	150
NC24	140	150	220	.26	170	140	120	150	.11	140	170	180	170	.03	170
NC25	200	240	330	.26	260	180	170	210	.11	190	180	190	180	.03	180
NC26	110	120	150	.16	130	110	100	120	.09	110	*	*	*	*	*
NC27	280	390	370	.17	350	240	240	270	.07	250	*	*	*	*	*
NC28	89	100	110	.11	100	90	<110	96	.10	<99	*	*	*	*	*
NC29	330	360	370	.06	350	270	270	290	.04	280	*	*	*	*	*
NC30	79	79	75	.03	78	85	220	73	.65	130	*	*	*	*	*
NC31	310	350	330	.06	330	250	<140	250	.30	<210	<39	<30	*	.18	<23
NC32	35	62	37	.34	45	48	<150	39	.78	<79	<42	<33	<24	.27	<33
NC33	120	130	<36	.54	<95	99	<170	110	.30	<130	<45	<35	<26	.27	<35
NC34	<22	38	<40	.30	<33	<34	<180	<39	.98	<84	<48	<38	<27	.28	<38
NC35	<24	<13	<44	.58	<27	<37	<200	<43	.99	<93	<52	<41	<30	.27	<41
NC36	<26	<14	<49	.60	<30	<41	<220	<47	.94	<100	<57	<45	<33	.27	<45
SUM	4800	4700	4800		4800	8400	6700	6200		7100	5300	4500	4500		4800

* Not quantifiable due to co-eluting interferences.

TABLE 3.10 Replicate GC/MS Determinations of PAH Concentrations in Sediment Extracts (ng.g-1 dry weight)

Sample I.D.	1-24C3-A					1-14C1-A					1-01B2-A				
Replicate No.	1	2	3	RSD	MEAN	1	2	3	RSD	MEAN	1	2	3	RSD	MEAN
NAPHTHALENE	36	40	35	.07	37	38	36	35	.04	36	37	27	33	.20	32
FLUORENE	14	20	17	.20	17	19	17	15	.10	17	19	12	17	.20	16
PHENANTHRENE	110	86	97	.10	98	84	110	95	.14	96	94	94	94	0	94
ANTHRACENE	<.05	<.27	<.09	.86	<.14	.4	3.4	<.09	1.4	<1.3	<.31	<.06	<.08	.93	<.15
FLUORANTHENE	18	16	72	.91	35	14	16	32	.50	21	21	15	34	.40	23
PYRENE	31	28	78	.61	46	26	30	30	.08	29	30	26	30	.08	29
BENZ(a)ANTHRACENE	11	9.5	8.9	.10	9.8	9.1	10	7.4	.15	8.8	11	8	9.1	.20	9.3
CHRYSENE	55	50	54	.05	53	49	53	57	.08	53	51	47	56	.09	51
BENZOFLUORANTHENES	55	54	53	.02	54	53	49	49	.05	50	53	43	49	.10	48
BENZO(e)PYRENE	70	68	67	.02	68	69	65	69	.03	68	66	53	64	.10	61
BENZO(a)PYRENE	14	14	13	.04	14	16	14	13	.10	14	14	11	12	.10	12
PERYLENE	170	160	170	.03	170	160	160	170	.04	160	150	140	150	.04	150
BENZO(g,h,i)PERYLENE	76	83	81	.05	80	85	85	64	.20	78	76	66	67	.08	70
DIBENZ(a,h)ANTHRACENE	18	29	23	.24	23	27	24	<2.8	.73	<18	30	18	30	.30	26
INDENO(1,2,3c,d)PYRENE	5.8	2.5	2.4	.54	3.6	1.2	2.5	8.5	.95	4.1	.59	1.8	1.6	.42	1.4
SUM	690	660	760		710	650	670	640		630	620	560	650		610

TABLE 3.11 Replicate Analyses of Sediments: Triplicate Subsamples per Jar

Sample I.D.	1-24C3-A MEAN	1-24C3-B	1-24C3		1-24C3	1-14C1-A MEAN	1-14C1-B	1-14C1		1-14C1	1-01B2-A MEAN	1-01B2-B	1-01B2		1-01B2
Replicate No.		2	3	RSD	MEAN		2	3	RSD	MEAN		2	3	RSD	MEAN
NC12	230	450	920	.66	530	780	500	340	.41	540	490	8.9	160	1.12	220
NC13	300	650	1300	.67	750	920	620	450	.36	660	610	8.7	300	.98	310
FARNESANE	63	160	310	.70	180	280	110	110	.58	170	130	21	86	.69	79
NC14	260	570	1100	.66	640	820	540	410	.36	590	550	66	320	.78	310
TRIMETH 13	160	320	600	.62	360	510	300	270	.37	360	330	130	260	.42	240
NC15	300	600	1100	.61	670	820	590	460	.29	620	620	170	450	.55	410
NC16	300	430	730	.46	480	690	460	430	.27	530	540	300	390	.30	410
NORPRIS	100	170	310	.54	190	260	190	160	.26	200	200	140	170	.18	170
NC17	280	370	580	.38	410	490	440	430	.07	450	490	320	420	.21	410
PRISTANE	230	300	630	.56	390	480	370	390	.14	410	400	300	360	.14	350
NC18	200	230	280	.18	240	280	270	280	.02	280	270	200	260	.16	240
PHYTANE	130	150	220	.29	170	210	180	200	.07	200	180	160	170	.06	170
NC19	210	200	200	.02	200	300	250	290	.10	280	200	180	210	.08	200
NC20	190	200	130	.22	170	170	200	260	.22	210	200	160	190	.11	180
NC21	200	180	130	.21	170	170	170	230	.19	190	160	170	140	.09	160
NC22	170	140	90	.30	130	130	130	170	.16	140	120	120	110	.05	120
NC23	240	190	120	.33	180	170	180	220	.13	190	150	150	150	0	150
NC24	170	150	76	.38	130	140	130	150	.07	140	170	110	98	.31	130
NC25	260	220	120	.36	200	190	200	200	.04	200	180	150	120	.20	150
NC26	130	130	67	.33	110	110	100	110	.05	110	*	89	80	.08	56
NC27	350	310	180	.31	280	250	260	220	.09	240	*	220	190	.10	140
NC28	100	100	73	.17	91	<99	96	72	.17	<89	*	73	60	.14	44
NC29	350	400	280	.18	340	280	320	210	.21	270	*	260	220	.12	160
NC30	78	86	62	.16	75	130	91	44	.47	87	*	63	45	.24	36
NC31	330	380	190	.33	300	<210	270	130	.34	<200	<23	240	170	.79	<140
NC32	45	45	55	.12	48	<79	38	35	.49	<51	<33	<51	36	.24	<40
NC33	<95	140	<29	.63	<88	<130	110	39	.51	<92	<35	<56	59	.26	<50
NC34	<33	38	<30	.12	<34	<84	<37	13	.81	<45	<38	<60	13	.64	<37
NC35	<27	160	<32	1.03	<73	<93	<41	<13	.83	<49	<41	<66	<12	.68	<40
NC36	<30	<33	<34	.07	<32	<100	<45	<14	.84	<54	<45	<74	<13	.69	<44
SUM	4700	6400	7800		6300	6800	6000	5200		6000	4800	3100	4200		4000

* Not quantifiable due to co-eluting interferences.

TABLE 3.11 Replicate Analyses of Sediment: Triplicate Subsamples per Jar (continued) (ng.g-1 dry weight)

Sample I.D.	1-24C3-A MEAN	1-24C3-B	1-24C3			1-14C1-A MEAN	1-14C1-B	1-14C1			1-01B2-A MEAN	1-01B2-B	1-01B2		
Replicate No.		2	3	RSD	MEAN		2	3	RSD	MEAN		2	3	RSD	MEAN
NAPHTHALENE	37	34	29	.12	33	36	32	41	.12	36	32	40	39	.12	37
FLUORENE	17	19	17	.06	18	17	17	18	.03	17	16	18	18	.07	17
PHENANTHRENE	98	100	83	.10	94	96	110	88	.11	98	94	98	89	.05	94
ANTHRACENE	<.14	<.52	3.1	1.24	1.3	1.3	<1.1	2.3	.40	<1.6	.15	<.51	2.6	1.2	<1.1
FLUORANTHENE	35	17	15	.49	22	21	19	17	.11	19	23	19	19	.11	20
PYRENE	46	28	28	.31	34	29	31	35	.10	32	29	28	33	.09	30
BENZ(a)ANTHRACENE	9.8	9.4	8.5	.07	9.2	8.8	9.3	9.8	.05	9.3	9.3	9.4	10	.04	9.6
CHRYSENE	53	55	59	.05	56	53	61	57	.07	57	51	56	65	.12	57
BENZOFLUORANTHENES	54	58	52	.06	55	50	62	55	.11	56	48	63	57	.13	56
BENZO(e)PYRENE	68	70	69	.01	69	68	79	79	.08	75	61	75	73	.11	70
BENZO(a)PYRENE	14	15	11	.16	13	14	17	15	.36	12	12	17	13	.19	14
PERYLENE	170	170	160	.03	170	160	180	210	.14	180	150	180	200	.14	180
BENZO(g,h,i)PERYLENE	80	81	67	.10	76	78	88	77	.08	81	70	89	83	.12	81
DIBENZ(a,h)ANTHRACENE	20	25	<20	.13	22	18	<5.2	17	.53	<13	26	43	12	.57	27
INDENO(1,2,3c,d)PYRENE	3.6	.63	<13	1.1	5.7	4.1	<3.0	7.0	.44	<4.7	1.4	1.1	8.2	1.12	3.6
SUM	710	680	610		670	650	710	730		670	620	740	720		700

that the sampling plus analysis variability is of the same magnitude as the analysis variability alone.

3.4.3 Particle Size

There is no standard material which can be used to assess accuracy of particle size measurements. Particle size is determined indirectly on the basis of other particle properties. The method most commonly used for size measurement in the silt and clay size range is based on particle settling velocity. In this study, a hydrometer test was used for all samples. Blind replicates were run as a measure of precision and some samples were analyzed with a Micrometrics Sedigraph 5000. This instrument also uses particle settling velocity as a means of estimating particle size, but uses a smaller settling tube and x-ray dispersion measurements as a means of measuring the particle settling rate.

Results of the two methods are given in Table 3.15 and blind replicate results are summarized in Table 3.16. The replication of the hydrometer method was excellent for clay size particulates. The maximum relative deviation from the mean of 2 analyses was 6%, but was typically less than 3%. Agreement between the results obtained by Sedigraph and hydrometer was also very close. Sedigraph analyses were systematically 1 - 4.5% higher for the percent clay in the samples and a corresponding amount lower for the percent sand.

3.4.4 Field Quality Control

As part of the sampling program, triplicate grabs were taken at 3 sites to estimate the within-site sampling variability and 3 subsamples were taken from single grabs at 3 stations to estimate the variability associated with sub-sampling from a single sample.

(a) Particle Size:

Variability in % clay or silt from within-grab subsampling and from multiple grabs at a single site is summarized in Table 4.11. In all cases, the variation was less than 3.7%, or about what would be expected from analytical variance alone (section 3.4.3). The results suggest that the particle size characteristics within each location are homogeneous and that sampling and sub-sampling was not a source of measureable bias in the results.

TABLE 3.12 Replicate Analyses of Sediments: Triplicate Samples per Grab

Sample I.D.	1-24C3 MEAN	1-24C1	1-24C2		1-24C	1-14C1 MEAN	1-14C2	1-14C3		1-14C	1-01B2 MEAN	1-01B1	1-01B3		1-01B
Replicate No.		2	3	RSD	MEAN		2	3	RSD	MEAN				RSD	MEAN
NC12	530	380	800	.37	570	540	620	380	.24	510	220	510	570	.43	430
NC13	750	550	1100	.35	800	660	930	560	.27	720	310	770	770	.43	620
FARNESANE	180	140	280	.36	200	170	230	140	.26	180	79	200	190	.06	160
NC14	640	500	960	.34	700	590	840	510	.27	650	310	740	670	.40	570
TRIMETH 13	360	340	670	.41	460	360	470	350	.17	390	240	510	430	.13	440
NC15	670	540	1100	.38	770	620	970	550	.31	710	410	820	660	.33	630
NC16	480	370	780	.39	540	530	740	440	.27	570	410	580	470	.11	540
NORPRIS	190	170	330	.37	230	200	310	200	.26	240	170	240	190	.13	220
NC17	410	400	690	.33	500	450	660	450	.23	520	410	500	420	.11	480
PRISTANE	390	390	670	.34	480	410	640	400	.28	480	350	490	410	.17	420
NC18	240	210	400	.37	280	280	370	270	.18	310	240	270	270	.07	260
PHYTANE	170	160	290	.36	210	200	320	200	.30	240	170	210	180	.14	210
NC19	200	170	275	.25	220	280	290	210	.17	260	200	200	220	.06	210
NC20	170	130	210	.23	170	210	200	160	.14	190	180	140	200	.18	170
NC21	170	170	210	.13	180	190	160	140	.15	160	160	120	200	.25	160
NC22	130	160	120	.15	140	140	110	92	.23	120	120	94	130	.16	110
NC23	180	280	150	.33	200	190	130	120	.26	150	150	120	170	.17	150
NC24	130	310	92	.65	180	140	85	81	.32	100	130	87	110	.20	110
NC25	200	460	130	.66	260	200	120	120	.30	150	150	130	150	.07	140
NC26	110	310	70	.79	160	110	58	65	.34	77	56	64	77	.16	66
NC27	280	*	160	.38	220	240	130	160	.33	180	140	170	190	.15	170
NC28	91	*	43	.51	67	<89	42	51	.41	<61	44	56	55	.13	52
NC29	340	*	170	.48	260	270	170	230	.22	220	160	260	190	.16	220
NC30	75	*	24	.73	50	87	33	42	.54	54	36	43	39	.17	45
NC31	300	<110	91	.69	<170	<200	97	130	.38	<140	<140	160	130	.11	<140
NC32	48	<130	<20	.87	<66	<51	<21	27	.48	<33	<40	<42	22	.31	<32
NC33	<88	<140	<20	.73	<83	<92	<22	50	.64	<55	<50	<45	<9.6	.64	<37
NC34	<34	<150	<20	1.05	<68	<45	<23	<18	.50	<29	<37	<49	<9.9	.67	<29
NC35	<73	<170	<21	.86	<88	<49	<25	<20	.50	<31	<40	<54	<10	.65	<35
NC36	<32	<200	<21	1.19	<84	<54	<26	<22	.51	<34	<44	<60	<11	.70	<35
SUM	6100	4900	7600		6200	5700	6800	4800		5800	3800	5800	5700		5100

* Not quantifiable due to co-eluting interferences.

TABLE 3.12 **Replicate Analyses of Sediments: Triplicate Samples per Grab (continued)** (ng.g-1 dry weight)

Sample I.D.	1-24C3	1-24C1			1-14C1	1-14C2	1-14C3			1-01B2	1-01B1	1-01B3		
	MEAN		RSD	MEAN	MEAN					MEAN				
Replicate No.								RSD	MEAN				RSD	MEAN
NAPHTHALENE	33	33	0	33	36	38	36	.03	37	37	40	33	.09	37
FLUORENE	18	16	.08	17	17	19	16	.09	17	17	20	14	.18	17
PHENANTHRENE	94	90	.03	92	98	98	76	.14	91	94	110	82	.15	95
ANTHRACENE	1.3	3.6	.65	2.1	1.6	3.5	1.8	.45	2.3	1.1	3.6	2.3	.54	2.30
FLUORANTHENE	22	3.3	1.0	13	19	19	17	.06	18	20	21	18	.08	20
PYRENE	34	5.3	1.0	20	32	39	30	.14	34	30	42	30	.20	34
BENZ(a)ANTHRACENE	9.2	10	.06	9.6	9.3	10	9.0	.05	9.4	9.6	11	11	.07	11
CHRYSENE	56	65	.10	61	57	78	50	.24	62	57	85	63	.22	68
BENZOFLUORANTHENES	55	54	.01	55	56	65	49	.14	57	56	70	51	.17	59
BENZO(e)PYRENE	69	70	.01	70	75	90	67	.15	77	70	91	71	.15	77
BENZO(a)PYRENE	13	12	.05	13	12	14	13	.08	13	14	14	12	.09	13
PERYLENE	170	180	.04	175	180	220	170	.14	190	180	240	180	.17	200
BENZO(g,h,i)PERYLENE	76	73	.03	75	81	91	63	.18	78	81	95	72	.14	83
DIBENZ(a,h)ANTHRACENE	22	17	.18	20	13	14	13	.04	13	27	18	11	.43	19
INDENO(1,2,3c,d)PYRENE	5.7	6.5	.09	6.1	4.7	7.3	5.8	.22	5.9	3.6	8.8	5.0	.46	5.8
SUM	680	640		660	690	810	620		710	700	870	660		740

TABLE 3.13 Replicate Analyses of Sediments: Triplicate Grabs per Site

Sample I.D.	1-24C MEAN	1-24B	RSD	1-24 MEAN	1-14C MEAN	1-14B	1-14	RSD	1-14 MEAN	1-01B MEAN	1-01	1-01C	RSD	1-01 MEAN
NC12	570	130	.89	350	510	610	680	.14	600	430	150	790	.70	460
NC13	800	210	.83	510	720	820	950	.14	830	620	220	1100	.68	650
FARNESANE	200	58	.78	130	180	210	240	.15	210	160	100	270	.49	180
NC14	700	190	.81	450	650	740	890	.16	760	570	280	910	.54	590
TRIMETH 13	460	10	1.35	230	390	540	610	.21	510	440	160	620	.58	390
NC15	770	220	.78	490	710	760	970	.17	810	630	300	950	.52	630
NC16	540	190	.68	370	570	530	760	.20	620	540	340	610	.28	480
NORPRIS	230	76	.72	150	240	270	330	.17	280	220	190	230	.10	210
NC17	500	210	.58	350	520	660	720	.16	630	480	580	450	.16	490
PRISTANE	480	150	.74	320	480	610	690	.17	590	420	390	430	.05	410
NC18	280	120	.57	200	310	420	380	.16	370	260	510	190	.53	320
PHYTANE	210	94	.53	150	240	300	300	.13	280	210	340	150	.44	230
NC19	220	93	.56	150	260	420	280	.27	320	210	690	150	.85	350
NC20	170	78	.53	120	190	330	160	.40	230	170	480	96	.82	250
NC21	180	84	.52	130	160	360	150	.52	220	160	500	8.8	1.13	220
NC22	140	66	.50	100	120	260	96	.57	160	110	430	72	.96	200
NC23	200	110	.42	160	150	310	110	.56	190	150	480	88	.88	240
NC24	180	70	.62	120	100	210	<21	.86	<110	110	340	55	.90	170
NC25	260	120	.53	190	150	270	120	.45	180	140	390	91	.77	210
NC26	160	65	.61	110	77	130	<25	.69	<77	66	180	45	.75	97
NC27	220	210	.75	440	180	290	<28	.80	<170	170	380	120	.62	220
NC28	67	67	.91	190	<61	78	<31	.42	<57	52	120	38	.63	70
NC29	260	270	1.25	2400	220	340	<34	.78	<200	200	290	190	.24	230
NC30	50	54	1.33	860	54	52	<37	.19	<48	45	93	<33	.60	<55
NC31	<170	230	.22	<200	<140	130	<40	.54	<100	<140	190	120	.24	<150
NC32	<66	40	.35	<53	<33	25	<44	.28	<34	<32	72	<36	.44	<48
NC33	<83	92	.08	<87	<55	<24	<47	.38	<42	<37	<9.6	<38	.57	<28
NC34	<68	<37	.42	<52	<29	<25	<51	.40	<35	<29	<9.8	<40	.57	<27
NC35	<88	<41	.52	<65	<31	<26	<57	.43	<38	<35	<10	<43	.59	<29
NC36	<84	<46	.42	<65	<34	<27	<63	.46	<41	<35	<11	<46	.58	<32
SUM	6300	2900		4600	5700	7700	6300		6600	5100	7000	6100		6100

TABLE 3.13 Replicate Analyses of Sediments: Triplicate Grabs per Site (continued) (ng.g-1 dry weight)

Sample I.D.	1-14C MEAN	1-14	1-14B	RSD	MEAN	1-01B MEAN	1-01	1-01C	RSD	MEAN
NAPHTHALENE	37	36	41	.07	38	37	40	39	.04	39
FLUORENE	17	17	18	.03	17	17	16	16	.04	16
PHENANTHRENE	91	100	92	.05	94	95	98	92	.03	95
ANTHRACENE	2.3	2.9	3.5	.21	2.9	2.3	5	3.9	.36	3.7
FLUORANTHENE	18	3.1	19	.67	13	20	20	25	.13	22
PYRENE	34	5.9	36	.67	25	34	32	41	.13	36
BENZ(a)ANTHRACENE	9.4	10	9.2	.04	9.5	11	8.3	8.5	.16	9.3
CHRYSENE	62	82	76	.14	73	68	68	60	.07	65
BENZOFLUORANTHENES	57	58	54	.04	56	59	59	64	.05	61
BENZO(e)PYRENE	77	80	79	.02	79	77	79	82	.03	79
BENZO(a)PYRENE	13	10	11	.13	11	13	13	14	.04	13
PERYLENE	190	200	190	.05	190	200	220	210	.05	210
BENZO(g,h,i)PERYLENE	78	82	84	.04	81	83	72	91	.12	82
DIBENZ(a,h)ANTHRACENE	13	13	13	0	13	19	12	17	.23	16
INDENO(1,2,3c,d)PYRENE	5.9	4.9	6.7	.16	5.8	5.8	7.9	6.9	.15	6.9
SUM	690	700	730		710	740	750	770		750

TABLE 3.14 Summary of Replicate Results

Sample I.D.	1-24 FOR ALL DETERMINATIONS		1-14 FOR ALL DETERMINATIONS		1-01 FOR ALL DETERMINATIONS	
	MEAN	RSD	MEAN	RSD	MEAN	RSD
NC12	420	.69	610	.30	410	.61
NC13	590	.69	790	.26	560	.60
FARNESANE	140	.72	210	.40	140	.52
NC14	510	.68	710	.27	510	.50
TRIMETH 13	300	.77	450	.29	350	.46
NC15	560	.65	750	.26	580	.42
NC16	420	.51	600	.32	480	.24
NORPRIS	170	.58	250	.32	200	.16
NC17	390	.44	540	.23	460	.17
PRISTANE	350	.56	500	.28	400	.13
NC18	230	.37	320	.27	280	.34
PHYTANE	160	.39	240	.34	200	.29
NC19	190	.26	290	.37	250	.67
NC20	170	.29	200	.31	210	.53
NC21	170	.26	190	.37	180	.73
NC22	140	.35	140	.37	150	.73
NC23	200	.37	180	.35	180	.72
NC24	150	.54	120	.44	150	.57
NC25	230	.52	180	.29	180	.49
NC26	130	.63	91	.38	59	.98
NC27	440	1.09	200	.41	140	.90
NC28	170	1.47	74	.37	45	.90
NC29	1900	2.36	240	.39	160	.78
NC30	670	2.55	75	.77	35	.90
NC31	250	.44	160	.49	120	.68
NC32	53	.63	47	.83	40	.38
NC33	89	.59	75	.67	36	.50
NC34	47	.90	47	1.10	33	.57
NC35	63	1.01	51	1.12	35	.59
NC36	53	1.15	56	1.13	39	.60
SUM	8200		6700		5300	
NAPHTHALENE	35	.10	37	.08	36	.13
FLUORENE	17	.13	17	.08	17	.15
PHENANTHRENE	94	.11	95	.12	95	.08
ANTHRACENE	1.3	1.3	2.1	.64	2.0	.94
FLUORANTHENE	24	1.0	17	.44	21	.26
PYRENE	33	.73	29	.33	32	.17
BENZ(a)ANTHRACENE	9.6	.09	9.3	.09	9.6	.13
CHRYSENE	56	.09	63	.20	61	.18
BENZOFLUORANTHENES	54	.04	55	.12	57	.15
BENZO(e)PYRENE	69	.02	75	.12	73	.15
BENZO(a)PYRENE	13	.11	14	.16	13	.13
PERYLENE	170	.04	180	.12	190	.18
BENZO(g,h,i)PERYLENE	77	.08	80	.13	79	.14
DIBENZ(a,h)ANTHRACENE	22	.21	14	.55	21	.52
INDENO(1,2,3c,d)PYRENE	5.1	.87	5.2	.48	4.7	.72
SUM	680		690		710	

Table 3.15

Comparison of Clay and Silt Sized Particulates
in Dumpsite Samples as Determined by a
Hydrometer Sedimentation Technique and a Micrometrics Sedigraph

Sample	Hydrometer		Sedigraph	
	% Clay	% Silt	Sample	% Clay
1-3	62	38	65	35
1-4	64	36	66	34
1-5	60.5	39.5	65	35
1-24	59.9	40.1	62	38
2-9	48.0	39.8	49	38
2-21	49.5	45.1	51	43
2-28	44.5	42.2	47	39
2-29	48.0	41.2	51	38

Table 3.16

Blind Duplicate Particle Size Analysis

Sample	% Clay	% Silt	Sample	% Clay	% Silt
1-2	62.0	38.0	2-7	55.0	37.5
	62.0	38.0		53.0	37.5
difference	0	0	difference	2.0	0
1-9	66.5	33.5	2-8	49.0	39.9
	66.0	34.0		52.0	39.9
difference	0.5	0.5	difference	3.0	0
1-16	65.0	35.0	2-12	50.0	39.9
	68.0	32.0		54.0	38.5
difference	3.0	3.0	difference	4.0	1.4
1-23	58.0	42.0	2-14	49.0	39.9
	63.0	37.0		50.5	39.3
difference	5.0	5.0	difference	1.5	0.6
1-26	62.0	38.0	2-18	53.0	40.5
	62.0	38.0		54.0	41.1
difference	0	0	difference	1.0	0.6

(b) Trace Metals:

The results of field replications for each metal are given in Tables 4.1 - 4.8 and worst case relative standard deviations summarized and compared to analytical precision in Table 3.17. Within-grab variation was greater in worst-case situations than analytical precision alone for Cr, Ni and Zn. However, the differences were small. The results suggest that sediments within each site, based on the triplicate grabs, have homogeneous trace metal levels within the analytical uncertainty, and that sample collection and sub-sampling techniques were in control.

(c) Hydrocarbons:

The results of field replications for alkanes and PAH are given in Table 3.11 and 3.12. Sampling and sub-sampling appear to have been in control as all the variability can be accounted for by the analysis alone (Section 3.4.2). As for trace metals, the results indicate that PAH and total alkane concentrations are homogeneous within each sampling site.

3.5 Processing of Biological Samples

3.5.1 Infauna

Within three weeks of collection, initial processing of grab samples was carried out in the laboratory. Excess mud was rinsed from each sample using tap water and fine mesh nets (≪0.5 mm), and the samples were then preserved in 4% formaldehyde (10% formalin): 90% distilled water buffered with sodium borate. At this time, it was noted that the condition of many specimens (especially polychaetes) in most samples was poor, likely as a result of inadequate fixation and preservation (excess mud, low formalin concentration, inadequate buffer).

Ten of the 30 samples of infauna collected at each dumpsite were analyzed. In order to select samples for analysis, field notes were used to eliminate samples where the volume was low (≤6 L; most grabs contained >9 L) or where the substrate surface was disturbed, and a random numbers table was used to select 10 samples from the remaining samples from each dumpsite. Each sample to be analyzed was rinsed through a fine mesh net to remove formalin and fine sediment. Small portions of the sample were systematically examined in a gridded tray using a binocular stereo microscope until the entire sample had been examined, and all metazoans except

Table 3.17

Comparison of Sampling Variability and Analytical Precision for Trace Metals

Metal	Analytical Precision[a] %	Within Grab Replication[b] %	Sampling Variability at a Particular Site[c] %
Cd	27.0	30.0	16.8
Cu	7.1	9.5	7.3
Cr	14.0	24.0	11.0
Ni	5.9	18.2	7.1
Pb	6.9	7.9	10.8
Zn	8.0	13.9	8.1
Hg	8.9	6.6	10.5
Ba	9.2	8.2	4.6

a - based on relative standard deviation of BCSS-1 analyses
b - based on relative standard deviation of within grab replication (worst case)
c - based on relative standard deviation of grab replication (worst case)

nematodes were removed and sorted into major taxonomic categories. The balance of the sample was then stored in 75% ethanol containing 3% propylene glycol. Seven of these 20 samples were stained with Rose Bengal and examined (as above) a second time to check for organisms missed the first time, and to enumerate nematodes and foraminiferans.

All animals were identified to species whenever possible; unidentified or tentatively identified species were sent to appropriate authorities for identification or verification (see 'Acknowledgements'). In cases where it is generally recognized that additional species descriptions or revisions of higher taxonomic levels are required, questionable species or genera were pooled at the next highest taxonomic level prior to analysis. For each taxon identified, individuals were counted. For each taxon with the dominate biomass, individuals were gently blotted dry and weighed together to the nearest milligram on a Mettler PC 220 balance. Unless otherwise specified (see below), all weights presented in this report are preserved (10% formalin) wet weights, including mollusc shells but excluding polychaete tubes. After laboratory examination, all taxa were stored in a solution of 3% propylene gylcol in 75% ethanol.

3.5.2 Epibenthos and Demersal Fish

All fish collected were identified to species level, and total length was measured to the nearest mm. All invertebrates collected in trawl samples were identified and counted, except for those species that were smaller than the mesh size of the trawl (2.5 cm). Pooling of questionable taxa at the next highest level and verifiction of species identifications were carried out as above (see Section 3.5.1).

4. RESULTS

4.1 Trace Metals

Trace metal sediment concentrations in each dumpsite are summarized in Tables 4.1 to 4.8 along with results for within-grab and multiple grabs/locations replication.

For all metals except Hg, there was no significant difference ($p \leq 0.05$) in metal concentrations between the means of the inner and outer strata or between the overall means between dumpsites. For Hg, there was a significant difference between the means of the inner and outer strata at Dumpsite A. Inner stratum samples were higher and more variable (Table 4.3).

4.2 Hydrocarbons

4.2.1 N-alkanes

Total n-alkane data (nC_{12} - nC_{38} exclusive of isoprenoids) for each dumpsite are summarized in Table 4.9. Individual alkane and isoprenoid data for each sample are given in Appendix C. There was no significant difference ($p \leq 0.05$) between the means of the inner and outer strata within each dumpsite. Total alkanes, ~~between,~~ however were significantly ($p \leq 0.05$) lower at dumpsite B compared to A. The relationship with grain size is discussed in Section 4.5.

4.2.2 PAH

Total PAH data (for compounds in Table 3.1) for each dumpsite are summarized in Table 4.10. Individual PAH data for each sample are given in Appendix C. As for total alkanes, there was no significant difference ($p \leq 0.05$) in total PAH between the inner and outer stratum at both dumpsite A and B. Total PAH concentration was lower at dumpsite B than dumpsite A.

Table 4.1

Concentrations of Lead in
Dumpsite Surface Sediments
(μg/g)

Dumpsite A Location	(Pb)	Dumpsite B Location	(Pb)
1-1*	23.0	2-1	24.4
1-2	22.8	2-2	20.1
1-3	21.3	2-3	21.1
1-5	19.3	2-5	21.6
1-6	22.2	2-6	18.4
1-8	29.0	2-7	16.7
1-9	21.3	2-9	25.5
1-10	20.6	2-10	20.7
1-11	26.2	2-12	20.8
1-13	19.8	2-14	24.0
1-14*	22.8	2-15	20.9
1-16	20.8	2-17	20.9
1-17	25.3	2-19	17.3
1-18	25.1	2-20	22.1
1-22	29.6	2-22	21.3
1-24*	24.2	2-23	19.7
1-25	22.9	2-25	22.8
1-27	24.9	2-27	22.8
1-28	24.0	2-29	21.5
1-29	23.1	2-30	22.2
inner stratum (n = 8)		inner stratum (n = 8)	
x	= 22.4	x	= 21.1
S.D.	= 2.9	S.D.	= 2.9
outer stratum (n = 12)		outer stratum (n = 12)	
x	= 24.1	x	= 21.4
S.D.	= 2.5	S.D.	= 1.7
overall (n = 20)		overall (n = 20)	
x	= 23.4	x	= 21.2
S.D.	= 2.7	S.D.	= 2.2

* mean of 5 analyses; 3 within grab subsamples and 3 grabs from each site.

within grab replication; (n = 3 subsamples per grab)

1-1	23.6	±	1.9	(25.7, 23.2, 22.4)
1-14	23.2	±	1.0	(28.6, 21.5, 19.3)
1-24	24.6	±	1.3	(23.8, 24.0, 26.1)

grab replication (n = 3 grabs per site)

1-1	23.0	±	2.5	(20.3, 25.1, 23.6)
1-14	22.8	±	1.0	(21.5, 23.2, 23.4)
1-24	24.2	±	1.0	(24.2, 24.6, 23.8)

uncertainty given as 1 std. deviation (individual values in brackets)

Table 4.2

Concentrations of Nickel in
Dumpsite Surface Sediments
(μg/g)

Dumpsite A Location	(Ni)	Dumpsite B Location	(Ni)
1-1*	38.2	2-1	45.7
1-2	32.6	2-2	32.3
1-3	41.0	2-3	29.2
1-5	36.2	2-5	31.9
1-6	40.3	2-6	27.4
1-8	30.0	2-7	35.6
1-9	40.4	2-9	37.0
1-10	39.8	2-10	33.5
1-11	39.2	2-12	34.1
1-13	40.2	2-14	31.4
1-14*	30.3	2-15	36.0
1-16	36.9	2-17	34.8
1-17	41.4	2-19	40.6
1-18	30.7	2-20	31.8
1-22	35.6	2-22	27.2
1-24*	33.9	2-23	35.9
1-25	30.6	2-25	32.6
1-27	35.0	2-27	33.5
1-28	40.0	2-29	35.6
1-30	37.7	2-30	29.9
inner stratum (n = 8)		inner stratum (n = 8)	
x =	37.3	x =	34.1
S.D. =	4.1	S.D. =	5.7
outer stratum (n = 12)		outer stratum (n = 12)	
x =	36.0	x =	33.6
S.D. =	3.9	S.D. =	3.4
overall (n = 20)		overall (n = 20)	
x =	36.5	x =	33.8
S.D. =	3.9	S.D. =	4.3

[a] omitted from mean
*mean of 5 analyses; 3 within grab subsamples and 3 grabs from each site.

within grab replication; (n = 3 subsamples per grab)

1-1	37.5	±	1.6	(35.8, 37.6, 38.9)
1-14	30.3	±	0.9	(29.5, 30.0, 31.3)
1-24	34.2	±	6.2	(39.8, 35.3, 27.5)

grab replication (n = 3 grabs per site)

1-1	38.1	±	1.2	(37.5, 39.6, 37.4)
1-14	30.3	±	1.0	(31.3)
1-24	33.9	±	2.4	(31.4, 34.2, 32.2)

(individual values in brackets)

Table 4.3

Concentrations of Mercury in
Dumpsite Surface Sediments
(μg/g)

Dumpsite A Location	(Hg)	Dumpsite B Location	(Hg)
1-1*	0.095	2-1	0.055
1-2	0.107	2-2	0.052
1-3	0.093	2-3	0.053
1-4	0.085	2-5	0.059
1-5	0.082	2-6	0.055
1-6	0.081	2-7	0.061
1-8	0.068	2-9	0.073
1-9	0.065	2-10	0.071
1-10	0.065	2-12	0.084
1-13	0.067	2-14	0.079
1-14*	0.067	2-15	0.082
1-16	0.066	2-17	0.074
1-17	0.073	2-19	0.072
1-18	0.057	2-20	0.066
1-22	0.051	2-22	0.063
1-24*	0.058	2-23	0.070
1-25	0.065	2-24	0.055
1-27	0.064	2-27	0.066
1-28	0.060	2-29	0.068
1-30	0.063	2-30	0.067
inner stratum (n = 9)		inner stratum (n = 8)	
x	= 0.082	x	= 0.060
S.D.	= 0.015	S.D.	= 0.008
outer stratum (n = 11)		outer stratum (n = 12)	
x	= 0.063	x	= 0.071
S.D.	= 0.006	S.D.	= 0.008
overall (n = 20)		overall (n = 20)	
x	= 0.072	x	= 0.066
S.D.	= 0.014	S.D.	= 0.010

* mean of 5 analyses; 3 within grab subsamples and 3 grabs from each site.

	1-1	1-14	1-24
within grab replicates	0.113	0.074	0.060
	0.106	0.067	0.059
	0.099	0.069	0.055
x =	0.106 ± 0.007	0.070 ± .004	0.058 ± 0.003
grab replicates	0.093	0.062	0.058
	0.086	0.070	0.057
	0.106	0.068	0.059
x =	0.095 ± 0.010	0.067 ± 0.004	0.058 ± 0.001

Table 4.4

Concentrations of Copper in Dumpsite Surface Sediments (µg/g)

Dumpsite A Location	Dumpsite A (Cu)	Dumpsite B Location	Dumpsite B (Cu)
1-1*	33.2	2-1	33.8
1-2	30.2	2-2	31.5
1-3	28.6	2-3	28.3
1-5	31.5	2-5	30.5
1-6	28.3	2-6	29.4
1-8	35.3	2-7	33.8
1-9	35.6	2-9	31.8
1-10	36.7	2-10	30.8
1-11	35.3	2-12	32.3
1-13	37.5	2-14	28.8
1-14*	33.2	2-15	31.3
1-16	33.4	2-17	28.4
1-17	34.5	2-19	32.4
1-18	40.4	2-20	31.4
1-22	39.9	2-22	29.9
1-24*	31.1	2-23	27.7
1-25	34.0	2-25	31.2
1-27	34.2	2-27	28.4
1-28	35.6	2-29	32.4
1-29	34.2	2-30	32.9
inner stratum (n = 8)		inner stratum (n = 8)	
x	= 32.4	x	= 31.2
S.D.	= 3.3	S.D.	= 1.9
outer stratum (n = 12)		outer stratum (n = 12)	
x	= 35.3	x	= 30.6
S.D.	= 2.7	S.D.	= 1.9
overall (n = 20)		overall (n = 20)	
x	= 34.1	x	= 30.9
S.D.	= 3.2	S.D.	= 1.9

* mean of 5 analyses; 3 within grab subsamples and 3 grabs from each site.

within grab replication; (n = 3 subsamples per grab)

1-1	32.1 ± 3.1	(35.6, 29.9, 30.8)
1-14	32.4 ± 2.9	(30.0, 31.7, 35.5)
1-24	31.8 ± 2.2	(29.2, 33.2, 32.9)

grab replication (n = 3 grabs per site)

1-1	33.2 ± 1.2	(34.3, 33.3, 32.1)
1-14	33.2 ± 2.1	(33.9, 32.4, 33.1)
1-24	31.1 ± 2.3	(28.6, 31.8, 33.0)

(individual values in brackets)

Table 4.5

Concentrations of Zinc in
Dumpsite Surface Sediments
(µg/g)

Dumpsite A Location	Dumpsite A (Zn)	Dumpsite B Location	Dumpsite B (Zn)
1-1*	134*	2-1	137
1-2	125	2-2	116
1-3	32	2-3	119
1-5	132	2-5	129
1-6	112	2-6	104
1-8	137	2-7	123
1-9	136	2-9	120
1-10	137	2-10	118
1-11	155	2-12	113
1-13	135	2-14	100
1-14*	144	2-15	119
1-16	141	2-17	121
1-17	138	2-19	123
1-18	140	2-20	120
1-22	123	2-22	142
1-24*	136	2-23	117
1-25	134	2-25	119
1-27	150	2-27	131
1-28	132	2-29	128
1-29	129	2-30	114
inner stratum (n = 8)		inner stratum (n = 8)	
x =	131	x =	121
S.D. =	9	S.D. =	10
outer stratum (n = 12)		outer stratum (n = 12)	
x =	138	x =	121
S.D. =	9	S.D. =	10
overall (n = 20)		overall (n = 20)	
x =	136	x =	121
S.D. =	13	S.D. =	10

* mean of 5 analyses; 3 within grab subsamples and 3 grabs from each site.

within grab replication (n = 3)

1-1	131 ± 10	(134, 140, 121)
1-14	138 ± 6	(138, 131, 144)
1-24	129 ± 19	(142, 138, 110)

grab replication (n = 3)

1-1	134 ± 4	(136, 138, 131)
1-14	144 ± 9	(142, 138, 153)
1-24	136 ± 12	(150, 129, 131)

(uncertainty given as 1 std. deviation (individual values in brackets)

Table 4.6

Concentrations of Cadmium in Dumpsite Surface Sediments (µg/g)

Dumpsite A Location	(Cd)	Dumpsite B Location	(Cd)
1-1	0.11	2-1	0.13
1-2	0.12	2-2	0.10
1-3	0.11	2-3	0.11
1-5	0.11	2-5	0.11
1-6	0.09	2-6	0.07
1-8	0.08	2-7	0.10
1-9	0.11	2-9	0.12
1-10	0.10	2-10	0.09
1-11	0.12	2-12	0.11
1-13	0.12	2-14	0.11
1-14	0.09	2-15	0.13
1-16	0.08	2-17	0.09
1-17	0.12	2-19	0.10
1-18	0.08	2-20	0.13
1-22	0.10	2-22	0.11
1-24	0.11	2-23	0.12
1-25	0.12	2-24	0.09
1-27	0.09	2-27	0.09
1-28	0.10	2-29	0.12
1-30	0.12	2-30	0.10
inner stratum (n = 8)		inner stratum (n = 8)	
x	= 0.10	x	= 0.10
S.D.	= 0.01	S.D.	= 0.02
outer stratum (n = 12)		outer stratum (n = 12)	
x	= 0.10	x	= 0.11
S.D.	= 0.02	S.D.	= 0.02
overall (n = 20)		overall (n = 20)	
x	= 0.10	x	= 0.11
S.D.	= 0.02	S.D.	= 0.02

within grab replication (n = 3 subsamples per grab)

1-1	0.09 ± 0.02	(0.11, 0.08, 0.08)
1-14	0.09 ± 0.03	(0.12, 0.07, 0.08)
1-24	0.11 ± 0.01	(0.11, 0.11, 0.11)

grab replication (n = 3 grabs per site)

1-1	0.11 ± 0.02	(0.11, 0.12, 0.09)
1-14	0.09 ± 0.01	(0.10, 0.09, 0.09)
1-24	0.11 ± 0.01	(0.10, 0.11, 0.11)

(individual values given in brackets)

Table 4.7

Concentrations of Chromium in Dumpsite Surface Sediments (µg/g)

Dumpsite A Location	Dumpsite A (Cr)	Dumpsite B Location	Dumpsite B (Cr)
1-1	137	2-2	121
1-2	130	2-3	109
1-3	128	2-4	116
1-4	149	2-5	108
1-5	126	2-6	132
1-6	133	2-7	139
1-9	148	2-9	117
1-10	135	2-10	124
1-11	110	2-12	110
1-13	132	2-14	120
1-14	141	2-15	115
1-16	136	2-17	105
1-17	116	2-18	118
1-18	118	2-19	148
1-22	137	2-22	110
1-24	130	2-23	126
1-25	131	2-24	125
1-27	124	2-27	119
1-28	119	2-29	130
1-30	137	2-30	128
inner stratum (n = 8)		inner stratum (n = 8)	
mean =	136	mean =	121
S.D. =	9	S.D. =	11
outer stratum (n = 12)		outer stratum (n = 12)	
mean =	128	mean =	121
S.D. =	10	S.D. =	12
overall (n = 20)		overall (n = 20)	
mean =	131	mean =	121
S.D. =	10	S.D. =	11

within grab replication; (n = 3 subsamples per grab)

1-1	134	±	008	(139, 138, 125)
1-14	145	±	016	(130, 140, 160)
1-24	137	±	033	(124, 160, 179)

grab replication (n = 3 grabs per site)

1-1	137	±	015	(154, 125, 134)
1-14	141	±	011	(151, 144, 129)
1-24	130	±	006	(128, 137, 125)

(individual values given in brackets)

Table 4.8

Concentrations of Barium in Dumpsite Surface Sediments (µg/g)

Dumpsite A		Dumpsite B	
Location	(Ba)	Location	(Ba)
1-1	920	2-1	840
1-2	860	2-2	880
1-3	820	2-3	870
1-4	900	2-5	880
1-5	840	2-6	890
1-6	890	2-7	870
1-9	860	2-9	870
1-10	880	2-10	880
1-11	850	2-12	840
1-13	910	2-14	870
1-14	880	2-15	920
1-16	840	2-16	850
1-18	830	2-17	800
1-22	940	2-22	870
1-24	810	2-23	830
1-25	830	2-24	800
1-27	870	2-25	850
1-28	850	2-27	800
1-29	830	2-29	850
1-30	870	2-30	850
inner stratum (n = 8)		inner stratum (n = 8)	
mean =	871	mean =	873
S.D. =	33	S.D. =	15
outer stratum (n = 12)		outer stratum (n = 12)	
mean =	859	mean =	844
S.D. =	37	S.D. =	35
overall (n =20)		overall (n = 20)	
mean =	864	mean =	856
S.D. =	35	S.D. =	31

within grab replication; (n = 3 subsamples per grab)

1-1	900	±	12	(910, 900, 890)
1-14	830	±	58	(800, 800, 900)
1-24	830	±	17	(820, 820, 850)

grab replication (n = 3 grabs per site)

1-1	920	±	20	(900, 940, 920)
1-14	880	±	47	(900, 830, 920)
1-24	810	±	21	(820, 830, 790)

(individual values given in brackets)

Table 4.9

Concentrations of Total Alkanes in Dumpsite Surface Sediments (ng/g)

Dumpsite A Location	Dumpsite A Total Alkanes*	Dumpsite B Location	Dumpsite B Total Alkanes*
1-1	5100	2-1	4700
1-2	-	2-2	4200
1-3	6900	2-3	4200
1-4	2700	2-5	4100
1-6	8600	2-6	8300
1-8	7100	2-7	6700
1-9	2900	2-9	7000
1-10	5100	2-10	4400
1-12	9200	2-12	6100
1-13	5500	2-14	6000
1-14	6500	2-15	5600
1-16	4800	2-17	4800
1-17	5800	2-19	5000
1-18	8600	2-20	6100
1-22	7200	2-22	4100
1-24	5600	2-23	3800
1-25	6000	2-24	3000
1-27	8300	2-27	4800
1-28	7400	2-29	3200
1-30	7900	2-30	4800
inner stratum (n = 7)		inner stratum (n = 8)	
x =	5500	x =	5400
S.D. =	2200	S.D. =	1600
outer stratum (n = 12)		outer stratum (n = 12)	
x =	6900	x =	4800
S.D. =	1400	S.D. =	1100
overall (n = 19)		overall (n = 20)	
x =	6400	x =	5000
S.D. =	1800	S.D. =	1300

within grab replication; (n = 3 subsamples per grab)				
1-1	5200	±	900	(5800, 4200, 5700)
1-14	5600	±	1100	(5200, 6800, 4800)
1-24	6900	±	1300	(5400, 7600, 7800)
grab replication (n = 3 grabs per sample)				
1-1	6300	±	620	(7000, 5800, 6100)
1-14	6400	±	1200	(6300, 7700, 5200)
1-24	4150			(2900, 5400)

(individual values in brackets)

*total of n-alkanes from C_{12} - C_{38} exclusive of isoprenoids

Table 4.10

Concentrations of Total PAH* in Dumpsite Surface Sediments (ng/g)

Dumpsite A		Dumpsite B	
Location	PAH*	Location	PAH*
1-1	750	2-1	560
1-3	680	2-3	480
1-4	620	2-5	560
1-6	740	2-6	530
1-8	660	2-7	610
1-9	430	2-9	500
1-10	630	2-10	550
1-12	710	2-12	440
1-13	620	2-15	550
1-14	720	2-19	630
1-17	590	2-23	610
1-18	730	2-24	560
1-22	640	2-27	470
1-24	630	2-30	510
1-25	560		
1-27	680		
1-28	680		
1-30	690		
inner stratum (n = 7)		inner stratum (n = 7)	
x =	640	x =	540
S.D. =	110	S.D. =	43
outer stratum (n = 11)		outer stratum (n = 7)	
x =	660	x =	540
S.D. =	58	S.D. =	70
overall (n = 18)		overall (n = 14)	
x =	660	x =	540
S.D. =	78	S.D. =	56

within grab replication; (n = 3 subsamples per grab)

1-1	750 (± 100)	(860, 720, 660)
1-14	720 (± 95)	(730, 810, 620)

grab replication (n = 3 grabs)

1-1	760 (± 17)	(750, 750, 780)
1-14	720 (± 10)	(710, 730, 720)

(individual values in brackets)
* Sum of individual PAH listed in Table 3.1.

4.3 Particle Size

A summary of surficial sediment particle size data (% clay, % silt, % sand) is given in Table 4.11. Detailed grain size curves and worksheets are included as Appendix F. Both dumpsites have fairly uniform within-site particle size characteristics. There was no significant difference ($p \leq 0.05$) between strata at each dumpsite in terms of mean clay or silt content. However, particle size characteristics are different at each site. Dumpsite A is predominantly clay (overall mean 63%) with only a trace (< 0.2%) of sand present. Dumpsite B has coarser, less compacted sediments with up to 10% sand content and an overall 50% mean clay content.

4.4 Number of Samples Analyzed: Comparison with Predictions

The formula for predicting the number of samples required to detect a change, σ, at a dumpsite with two samplings is

$$n = \frac{2(Z_{\alpha} + Z_{1-\beta})\sigma^2}{\delta^2}$$

where α is the significance level and β is the power of the test. The variance σ^2 is the population variance for the dumpsite, which was assumed to be equal to that for the whole Beaufort Sea as calculated from the 1984 EPS survey data (CanTest Ltd., 1985), (i.e. $\sigma^2 = \sigma_0^2$ in the notation used in Hoff and Thomas (1986)). When the criterion for detectability is $\delta = \sigma_0$, the formula reduces to $n = 2\,(Z_{\alpha} + Z_{1-\beta})$, which is equal to 22 when $\alpha = \beta = .05$.

If the contaminant-percent clay relationship determined by Hoff and Thomas (1986) from the 1984 EPS survey data was to hold at the dumpsite, a significant reduction in the number of samples analyzed for contaminants could be achieved by using the technique of double sampling in which n' samples are collected at a dumpsite, percent clay is determined for all of the n' samples and the concentration of contaminant "i" is determined for only a subset, n_i, of the samples. The formula for n_i using double sampling is

$$n_i = \frac{\sigma^2(1-\rho)^2}{\frac{\sigma_0^2}{22} - \frac{\sigma^2\rho^2}{n'}}$$

where σ^2 is the variance and ρ^2 is the squared correlation coefficient for the

Table 4.11.
Sediment Particle Size at Dumpsites A and B

Dumpsite A				Dumpsite B			
Sample	% Clay	% Silt	% Sand	Sample	% Clay	% Silt	% Sand
1-1**	61.7	38.3	Trace	2-1	48.0	41.4	10.6
1-2*	62.0	38.0	"	2-2	46.0	44.2	9.8
1-3	62.0	38.0	"	2-3	50.0	42.0	8.0
1-4	64.0	36.0	"	2-4	54.0	38.5	7.5
1-5	60.5	39.5	"	2.5	54.0	34.0	12.0
1-6	66.0	34.0	"	2-6	52.5	40.3	7.2
1-7	66.0	34.0	"	2-7*	54.0	37.5	8.6
1-8	61.0	39.0	"	2-8*	50.5	39.9	9.6
1-9*	66.3	33.8	"	2-9	48.0	39.8	12.2
1-10	64.0	36.0	"	2-10	50.0	40.1	9.9
inner stratum				inner stratum			
mean	63.4	36.7		mean	50.7	39.8	
std. deviation	.2	2.2		std. deviation	2.9	2.8	
1-11	64.0	36.0	"	2-11	50.0	39.7	10.3
1-12	63.0	37.0	"	2-12	52.0	39.2	8.8
1-13	64.0	36.0	"	2-12*	49.8	42.5	7.7
1-14**	64.7	35.3	"	2-14*	49.8	39.6	10.7
1-15	64.0	36.0	"	2-15	52.0	37.5	10.5
1-16*	66.5	33.5	"	2-16	47.5	40.2	12.3
1-17	61.5	38.5	"	2-17	51.0	39.9	9.1
1-18	62.0	38.0	"	2-18*	53.5	40.8	5.7
1-19	62.0	38.0	"	2-19	51.0	40.6	8.4
1-20	60.0	40.0	"	2-20	54.5	38.7	6.8
1-21	62.5	37.5	"	2-21	49.5	45.1	5.4
1-22	60.5	39.5	"	2-22	52.0	42.1	5.9
1-23*	60.5	39.5	"	2-23	50.0	43.9	6.1
1-24**	59.9	40.1	"	2-24	45.0	43.6	12.4
1-25	62.0	38.0	"	2-25	45.0	41.7	13.3
1-26*	62.0	38.0	"	2-26	47.0	44.6	8.4
1-27	62.5	37.5	"	2-27	49.5	38.4	12.1
1-28	64.0	36.0	"	2-28	44.5	42.2	13.3
1-29	62.5	37.5	"	2-29	48.0	41.2	10.8
1-30	65.0	35.0	"	2-30	45.0	44.4	10.6
outer stratum				outer stratum			
mean	62.7	37.3		mean	50.0	41.3	
std. deviation	1.8	1.8		std. deviation	2.7	2.2	

* is the mean of duplicate analysis **is the mean of 5 samples

clay is defined as particles < 0.002 mm silt is defined as particles < 0.063 mm and > 0.002 mm sand is defined as particles > 0.063 mm

within grab replication; (n = 3 subsamples per grab)

1-1	63.0 ± 1.7% clay;	37.0 ± 1.7% sand	(65, 35; 62, 38; 62, 38)
1-14	65.8 ± 1.3% clay;	34.2 ± 1.3% sand	(67,33; 64.5, 35.5; 66; 34)
1-24	59.8 ± 0.8% clay;	40.2 ± 0.8% sand	(60, 40; 59, 41; 60.5, 39.5)

grab replication; (n = 3 grabs from one site)

1-1	61.7 ± 2.3% clay;	38.3 ± 2.3% sand	(59, 41; 63, 37; 63, 37)
1-14	64.7 ± 0.9% clay;	35.3 ± 0.9% sand	(64, 36; 65.8, 34.2; 64.4, 35.6)
1-24	59.9 ± 0.1% clay;	40.1 ± 0.1% sand	(60, 40; 59.8, 40.2; 60, 40)

(individual values given in brackets)

dumpsite. In calculating the n_i's for the dumpsite monitoring program, it was assumed that $\sigma^2 = \sigma_0^2$ and $\rho^2 = \rho_0^2$ (the population values for the whole Beaufort Sea were used as estimates for the dumpsites, since no better values were available). This was a conservative approach, since it was thought that the variance from a single dumpsite would be smaller than that for the whole Beaufort Sea. However, the historical data set was inadequate to determine how much smaller the variance would be.

The predicted values for n_i given on p 84 of Hoff and Thomas (1986) were proposed for this study with the modification that n' would be 30 and n_i would not be less than 8 so that the contaminant-percent clay relationship could be adequately tested. Initially, this number of samples (see Table 2.1, minimum of 8 for each contaminant) was used to test whether the contaminant-percent clay relationship determined using the 1984 EPS data was valid at the dumpsites (see Section 4.5). Subsequently, 20 samples were analyzed for all contaminants and these data used to test whether the predicted number of samples (n_i) for contaminants were really adequate to test $\delta = \sigma_0$ at $\alpha = \beta = 05$. This test was made using $n_i = 20$ for each contaminant. The formula for calculating n_i when the percent clay data are not taken into account is

$$n_i = \frac{2(Z_\alpha + Z_{1-\beta})^2}{\sigma_0^2}$$

In this case ^{2} is the (pooled) variance for the dumpsites and $\sigma_0{}^2$ is the variance for the whole Beaufort Sea (i.e. $\delta = \sigma_0$). When $\alpha = \beta = 05$,

$$n_i = \frac{22\,\sigma^2}{\sigma_0^2}$$

These values are given below along with the n_i's given on p. 84 of Hoff and Thomas (1986).

	LTALK	LTPAH	Ba	Cd	Cr	Cu	Hg	Ni	Pb	Zn
	0.451	1.388	27782	14.9	537.6	84.	0.685		107.	29.7
	0.090	0.014	1088	0.235	110.1	6.91	0.156	17.1	6.21	91
n_i	4	2	1	1	5	2	5	4	5	2
n_i (as per Hoff & Thomas, 1986)	18	11	19	21	5	6	9	14	7	8

From this table, it can be seen that the number of samples predicted by Hoff and Thomas (1986) is adequate in every case to detect a change, δ, of σ at $\alpha = \beta =$ .05. Because the sediments are very homogeneous at the dumpsites, there is no advantage to using the technique of double sampling. This can be seen from the formula for n_i with double sampling:

$$n_i = \frac{\sigma^2(1-\rho^2)}{\frac{\sigma_o^2}{22} - \frac{\sigma^2\rho^2}{n'}}$$

which reduces to

$$n_i = \frac{\sigma^2}{\sigma^2} \times 22 \qquad \text{when} \quad \rho^2 \simeq 0.$$

4.4.1 Conclusions

The double sampling technique does not provide an increase in precision (or reduction in cost) in a small area when the parameters are so narrowly dispersed. However, the assumption that the contaminant-percent clay relationship holds for a site specific monitoring program did result in a prediction for the required number of samples which is adequate to meet the criterion for detectability of impacts. In some cases (e.g., LTPAH, Ba, Cd), the predicted number of samples was much larger than that actually required. It is obviously not good practice to collect only one sample from a dumpsite, even though sufficient to meet the criterion. Therefore, it is recommended that a minimum of eight samples be collected in any future sampling programs. Samples should be analyzed for the contaminants and the grain size parameters, since the use of grain size as a covariate guarantees that a change in contaminant concentration that is due to a concommitant change in grain size distribution will be recognized as such.

4.5 Contaminant-Grain Size Relationship

4.5.1 Objectives

In addition to defining the baseline (pre-dumping) levels, the data were used to test the hypothesis that the sediments at the two dumpsites were consistent with the contaminant - grain size relationships determined by the 1984 EPS survey (CanTest Ltd., 1985). The 1984 survey sampled sediments from the eastern to the western margins of the the Canadian Beaufort Sea shelf, mostly along the 10 m depth contour. It is reasonable to assume that the sediments at the two dumpsites, which are between the 100 m and the 200 m depth contours, would not have different grain size relationships. In most cases the grain size effect explains most of the environmental variability in contaminant concentrations, since the physical and chemical processes which are responsible for causing horizontal gradients in the deeper and shallower parts of the Beaufort Sea are essentially the same.

4.5.2 Methods

The baseline concentrations were defined for each contaminant variable by specifying the means, standard deviations and number of observations in the inner and outer strata of each dumpsite. These data are given in Tables 4.1 - 4.10. Confidence intervals for the contaminants can be calculated from the formula for the variance of the mean when double sampling is employed (Hoff and Thomas, 1986; page 65). The confidence intervals will not be needed until data from a post-dumping survey are used to test the hypothesis of no contaminant changes due to dumping.

The method used for testing whether the data for the two dumpsites are consistent with the 1984 EPS data consists of:

1) examining scatterplots of contaminant concentration versus percent clay for obvious discrepancies, and

2) applying statistical tests.

The scatterplots immediately show the large differences, while the statistical tests are able to detect more subtle differences and to classify the equivocal cases in an objective way.

4.5.3 Results

The scatterplots are given for the trace metals in Figures 4.1 - 4.8. It can be seen from the figures that only for Cr and Cd do the dumpsite data obviously depart from the metal-grain size relationships defined by the 1984 EPS data. Figures 4.9 and 4.10 show the scatterplots for total n-alkanes and total PAH; these variables are

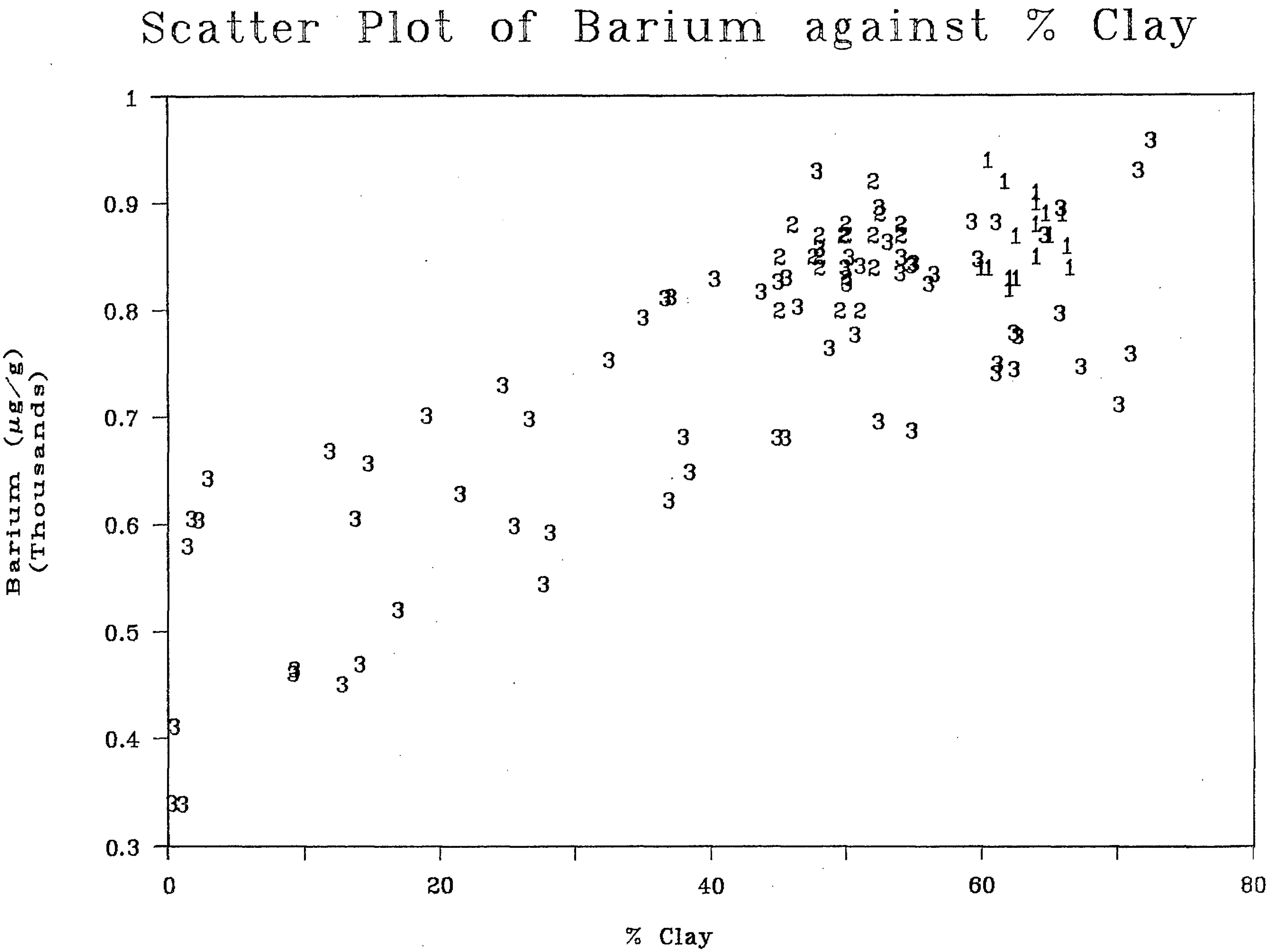

Figure 4.1 Scatter plot of total Ba in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

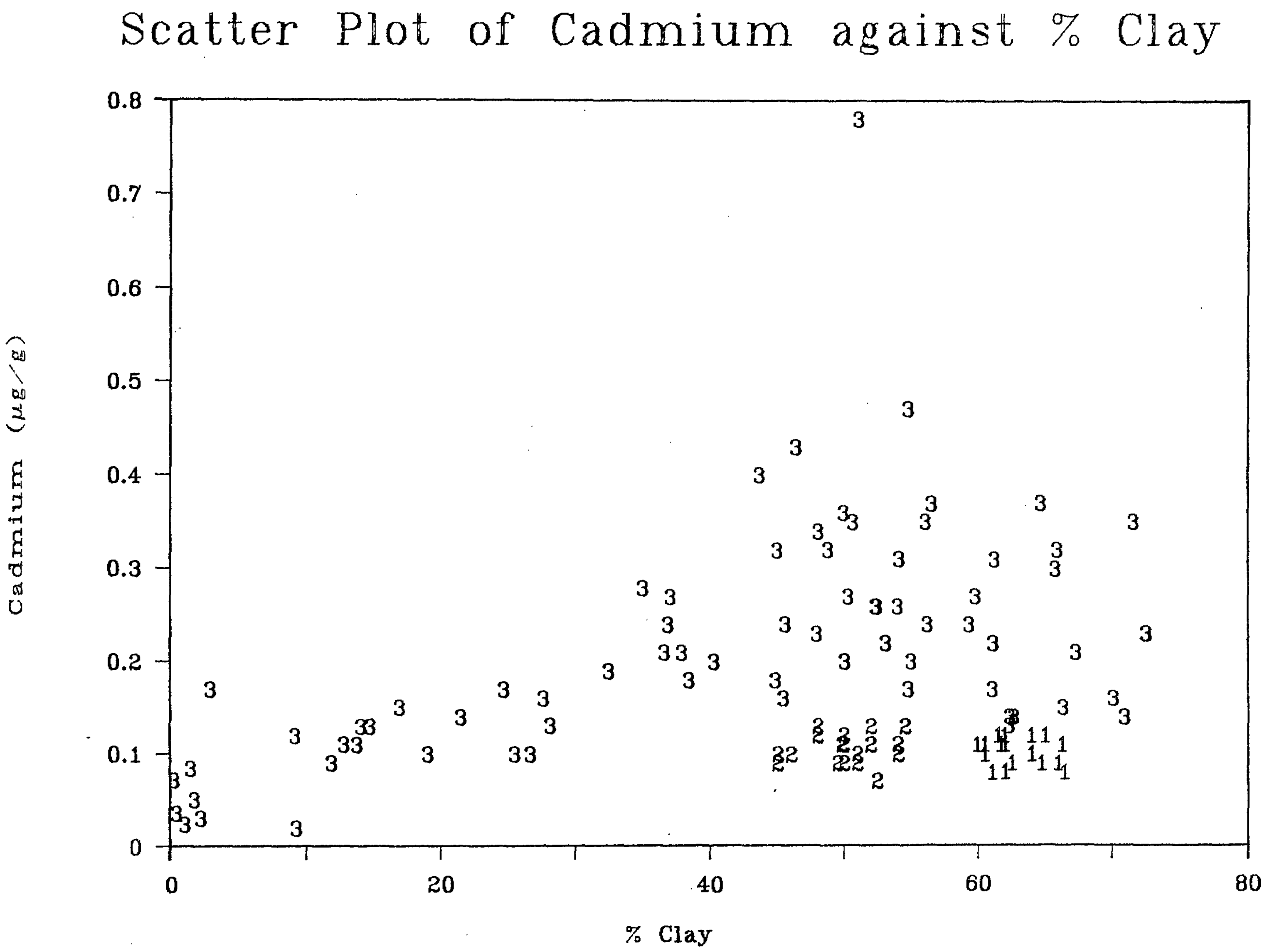

Figure 4.2 Scatter plot of total Cd in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

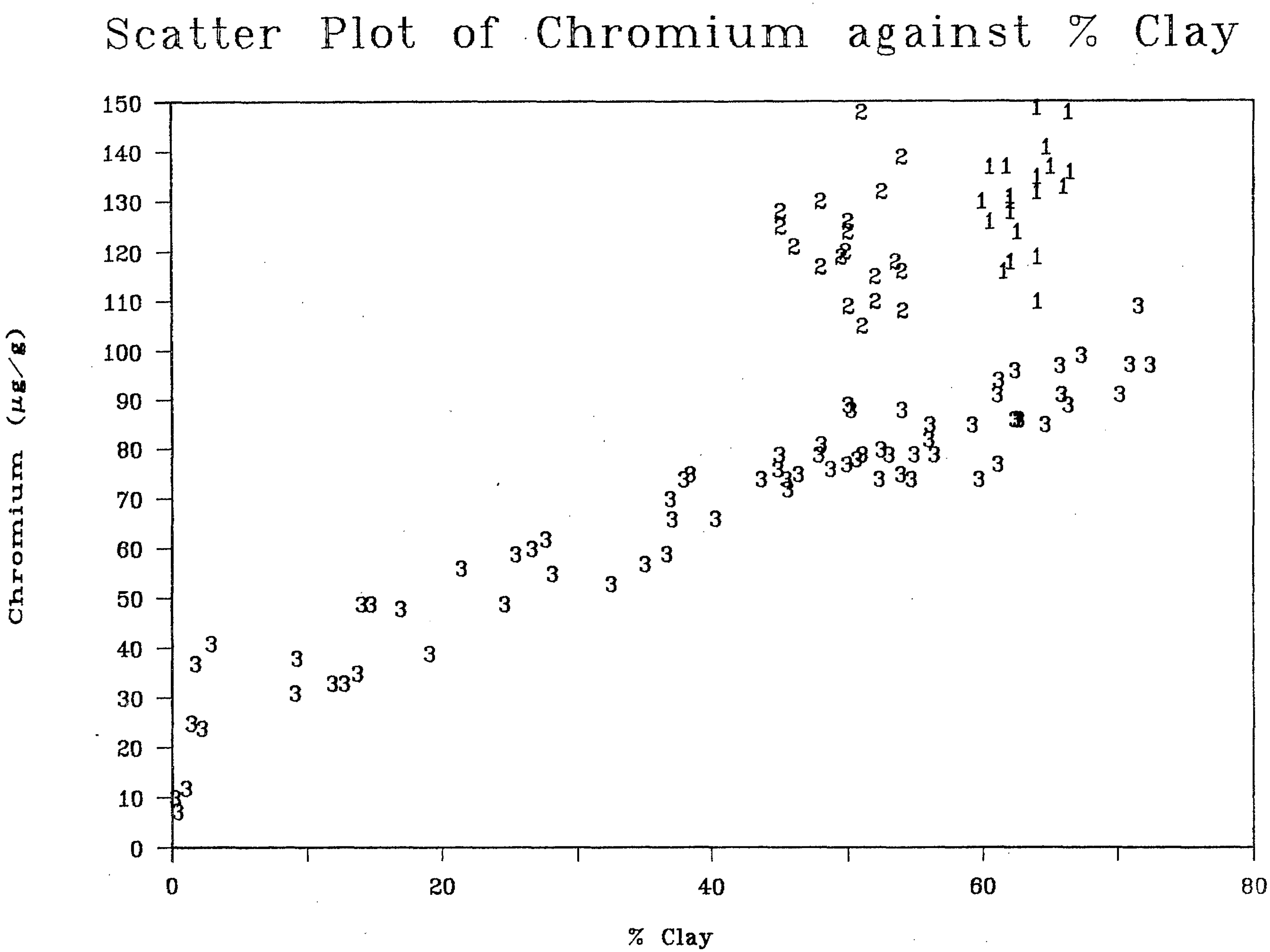

Figure 4.3 Scatter plot of total Cr in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

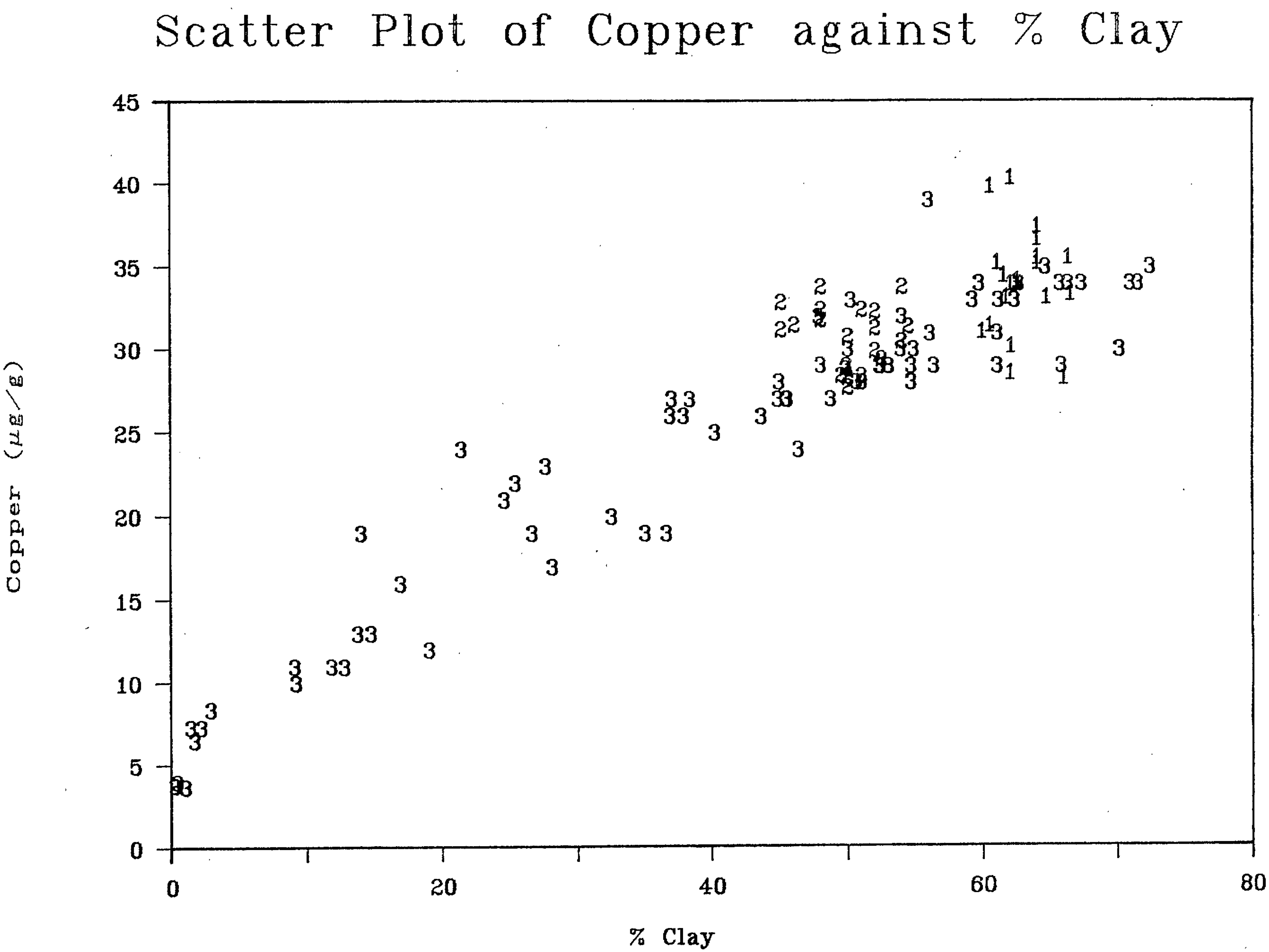

Figure 4.4 Scatter plot of total Cu in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

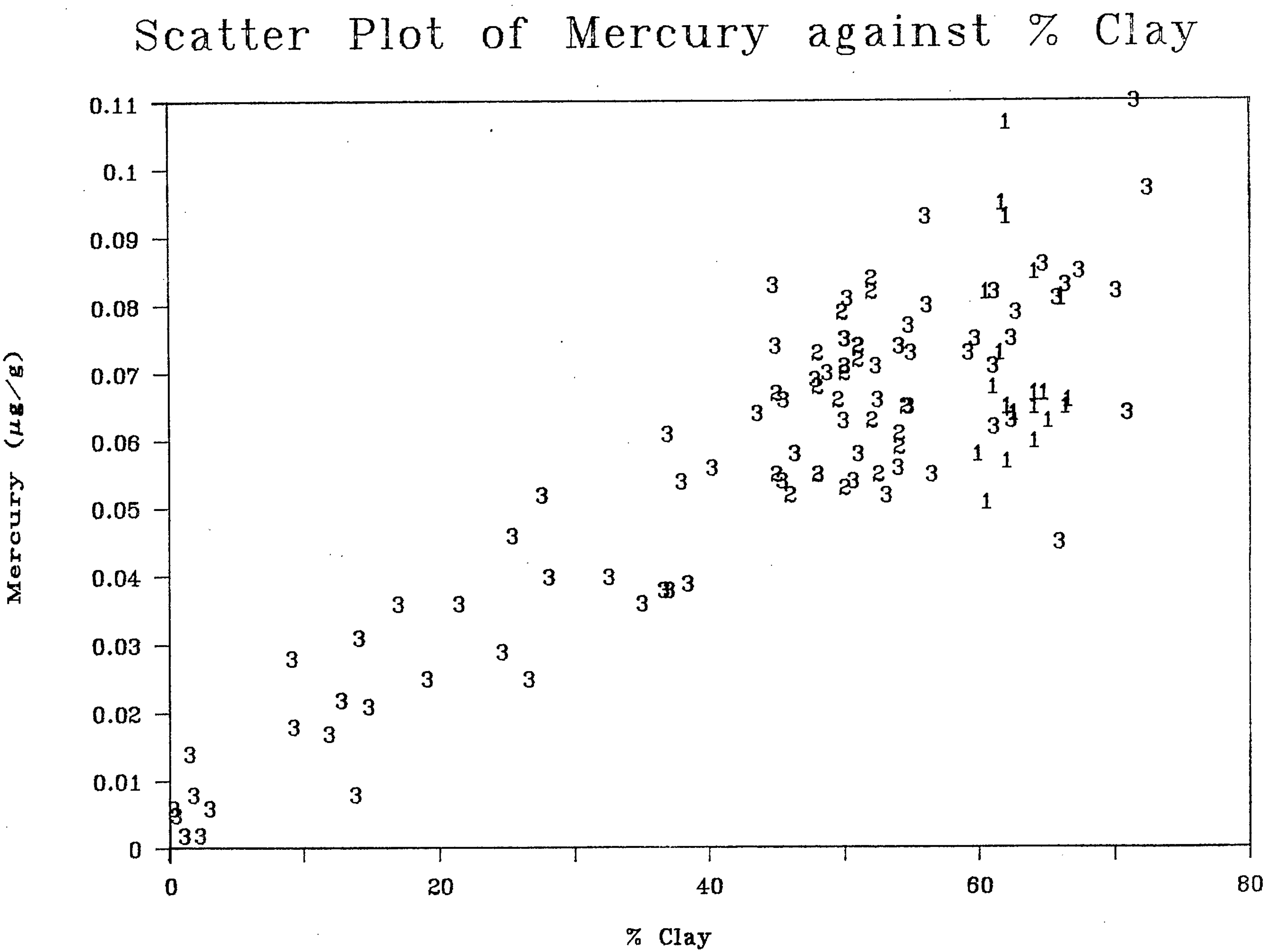

Figure 4.5 Scatter plot of total Hg in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

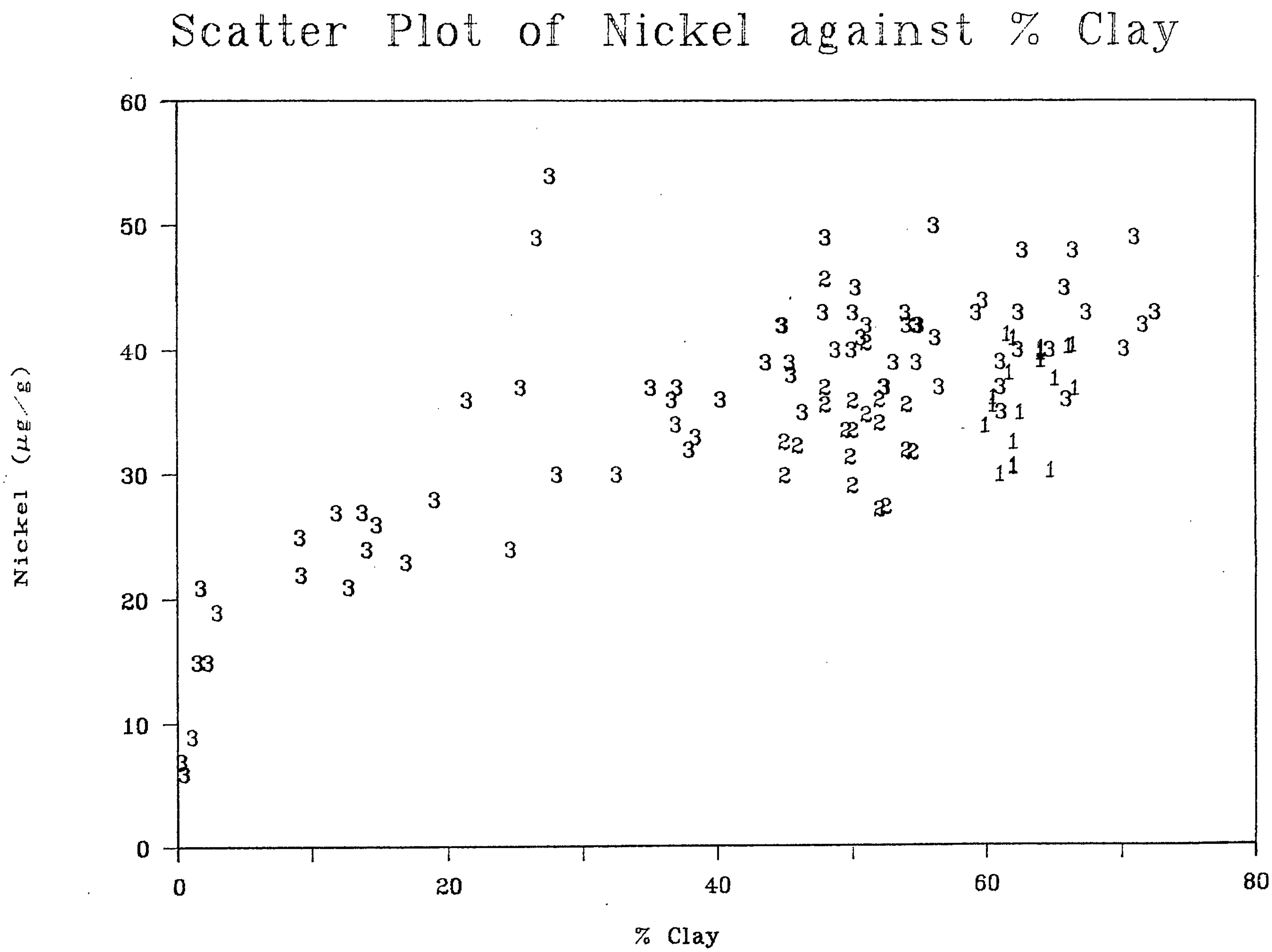

Figure 4.6 Scatter plot of total Ni in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

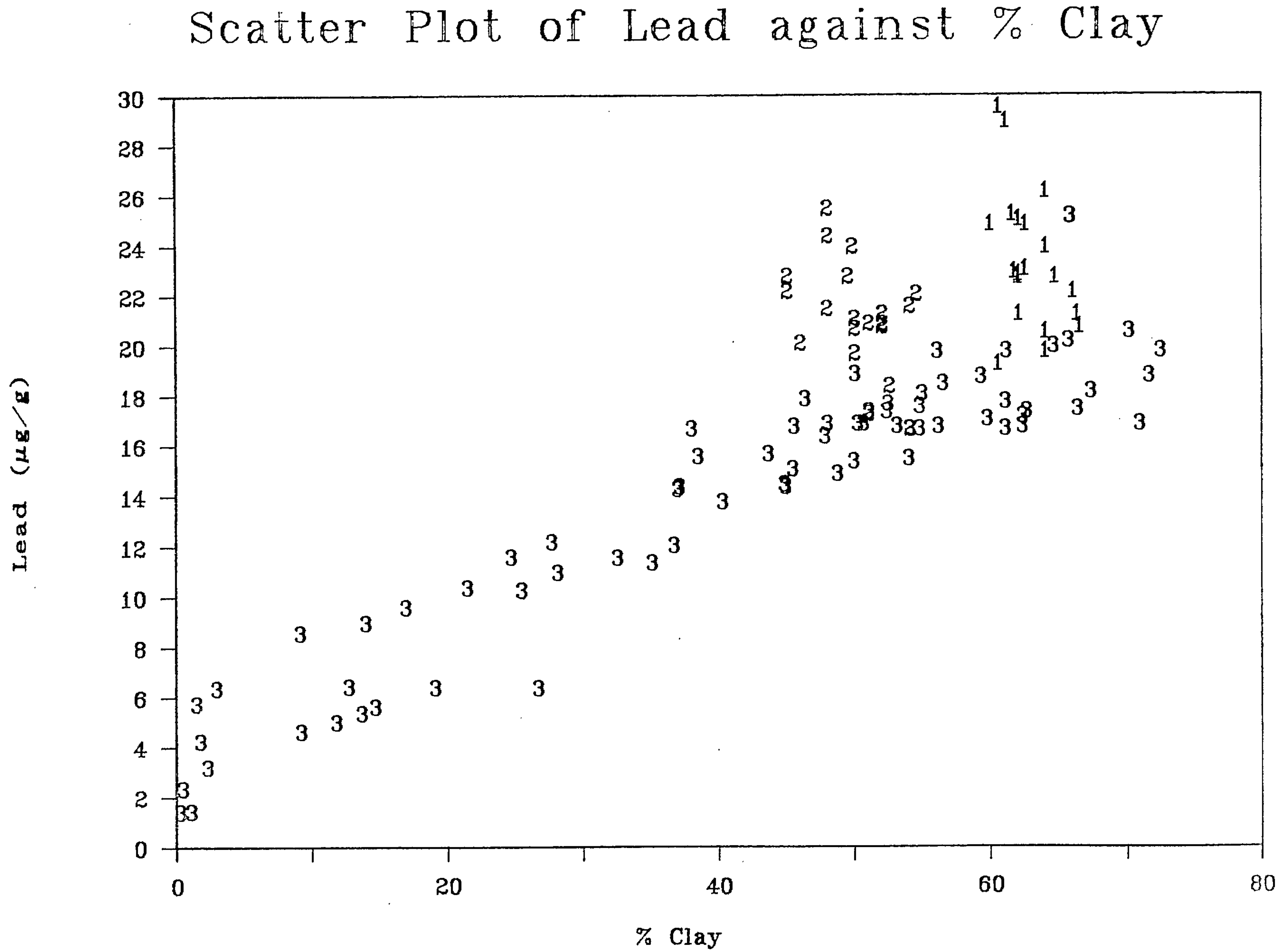

Figure 4.7 Scatter plot of total Pb in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

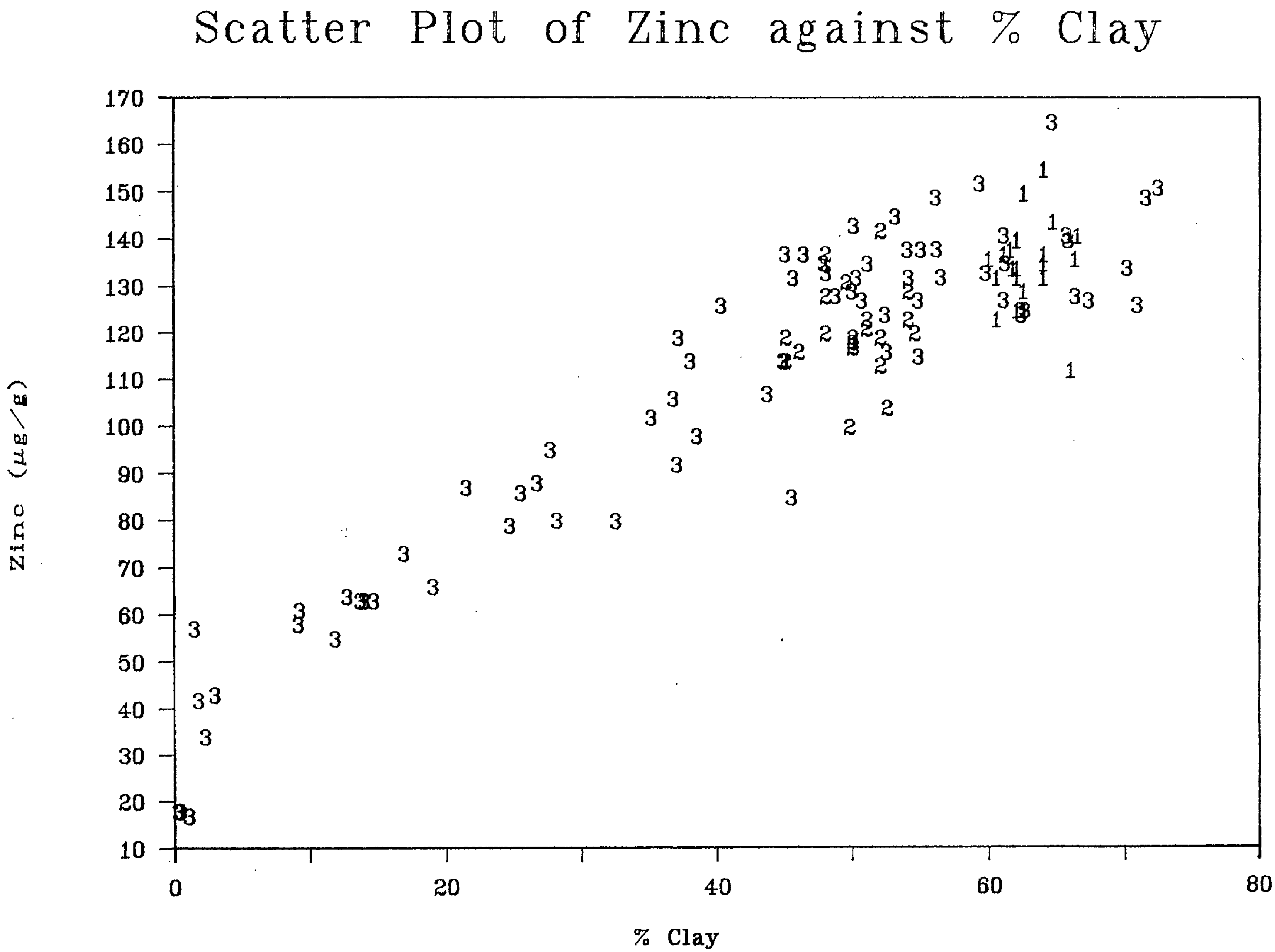

Figure 4.8 Scatter plot of total Zn in surficial sediment at Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

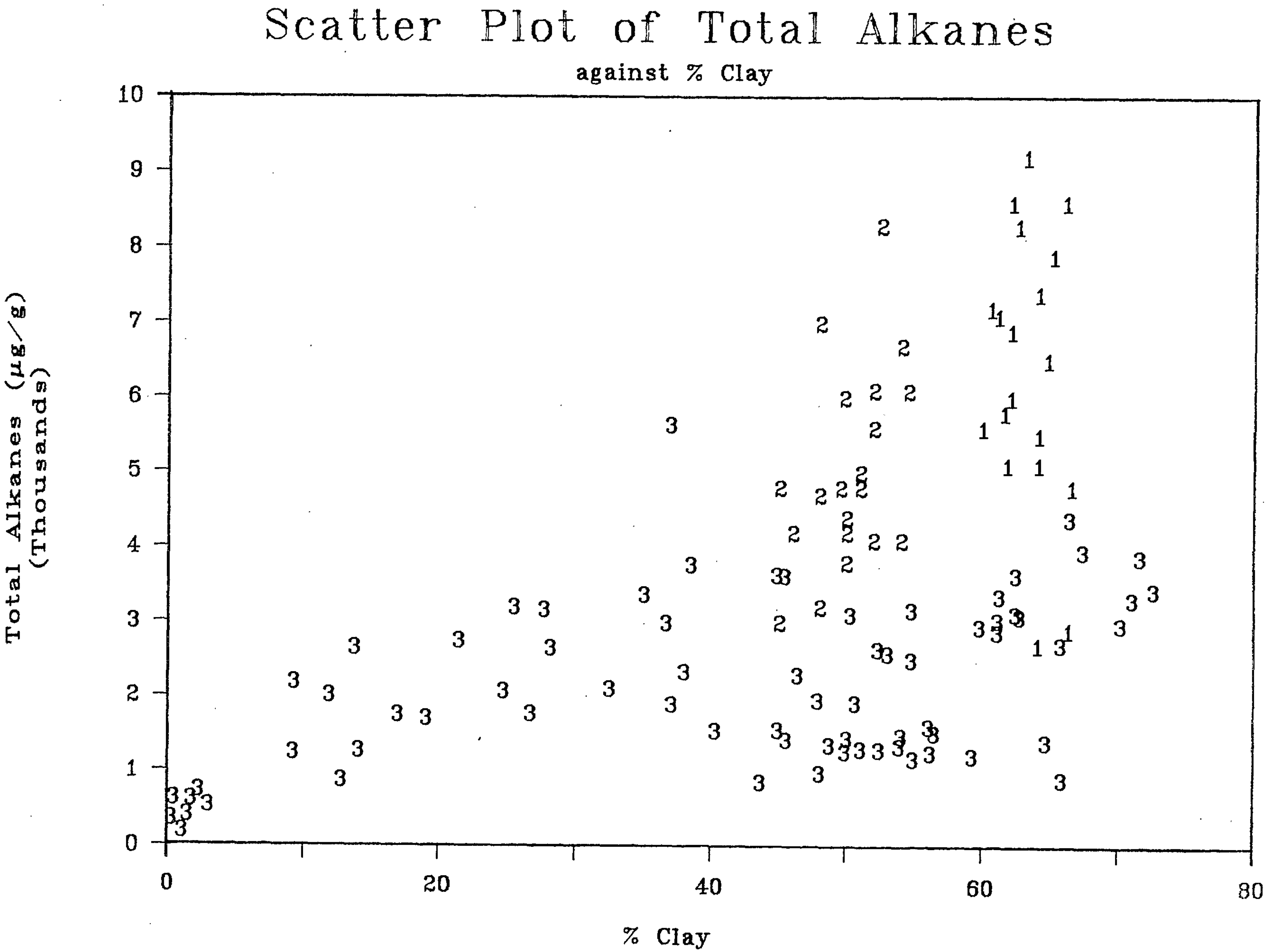

Figure 4.9 Scatter plot of surficial sediment total n-alkanes for Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

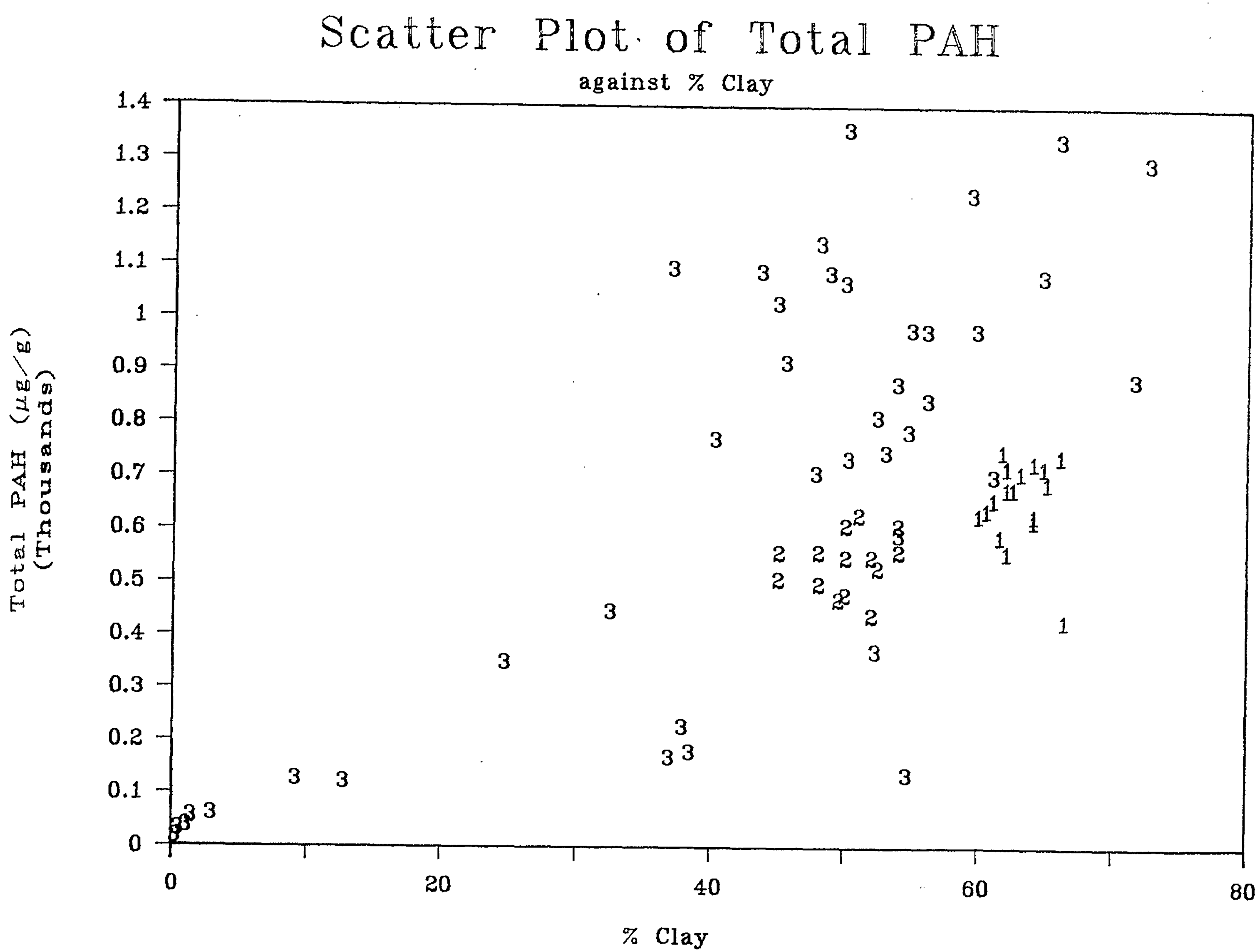

Figure 4.10 Scatter plot of surficial sediment total PAH for Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

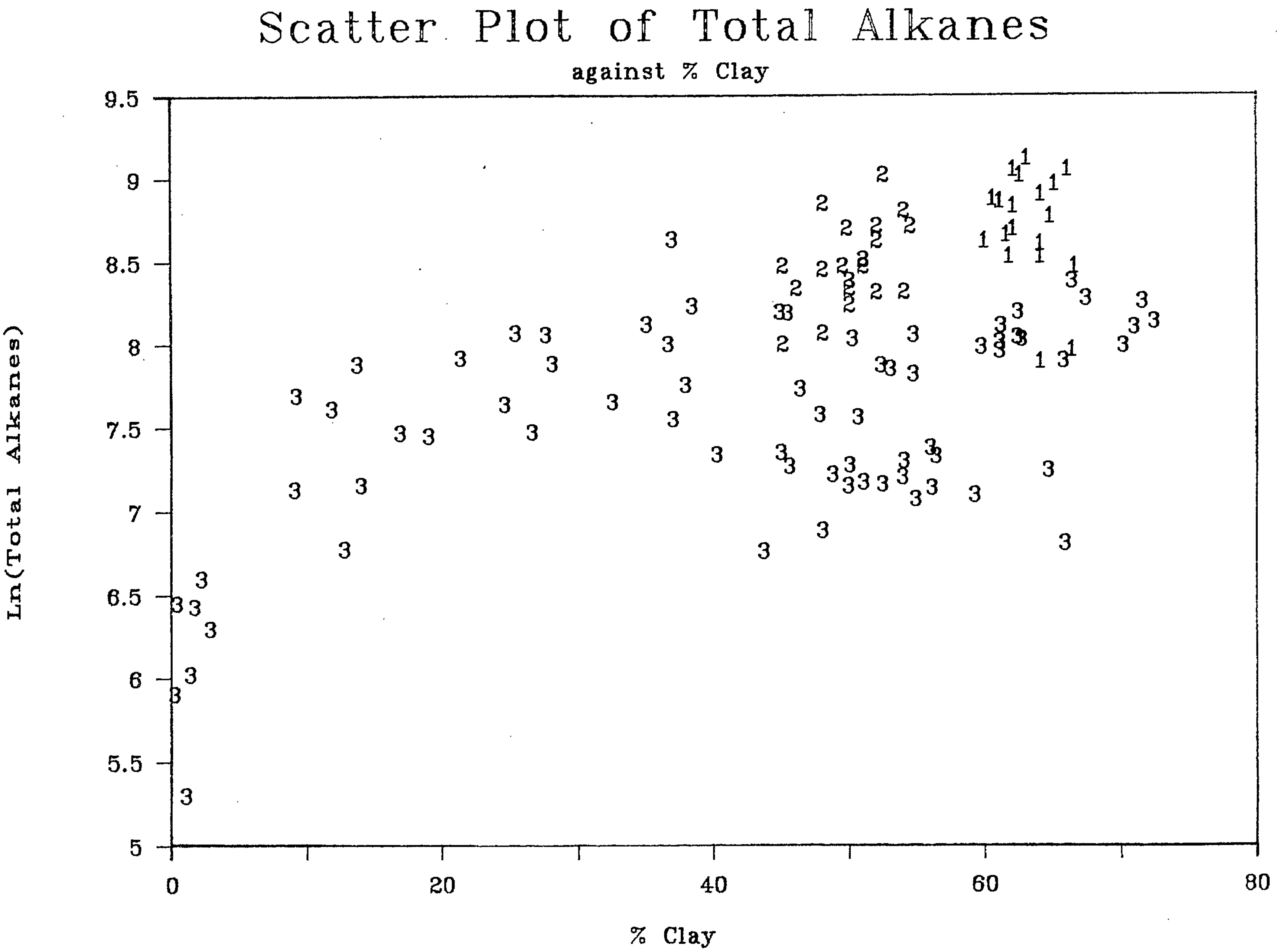

Figure 4.11 Scatter plot of the natural logarithm of surficial sediment total n-alkanes for Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

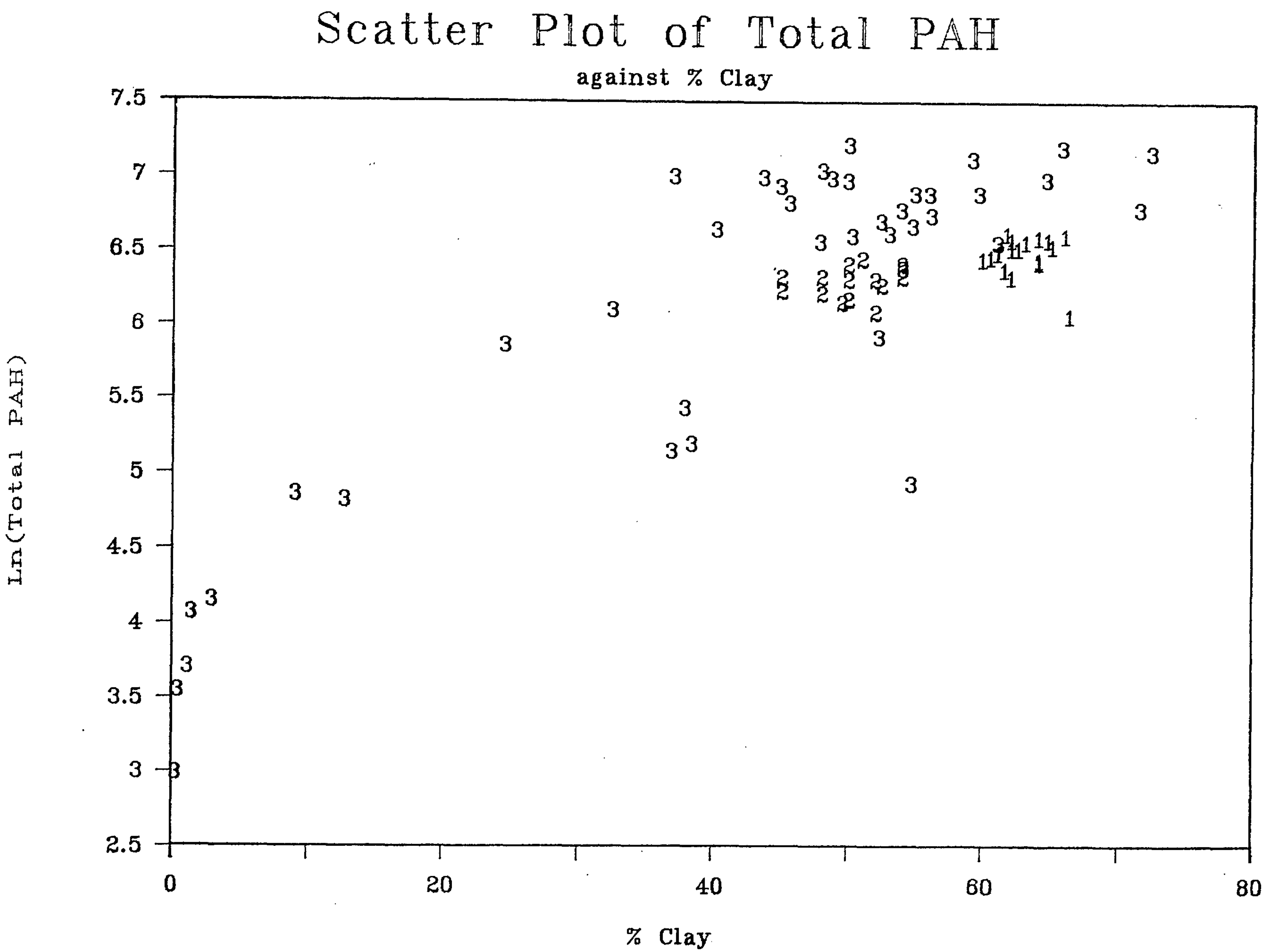

Figure 4.12 Scatter plot of the natural logarithm of surficial sediment total PAH for Dumpsite A (1), Dumpsite B (2) and 1984 EPS locations (3) vs % clay.

composed of the same individual compounds in the dumpsite and 1984 EPS data sets. Figures 4.11 and 4.12 give the corresponding plots for log(total n-alkanes) (LTALK) and log(total PAH) (LTPAH). By comparing these two sets of figures, it can be seen why the log(base e)-transformed variables are preferred for developing linear regressions of contaminant on percent clay. The variance about the regression line is equal at the two extremes of percent clay for the transformed variables, while the variance increases as percent clay increases for the untransformed variables. Using the log transformed data (Figures 4.11 and 4.12), it can be seen that obvious departures of the dumpsite data from the 1984 EPS data exist for log(total n-alkanes) but not for log(total PAH).

In order to confirm the discrepancies identified above and to detect others that are not obvious in the scatterplots, statistical tests were performed according to the method given by Sokal and Rohlf (1969; pages 424-5). The model assumes that a cluster of data points for a single dumpsite can be adequately represented as having a single fixed value of percent clay, and it is obvious from the figures that this is a reasonable approximation for these data. Table 4.12 summarizes the results of the tests for all of the contaminant variables. The difference between the measured concentration and the concentration predicted from the regression line defined by the 1984 EPS data is significant ($p \leq .05$) at both dumpsites for the following contaminants: Cd, Cr, Ni, Pb and total n-alkanes. It is notable that for these contaminants, the discrepancies (differences) are nearly equal for the two dumpsites. This result would be expected if there were systematic errors due to the fact that the dumpsite and 1984 EPS sets of samples were analyzed by two different laboratories. If the departures were due to non-uniformity of the grain size relationship, (for example, if the grain size relationship for dumpsite sediments were different from that for the shallower sediments samples in the 1984 EPS survey), then the discrepancies for the two dumpsites would not necessarily be equal.

4.5.4 Discussion

It is well established that analytical results produced by different laboratories are often at variance. A recent interlaboratory calibration exercise for trace metals in sediments (Macdonald and Nelson, 1984) demonstrated that laboratory bias can be expected among commercial Canadian laboratories, particularly for the difficult-to-determine metals such as Cd, Pb and Hg. Chromium is also prone to laboratory bias due to the refractory nature of certain Cr-containing minerals in

Table 4.12

Summary of the Results of Testing H_o:

No difference between dumpsite data set A or B and the regression line fitted to the 1984 EPS data using percent clay as the independent variable. The calculation is given by Sokal and Rohlf (1969) on pages 424-5.

Site A

	$S^2_{y \cdot X}$	n	k	Sy	$t \cdot S_y$	$\hat{Y}i-Yi$
Ba	16689.	72	19	36.8	77.4	33.
Cd	0.0104	72	19	0.03	0.06	0.18*
Cr	46.0	72	8	2.66	6.29	-50.4*
Cu	7.94	72	8	1.11	2.62	-.152
Hg	0.000114	72	16	0.00213	0.00682	0.006
Ni	35.2	72	14	1.88	4.06	9.86*
Pb	3.18	72	8	0.70	1.66	-4.97*
Zn	178.	72	8	5.24	12.4	6.34
LTALK	2.89	71	16	.163	.347	-.79*
LTPAH	.344	40	10	.230	.520	.65*

$\sum(X_i - \bar{X})^2/\sum x^2 = .0150$

Site B

	$S^2_{t \cdot X}$	n	k	Sy	$t \cdot S_y$	$\hat{Y}i-Yi$
Ba	16689.	72	14	38.2	82.4	-97.5*
Cd	0.0104	72	20	.03	.05	.13*
Cr	46.0	72	8	2.55	6.03	4.84*
Cu	7.94	72	8	1060.	2515	-1257.
Hg	.000114	72	16	.003	.006	-.006
Ni	35.2	72	14	1.76	3.79	6.69*
Pb	3.18	72	8	0.67	1.59	-5.18*
Zn	178.	72	8	5.02	11.9	1.81
LTALK	.289	71	18	.144	.304	-.62*
LTPAH	.344	40	11	.209	.474	.13

$\sum(X_i - \bar{X})^2/\sum x^2 = .00209$

* $(\hat{Y}_i - Y_i) \neq 0$ at $\alpha = 0.05$

sediments (Arctic Laboratories Limited, 1985). The magnitudes of the discrepancies encountered here (20-60%) are not large compared to those that typically occur in interlaboratory comparison exercises where aliquots of the same well-homogenized sample are distributed to the participating laboratories. In the last I.C.E.S. interlaboratory calibration of trace metals in marine sediments (Loring, 1986), discrepancies of a factor of two were not uncommon. It is therefore concluded that interlaboratory errors are the most likely explanation of the observed differences in data sets.

Biases should be reduced when the laboratories use standard reference materials (S.R.M.s) such as those provided by the N.R.C. (BCSS-1 and MESS-1), but may not be entirely eliminated. The magnitudes of the differences between the CanTest Ltd. (C.T.L.) and Arctic Laboratories Limited (A.L.L.) results for BCSS-1 and MESS-1 were compared with the magnitude of the discrepancies between the Beaufort Sea data sets produced by the two laboratories in order to see whether the latter could be explained by the former. It was found that there was little consistency in the interlaboratory biases for the two reference materials. Moreover, the discrepancies between the C.T.L. and the A.L.L. results for the Beaufort Sea samples did not match the discrepancies for the S.R.M.'s. The former were generally greater, but there was some consistency of sign. These findings do not necessarily contradict the hypotheses that the discrepancies in the Beaufort Sea data are due to interlaboratory errors, however, since the S.R.M.'s were not analyzed "blind" by the two laboratories.

Confirmatory evidence could be obtained by having A.L.L. and C.T.L. re-analyze some of the dumpsite or the 1984 EPS survey samples using the same methods used previously, but this would be expensive and the results would not be conclusive (analysts might not be the same, for instance). A practical measure to improve the comparability of future data sets taken at the dumpsites would be to archive four samples (two from each dumpsite) selected at random from the 1986 suite of samples for the purpose of providing reference samples which would be re-analyzed in triplicate along with the next suite of samples taken from either of the dumpsites. It is important that the reference samples are randomly chosen from the 1986 suite, and that the laboratory analyzing the next suite of samples does not know their identities. This ensures that the samples will be treated in the same manner as all other samples in the suite. In view of the results obtained in this study, this form of control will be necessary to ensure the comparability of data sets produced by different laboratories at different times, and is essential for detecting trends or changes over time at a dumpsite.

The fact that significant discrepancies were also found at both dumpsites for total n-alkanes is attributed to the same cause (i.e. interlaboratory errors). The discrepancy was approximately the same magnitude at the two dumpsites. Standard reference materials are not available for petroleum hydrocarbons in marine sediments as they are for trace metals, so interlaboratory errors are even more likely to occur. Recent intercalibration results show that laboratory bias is prevalent for petroleum hydrocarbons (MacLeod, 1982). It is recommended that a similar procedure for laboratory bias be adopted for the hydrocarbons. It may suffice to store the sediments in a very tight metal container (e.g., a sealed aluminum can) in a deep freezer. Re-analysis by the same laboratory, however, may also be necessary to control for potential losses during storage.

4.5.5 Conclusions

It is concluded in the present study that the grain size relationship established by Hoff and Thomas (1986) holds true for the dumpsite sediments, or at least that the relationship was not disproved. The original argument presented by Hoff and Thomas to provide a rationale for determining the number of samples to take in future surveys at the dumpsites is, therefore, still valid. The analysis of four additional samples for all contaminants and grain size parameters is recommended to control for interlaboratory errors in the same way as control sites are used in an optimal impact assessment sampling design (Green, 1979; pages 29-31).

The sediments within each of the two dumpsites are very homogeneous; the strata are equal with respect to percent clay and the variance of percent clay within the dumpsites is very small. Therefore, the use of percent clay as covariate in analysis of covariance is not essential to obtain statistical power. Nevertheless, it is recommended that percent clay be determined on the next suite of samples because the measurement is relatively inexpensive and will detect any unforseen changes in sediment particle size distribution. It is recommended that:

1) a minimum of eight samples be collected in future samplings at the potential dumpsites, and that these samples be analyzed for contaminants and grain size parameters, and

2) four samples, selected at random from the existing samples from the dumpsites, be re-analyzed (blind, in triplicate) along with the next set of samples taken from the potential dumpsites.

4.6 Benthic Infauna, Epibenthos and Dermersal Fish

All counts and biomasses of organisms collected in grab samples are reported per se (i.e. number or weight per 0.1 m^2). All counts of invertebrates and fish collected in trawls are presented on a 'per trawl' basis. As previously mentioned (Section 2.2.3), some of the data presented for invertebrates are estimates based on a combination of laboratory results and data recorded at the time of collection. Where numbers are given, there is reasonable confidence in the results because species were easily distinguished in the field. In other cases, species identified in the laboratory are recorded only as 'Present'; 'Absent' is not recorded and should not be inferred, because all species from all trawls were not returned to the laboratory.

Numbers and wet weights of infaunal organisms are given in Tables 4.13 and 4.14. Numbers of fishes and invertebrates collected in trawls from the two dumpsites are summarized in Table 4.15. Length-frequency data for fish are given in Appendix D.

Polychaetes were the dominant infaunal taxon found at each dumpsite in terms of numbers of organisms (~66%, Table 4.16). Polychaetes accounted for 57% of the total biomass at Site A but only 31% at Site B. Bivalves at Site B accounted for only 7.4% of the total number but almost 45% of the biomass. Dumpsite B had twice the density of organisms as Dumpsite A and over four times the biomass. Mean densities and biomass of the dominant species or genera of benthos from each site are summarized in Table 4.17.

4.7 Seabed Features and Bathymetry

The side scan sonar, sub-bottom profiling and bathymetry results are provided in reports by John Lewis of Earth and Oceans Research Ltd. and are included here as Appendices A and B.

Table 4.13

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
Depth (m)	152		157		152		150		148		147		148		150		155		148	
Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
CNIDARIA																				
Alcyonacea																				
Gersemia sp.							1	4050			1	32								
Actiniaria																				
Edwardsia sp.			2	207	1	214	1	245	1	8										
Unidentified			1	187											1	51				
NEMERTINEA																				
Unidentified	6	126	11	84	8	67	7	70	10	299	2	230	10	26	6	17	5	691	4	20
POLYCHAETA																				
Orbiniidae																				
Scoloplos armiger	1	3					2	4	5	21	9	15	2	2	6	13	10	8	1	2
Paraonidae																				
Aricidea nr. *lopezi*	2	1	20	4	3	1	6	2	12	4	9	5	10	4	14	3	8	3	4	2
Aricidea quadrilobata	4	11	11	7	12	10	9	14	7	6	9	16	21	35	10	6	13	34	4	4
Tauberia gracilis	41	17	50	18	76	29	126	40	81	22	62	20	68	26	49	20	42	18	64	26
Unidentified											1	3					1	2		
Cossuridae																				
Cossura longocirrata	7	3	41	5	21	2	15	5	7	2	13	4	19	4	9	2	15	5	18	5
Spionidae																				
Laonice cirrata	3	974	4	900	4	1791			1	779	2	834	5	1919	5	1031	2	738	3	268
Polydora sp.									1	2			7	7						
Prionospio cirrifera											7	9	9	17	5	4	11	10	9	6
Prionospio steenstrupi	5	8			15	14	6	6	10	10	5	6	5	5	7	7	4	10	3	2
Unidentified	2	3	26	58					4	3	6	3	7	10		6	4	20	7	9
Trochochaetidae																				
Trochochaeta carica	2	4	1	3	3	3	2	2	10	4			6	7	2	8	12	7	1	3
Unidentified																				
Chaetopteridae																				
Spiochaetopterus typicus	5	76	2	45	1	8			6	65	2	30	6	348	4	218	2	104	4	79
Capitellidae																				
Heteromastus filiformis			2	5			2	16												
Mediomastus sp.			14	17																
Unidentified	17	98	9	60	23	80	26	134	35	171	30	86	41	169	26	77	37	174	14	71

Continued...

Table 4.13, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
Depth (m)	152		157		152		150		148		147		148		150		155		148	
Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Nephtyidae																				
Aglaophamus malmgreni									1	92										
Micronephthys minuta	1	1	16	9	9	5	9	5	4	3	3	2	19	7	7	4	10	3	8	4
Sphaerodoridae																				
Sphaerodoropsis biserialis	1	2	1	1							1	4	1	2						
Eunicidae																				
Eunice kobiensis									1	124									1	14
Eunice norvegica							1	159												
Lumbrinereidae																				
Lumbrinereis fragilis																				
Lumbrinereis minuta	38	96	43	130	48	191	15	86	28	114	56	220	38	166	46	158	32	101	49	213
Dorvilleidae																				
Dorvillea annulata																				
Sternaspidae																				
Sternaspis scutata							1	481			1	133								
Oweniidae																				
Myriochele heeri	3	4	6	8	2	2	19	17	2	2	9	10	8	5	2	3	3	2	3	4
Owenia fusiformis							1	4					1	2						
Unidentified	1	1							3	3							2	1		
Flabelligeridae																				
Diplocirrus longisetosus			1	4																
Unidentified																				
Pectinariidae																				
Pectinaria hyperborea	1	57			1	230					3	580	2	286					1	162
Ampharetidae																				
Amphicteis gunneri							1	6			3	9			2	95				
Amphicteis sp.									1	6										
Eclysippe sp.					3	1														
Glyphanostomum pallescens			7	25	1	3	1	5	4	5					1	6				
Lysippe labiata	1	16	1	2			1	12	4	7	1	2			5	12	1	6	2	6
Melinna cristata																				
Sabellides borealis									1	7										
Unidentified	6	30	2	2	2	1	12	6	14	11	8	7	10	34	8	5	10	10		

Continued..

Table 4.13, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
Depth (m)	152		157		152		150		148		147		148		150		155		148	
Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Terbellidae																				
Artacama proboscidea					1	267											1	31		
Nicolea sp.																	1	144		
Proclea graffi			1	2									9	16	21	31	9	7	13	12
Trichobranchidae																				
Terebellides stroemi	11	85	14	74	24	111	18	42	28	73	33	99	25	38	24	102	21	66	21	32
Sabellidae																				
Unidentified	5	5	5	2	3	2	14	8	6	2	13	4	9	3	12	4	7	2	8	2
Unidentified		170	2	290	1	460	21	219	6	174	4	176	10	272	6	133	2	129	7	133
MOLLUSCA																				
Bivalvia																				
Arctinula greenlandica			14	42	4	10					1	1	1	6					1	2
Bathyarca glacialis	4	1296	5	2787	1	441	4	929			8	5485	18	7751	8	2895	16	5400	12	7519
Cuspidaria subtorta																				
Dacrydium vitreum			4	8	1	19			1	4	1	3	4	23			1	2	3	14
Macoma calcarea	1	16									1	106	2	96						
Mysella tumida							1	4			2	10	1	4	1	7			1	5
Nucula belloti					1	9														
Nuculana pernula	1	5	2	190	3	59			1	56			1	3	3	2009	3	25		
Portlandia frigida	29	171	44	266	30	204	5	19	11	57	13	72	35	236	18	103	32	200	14	82
Portlandia lenticula	4	126	4	19	5	55	2	16	3	65	4	50	2	34			11	137	9	159
Portlandia juveniles	8	10			9	8	1	1	1	1			8	5	1	3	8	8	2	4
Thracia devexa					1	140														
Thyasira gouldii	9	25	8	161	9	113	3	83	12	197	8	294	21	350	12	239	10	94	4	40
Unidentified juveniles	3	3	8	5	2	2			1	1	4	4	3	3			3	1	1	1
Gastropoda																				
Admete couthouyi																				
Cylichna alba			1	23									1	96	2	75				
Gastroperon pacificum																				
Margarites costalis			1	162																
Propebela sp.													1	34						
Unidentified																	1	2		
Aplacophora																				
Chaetoderma cf. *productum*	2	8	3	7			6	136	2	14	1	16	1	2	2	12	1	6	1	66

Continued...

Table 4.13, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Taxon	Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
	Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
	Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
	Depth (m)	152		157		152		150		148		147		148		150		155		148	
	Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
		#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
AMPHIPODA			7		38		112		20		11		23		280		27		15		54
Ampeliscidae																					
Ampelisca eschrichti														1	-						
Ampelisca sp.																					
Byblis gaimardi				2	-																
Byblis sp.																		3	-		
Haploops setosa		1	-	5	-			2	-			1	-							1	-
Haploops tubicola										1	-					2	-			1	-
Isaeidae																					
Photis tenuicornis																		1	-		
Ischyroceridae																					
Ischyrocerus megalops		1	-	2	-											1	-				
Lysianassidae																					
Anonyx sp.																		1	-	1	-
Centromedon productus		2	-	1	-							1	-								
Hippomedon propinquus																					
Oedicerotidae																					
Aceroides latipes												3	-								
Arrhinopsis longicornis												1	-								
Arrhis phyllonyx						1	-							4	-			1	-		
Monoculodes sp.																					
Unidentified																					
Pardaliscidae																					
Pardaliscella lavrovi										5	-										
Pardaliscella malygini																					
Phoxocephalidae																					
Harpiniopsis kobjakovae		10	-	6	-	13	-	8	-	8	-	13	-	10	-	7	-	12	-	9	-
Paraphoxus oculatus		3	-	2	-							1	-					2	-	1	-
Pontoporeiidae																					
Pontoporeia n.sp.				1	-	1	-					1	-	1	-					1	-
Stenothoidae																					
Metopa cf. bruzeli								10	-												
Metopella longimana																		1	-		
Stenula nordmanni								1	-												
Unidentified														1	-			2	-		

Continued...

Table 4.13, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
Depth (m)	152		157		152		150		148		147		148		150		155		148	
Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg		mg
CUMACEA																				
Unidentified	8	3	27	10	15	6	6	2	14	28	13	3	21	7	14	4	18	23	12	3
OSTRACODA																				
Podocopa	43	12	150	37	32	8	169	45	80	22	45	12	38	13	23	6	30	7	21	7
Myodocopa	16	24	13	25	19	47	11	13	17	38	14	17	29	18	14	10	24	31	10	7
TANAIDACEA																				
Unidentified	34	9	35	10	29	7	6	2	8	2	5	2	13	5	13	4	20	5	7	3
NEBALIACEA																				
Nebalia sp.																				
ISOPODA																				
Calathura brachiata					1	1			1	94					1	13				
Munnopsurus longipes	2	4	2	7			1	1					1	2	1	2	2	7		
Unidentified									1	10										
DECAPODA																				
Sabinea septemcarinata			1	4840																
ECHINODERMATA																				
Asteroidea																				
Ctenodiscus crispatus																			1	5831
Ophiuroidea																				
Amphiura sundevalli					1	601														
Amphiura sp.																				
Ophiocten sericeum			8	150	11	413	1	5	2	60	2	170	5	150	1	205	9	106	5	21
Unidentified					1	2					1	5	1	3			1	1		
SIPUNCULIDA																				
Phascalion strombi	2	192			4	126	1	27	3	64	3	69	2	36						
Phascalosoma minutum	1	2	3	4	2	2	4	5	2	1	1	1	2	2	3	4	1	1		
ASCIDIACEA																				
Unidentified	1	19			1	15	2	4	2	7	3	5	3	29	2	13			1	3

Table 4.13, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) near Herschel Island in the southeastern Beaufort Sea during August 1986.

Sample Number	D2-003		D2-006		D2-009		D2-011		D2-017		D2-018		D2-019		D2-021		D2-024		D2-028	
Latitude (° ' ")	69.40.27		69.41.24		69.40.27		69.39.54		69.39.34		69.39.23		69.39.36		69.40.04		69.41.01		69.39.34	
Longitude (° ' ")	138.32.36		138.32.05		138.31.46		138.30.59		138.29.55		138.28.33		138.28.40		138.28.21		138.29.03		138.26.37	
Depth (m)	152		157		152		150		148		147		148		150		155		148	
Grab Volume (L)	10		8		9		10		9		9		10		9		9		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Cirratulidae		19		75		37		140		71		140		91		78		155		218
Chaetozone setosa									1	-	1	-	2	-	1	-				
Chaetozone sp.	5	-	14	-	6	-	4	-	8	-					6	-				
Tharyx sp.	10	-	44	-	24	-	31	-	24	-	38	-	37	-	28	-	43	-	68	-
Unidentified	2	-	16	-	2	-			1	-	30	-	24	-	2	-	12	-	35	-
Maldanidae																				
Maldane sarsi	33	205	35	128	13	354	33	117	17	64	41	456	40	218	38	187	24	150	32	123
Microclymene sp.	6	44	2	6	8	40			12	29					7	19			18	58
Praxillella gracilis																				
Praxillella praetermissa							2	58	1	4										
Rhodine loveni									1	7										
Unidentified	3	1	2	17	1	1	8	50	9	75	11	18	24	42	6	40	16	72	19	46
Opheliidae																				
Ophelina breviata	14	13	4	6	12	13	5	9	6	3	11	13	10	5	8	9	6	4	10	10
Scalibregmidae																				
Hyboscolex pacificus																				
Scalibregma inflatum							2	8			1	4			1	2	1	358		
Phyllodocidae																				
Eteone flava							2	26												
Eteone longa							2	4					2	3						
Eteone sp.	2	5	1	1													1	4		
Phyllodoce groenlandica															1	455				
Phyllodoce mucosa									1	607										
Polynoidae																				
Gattyana ciliata			1	63			1	725							1	16	1	111		
Gattyana cirrosa																				
Unidentified	1	3									1	2478	1	13						
Sigalionidae																				
Pholoe minuta	28	15	33	12	34	16	15	5	20	8	37	11	43	15	19	7	49	15	26	9
Syllidae																				
Pionosyllis compacta			7	4					5	2	2	1	4	2	3	1	4	2	3	2
Syllis cornuta					4	12	2	6					1	5	1	3				
Unidentified	1	1	2	1											2	1	4	1		

Continued...

Table 4.14

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
CNIDARIA																				
Alcyonacea																				
Gersemia sp.			1	9					1	6	1	13							1	19
Actiniaria																				
Edwardsia sp.			2	15			2	381			31	26			2	7			1	95
Unidentified			26	33							3	2	18	20	33	27	4	3		
NEMERTINEA																				
Unidentified	1	3	5	38	1	10	4	58	5	281	5	91	1	2	6	30	3	6	7	20
POLYCHAETA																				
Orbiniidae																				
Scoloplos armiger	2	3	1	3					2	2					2	4				
Paraonidae																				
Aricidea nr. lopezi	12	4	30	8	6	3	17	5	20	5	36	10	18	8	30	6	38	10	31	12
Aricidea quadrilobata	8	7	12	13	9	7	17	15	17	18	23	18	19	37	15	10	22	18	17	13
Tauberia gracilis					2	1	4	2	2	1	3	1	1	1	2	1	3	1	1	1
Unidentified									1	2										
Cossuridae																				
Cossura longocirrata	1	1	4	4	5	3	4	2	2	1					1	1	2	1	1	1
Spionidae																				
Laonice cirrata	2	925			1	638			4	642			1	400			2	428		
Polydora sp.			1	2													1	3		
Prionospio cirrifera																	1	3	22	47
Prionospio steenstrupi	21	96					25	52	15	38	65	154	27	60	62	167	44	186		
Unidentified			32	81	2	5	1	1	5	8			5	3					6	67
Trochochaetidae																				
Trochochaeta carica			1	2	1	2	2	4	2	4	1	2	1	5			2	4	6	23
Unidentified									2	5										
Chaetopteridae																				
Spiochaetopterus typicus	2	36			1	19			1	6	1	5			1	4			1	2
Capitellidae																				
Heteromastus filiformis					1	11	4	3												
Mediomastus sp.							5	2												
Unidentified	3	40	9	45			2	16	5	28	8	7	12	86	7	51	9	57	19	53

Continued...

Table 4.14, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Cirratulidae		115		147				174		134		95		143		262		219		250
Chaetozone setosa													1	–	1	–			6	–
Chaetozone sp.	14	–	21	–					4	–							42	–		
Tharyx sp.	24	–	44	–	36	213	42	–	36	–	27	–	23	–	48	–	51	–	50	–
Unidentified	1	–	4	–			21	–			51	–	33	–	62	–	3	–	24	–
Maldanidae																				
Maldane sarsi			3	67	4	193	9	320	11	118	6	67	11	44	8	182	2	15	3	3
Microclymene sp.									2	12										
Praxillella gracilis																	2	82		
Praxillella praetermissa																				
Rhodine loveni																				
Unidentified			4	19	4	5	1	1						113						
Opheliidae																				
Ophelina breviata			1	2			1	3			1	1	2	5	6	14			1	2
Scalibregmidae																				
Hyboscolex pacificus			1	75																
Scalibregma inflatum			1	56																
Phyllodocidae																				
Eteone flava						–														
Eteone longa									1	3	1	12							1	5
Eteone sp.	1	1	1	2																
Phyllodoce groenlandica																				
Phyllodoce mucosa																				
Polynoidae																				
Gattyana ciliata	1	20	1	337	1	111	1	435	2	428			2	241	1	20	1	25	2	310
Gattyana cirrosa			1	10									1	25	1	7	5	17		
Unidentified			1	38			1	3					1	5					2	20
Sigalionidae																				
Pholoe minuta	1	1	7	7	1	2	3	2	8	2	12	4	2	1	9	3	8	3	1	1
Syllidae																				
Pionosyllis compacta	2	1	3	3			1	1	2	1	5	2	2	1	5	3	5	4	3	2
Syllis cornuta	2	2	4	16									3	4	6	16	3	8	2	4
Unidentified			3	2									1	1						

Continued...

Table 4.14, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Nephtyidae																				
Aglaophamus malmgreni					1	57														
Micronephthys minuta			11	6			4	4	11	4							5	3	11	4
Sphaerodoridae																				
Sphaerodoropsis biserialis			2	2			1	2			8	3			1	2	3	5		
Eunicidae																				
Eunice kobiensis																				
Eunice norvegica																				
Lumbrinereidae																				
Lumbrinereis fragilis																				
Lumbrinereis minuta	19	77	43	124	3	12	39	149	24	66	19	86	23	116	16	119	31	118	40	100
Dorvilleidae																				
Dorvillea annulata															1	4				
Sternaspidae																				
Sternaspis scutata																				
Oweniidae																				
Myriochele heeri			4	3					2	1	1	1			3	3			1	2
Myriochele sp.																				
Owenia fusiformis																				
Unidentified																				
Flabelligeridae																				
Diplocirrus longisetosus	1	5																		
Unidentified													1	2						
Pectinariidae																				
Pectinaria hyperborea																				
Ampharetidae																				
Amphicteis gunneri	1	99									1	118								
Amphicteis sp.																				
Eclysippe sp.			3	2	2	2	7	2												
Glyphanostomum pallescens			21	9			8	44	3	4			2	3					1	7
Lysippe labiata									1	7									1	1
Melinna cristata					1	6														
Sabellides borealis																				
Unidentified			6	3			7	2			3	2	3	3					12	3

Continued...

Table 4.14, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
Terbellidae																				
Artacama proboscidea																				
Nicolea sp.																			1	6
Proclea graffi																				
Trichobranchidae																				
Terebellides stroemi	3	2	15	30	1	4	19	45	7	22	5	3	1	2	3	3	4	3	11	48
Sabellidae																				
Unidentified	2	1	3	1			1	1											1	1
Unidentified		52	2	229	6	85	2	181	10	149	4	162	5	81	6	104		305	11	79
MOLLUSCA																				
Bivalvia																				
Arctinula greenlandica																				
Bathyarca glacialis							1	2	3	10							1	5		
Cuspidaria subtorta			1	3																
Dacrydium vitreum									2	37			1	3	1	4			1	18
Macoma calcarea																				
Mysella tumida							1	3												
Nucula belloti																				
Nuculana pernula																				
Portlandia frigida											2	5	1	5					1	3
Portlandia lenticula									1	218	2	7								
Portlandia juveniles			1	3			1	1	4	4	1	1					1	1		
Thracia devexa																				
Thyasira gouldii	4	132	14	106	5	115	15	160	8	99	21	119	23	165	32	183	19	134	13	112
Unidentified juveniles	3	1	2	1			5	3	3	4	11	10	2	1	9	5	10	3	11	10
Gastropoda																				
Admete couthouyi									1	219										
Cylichna alba									2	15										
Gastroperon pacificum											1	10								
Margarites costalis																				
Propebela sp.															1	33				
Unidentified			1	4													1	3		
Aplacophora																				
Chaetoderma cf. productum	4	51	10	206	1	8	6	78			5	27	3	5	1	2	2	4	2	3

Continued...

Table 4.14, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
AMPHIPODA		12		27		1		27		22		20		14		7		35		25
Ampeliscidae																				
<u>Ampelisca eschrichti</u>																				
<u>Ampelisca</u> sp.											2	–								
<u>Byblis gaimardi</u>	1	–																		
<u>Byblis</u> sp.																				
<u>Haploops setosa</u>																				
<u>Haploops tubicola</u>													2	–						
Isaeidae																				
<u>Photis tenuicornis</u>																				
Ischyroceridae																				
<u>Ischyrocerus megalops</u>																				
Lysianassidae																				
<u>Anonyx</u> sp.																				
<u>Centromedon productus</u>	2	–	2	–					3	–							1	–		
<u>Hippomedon propinquus</u>											1	–								
Oedicerotidae																				
<u>Aceroides latipes</u>													1	–						
<u>Arrhinopsis longicornis</u>																				
<u>Arrhis phyllonyx</u>			1	–																
<u>Monoculodes</u> sp.									1	–										
<u>Unidentified</u>																				
Pardaliscidae																				
<u>Pardaliscella lavrovi</u>														4	–					
<u>Pardaliscella malygini</u>														1	–					
Phoxocephalidae																				
<u>Harpiniopsis kobjakovae</u>	6	–	4	–	1	–	3	–	6	–	5	–	3	–	2	–	5	–		
<u>Paraphoxus oculatus</u>	1	–	17	–			14	–			9	–			1	–	7	–		
Pontoporeiidae																				
<u>Pontoporeia</u> n.sp.	1	–					4	–	10	–	4	–	3	–	2	–	6	–	6	–
Stenothoidae																				
<u>Metopa</u> cf. <u>bruzeli</u>																				
<u>Metopella longimana</u>																				
<u>Stenula nordmanni</u>																				
Unidentified																				

Continued...

Table 4.14, cont'd.

Numbers and wet weight (per 0.1 m^2 grab) of fauna collected in grab samples at 10 stations within a potential dumpsite (area 28 km^2) north of Pullen Pingo Area in the southeastern Beaufort Sea during August 1986.

Sample Number	D1-002		D1-003		D1-009		D1-010		D1-012		D1-017		D1-019		D1-021		D1-028		D1-030	
Latitude (° ' ")	70.38.20		70.38.08		70.38.41		70.38.10		70.37.55		70.38.23		70.38.51		70.39.19		70.39.07		70.38.39	
Longitude (° ' ")	135.50.13		135.50.00		135.49.47		135.49.01		135.47.42		135.53.28		135.54.20		135.52.23		135.46.05		135.47.42	
Depth (m)	226		217		240		211		186		240		268		275		231		222	
Grab Volume (L)	9		9		9		10		10		11		11		10		10		9	
Taxon	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg	#	mg
CUMACEA																				
Unidentified	3	2	21	7			15	9	25	10	30	8	16	4	14	4	25	8	22	6
OSTRACODA																				
Podocopa	1	1	2	1	1	1	2	1	22	6	3	1	2	1	3	1			1	1
Myodocopa	4	3	29	44	1	1	16	26	35	30	13	11	12	19	12	14	9	6	16	21
TANAIDACEA																				
Unidentified	1	1	10	3	2	1	6	2	15	4	11	3	2	1	10	3	7	4	6	2
NEBALIACEA																				
Nebalia sp.																				
ISOPODA																				
Calathura brachiata			1	9			1	1			2	12					2	24		
Munnopsurus longipes	4	3	2	3			3	4	1	5	1	1	1	2	4	7	4	4	2	5
Unidentified																	1	1	1	1
DECAPODA																				
Sabinea septemcarinata																				
ECHINODERMATA																				
Asteroidea																				
Pontaster tenuispinus													<1	1702						
Ophiuroidea																				
Amphiura sundevalli	1	585					1	50												
Amphiura sp.																	1	42		
Ophiacantha bidentata							1	1034	1	1689										
Ophiocten sericeum					1	8	2	5	14	23	2	65	1	74	1	8	4	29		
Unidentified	2	5	1	2							1	1					2	2		
SIPUNCULIDA																				
Phascalion strombi																				
Phascolosoma minutum	1	2											13	26	15	52				
ASCIDIACEA																				
Unidentified			7	3	1	1	8	7	2	1	8	8	8	58	10	108	7	6	5	18

Table 4.15

Numbers of fishes and invertebrates collected in trawls at 150-240 m depths at two locations in the Canadian Beaufort Sea during August 1986. Large numbers are estimates based on counts and subsampling carried out in the field, together with identifications and counts of small subsamples carried out in the laboratory (see text for details).

	Dumpsite A Tuktoyaktuk				Dumpsite B Herschel Island			
Station Number	2	3	4	5	1	2	4	5
Depth (m)	232	233	234	240	150	150	152	152
Taxon / Distance (km)	1	1	1	1	2	2	2	2
PISCES								
Rajidae								
Raja hyperborea			1					
Gadidae								
Arctogadus glacialis	6	1	24	45				
Boreogadus saida	10	12	44	61	2	3	15	12
Unidentified		1						
Zoarcidae								
Lycodes polaris			3	3	4		3	
Lycodes sagittarius			7	4			2	
Cottidae								
Icelus bicornis					9	1	5	
Icelus spatula					7		7	
Triglops nybelini			3	1				
Triglops pingelii	1				3			
Agonidae								
Aspidophoroides olriki					2			
Cyclopteridae								
Careproctus reinhardi			4	1				
Eumicrotremus derjugini					1		2	
Liparis fabricii			2	1	2	1	5	
ECHINODERMATA								
Crinoidea								
Heliometra glacialis			2		P			
Asteroidea								
Ctenodiscus crispatus					1,000	10		35
Hymenaster pellucidus	4	2	21	1				
Icasterias panopla	2		5	5				
Pontaster tenuispinus	7	18	288	91	40		4	13
Poraniomorpha tumida								3
Pteraster obscurus								4
Solaster papposus					20	1		3
Urasterias lincki		3	82	11	40	6	2	30
Unidentified		1						
Ophiuroidea								
Gorgonocephalus arcticus	4	1	10	4	70		2	2
Ophiacantha bidentata	11	6	39	16				3,750
Ophiocten sericeum					400		20	6,250
Ophiopleura borealis	6	6	127	11				

Continued...

Table 4.15 (continued). Numbers of fishes and invertebrates collected in trawls at 150-240 m depths at two locations in the Canadian Beaufort Sea during August 1986. Large numbers are estimates based on counts and subsampling carried out in the field, together with identifications and counts of small subsamples carried out in the laboratory (see text for details).

		Dumpsite A Tuktoyaktuk				Dumpsite B Herschel Island			
	Station Number	2	3	4	5	1	2	4	5
	Depth (m)	232	233	234	240	150	150	152	152
Taxon	Distance (km)	1	1	1	1	2	2	2	2
MOLLUSCA									
Bivalvia									
Arctinula greenlandica						500	160	75	300
Astarte borealis						200			
Astarte crenata		2	2	14	42	40	9		9
Astarte montagui						2000			
Bathyarca glacialis		1	5	7		18000	500	10	1000
Nuculana pernula						200	4		15
Portlandia lenticula					1				
Thracia devexa						P			
Cephalopoda									
Octopus cf. *dofleini appolyon*		2	1	5	2				1
Rossi cf. *moelleri*						1			2
Gastropoda									
Beringius beringi						10			
Boreotrophon clathratus						10			
Buccinum angulosum				1		10			
Buccinum hydrophanum			1		1				
Buccinum polare						30			1
Buccinum tenue				4	2	30	1		1
Buccinum cf. *totteni*						10			
Colus pubescens					1	40			3
Colus togatus				1		20			2
Colus cf. *togatus*			1		5				
Lunatia pallida						10	1		
Volutopsius deformis						10			
Unidentified			3	69	4	150	20		22
ARTHROPODA									
Pycnogonida									
Boreonymphon ossiansarsi		5		8	2	80	1		16
Colossendeis proboscidea						10			
Cordylochele brevicollis				1	2				
Nymphon hirtipes		3		1		10	1		2
Nymphon longitarse						40			
Nymphon stromi		5	2	4	2				
Unidentified								25	
Amphipoda									
Acanthostephia behringiensis			2	3	2	100	2	40	14
Ampelisca eschrichti					2	10			
Anonyx nugax				4	4	100			

Continued...

Table 4.15 (concluded). Numbers of fishes and invertebrates collected in trawls at 150-240 m depths at two locations in the Canadian Beaufort Sea during August 1986. Large numbers are estimates based on counts and subsampling carried out in the field, together with identifications and counts of small subsamples carried out in the laboratory (see text for details).

		Dumpsite A Tuktoyaktuk				Dumpsite B Herschel Island			
	Station Number	2	3	4	5	1	2	4	5
	Depth (m)	232	233	234	240	150	150	152	152
Taxon	Distance (km)	1	1	1	1	2	2	2	2
Boeckosimus affinis						40			
Byblis gaimardi						10			
Epimeria loricata		2		13	3				
Haploops setosa						10			
Paramphithoe hystrix						10	1		1
Stegocephalus inflatus		3		18	9	40	3	90	4
Tmetonyx cicada						20			
Unidentified			2						
Isopoda									
Calathura brachiata				1		10			1
Mesidothea sabini					1				
Munnopsis typica								9	
Munnopsurus longipes			1			10	8	5	7
Decapoda									
Argis lar						10			
Bythocaris sp.				1					
Eualus gaimardi		4	1	8	63	80		20	72
Pagurus rathburni									1
Sabinea septemcarinata		7	1	10	22	300		200	
Unidentified						80			
NEMERTINEA									
Unidentified					1	30	6		4
CNIDARIA									
Alcyonacea									
Gersemia sp.		6	2	18	5	90	3	10	10
Pennatulacea									
Umbellula bairdi		1	4	4	1				
Actiniaria									
Unidentified		1	1	29	6	400	29	2	75
ANNELIDA									
Polychaeta									
Brada granulata				P		10			P
Onuphis conchylega				P		40		P	P
Unidentified				12	11	200	12	12	150
SIPUNCULIDA									
Phascalion strombi						3500	64		40
PRIAPULIDA									
Priapulus bicaudatus				2					

Table 4.16

Group composition of benthos collected in grab samples at 147-275 m depths at two potential dumpsites in the Canadian Beaufort Sea during August 1986.

Taxon	% of Total			
	Numbers		Biomass	
	Dumpsite A	Dumpsite B	Dumpsite A	Dumpsite B
Cnidaria				
Alcyonacea	0.12	0.03	0.21	4.46
Actiniaria	3.51	0.11	2.67	1.00
Nemertinea	1.09	1.11	2.36	1.78
Polychaeta	66.75	66.51	57.42	31.29
Mollusca				
Aplacophora	0.98	0.31	1.68	0.29
Gastropoda	0.20	0.11	1.24	0.43
Bivalvia	6.79	9.23	7.43	44.94
Sipunculida	0.83	0.55	0.35	0.59
Crustacea				
Ostracoda	5.30	12.87	0.83	0.44
Cumacea	4.92	2.39	0.25	0.10
Tanaidacea	2.01	2.74	0.11	0.05
Isopoda	0.86	0.21	0.36	0.15
Amphipoda	3.94	2.76	0.83	0.64
Decapoda	0	0.02	0	5.29
Echinodermata				
Asteroidea	0.03	0.02	7.45	6.38
Ophiuroidea	1.04	0.79	15.86	2.07
Ascidiacea	1.61	0.24	0.92	0.10
Total number (no./m^2) or biomass (g/m^2)	3474	6199	22.83	91.47

Table 4.17

Densities (no./m^2) of dominant species or genera of benthos collected in grab samples at 147-275 m depths at two potential dumpsites in the Canadian Beaufort Sea during August 1986.

Taxon	Dumpsite A Mean ± SD (n = 10)	Dumpsite B Mean ± SD (n = 10)
Tharyx sp.	381 ± 106	347 ± 156
Tauberia gracilis	18 ± 13	659 ± 252
Lumbrinereis minuta	257 ± 126	393 ± 119
Prionospio spp.	282 ± 227	101 ± 49
Maldane sarsi	52 ± 40	304 ± 109
Pholoe minuta	57 ± 39	306 ± 96
Aricidea nr. lopezi	238 ± 107	88 ± 55
Terebellides stroemi	69 ± 62	219 ± 65
Aricidea quadrilobata	159 ± 50	100 ± 49
Thyasira gouldii	154 ± 87	96 ± 50

Biomasses (g/m^2) of dominant species or genera of benthos collected in grab samples at 147-275 m depths at two potential dumpsites in the Canadian Beaufort Sea during August 1986.

Taxon	Dumpsite A Mean ± SD (n = 10)	Dumpsite B Mean ± SD (n = 10)
Bathyarca glacialis	0.02 ± 0.03	34.50 ± 29.00
Laonice cirrata	3.03 ± 3.49	9.23 ± 5.87
Ctenodiscus crispatus	0	5.83 ± 18.44
Gersemia sp.	0.05 ± 0.07	4.08 ± 12.80
Sabinea septemcarinata	0	4.84 ± 15.31
Maldane sarsi	1.01 ± 1.03	2.00 ± 1.20
Thyasira gouldii	1.33 ± 0.28	1.60 ± 1.09
Gattyana ciliata	1.93 ± 1.77	0.92 ± 2.26
Ophiacantha bidentata	2.72 ± 5.95	0
Nuculana pernula	0	2.35 ± 6.26

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APPENDIX A

DUMPSITE A
DEEPWATER OCEAN DISPOSAL OF BULKY INERT MATERIALS
BEAUFORT SEA
SURFICIAL GEOLOGY AND SEABED DESCRIPTION
AUGUST 1986

Submitted by:
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DUMPSITE A
DEEPWATER OCEAN DISPOSAL OF BULKY INERT MATERIALS
BEAUFORT SEA
SURFICIAL GEOLOGY AND SEABED DESCRIPTION
AUGUST 1986

Submitted to
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E.P. Project Leader:	N.W.T	Glen Pachman
E.P. Project No.:		
E.O.R. Project Mgr:		John Lewis
E.O.R. Project No.:		86-11
Submission Date:		January 10, 1987

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SUMMARY

This preliminary survey of a dumping site off the Northwest Territories coast was conducted during August of 1986 on board the CSS TULLY as a combined Biological, Chemical and Geological reconnaisance. The program was designed as a baseline evaluation of a potential solid waste dumpsite. This report presents a preliminary evaluation of the surficial geology and bathymetry over the site.

The site area bathymetry dips gently toward the north-northwest at a slope of approximately 1 in 37 (1.55°). The contours are slightly concave in a north-nortwestward direction and the water depths range from 120 metres in the southsoutheast to 300 metres at the north-northwestern edge of the site. The seabed is smooth and regular with very occassional and scattered features observed on the seabed. With the limited sidescan coverage of the site the features observed consisted of a single pock mark feature (shallow gas venting) and numerous shallow trench features which are not associated with any known geological phenomena. These features are observed in a random distribution though normally parallel or sub-parallel to the contour orientation (possibly biased by the direction of survey) and are thought to be related to some form of biological activity.

Within the shallow subsurface sediments of the site area the acoustic records show a thick sequence of conformable soft marine sediments. These sediments range from 38 to 60 metres in thickness and are well banded in nature suggesting thin layers of silts and clays similar to the type of materials recovered in the grab sampling program conducted during this investigation. The conformable sediments overly an acoustically homogeneous sediment body along an indistinct boundary. This boundary may be associated with a change in morphology or depositional environment of the slope materials though the systems employed for this survey were unable to define this. The soft conformable subbottom sediments show some localized undulations or troughs and mounds in the order of 2 to 5 metres which appear to be conformable drape of the pelagic sediments onto deeper stuctural irregularities that are not clearly observed on the present acoustic records.

SECTION 1

INTRODUCTION

During the period August 27 to 29 of 1986 a program of survey, biological and chemical sampling was conducted over a 36 km^2 area on the upper continental slope of the Beaufort Shelf. The site is centered on the location 70°39'North and 135°50' West. This area is indicated on the location map of Figure 1. The program was designed as a baseline evaluation of a potential dumpsite for metal and concrete waste materials associated with northern oil exploration and construction. The program was conducted under the direction of Environmental Protection, Environment Canada, Western and Northern Region using the CSS TULLY as a vessel of opportunity. The chemical and biological evaluations of the region are described under separate reports while this report is oriented to the bathymetry, sidescan sonar and subbottom profiler physical description of the site area.

The survey program consisted of 16 survey lines of 6 km length run in a west-southwest to east-northeast orientation and 1 tie line of 7 km length run in a north-northwest to south-southeast direction. The survey track plot is shown in Figure 2, Enclosure 1. The basic east-west lines were run at a 500 metre line spacing at a reasonably fast survey speed without the sidescan system deployed due to a significant amount of floating ice in the area. Line EPB-A-SSS was a first attempt to acquire some sidescan coverage which was blocked by ice and resulted in the major diversion toward the north. On the following day the ice cleared and 4 reasonably straight sidescan lines were completed giving some coverage over the south and central portion of the site. These lines are indicated by "A" designators after the line number, and are indicated on the track plot. During the program depth sounding data were collected on all survey lines, 3.5 kHz data were collected over the entire first pass of the site, while sidescan data were collected only on the specific lines completed when ice conditions allowed. The sidscan data were also limited to the southern portion of the site (less than 230 metres of water) because of the water depth and the limited amount of towing cable available for the system. The sidescan system was operated at a 250 metre scan range on each side of the survey track. The subbottom profiler system was operated at a 250 msec display scan with appropriate delays of the start of sweep to accommodate the water depths in the region. The sounding data were collected by the Canadian Hydrographic Service (CHS) who were in charge of the vessel under the direction of Chief Hydrographer Mike Woods. The subbottom and sidescan equipment was provided by agreement from Mr Steve Blasco of the Atlantic Geoscience Centre, Department of Energy Mines and Resources, and was operated and maintained through this program by Mr J. Lewis of Earth & Ocean Reasearch Ltd. This report represents an evaluation of these data with the view of an initial evaluation / characterization of the site for a clear and stable dumping area.

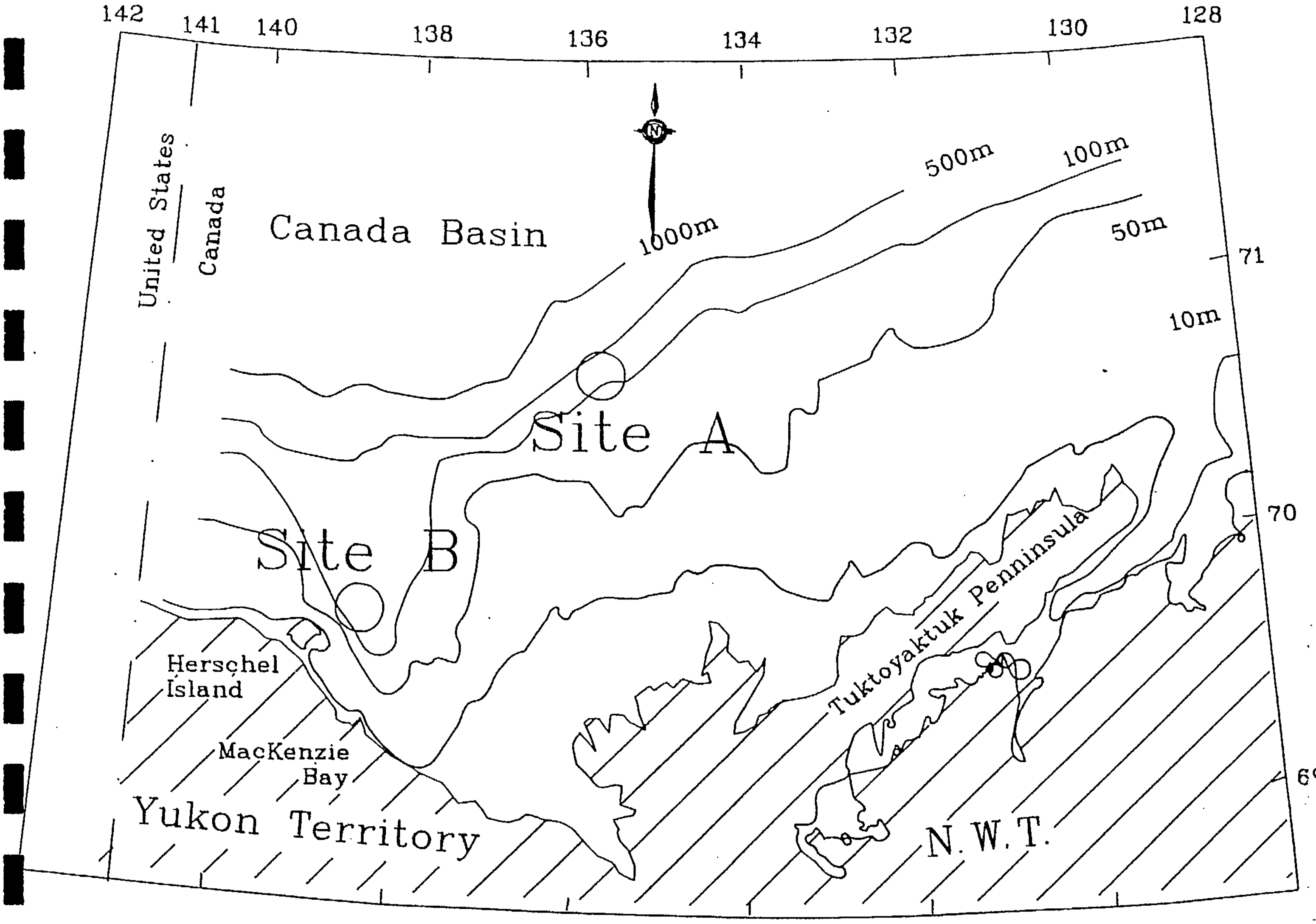
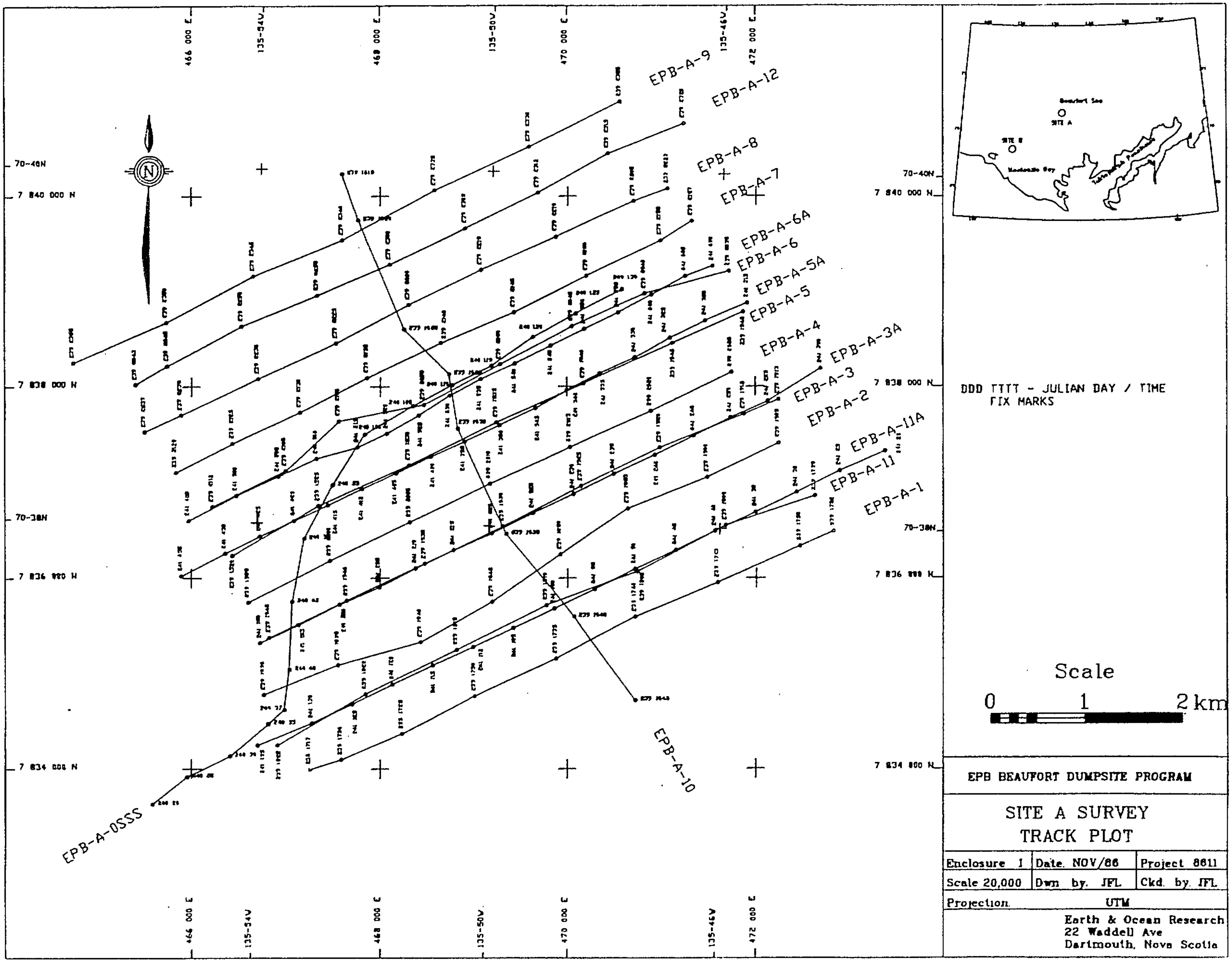


Figure 1: Location Diagram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SITE A SURVEY
TRACK PLOT
Enclosure 1
Date. NOV/86
Project 8611
Scale 20,000
Dwn by. JFL
Ckd. by. JFL
Projection UTM
Earth & Ocean Research
22 Waddell Ave
Dartmouth, Nova Scotia

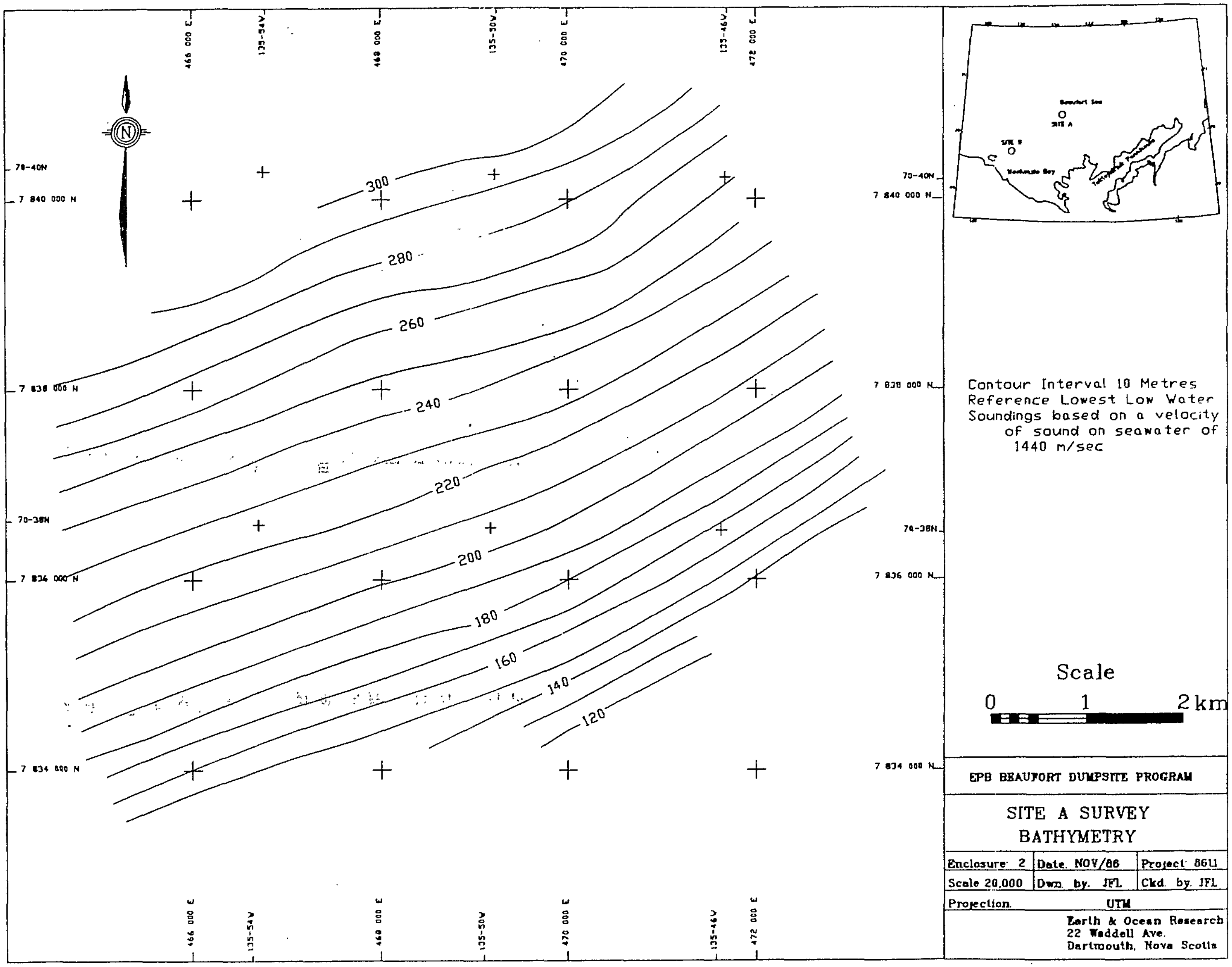
FIGURE 2

SECTION 2

SITE BATHYMETRY

The bathymetric soundings over this site were collected to Hydrographic Survey standard by the CHS surveyors aboard the vessel. The soundings were taken using a Raytheon DSF 6000 survey sounder and logged on magnetic tape. These data were edited, corrected for vessel draft, tide variations, and velocity of sound in seawater before being posted on the survey track map. The velocity of sound in seawater was 1440 metres per second as measured by velocimeter profile within the site area. Tidal corrections were based on predicted tides for the region and sounding crossover errors were less than one metre within the region.

The bathymetric contour map of Figure 3, and Enclosure 2 shows the ten metre isobaths within the site area and indicates that the seabed is smooth and regular forming a gently north-northeastward dipping, slightly concave surface. The regional dip over the site area is approximately 1 in 37 (1.55°). In the southern portion of the site area the slope increases to approximately 1 in 26 (2.23°) while in the northern regions of the site the slope shallows to approximately 1 in 41 (1.40°). Review of the actual sounding records indicate that small scale bathymetric undulations in the order of 2 to 3 metres over a distance of 200 to 300 metres are superimposed on the general slope within the area. These will be discussed further in Section 4.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7 840 000 N
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Beaufort Sea
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Reference Lowest Low Water
Soundings based on a velocity
of sound on seawater of
1440 m/sec
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EPB BEAUFORT DUMPSITE PROGRAM
SITE A SURVEY
BATHYMETRY
Enclosure 2
Date NOV/86
Project 8611
Scale 20,000
Dwn. by JFL
Ckd. by JFL
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FIGURE 3

SECTION 3

SEABED FEATURES

The seabed features over the site area were investigated using a Klein Sidescan Sonar system equipped with the 100 kHz standard towfish. The fish was towed behind the survey vessel while on the "A" and "SSS" designated sounding lines with the return acoustic signals being recorded on a wet paper recorder aboard the vessel. The signals represent a perpendicular acoustic scan of the seabed out to a range of 250 metres on either side of the vessel track. The scans were repeated at intervals of 0.33 seconds while the line was transited and were recorded on a linescan recorder to build a composite acoustic reflectivity picture of the seabed. The system used for this program additionally had the capability of correcting the slant range display of the data to represent true distances on either side of the track line. Because of sea ice and water depth limitations in the site area, only five sidescan lines were completed. The lines were run in an east west orientation, parallel to the bathymetric contours, such that disruptive fish elevation changes would be avoided. These lines provided a characterization of the seabed though full coverage of the area could not be acheived.

The sidescan records indicate that the seabed is of a uniform low reflectivity within the coverage attained. One feature was observed that appears to be a shallow circular depression. This feature is similar to the "pock mark" features commonly observed in other regions where soft marine sediments are found. These pock mark features are commonly associated with venting of gas from the sediments which re-suspends the sediment particles and leaves a characteristic shallow depression. This feature was obseved on line 11A at 0042 GMT which places the feature in the southeastern corner of the site grid (Figure 4). Numerous small linear depression features of 1 to 3 metres width and 5 to 15 metres length (unknown depth though probably less than 1 metre) were observed over the entire site area at an approximate density of 5 to 20 features per square km. These features appear primarily oriented parallel to the bathymetric contours though this may be biased by the orientation of the acoustic scans in that this type of feature is best seen on the sidescan data when the features are parellel to the vessel track. The cause of these shallow depression features does not appear related to any geologic phenomena such as slumping, sliding, gas venting or ice gouging. They may be associated with some form of biological activity though this is not confirmed at this time. No other noteable features were observed on the sidescan sonar records over this site region.

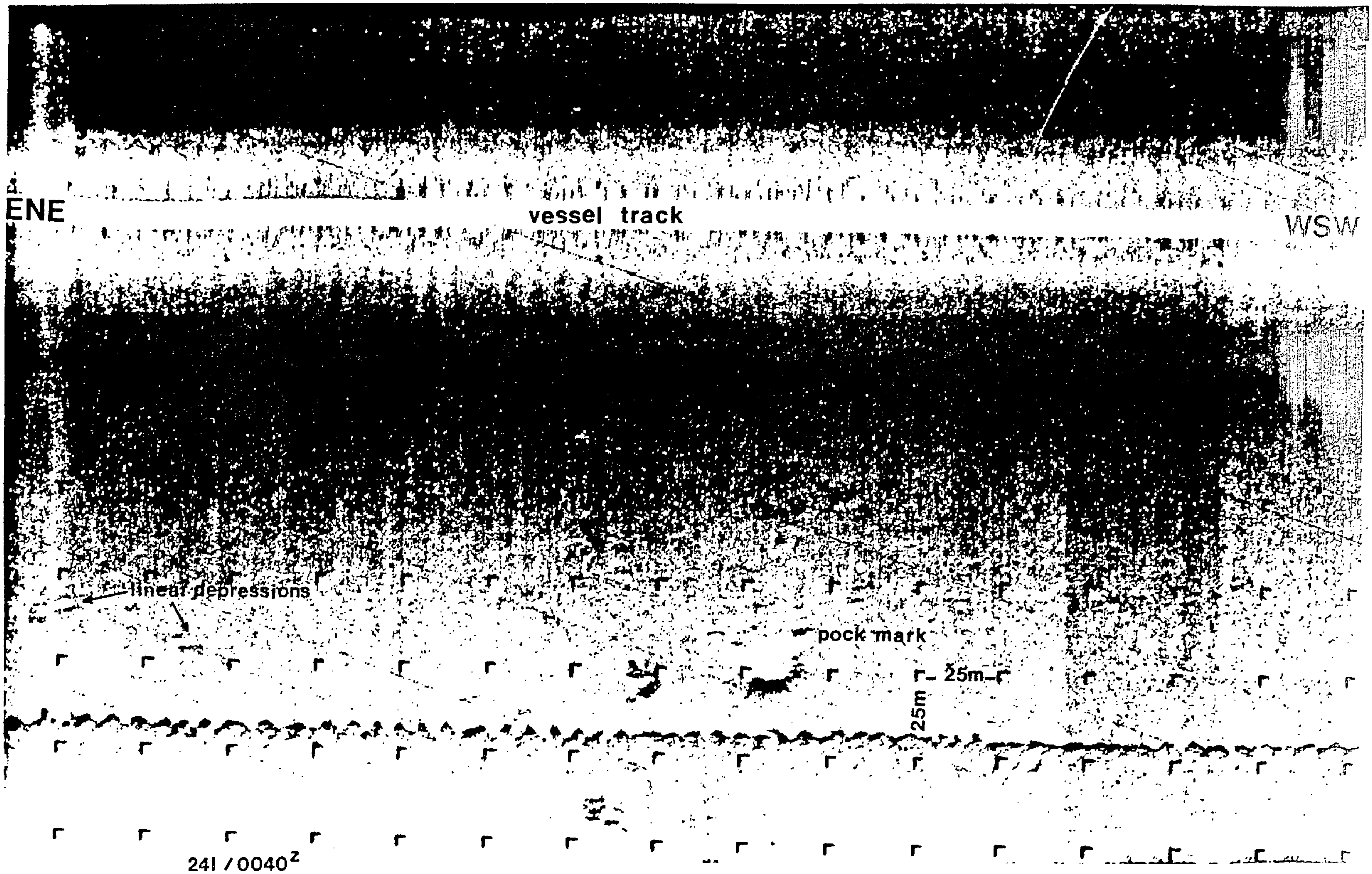

FIGURE: 4

Example Sidescan Sonar record indicating featureless seafloor with occassional Trough features and the single pock mark feature observed on the site.

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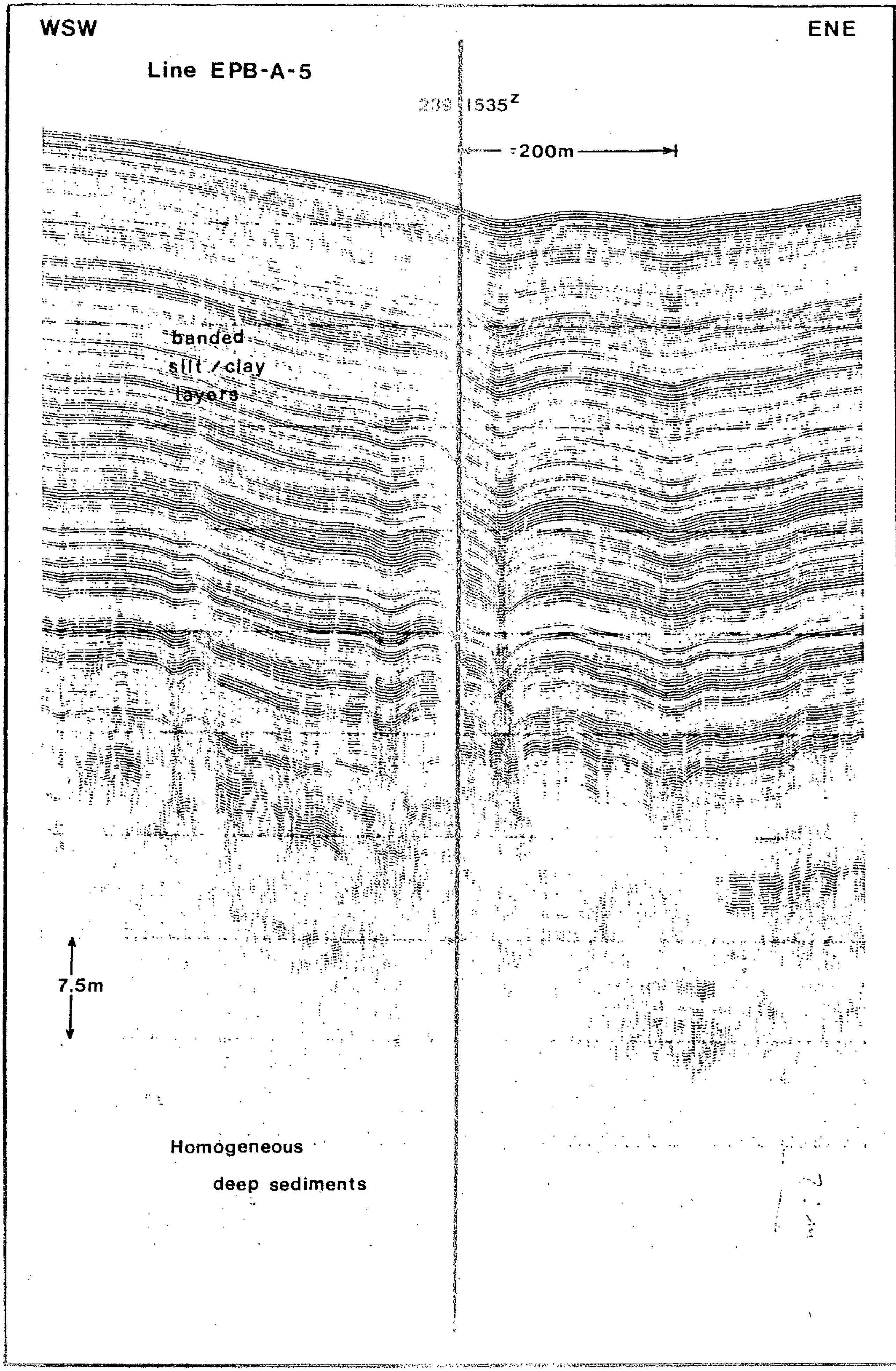
SECTION 4

SUBSURFACE GEOLOGY

The 3.5 kHz acoustic profiler records collected on this program show a sequence of finely layered acoustic reflectors that are conformable in nature to a depth of 50 to 80 msec. below the seabed (38 to 60 metres). Figure 5 shows an example profiler record from within the site region with the layered conformable sediment overlying an homogeneous deeper sedimentary unit which shows little of no structure on these data. The deeper sediments are likely associated with a different depositional environment possibly during a lower stand of sea level during the late Pleistocene or early Holocene periods. Little can be said about these deeper sediments from the acoustic records obtained during this study. The shallower sediments are conformably draped on the more irregular deeper stucture and show virtually no deformations such as slumping or sliding within the site region. The acoustic and geometric character of the soft layered sediments is suggestive of pelagic sedimentation in that the deeper topography is carried upward through the section showing a slow decrease in the amplitude of the topographic features with increasing thickness of the sediments. This character indicates deposition under quiescent conditions with the sediments being rained gently down upon the seabed with little or no influence from currents or more active processes.

The relatively deep penetration of the high reolution 3.5 kHz profiler system is indicative of soft marine sediments with a high water content and generally associated low shear strength. The surficial samples of these sediments indicated fine grained silts and clays, from visual inspection, and these materials are most likely continuous to the depth limit of the well banded acoustic horizons. The banding is normally associated with very minor differences in composition or density of the sediments that may simply represent variations in the rate or source of sediment supply or some other subtle change during deposition. Over the site area these materials are thickened slightly within the south central region of the site (60 metres, 80 msec.) but thin both up and down slope to a nominal thickness of 38 metres (50 msec.). Within the site survey region there is no indication of a cause of this observation though it is probably associated with the shape of the underlying basal unit and the fact that in the upper slope region the area is closer to a source of additional material from up on the shelf. The north south tie line through the site indicated a small scale topography within the site region which is not observed on the 10 metre bathymetric contour map. These smaller scale irregularities on the topography are thought to be the remnant expression of the deeper (40-60 metre subseabed) subbottom surface which has been preserved through the pelagic sedimentation to the current seabed. These features are felt to be of little or no concern with regard to the disposal of materials on the seabed.

In the northwestern corner of the site area a localized region (Figure 6) was noted where extensive masking of the conformable layering occurs. Within this area a noteable increase in the acoustic signal strength from the top of the feature is observed and a brightening or increase in reflectivity of the conformable layering adjacent to zone is seen. This phenomenon is normally associated with shallow gases trapped within the sediments which mask deeper penentration and provide a strong acoustic signal themselves. This shallow gas phenomenon was only observed within the one local area in approximately 300 metres of water. Because no other indications of shallow gas were noted within the shallow sediments it is assumed the gas has leaked upward from deeper within the sediment column. From these data it cannot be determined if this is biogenic (methane) derived gas or if it is associated with some much deeper structure. The pock mark feature noted on the sidescan records may be related to an earlier gas leak of a similar nature which has vented the gases completely from the shallow sediments and thus removed the characteristic high amplitude acoustic signature.



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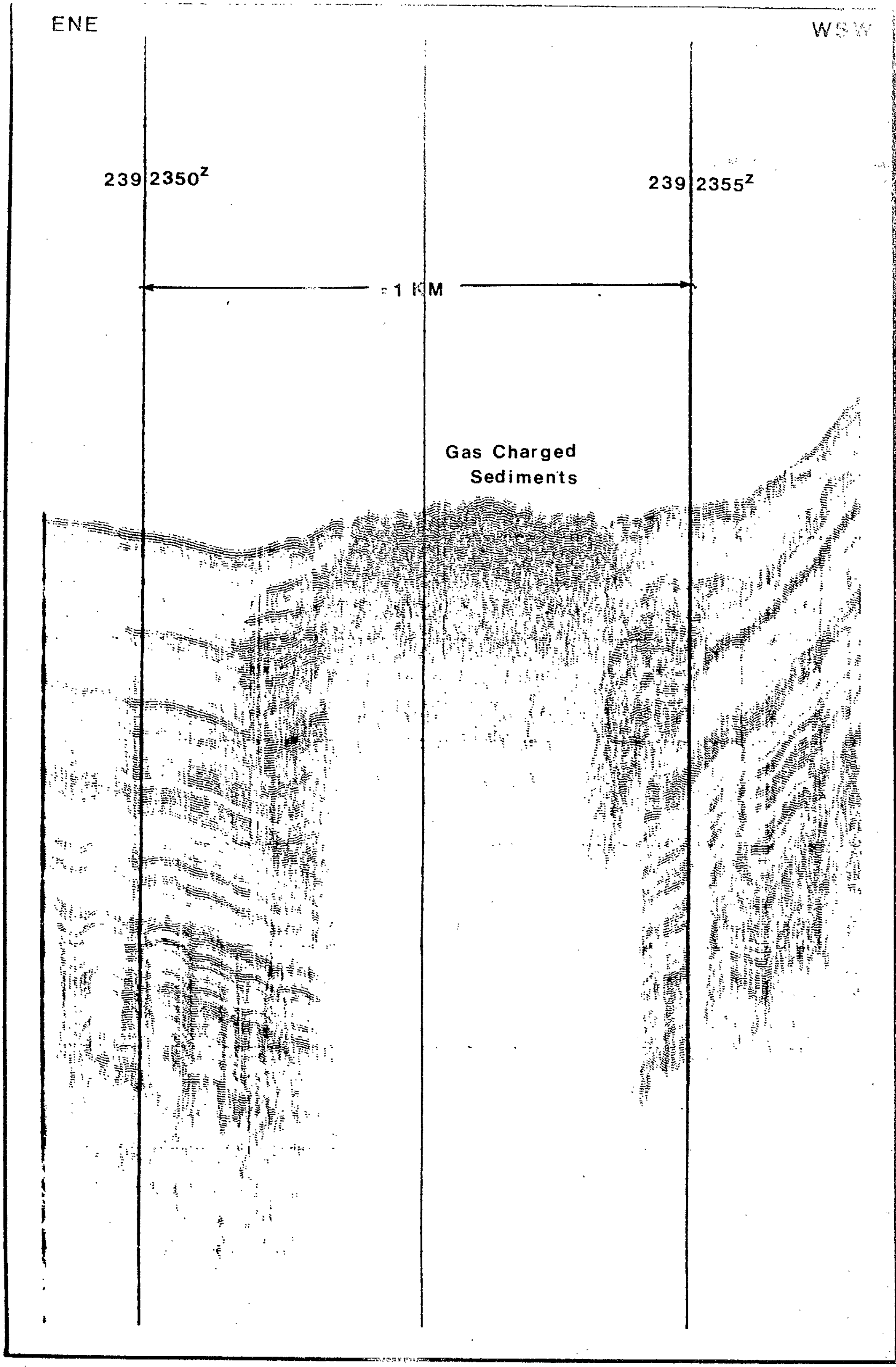
Example 3.5 kHz profiler record showing the finely layered silt and clay sedimentary cover on the site

FIGURE: 5



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Shallow gas feature observed in the northwest corner of the site area

FIGURE 6

APPENDIX B

DUMPSITE B
HERSCHEL-MACKENZIE TROUGH AREA
BEAUFORT SEA
SURFICIAL GEOLOGY AND SEABED DESCRIPTION
AUGUST 1986

Submitted by:
John Lewis
Earth & Ocean Research Limited
22 Waddell Avenue
Dartmouth, Nova Scotia

DUMPSITE B
HERSCHEL-MACKENZIE TROUGH AREA
BEAUFORT SEA
SURFICIAL GEOLOGY AND SEABED DESCRIPTION
AUGUST 1986

Submitted to
Glen Packman
Environmental Protection Service
Environment Canada
Western and Northern Region
NWT District Office
Box 370
Yellowknife NWT
X1A 2N3

Submitted by:
John Lewis
Earth & Ocean Research Ltd.
22 Waddell Ave
Dartmouth Nova Scotia

E.P. Project Leader:	N.W.T	Glen Pachman
E.P. Project No.:		
E.O.R. Project Mgr:		John Lewis
E.O.R. Project No.:		86-11
Submission Date:		January 10, 1987

TABLE OF CONTENTS

SUMMARY

This preliminary survey of a dumping site off the Yukon Beaufort coast was conducted during August of 1985 on board the CSS TULLY as a combined Biological, Chemical and Geological reconnaisance. The program was designed as a baseline evaluation of a potential solid waste dumpsite. This report presents an evaluation of the surficial geology and bathymetry over the site in it's pre use configuration.

The site area bathymetry dips gently toward the North at a slope of approximately 1 in 360 (0.16^{o}). The contours are slightly concave in a northward direction and the water depths range from 137 metres in the southwest corner to 158 metres in the north central portion of the site. The seabed is smooth and regular with very occassional and scattered debris observed on the seabed. Some of these debris appear to be logs or branches that had become water logged after drifting to the site region via the Mackenzie River, other features observed consist of shallow depressions that are linear in shape and from 5 to 15 metres in length. These features are of unknown origin and may be related to some form of biological activity. Within the southeastern quadrant of the site area the seabed shows a patchy higher reflectivity pattern that has no particular orientation and is probably associated with biological concentrations of organisms as no indications of sedimentological grain size differences were noted from the grab sampling program conducted during the survey. The subseabed conditions show a finely layered conformable soft sedimentary cover of at least 25 to 35 metres thickness over the entire site with no unusual features observed. These surficial sediments are composed of fine silts and clays as determined from the 30 grab stations over the site region and the acoustic transparency of the 30 metre thick surficial sediments indicates this is consistent to at least these depths. These finely banded sediments overly a more irregular surface that is not clearly defined on the profiler data. These deeper sedimentary horizons most likely constitute similar sedimentary characteristics and type that have been structurally modified (to the acoustic records) by sediment loading and de-watering or degassification of these deeper materials. These material types are consistent to the limits of penetration of the acoustic system used on this program.

SECTION 1

INTRODUCTION

During the period August 24 to 26 of 1986 a program of survey and biological and chemical sampling was conducted over a 36 km^2 area within the Mackenzie Trough centered on the location 69°40'North and 138°30' West. This area is shown in the Location map of Figure 1. The program was designed as a baseline evaluation of a potential dumpsite for metal and concrete waste materials associated with northern oil exploration and construction. The program was conducted under the direction of Environmental Protection, Environment Canada, Western and Northern Region using the CSS TULLY as the survey vessel. The chemical and biological evaluations of the region are covered under separate reports while this report is oriented to the bathymetry, sidescan sonar and subbottom profiler physical description of the site area.

The survey program consisted of 9 survey lines of 6 km length run in a north south orientation and 1 tie line of 10 km length run in an east west orientation. The survey track plot is shown in Figure 2, Enclosure 1. The central 7 north south lines were run at a 500 metre line spacing to allow a 100% bottom coverage of the sidescan sonar (250 metre range per side) while the outer lines and tie lines represent a continuity coverage over the whole site area. Bathymetric sounding, 3.5 kHz subbottom profiler and sidescan sonar were run on all lines of this grid program. The sounding data were collected by the Canadian Hydrographic Service (CHS) who were in charge of the vessel under the direction of Chief Hydrographer Mike Woods. The subbottom and sidescan equipment was provided by agreement from Mr Steve Blasco of the Atlantic Geoscience Centre, Department of Energy Mines and Resources, and was operated and maintained through this program by Mr J. Lewis of Earth & Ocean Reasearch Ltd. This report represents an evaluation of these data with respect to the surficial geology and seabed characterization of the site prior to initiation of any dumping within the region.

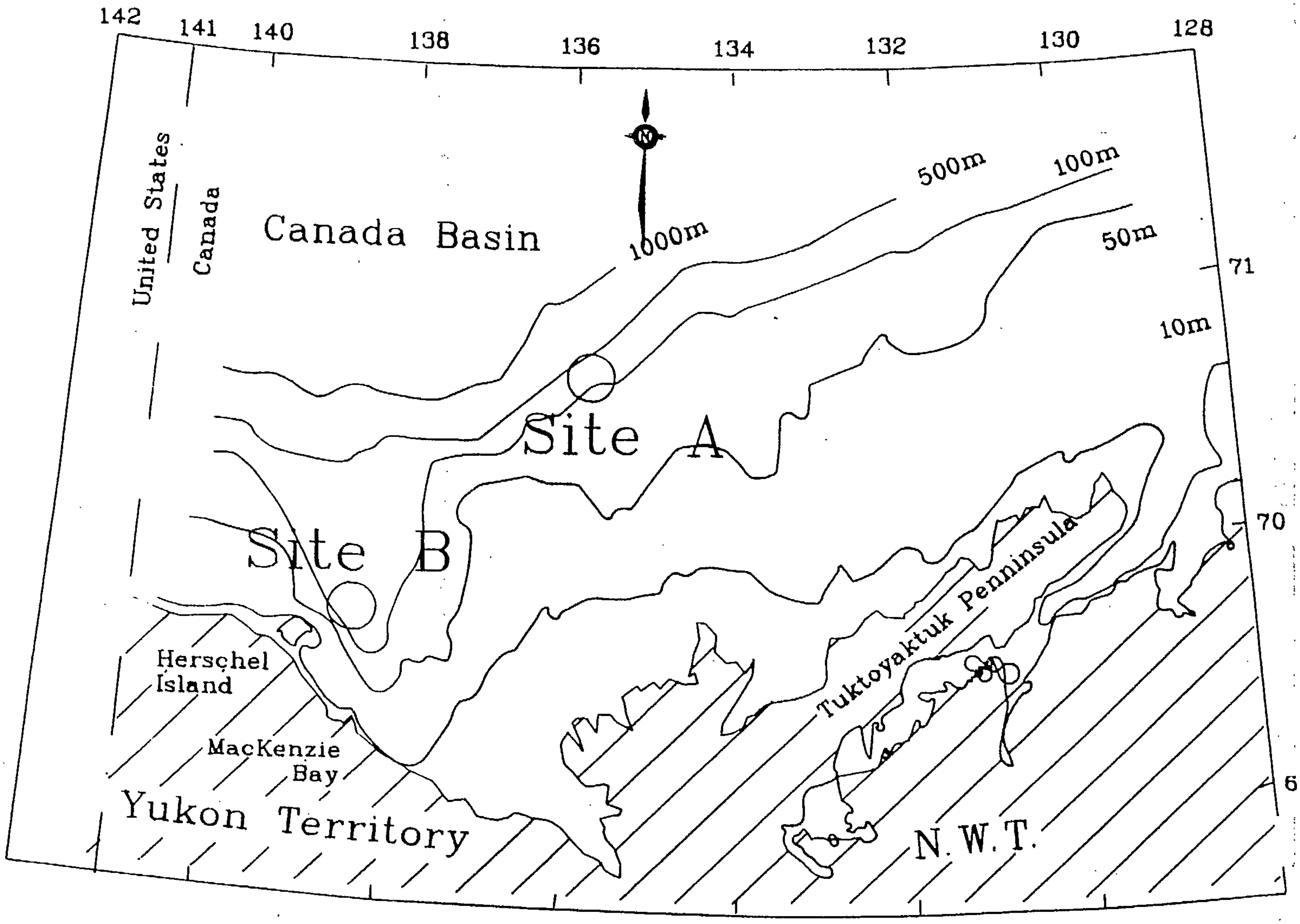
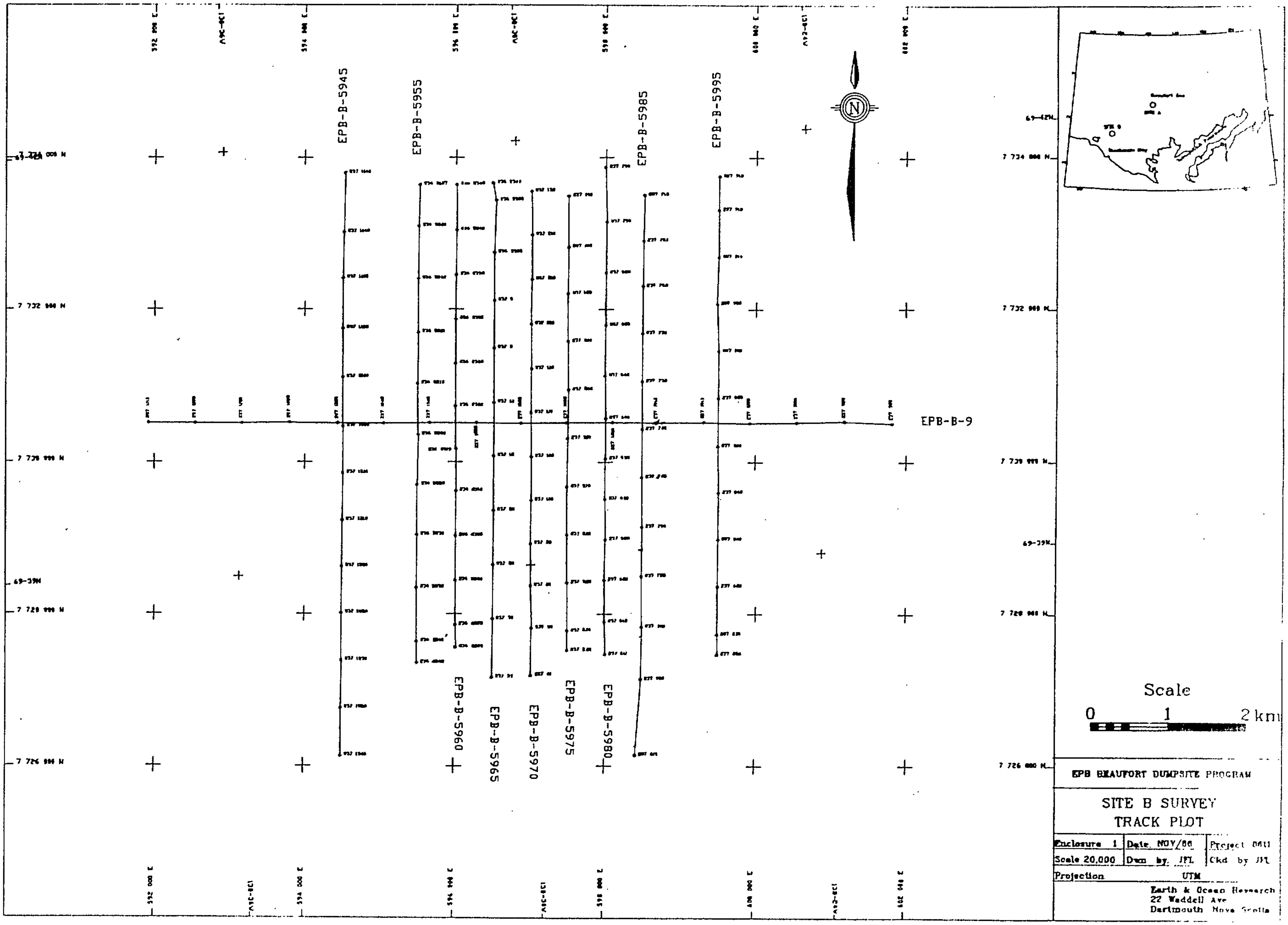


Figure 1: Location Diagram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EPB BEAUFORT DUMPSITE PROGRAM
SITE B SURVEY
TRACK PLOT
Enclosure 1
Date NOV/86
Scale 20,000
Projection
UTM
Earth & Ocean Research
22 Waddell Ave
Dartmouth Nova Scotia

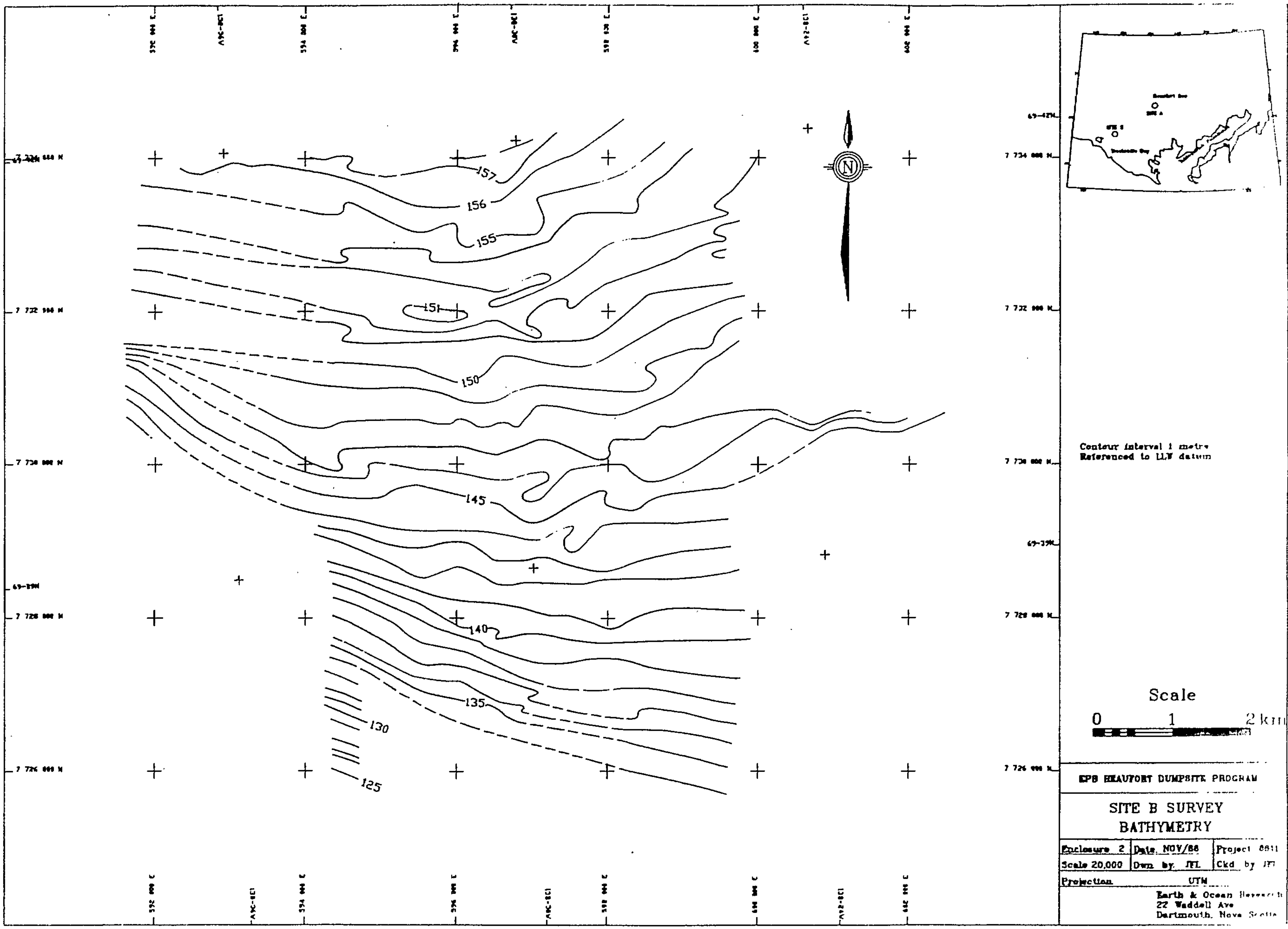
FIGURE 2

SECTION 2

SITE BATHYMETRY

The bathymetric soundings over this site were collected to Hydrographic Survey standard by the CHS surveyors aboard the vessel. The soundings were taken using a Raytheon DSF 6000 survey sounder and logged on magnetic tape. These data were edited, corrected for vessel draft, tide variations, and velocity of sound in seawater before being posted on the survey track map. The velocity of sound in seawater was 1440 metres per second as measured by velocimeter profile within the site area. Tidal corrections were based on predicted tides for the region and sounding crossover errors were less than one metre within the region.

The bathymetric contour map of Figure 3, and Enclosure 2 shows the one metre isobaths for the site and indicates that the seabed is slightly undulous forming a gently northward dipping, concave surface. The regional dip over the site area is approximately 1 in 360 (0.16°) over the central regions of the area. At the southern extremities of the site area the slope increases slightly to approximately 1 in 240 (0.24°). The undulations within this overall shape are very low amplitude being in the order of one metre or less over 200 to 400 metres.



157
156
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Contour interval 1 metre
Referenced to LLW datum
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EPB BEAUFORT DUMPSITE PROGRAM
SITE B SURVEY
BATHYMETRY
Enclosure 2
Date NOV/86
Scale 20,000
Dwn by JFL
Ckd by JFL
Projection UTM
Earth & Ocean Research
22 Waddell Ave
Dartmouth, Nova Scotia

FIGURE 3

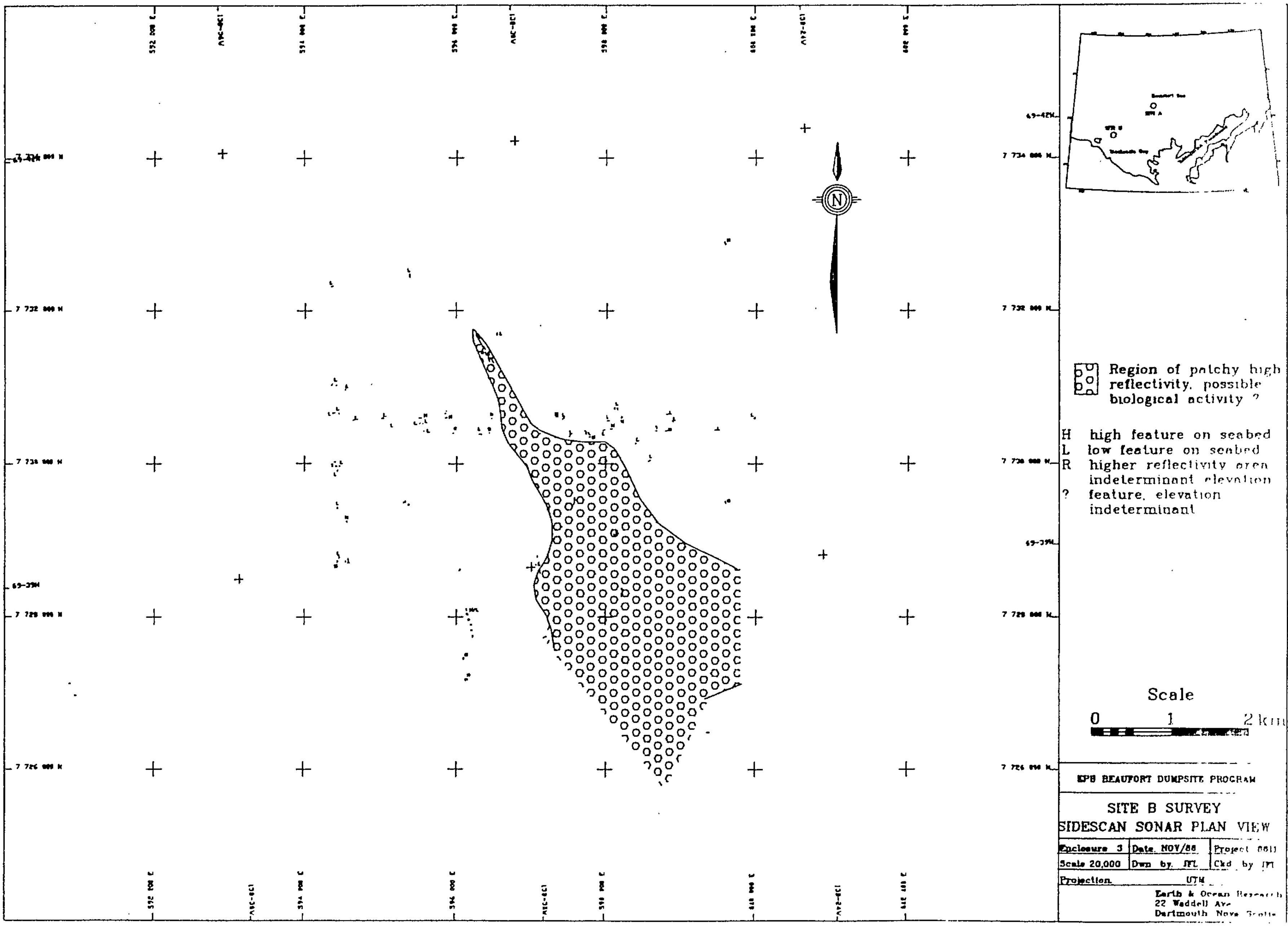
SECTION 3

SEABED FEATURES

The seabed features over the site area were investigated with a Klein Sidescan Sonar system using a 100 kHz standard towfish. The fish was towed behind the survey vessel during the sounding lines with the return acoustic signals being recorded on a wet paper recorder aboard the vessel. The signals represent a perpendicular acoustic scan of the seabed out to a range of 250 metres on either side of the vessels track. The scans were repeated at intervals of 0.33 seconds while the line was transited and were recorded on a linescan recorder to build a composite acoustic reflectivity picture of the seabed. The system used for this program additionally had the capability of correcting the slant range display of the data to represent true distances on either side of the track line. Within the central 4 km. of the grid area the program was designed for 100% coverage while at the extremities of the region only 50% coverage was achieved.

The sidescan records indicate two basic seabottom characteristic types within the site area. The majority area is in the north and west and consists of a featureless seafloor that is of uniform low acoustic reflectivity. In the southeastern quadrant of the site area the seabed takes on a mottled appearance of slightly higher reflectivity patches. These regions are identified on the maps of Figure 4 and Enclosure 3. The patchy character of this area is subtle in nature and may simply indicate a slightly higher concentration of biota within the region. No indications of significant variation in sediment grain size were noted by visual observation during the seabed sampling program that would suggest a geological cause for this mottled higher reflectivity pattern.

Other features noted within the site area were small (5 to 10 metre length) depressions within the surficial sediments and some localized features that had a small positive relief which would probably be logs or branches that had travelled down the Mackenzie and become waterlogged and sunk on site. Some of these features are shown in the example record of Figure 5 and they have been mapped on Figure 4. The features are randomly spaced over the site and average approximately 2 to 5 features per half square km. At present there is no apparent geologic or current derived phenomena that can adequately explain the cause of the shallow depression features. The depth of the depressions cannot be accurately determined with sidescan sonar and no features were observed on the profiler or sounder records which could be correlated to those features observed on the sidescan records.


Region of patchy high reflectivity, possible biological activity ?
H high feature on seabed
L low feature on seabed
R higher reflectivity area indeterminant elevation
? feature, elevation indeterminant
Scale
0 1 2 km
EPB BEAUFORT DUMPSITE PROGRAM
SITE B SURVEY
SIDESCAN SONAR PLAN VIEW
Enclosure 3
Date NOV/88
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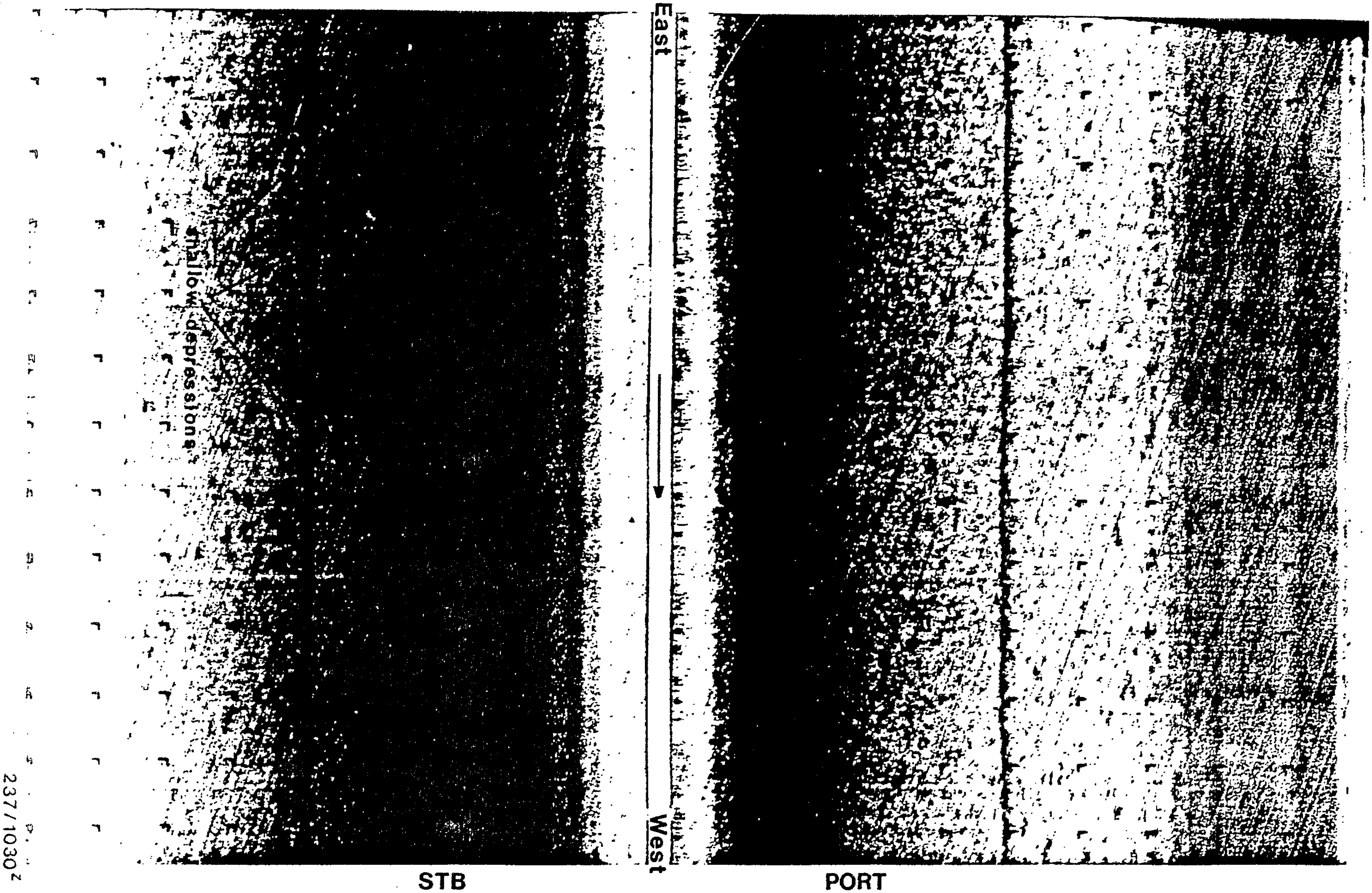
Projection UTM
Earth & Ocean Research
22 Waddell Ave
Dartmouth Nova Scotia

FIGURE 1



Example Sidescan Sonar record indicating featureless seafloor with occassional debris

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FIGURE: 5

SECTION 4

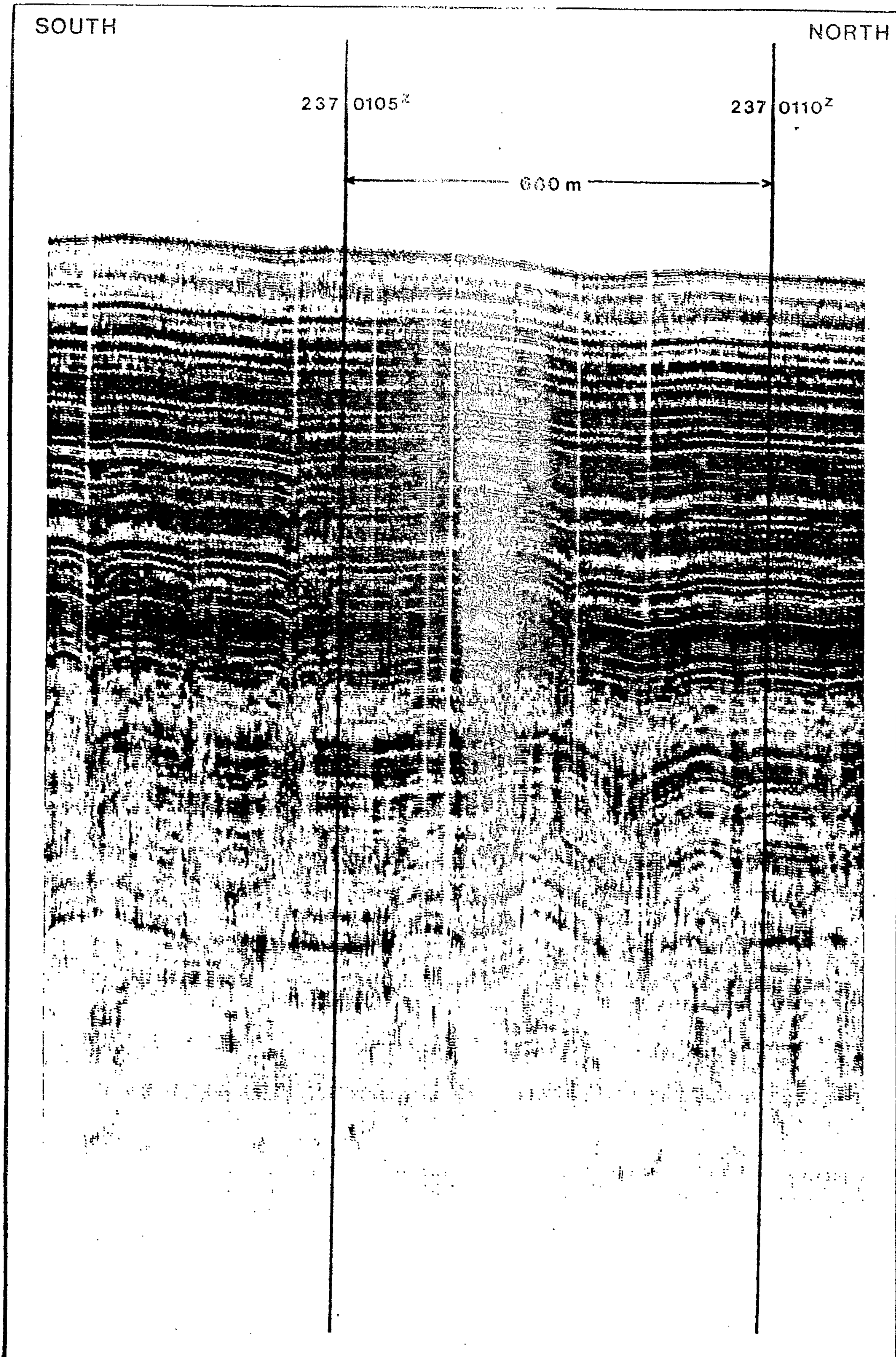
SUBSURFACE GEOLOGY

The 3.5 kHz acoustic profiler records collected on this program show a sequence of finely layered acoustic reflectors that are conformable in nature to a depth of 35 to 48 msec. below the seabed (26 to 36 metres). These conformable sedimentary horizons thin in a northward direction and and are uniform in acoustic appearance over the site area. The reflecting horizons are shown in Figure 6, as an example of the structure near the centre of the site area. Below the upper conformable sequence the sediments appear to be similar in nature though they have lost some of their well banded regular appearance and appear slightly more deformed than the upper materials. These sediments were most likely deposited in a conformable manner to those overlying and a process of de-watering or de-gassification has taken place which has resulted in the minor contortions observed on these reflecting horizons. Over much of the site area the lower horizons show a similar banded reflecting character to the overlying sediments though they have been disturbed or broken by one or more of the processes described above or possibly by ice scouring during a lower stand of sea level in the past. These lower sediments are continuous to the limit of penetration of the system employed or approximately 60 to 70 metres below the seafloor.

Localized areas show regions where the layering of the deeper sediments has been masked or blanked out. A similar phenomena has been reported by Josenhans (personal comm.) in soft sediment areas of the Yukon Shelf and he believed it to be the result of ice or iceberg grounding which have disturbed the highly water saturated sediments in such a manner that the acoustic reflectivity of the sediments have been modified and the banding no longer appears. This is consistent with the deep penetration of this high resolution system and the approximate depth of the boundary possibly represent a low stand of sea level where sea ice has influenced the bottom sediments. The thickness of the overlying sediments implies something greater than a few thousand years in age for these deeper sediments.

The strong reflecting horizons noted in the upper sediments are indicative of significant acoustic reflectivity contrast between the layering, though this is inconsistent with the depth of penetration observed with the high frequency system used. Thus the strong signals and banded nature of the sediments may be enhanced by gas entrapment within these sediments. This phenomenon is not well understood and has different effects on the different acoustic systems used in marine profiling related to their frequency spectrums. The gasses would most likely be of biogenic origin (methane) as opposed to authogenic gases (ethane etc.) leaking up from deeper structures because of their widespread and even distribution. The presence of these gasses is consistent with a deltaic sedimentary environment and would normally be expected in a region such as the Mackenzie Trough. Gassy sediments have been reported by Meagher (1985), Meagher and Lewis (1986) and O'Connor (1984) within other areas of the MacKenzie Trough region.

The surficial sediments on the site consisted of fine grained silts and clays as seen from the sampling program conducted on this reconaissance. The acoustic records suggest these sediments are highly water saturated and therefore relatively low in shear strength as normally stiffer sediments would severely restrict the depth of penetration of the 3.5 kHz profiler system. This is consistent with a sediment composition of fine grained silty clays to approximately 60 - 70 metres sub seabed. No significant unconformity structures or structures indicating tectonic activities such as faulting or folding were noted on any of the records collected from the site area.



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Example 3.5 kHz profiler record showing the finely layered silt and clay sedimentary cover on the site

FIGURE: 6

REFERENCES

Lewis, C.F. and Meagher, L.M., 1986. Upper tertiary and Quaternay Geology and Morphology of the Beaufort (Yukon) Continental Shelf and Slope. Preliminary Report submited to the Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

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APPENDIX C

INDIVIDUAL HYDROCARBONS IN DUMPSITE SEDIMENTS

COMPOSITE

SAMPLE ID	1-01	1-01B1	1-01B2	1-01B3	1-01C	1-03	1-04	1-05	1-08	1-09	1-10
NAPHTHALENE	40	43	39	33	39	35	4	35	34	23	37
FLUORENE	16	20	18	14	16	17	11	18	14	15	15
PHENANTHRENE	99	110	89	92	92	101	110	100	100	71	110
ANTHRACENE	3	3.6	2.6	2.3	3.9	3.7	15	3.4	13	3	16
FLUORANTHENE	20	21	19	18	25	17	12	16	14	10	14
PYRENE	32	42	33	30	41	28	25	26	29	18	24
BENZ(a)ANTHRACENE	8.3	11	10	11	8.5	8.2	5.2	12	8.3	6.4	6
CHRYSENE	68	85	65	63	60	75	62	91	60	52	50
BENZOFLUORANTHENES	59	70	57	51	64	56	55	57	58	30	45
BENZO(e)PYRENE	79	91	73	71	82	77	69	74	77	38	62
BENZO(a)PYRENE	13	14	13	12	14	10	17	14	16	5.7	14
PERYLENE	220	240	200	180	210	180	160	200	170	110	170
BENZO(g,h,i)PERYLENE	72	95	83	72	91	<18	69	78	50	39	60
DIBENZ(a,h)ANTHRACENE	12	18	12	11	17	<20	<3.1	8.8	<1.3	<4.1	.61
INDENO(1,2,3c,d)PYRENE	7.9	8.8	8.2	5.0	6.9	43	11	8.7	11	3.6	8.8
SUM	750	870	720	660	770	650	620	740	650	420	630

SAMPLE ID	1-12	1-13	1-14	1-14B	1-14C1	1-14C2	1-14C3	1-17	[illegible]	1-22
NAPHTHALENE	40	33	36	41	41	38	36	30	38	32
FLUORENE	18	23	17	18	18	19	16	15	22	15
PHENANTHRENE	88	97	100	92	88	98	76	86	88	96
ANTHRACENE	4.2	15	2.9	3.5	2.3	3.5	1.8	2	3.7	3
FLUORANTHENE	21	16	3.1	19	17	19	17	12	21	3
PYRENE	37	32	5.9	36	35	39	30	24	31	6
BENZ(a)ANTHRACENE	13	6.8	10	9.2	9.8	10	9.0	8.4	16	10
CHRYSENE	65	51	82	73	57	78	50	55	63	73
BENZOFLUORANTHENES	53	49	58	54	55	65	49	49	57	54
BENZO(e)PYRENE	74	65	80	79	79	90	67	67	78	69
BENZO(a)PYRENE	7.1	14	10	11	15	14	13	11	18	10
PERYLENE	200	150	200	190	210	220	170	150	190	170
BENZO(g,h,i)PERYLENE	75	65	82	84	77	91	63	64	69	75
DIBENZ(a,h)ANTHRACENE	<5.9	<.93	13	13	17	14	13	16	10	21
INDENO(1,2,3c,d)PYRENE	8.2	3.2	4.9	6.7	7.0	7.3	5.8	4.1	8.2	4.4
SUM	700	620	700	730	730	810	620	590	730	640

SAMPLE ID	1-24C1	1-24C3	1-25	1-27	1-28	1-30	2-01	2-03	2-05	2-06
NAPTHALENE	33	29	35	34	44	37	31	26	27	41
FLUORENE	16	17	1	19	17	19	11	14	12	15
PHENANTHRENE	90	83	99	100	85	110	66	62	74	69
ANTHRACENE	3.6	3.1	9.6	4.2	3.8	4.6	3.4	1.8	1.9	2.1
FLUORANTHENE	3.3	15	17	3.2	20	3.6	15	13	13	15
PYRENE	5.3	28	29	5.4	32	6.1	26	23	24	27
BENZ(a)ANTHRACENE	10	8.5	8.4	10	14	10	10	6.7	7.2	9.7
CHRYSENE	65	59	49	79	58	78	46	37	49	47
BENZOFLUORANTHENES	54	52	43	54	56	54	44	35	47	[illegible]
BENZO(e)PYRENE	70	69	55	75	77	69	33	49	55	50
BENZO(a)PYRENE	12	11	12	9.5	19	[illegible]	14	[illegible]	9.2	9.2
PERYLENE	180	160	140	180	200	190	180	150	170	140
BENZO(g,h,i)PERYLENE	73	67	57	58	72	89	59	37	54	51
DIBENZ(a,h)ANTHRACENE	17	20	<1.0	14	14	<7	7.1	<.90	18	<1.0
INDENO(1,2,3c,d)PYRENE	3.5	6	6.6	3.1	9.5	3.8	6.0	4.9	[illegible]	12
SUM	640	510	560	680	720	630	[illegible]	400	550	530

SAMPLE ID	2-07	2-09	2-10	2-12	2-15	2-19	2-23	2-24	2-27	2-30
NAPTHALENE	50	26	31	24	28	30	30	23	25	32
FLUORENE	14	13	16	12	13	22	16	13	13	20
PHENANTHRENE	78	69	69	60	74	84	77	65	71	97
ANTHRACENE	2.5	2.2	2.9	2.3	2.5	1.8	2.2	1.8	1.4	3.0
FLUORANTHENE	18	12	14	14	16	17	15	14	12	14
PYRENE	29	21	24	22	26	26	26	24	22	26
BENZ(a)ANTHRACENE	11	6.0	8.6	5.5	7.3	8.5	7.5	5.9	10	10
CHRYSENE	61	43	48	36	45	50	47	37	39	51
BENZOFLUORANTHENES	46	38	41	30	49	51	47	45	33	31
BENZO(e)PYRENE	[illegible]	48	57	38	52	60	54	[illegible]	41	36
BENZO(a)PYRENE	11	[illegible]	10	6.7	9.1	13	10	10	6.7	6.4
PERYLENE	160	[illegible]	160	130	160	170	190	190	140	150
BENZO(g,h,i)PERYLENE	56	55	52	39	32	65	60	58	42	42
DIBENZ(a,h)ANTHRACENE	6.4	12	[illegible]	13	15	20	22	14	11	12
INDENO(1,2,3c,d)PYRENE	14	[illegible]	13	[illegible]	3.0	6.9	2.5	4.2	3.6	3.2
SUM	610	[illegible]	[illegible]	[illegible]	590	630	610	560	470	510

DUMPSITE ALKANES APPENDIX

DUMPSITE ALKANES

SAMPLE ID	1-01	1-01B1	1-01B2	1-01B2A	1-01B2A	1-01B2A	1-01B2B	1-01B3	1-01C	1-03	1-04	1-06	1-08	1-08	1-08	1-09	1-10	1-12
nC-12	150	510	160	450	460	560	8.9	570	790	660	270	350	770	650	770	290	200	300
nC-13	220	770	300	560	570	700	8.7	770	1100	860	360	490	990	870	1100	370	300	430
FARNESANE	100	200	86	160	110	130	21	190	270	320	77	200	260	230	280	130	110	180
nC-14	280	740	320	530	500	610	66	670	910	810	240	580	780	580	890	350	340	650
TM-13	160	510	260	330	310	360	130	430	620	600	120	430	460	410	610	190	270	410
nC-15	300	820	450	610	570	690	170	660	950	1000	240	590	840	820	860	350	410	900
nC-16	340	580	390	510	500	600	300	470	610	530	210	620	560	640	660	220	330	930
NORPRIS	190	240	170	210	180	220	140	190	230	210	70	490	250	280	230	100	150	280
nC-17	580	500	420	480	420	560	320	420	450	550	180	710	500	520	570	230	450	640
PRISTANE	390	490	360	380	380	430	300	410	430	480	150	630	470	480	340	240	380	740
nC-18	510	270	260	270	240	290	200	270	190	400	130	620	240	240	210	160	370	480
PHYTANE	340	210	170	200	160	190	160	180	150	290	73	420	180	170	190	120	260	390
nC-19	630	200	210	230	170	190	180	220	150	310	110	490	210	210	200	150	360	710
nC-20	480	140	190	190	180	220	160	200	96	270	82	480	180	160	180	130	290	330
nC-21	500	120	140	160	150	170	170	200	8.8	240	75	520	170	150	140	120	270	480
nC-22	430	94	110	130	130	110	120	130	72	170	60	280	130	120	120	88	210	280
nC-23	480	120	150	20	220	200	150	170	88	220	80	390	170	160	180	110	270	310
nC-24	340	87	98	170	180	170	110	110	55	140	57	280	120	110	130	80	160	220
nC-25	390	130	120	180	190	180	150	150	91	180	83	420	200	170	200	100	230	320
nC-26	180	64	80	*	*	*	89	77	45	91	47	200	100	91	96	<13	120	170
nC-27	380	170	190	*	*	*	220	190	120	190	120	460	290	250	250	120	260	430
nC-28	120	56	60	*	*	*	73	55	38	<15	38	140	100	90	90	<15	86	160
nC-29	290	260	220	*	*	*	260	190	190	180	140	460	350	330	290	<16	250	520
nC-30	93	43	45	*	*	*	63	39	<33	<16	26	96	75	69	54	<17	63	100
nC-31	190	160	170	*	<30	<39	240	130	120	120	87	340	300	280	270	<19	180	460
nC-32	72	<42	36	<24	<33	<42	<51	22	<36	<16	37	74	66	68	140	<20	<13	70
nC-33	<9.6	<45	59	<26	<35	<45	<56	<9.6	<38	<16	29	<15	<31	<40	150	<21	<13	69
nC-34	<9.8	<49	13	<27	<38	<48	<60	<9.9	<40	<17	<22	<15	34	<42	20	<22	<14	260
nC-35	<10	<54	<12	<30	<41	<52	<66	<10	<43	<18	<23	<16	<36	<46	<18	<25	<15	<44
nC-36	<11	<60	<13	<33	<45	<57	<74	<11	<46	<19	<25	<18	<39	<49	<19	<28	<15	<48
SUM	7000	5800	4200	4500	4500	5300	3100	5700	6100	6900	2700	8600	7200	6600	7600	2900	5100	9200

SAMPLE ID	1-13	1-14	1-14B	1-14C1	1-14C1A	1-14C1A	1-14C1A	1-14C1B	1-14C2	1-14C3	1-16	1-17	1-18	1-22	1-24B	1-24C1	1-24C2	1-24C3	1-24C3A
nC-12	360	680	610	340	610	840	880	500	620	380	380	500	300	930	130	380	800	920	200
nC-13	490	950	820	450	770	1000	1000	620	930	560	510	660	420	1200	210	550	1100	1300	260
FARNESANE	130	240	210	110	210	240	380	110	230	140	120	160	170	280	58	140	280	310	70
nC-14	120	890	740	410	660	880	930	540	840	510	420	540	610	950	190	500	960	1100	230
TM-13	210	610	540	270	390	510	640	300	470	350	280	270	390	640	10	340	670	600	150
nC-15	460	970	760	460	660	860	940	590	970	550	460	500	530	940	220	540	1100	1100	270
nC-16	280	760	530	430	460	610	990	460	740	440	370	380	730	560	190	370	780	730	270
NORPRIS	120	330	270	160	180	220	390	190	310	200	150	140	310	280	76	170	330	310	99
nC-17	430	720	660	430	400	470	590	440	660	450	380	360	700	570	210	400	690	580	260
PRISTANE	320	690	610	390	340	450	640	370	640	400	350	290	790	590	150	390	670	630	210
nC-18	260	380	420	280	130	230	430	270	370	270	240	240	690	320	120	210	400	280	180

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SAMPLE ID	2-01	2-02	2-03	2-05	2-06	2-07	2-09	2-10	2-12	2-14	2-15	2-17	2-19	2-20	2-22	2-23	2-24	2-27	2-29	2-30
nC-12	130	270	270	490	480	150	750	350	330	530	350	200	<10	320	300	260	300	240	110	200
nC-13	210	330	340	590	610	250	940	460	390	780	470	280	250	330	410	350	380	330	170	270
FARNESANE	120	80	85	120	140	120	200	120	89	190	120	73	72	96	97	83	90	82	44	70
nC-14	290	270	290	400	540	360	720	350	330	670	410	220	250	330	360	310	300	240	130	250
IM-13	190	200	190	240	360	370	420	180	210	430	270	130	150	180	240	210	160	140	74	140
nC-15	440	290	280	350	550	710	630	350	380	640	430	260	310	370	390	330	270	260	150	260
nC-16	180	200	210	230	420	570	380	260	290	390	320	170	240	160	290	260	230	170	120	170
NORPRIS	120	97	84	87	180	220	140	94	130	140	140	110	110	140	130	110	80	71	52	72
nC-17	190	250	220	220	480	320	300	250	380	320	390	260	260	300	300	280	190	170	150	190
PRISTANE	310	220	180	180	380	510	260	190	300	270	290	200	250	260	290	200	180	150	95	150
nC-18	170	170	130	140	300	410	160	140	260	160	230	180	160	180	190	170	110	100	85	110
PHYTANE	170	120	96	87	210	620	100	95	170	110	150	120	120	120	150	120	83	77	61	69
nC-19	205	170	120	130	280	490	120	120	250	120	210	170	150	20	150	160	100	88	75	110
nC-20	93	200	100	140	320	585	160	120	270	110	200	150	150	180	150	140	93	77	81	110
nC-21	160	190	110	120	270	390	120	120	270	100	180	160	170	200	130	140	82	110	96	130
nC-22	130	130	93	82	220	160	87	96	230	79	160	150	150	160	84	100	60	95	82	110
nC-23	200	220	170	120	360	230	170	160	330	150	240	240	240	290	130	160	95	180	140	230
nC-24	150	120	110	79	230	160	120	110	190	110	160	160	160	210	87	97	58	140	100	120
nC-25	34	230	220	140	440	290	210	200	340	180	270	300	290	380	150	170	110	270	200	310
nC-26	320	95	99	65	210	140	96	99	140	76	130	140	130	170	63	73	42	100	99	110
nC-27	140	300	340	200	610	450	340	310	430	290	350	430	460	570	230	220	160	480	330	520
nC-28	510	65	75	49	180	130	90	77	110	75	100	110	120	150	55	54	36	110	79	110
nC-29	120	310	400	280	750	570	450	370	480	380	400	470	580	700	330	250	200	650	440	700
nC-30	66	42	60	33	220	80	75	53	74	60	72	73	100	110	46	32	25	87	63	77
nC-31	120	230	370	170	560	590	470	360	450	560	330	430	530	650	240	180	160	670	390	690
nC-32	640	32	67	27	95	29	66	48	65	43	57	63	86	94	28	23	19	<39	56	<65
nC-33	110	65	140	47	170	<28	150	<15	110	140	94	130	190	210	<27	51	<11	200	81	<71
nC-34	120	12	<18	<7.6	35	250	<37	<16	15	<33	15	18	<35	28	<29	<7.9	<11	<47	<27	<76
nC-35	<61	<4.8	<20	<7.8	<24	<32	380	<17	<8.1	<36	<9.1	<20	<38	<24	<33	<8.5	<12	<52	<30	<85
nC-36	<67	<4.7	<21	<8.1	<26	<35	<46	<19	<8.7	<40	<9.8	<21	<42	<26	<36	<9.1	<12	<57	<33	<94
SUM	4700	4200	4200	4100	8300	6700	7000	4400	6100	6000	5600	4800	5000	6100	4100	3800	3000	4800	3200	4800

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PHYTANE	180	300	300	200	130	150	340	180	320	200	170	140	450	260	94	160	290	220	130
nC-19	300	280	420	290	210	180	520	250	290	210	230	230	480	260	93	170	280	200	190
nC-20	270	160	330	260	160	130	220	200	200	160	190	210	310	180	78	130	210	130	170
nC-21	240	150	360	230	190	140	170	170	160	140	190	230	770	190	84	170	210	130	220
nC-22	290	96	260	170	140	120	130	130	110	92	140	170	310	120	66	160	120	90	230
nC-23	260	110	310	220	190	160	170	180	130	120	190	210	260	140	110	280	150	120	310
nC-24	200	<21	210	150	150	120	140	130	85	81	130	150	190	83	70	310	92	76	220
nC-25	260	120	270	200	210	170	180	200	120	120	210	220	300	130	120	460	130	120	330
nC-26	130	<25	130	110	120	100	110	100	58	65	99	110	160	56	65	310	70	67	150
nC-27	270	<28	290	220	270	240	240	260	130	160	210	290	430	150	210	1600	160	180	370
nC-28	100	<31	78	72	96	<110	90	96	42	51	58	92	150	40	67	8100	43	73	110
nC-29	280	<34	340	210	290	270	270	320	170	230	170	300	540	310	270	13000	170	280	370
nC-30	72	<37	52	44	73	220	85	91	33	42	37	67	<82	23	54	4900	24	62	75
nC-31	170	<40	130	130	250	<140	250	270	97	130	110	240	500	80	230	<110	91	190	330
nC-32	170	<44	25	35	39	<150	48	38	<21	27	31	38	<100	<15	40	<130	<20	55	37
nC-33	50	<47	<24	39	110	<170	99	110	<22	50	<11	80	<110	<15	92	<140	<20	<29	<36
nC-34	87	<51	<25	13	<39	<180	<34	<37	<23	<18	<12	<22	210	<15	<37	<150	<20	<30	<40
nC-35	<8.0	<57	<26	<13	<43	<200	<37	<41	<25	<20	<12	<24	<130	<15	<41	<170	<21	<32	<44
nC-36	<9.5	<63	<27	<14	<47	<220	<41	<45	<26	<22	<13	<26	<140	<16	<46	<200	<21	<34	<49
SUM	5500	6300	7700	5200	6200	6700	8500	6000	6800	4800	4800	5800	8600	7200	2900	33000	7600	7800	4800

SAMPLE ID	1-24C3A	1-24C3A	1-24C3B	1-25	1-27	1-28	Q1-28	1-30
nC-12	280	220	450	470	910	240	130	700
nC-13	370	280	650	660	1200	340	220	930
FARNESANE	60	59	160	160	300	140	150	230
nC-14	310	240	570	570	970	500	370	770
TM-13	170	150	320	380	530	340	260	440
nC-15	350	270	600	600	970	620	500	610
nC-16	330	280	430	430	620	610	590	630
NORPRIS	120	90	170	190	230	250	220	260
nC-17	310	260	370	430	460	340	210	580
PRISTANE	260	210	300	420	440	630	450	620
nC-18	230	180	230	270	220	290	380	350
PHYTANE	130	120	150	190	170	480	460	270
nC-19	210	220	200	200	180	620	690	340
nC-20	200	210	200	160	120	370	260	300
nC-21	190	180	180	200	130	310	430	330
nC-22	130	160	140	150	110	210	240	230
nC-23	190	220	190	230	150	260	280	280
nC-24	140	150	150	150	120	180	220	190
nC-25	200	240	220	270	220	24	23	280
nC-26	110	120	130	<31	120	330	360	140
nC-27	280	390	310	390	360	160	150	370
nC-28	89	100	100	<40	130	570	470	<30
nC-29	330	360	400	470	520	160	200	370
nC-30	79	79	86	<49	100	510	490	<32
nC-31	310	350	380	310	410	120	180	270
nC-32	35	62	45	<58	79	500	450	<35
nC-33	120	130	140	<64	160	81	92	<36
nC-34	<22	38	38	<70	<47	190	150	<38
nC-35	<24	<13	160	<78	<52	51	33	<40
nC-36	<26	<14	<33	<87	<58	56	<31	<43

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SUM	4800	4700	6400	6000	8300	7600	7100	7900

* Not quantifiable due to co-eluting interferences.

APPENDIX D

LENGTH-FREQUENCY DATA FOR FISH COLLECTED IN TRAWLS AT 150-240 M DEPTHS AT TWO LOCATIONS IN THE CANADIAN BEAUFORT SEA

Appendix . Length - frequency data for fish collected in trawls at 150-240m depths at two locations in the Canadian Beaufort Sea.

Boreogadus saida (Arctic Cod)

Length Interval	Area A				Area B			
	A-2	A-3	A-4	A-5	B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55			2					
56-60			3	4				
61-65	1		17	11				
66-70	1	3	6	12				1
71-75	1	3	5	10				
76-80		3	1	4				
81-85				3				
86-90			1	4				
91-95			2	2				
96-100			1					
101-105	1	1	1	1	1		1	
106-110			1	3			1	
111-115	1			3			1	1
116-120	1		1			1		
121-125	2		1	1	1		1	4
126-130				3			2	2
131-135	2						1	3
136-140		2	1				2	1
141-145			1				1	
146-150						1	1	2
151-155								1
156-160							1	
161-165						1		
166-170								
171-175								

Appendix . Continued.

Arctogadus glacialis (Polar Cod)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60			3	8				
61-65	2		13	19				
66-70	2		4	13				
71-75	2	1	3	5				
76-80			1					

Triglops pingelii (Ribbed Sculpin)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65								
66-70	1							
71-75								
76-80								
81-85								
86-90								
91-95					1			
96-100								
101-105								
106-110								
111-115					1			
116-120								
121-125					1			
126-130								

Appendix . Continued.

Triglops nybelini (Mailed Sculpin)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65			2	1				
66-70			1					
71-75								

Liparis fabricii (Gelatinous Snailfish)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65				1				
66-70								
71-75			1					
76-80			1					
81-85								
86-90								
91-95								2
96-100								
101-105								2
106-110								
111-115								
116-120						1		1
121-125					1			
126-130								
131-135								
136-140								
141-145					1			
146-150								

Appendix . Continued.

Icelus spatula (Spatulate Sculpin)

Length Interval	Area A				Area B			
	A-2	A-3	A-4	A-5	B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60					2			1
61-65					3			2
66-70								2
71-75					1			
76-80								1
81-85								
86-90					1			1
91-95								
96-100								

Icelus bicornis (Twohorn Sculpin)

Length Interval	Area A				Area B			
	A-2	A-3	A-4	A-5	B-1	B-2	B-4	B-5
36-40								
41-45								
46-50					1			
51-55					1			
56-60					1	1		2
61-65					2			
66-70								1
71-75					3			2
76-80					1			
81-85								

Appendix . Continued.

Aspidophoroides olrikii (Arctic aligatorfish)

Length Interval	Area A: A-2	A-3	A-4	A-5	Area B: B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65								
66-70					2			
71-75								

Eumicrotremus derjugini (Leatherfin Lumpsucker)

Length Interval	Area A: A-2	A-3	A-4	A-5	Area B: B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65					1			
66-70								
71-75								
76-80								
81-85								
86-90								1
91-95								1

Raja hyperborea ?

Length Interval	Area A: A-2	A-3	A-4	A-5	Area B: B-1	B-2	B-4	B-5
496-500			1					

Appendix . Continued.

Careproctus reinharti (Sea Tadpole)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55			1					
56-60								
61-65			1					
66-70								
71-75								
76-80			1					
81-85			1					
86-90								
91-95								
96-100				1				
101-105								
106-110								
111-115								
116-120								
121-125								
126-130								
131-135								
136-140								
141-145								
146-150								
151-155								
156-160								
161-165								
166-170								
171-175								
.								
.								
196-200								
.								
.								
221-225								
.								
.								
496-500								

Appendix . Continued.

Lycodes sagittarius (Archer eel Pout)?

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55			1					
56-60								
61-65								
66-70								
71-75			1					
76-80			1					
81-85								
86-90								
91-95			1					
96-100			1					
101-105				1				
106-110				2				
111-115			2					
116-120				1				
121-125								
126-130								
131-135								
136-140								
141-145								
146-150						1		
151-155								
156-160								
161-165								
166-170								
171-175						1		

Appendix . Concluded.

Lycodes polaris (Canadian eel Pout)

Length Interval	Area A A-2	A-3	A-4	A-5	Area B B-1	B-2	B-4	B-5
36-40								
41-45								
46-50								
51-55								
56-60								
61-65								
66-70								
71-75								
76-80								
81-85								
86-90								
91-95								
96-100								
101-105			1		2			
106-110				1				
111-115								
116-120								
121-125			1					
126-130			1					
131-135								
136-140								
141-145				1				
146-150								
151-155					1			
156-160								
161-165					1	1		
166-170								
171-175						1		
.								
.								
196-200						1		
.								
.								
221-225				1				
.								
.								
496-500								

APPENDIX E

DETAILS OF SAMPLE LOCATIONS

Station Locations
Benthic Invertebrates

Dumpsite: "A"

Site Designation	Coordinates (degrees, minutes, seconds) N	W	Depth (m)
1-1	70-38-33	135-50-35	236
1-2	70-38-20	135-50-13	226
1-3	70-38-08	135-50-00	217
1-4	70-37-53	135-50-00	205
1-5	70-37-50	135-51-40	211
1-6	70-38-47	135-50-50	247
1-7	70-39-03	135-49-47	257
1-8	70-38-54	135-48-21	240
1-9	70-38-41	135-49-47	240
1-10	70-38-10	135-49-01	211
1-11	70-38-09	135-47-53	200
1-12	70-37-55	135-47-42	186
1-13	70-37-20	135-47-19	141
1-14	70-37-02	135-51-44	163
1-15	70-37-45	135-51-49	207
1-16	70-37-52	135-52-56	218
1-17	70-38-23	135-53-28	240
1-18	70-38-38	135-52-57	249
1-19	70-38-51	135-54-20	268
1-20	70-39-08	135-54-34	283
1-21	70-39-19	135-52-23	275
1-22	70-39-39	135-52-28	295
1-23	70-39-43	135-51-15	292
1-24	70-39-42	135-49-32	283
1-25	70-39-22	135-49-30	270
1-26	70-39-09	135-48-22	252
1-27	70-39-06	135-47-42	244
1-28	70-39-07	135-46-05	231
1-29	70-39-53	135-46-10	222
1-30	70-38-39	135-47-42	222

Station Locations
Benthic Invertebrates

Dumpsite: "B"

Site Designation	Coordinates (degrees, minutes, seconds) N	W	Depth (m)
2-1	69-39-34	138-29-55	148
2-2	69-39-23	138-28-33	147
2-3	69-39-36	138-28-40	148
2-4	69-39-53	138-28-44	149
2-5	69-40-04	138-28-21	150
2-6	69-40-17	138-27-57	151
2-7	69-40-42	138-29-07	154
2-8	69-40-09	138-30-31	151
2-9	69-39-54	138-30-59	150
2-10	69-40-27	138-31-46	152
2-11	69-40-27	138-32-36	152
2-12	69-40-34	138-31-52	154
2-13	69-41-08	138-33-02	156
2-14	69-41-07	138-31-58	156
2-15	69-41-24	138-32-06	157
2-16	69-41-00	138-30-32	156
2-17	69-41-01	138-29-03	155
2-18	69-41-20	138-27-34	156
2-19	69-40-33	138-26-45	152
2-20	69-39-51	138-26-36	149
2-21	69-39-33	138-25-42	147
2-22	69-39-34	138-26-37	148
2-23	69-39-22	138-27-30	147
2-24	69-38-58	138-29-59	145
2-25	69-38-35	138-31-30	140
2-26	69-38-45	138-31-32	143
2-27	69-38-54	138-33-06	142
2-28	69-39-20	138-32-09	146
2-29	69-39-42	138-32-17	148
2-30	69-39-35	138-33-23	149

Station Locations
Sediment Chemistry and Particle Size

Dumpsite "A"

Site Designation	Coordinates (degrees, minutes, seconds) N	W	Depth (m)
1-1	70-38029	135-50-56	235
1-2	70-38-22	135-50-19	228
1-3	70-38-15	135-50-14	222
1-4	70-37-53	135-50-18	206
1-5	70-37-54	135-51-26	213
1-6	70-38-49	135-50-54	248
1-7	70-39-02	135-49-39	255
1-8	70-38-55	135-48-23	240
1-9	70-38-55	135-50-17	252
1-10	70-38-09	135-48-58	211
1-11	70-38-08	135-47-50	199
1-12	70-37-55	135-47-40	186
1-13	70-37-23	135-47-27	146
1-14	70-37-02	135-51-39	162
1-15	70-37-39	135-51-58	203
1-16	70-37-54	135-52-53	218
1-17	70-38-23	135-53-29	240
1-18	70-38-38	135-52-56	249
1-19	70-38-52	135-54-17	269
1-20	70-39-07	135-54-32	283
1-21	70-39-20	135-52-24	278
1-22	70-39-41	135-52-28	294
1-23	70-39-46	135-51-06	293
1-24	70-39-43	135-49-39	284
1-25	70-39-24	135-49-36	271
1-26	70-39-08	135-48-25	251
1-27	70-39-06	135-47-46	245
1-28	70-39-10	135-46-10	234
1-29	70-38-54	135-46-26	224
1-30	70-39-36	135-47-43	219

Station Locations
Sediment Chemistry and Particle Size

Dumpsite: "B"

Site Designation	Coordinates (degrees, minutes, seconds) N	Coordinates (degrees, minutes, seconds) W	Depth (m)
2-1	69-39-36	138-29-54	148
2-2	69-39-26	138-28-25	147
2-3	69-39-38	138-28-40	148
2-4	69-39-48	138-28-47	149
2-5	69-40-04	138-29-49	150
2-6	69-40-20	138-27-57	151
2-7	69-40-43	139-29-07	154
2-8	69-40-08	138-30-22	151
2-9	69-39-54	138-31-03	150
2-10	69-40-23	138-31-32	153
2-11	69-40-26	138-32-16	152
2-12	69-40-33	138-32-12	153
2-13	69-41-09	138-32-58	156
2-14	69-41-07	138-31-40	156
2-15	69-41-31	138-32-16	158
2-16	69-40-57	138-30-47	156
2-17	69-41-00	138-29-04	155
2-18	69-41-19	138-27-37	156
2-19	69-40-35	138-26-48	152
2-20	69-39-49	138-26-53	149
2-21	69-39-33	138-25-42	147
2-22	69-39-31	138-26-22	147
2-23	69-39-22	138-27-29	147
2-24	69-38-56	138-30-03	144
2-25	69-38-33	138-31-28	142
2-26	69-38-44	138-31-31	143
2-27	69-38-48	138-32-48	142
2-28	69-38-48	138-32-48	142
2-29	69-39-40	138-32-17	145
2-30	69-39-35	138-33-23	149

Field Quality Control - Replicates
(Sediment Chemistry and Particle Size Only)

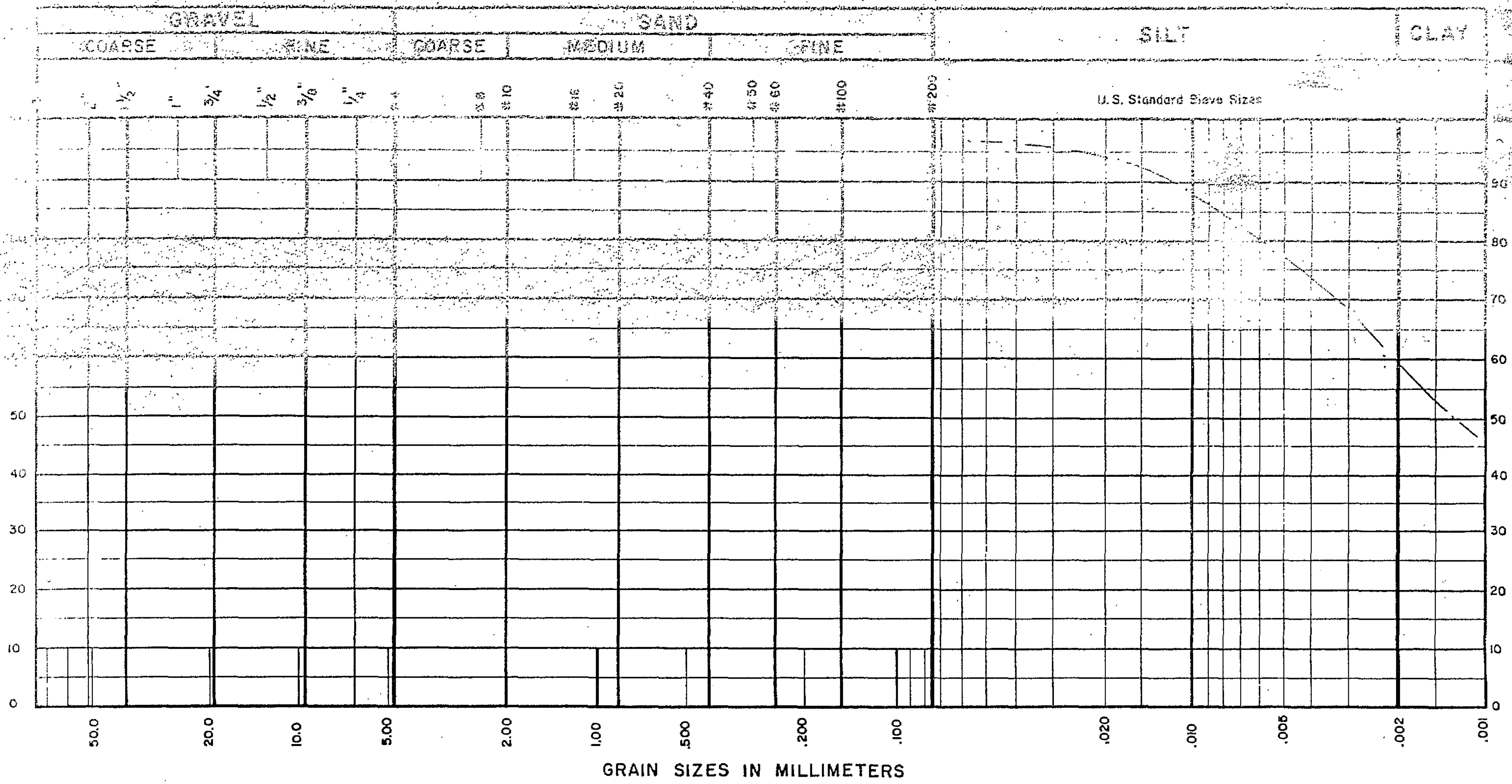
Site Designation	Coordinates (degrees, minutes, seconds) N	W	Depth (m)
1-24b	70-39-43	135-49-43	285 triplicate subsamples taken
1-24C	70-39-43	135-49-22	285
1-14b	70-37-01	135-51-49	164 triplicate subsamples taken
1-14c	70-37-01	135-51-50	164
1-1b	70-38-34	135-50-42	237
1-1c	70-38-33	135-50-37	236 triplicate subsamples taken

Stations in from Dumpsite "A" to Tuktoyaktuk
(Sediment Chemistry and Particle Size Only)

Site Designation	Coordinates (degrees, minutes, seconds) N	W	Depth (m)
EPS-1	70-25-24	135-12-07	59
EPS-2	70-18-59	134-52-04	49
EPS-3	70-12-17	134-30-59	38
EPS-4	70-08-49	134-19-58	33
EPS-5	70-05-30	134-09-59	26
EPS-6	70-02-12	134-00-02	24
EPS-7	69-58-23	133-49-07	16
EPS-8	69-55-01	133-38-35	16
EPS-9	69-51-30	133-28-00	11

APPENDIX F

GRAIN SIZE CURVES, DUMPSITE A (SAMPLES 1-1 TO 1-30) AND DUMPSITE B (SAMPLES 2-1 TO 2-30)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	59.0		%
Silt	41.0		
Sand	TR		
Gravel			

Classification

CLIENT Sarkem Ocenna Stations

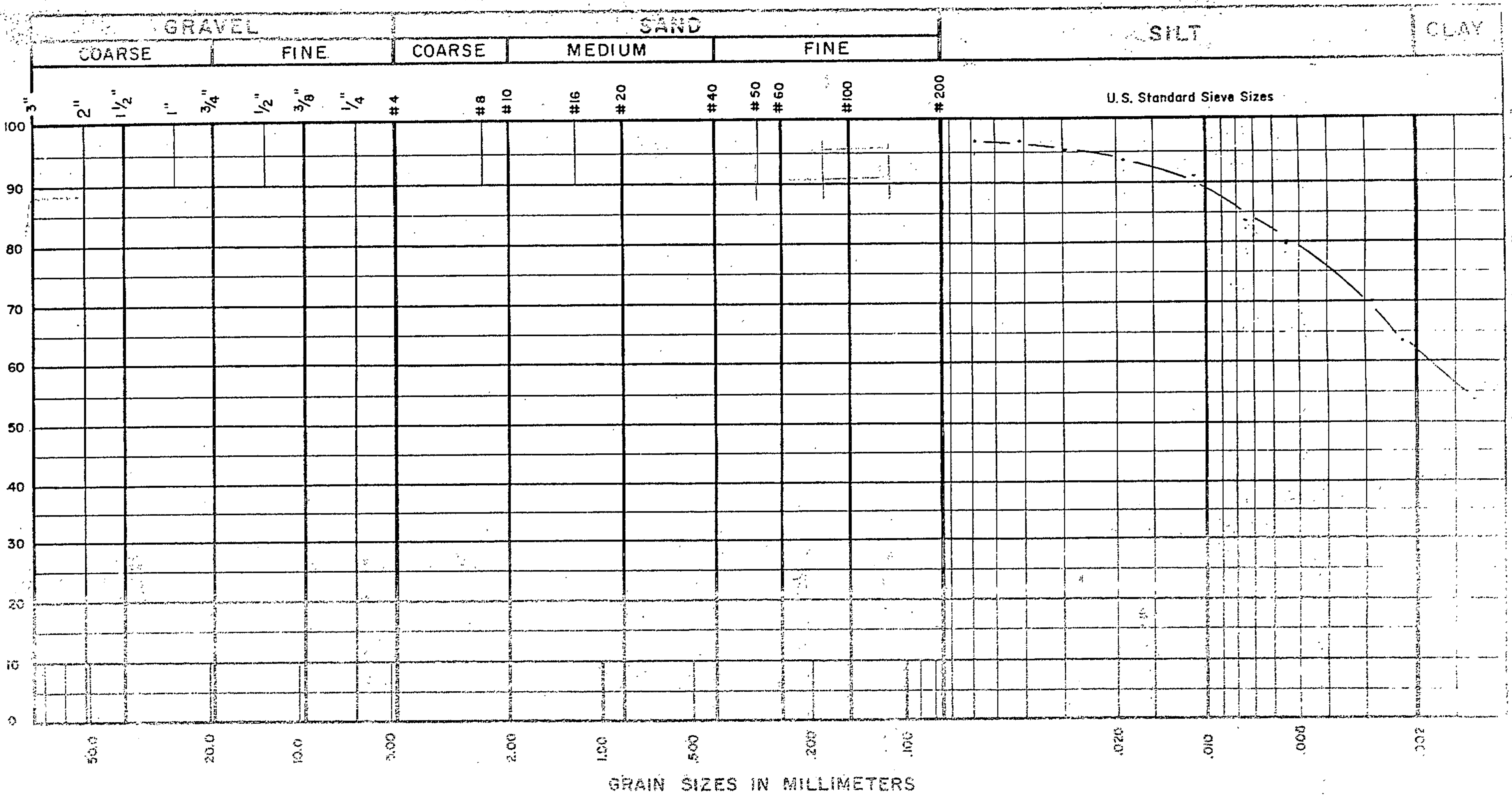
PROJECT

LOCATION

SAMPLE 1-1

TEST DATE Dec /85 FILE NO 9-39

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%	
Liquid Limit				
Plastic Limit				
Plastic Index				

Clay	62.0		%
Silt	38 "		
Sand	78		
Gravel			

Classification

CLIENT Seakem Oceanography

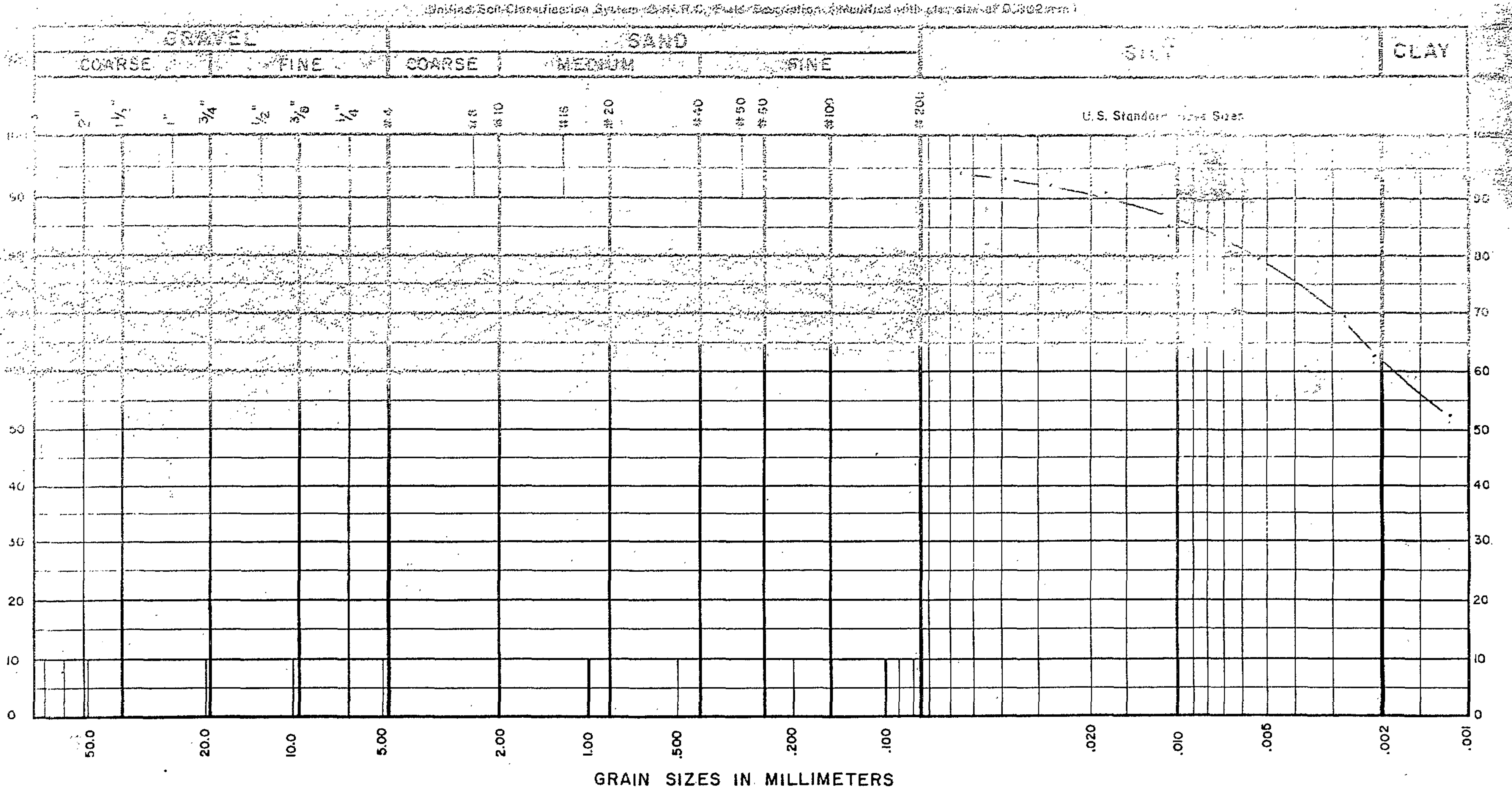
PROJECT

LOCATION

SAMPLE 1-2

TEST DATE Dec 17/86 FILE Nº

THURBER CONSULTANTS LTD., Geotechnical Engineers



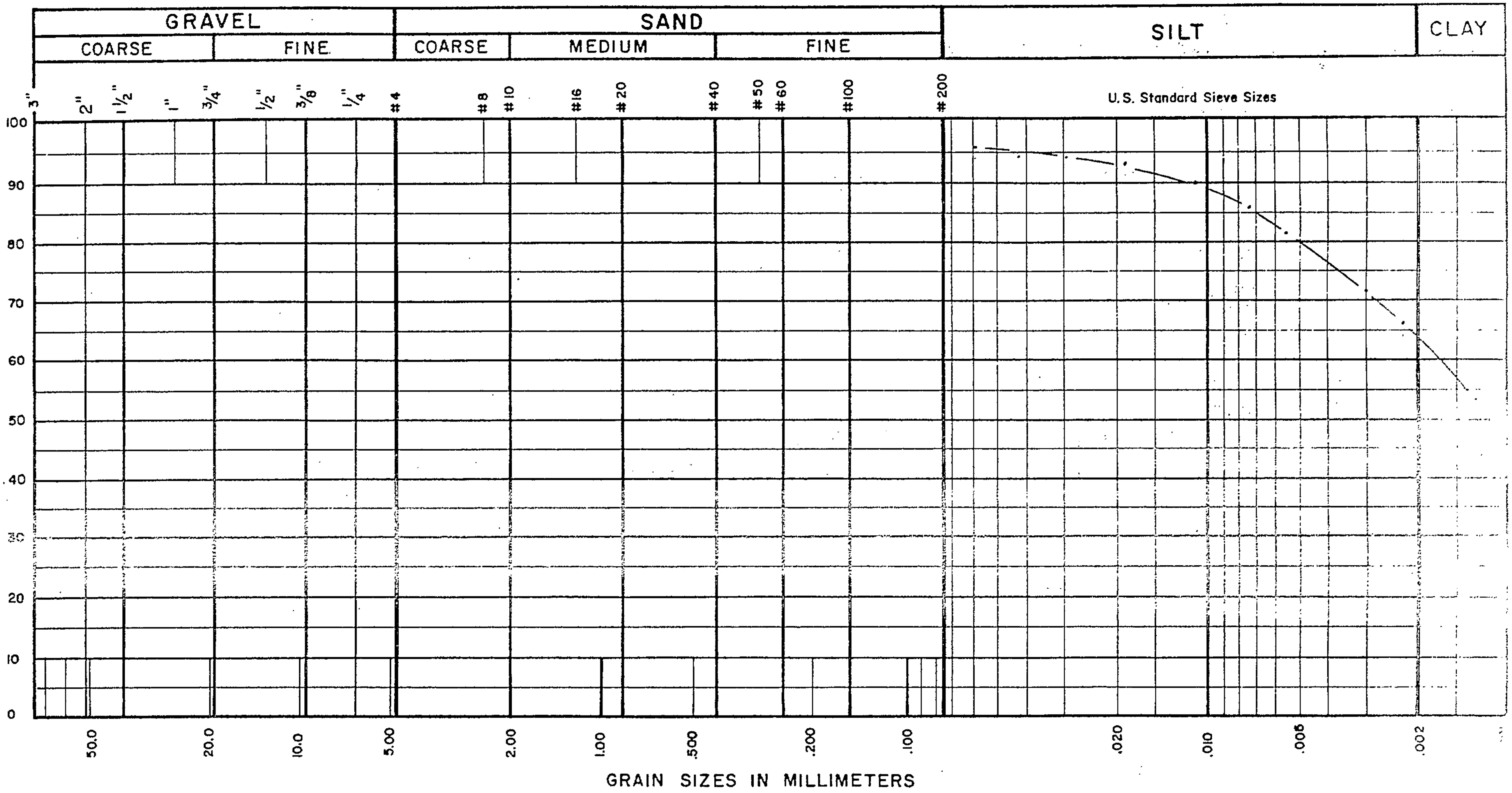
Nat. Water Content			%	Clay	62.0		%
Liquid Limit				Silt	38.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification

CLIENT Seakem [illegible]
PROJECT
LOCATION
SAMPLE 1-3
TEST DATE Dec [illegible]/8[illegible] FILE Nº [illegible]

HURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

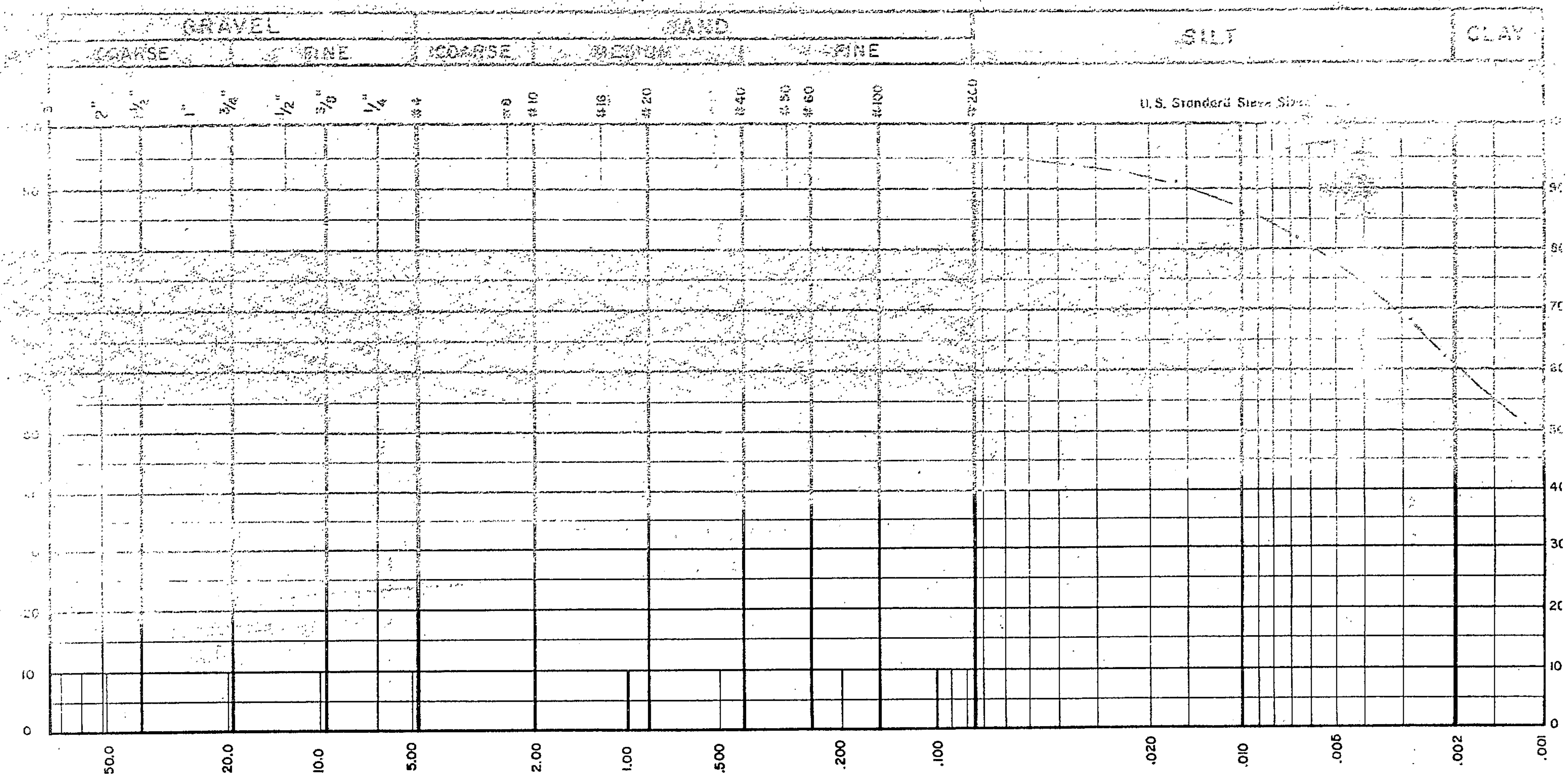
Clay	64.0		%
Silt	36.0		
Sand	TR		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-4
TEST DATE	Dec [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



GRAIN SIZES IN MILLIMETERS

Nat. Water Content				%
Liquid Limit				
Plastic Limit				
Plastic Index				

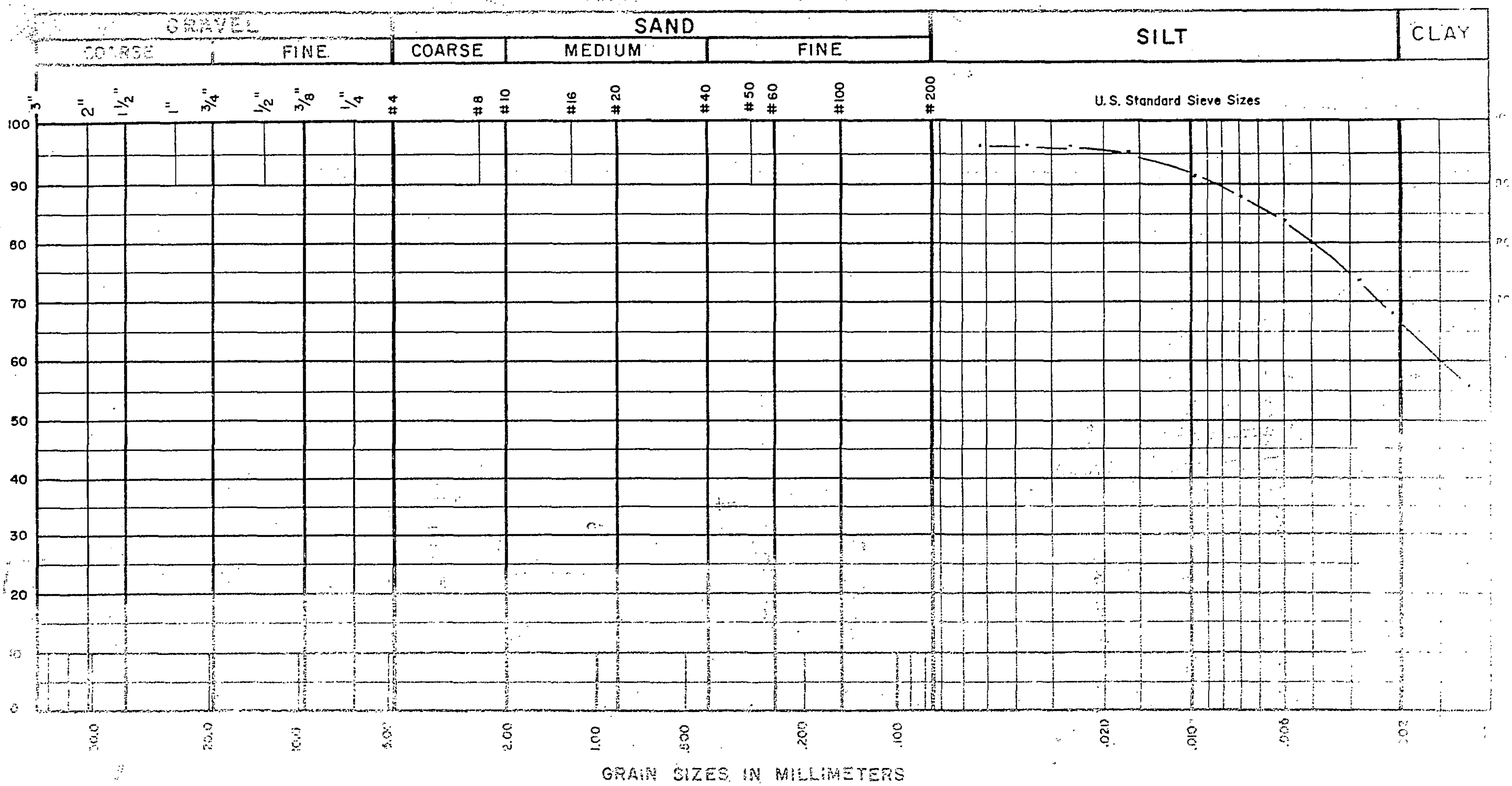
Clay	60.5			%
Silt	39.5			
Sand	TR			
Gravel				

Classification

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 1-5
TEST DATE Dec [illegible] FILE Nº [illegible]

[illegible] CONSULTANTS LTD. Geotechnical Engineers

Unified Soil Classification System / M.I.T. Grade Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	66.0		%
Liquid Limit				Silt	34.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification

CLIENT Seakem Oceanography

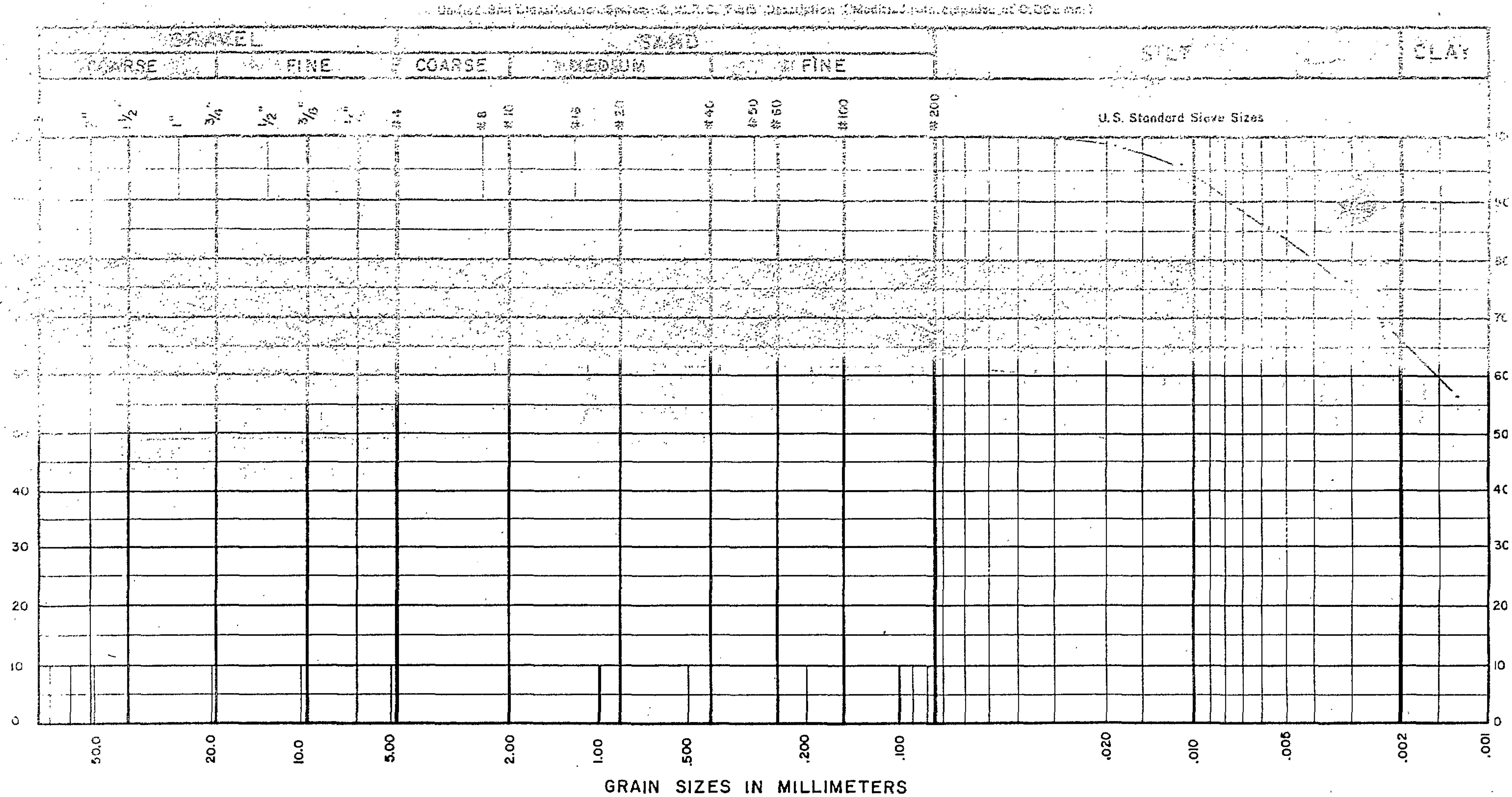
PROJECT

LOCATION

SAMPLE 1-E

TEST DATE Dec 17/80 FILE Nº

THURBER CONSULTANTS LTD., Geotechnical Engineers



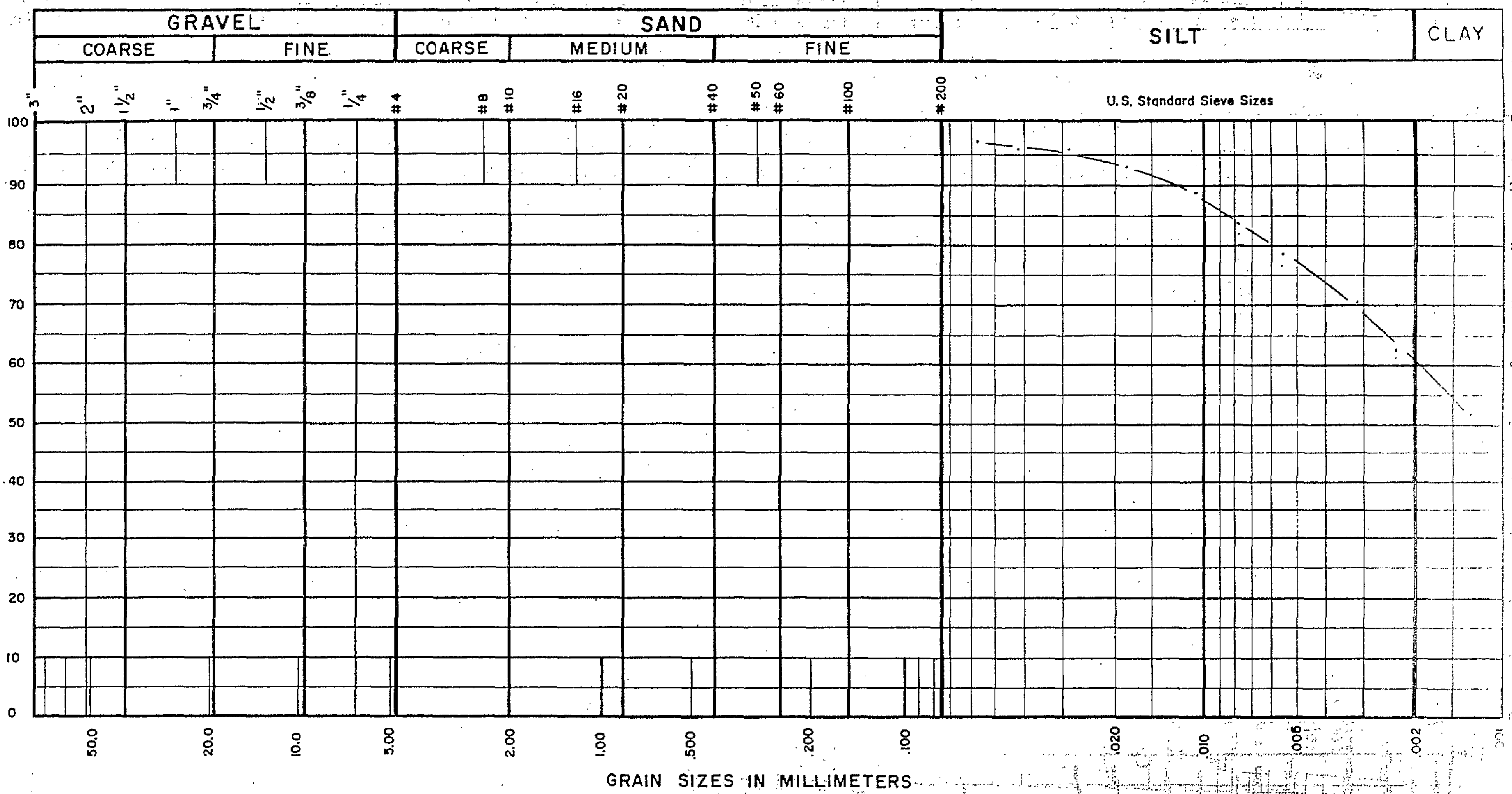
Nat. Water Content			%	Clay	66.0		%
Liquid Limit				Silt	34.0		
Plastic Limit				Sand	—		
Plastic Index				Gravel			

Classification

CLIENT	Seakem - Oceanographic
PROJECT	
LOCATION	
SAMPLE	V-7
TEST DATE	Dec 17/86 FILE Nº 19-3-9?-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

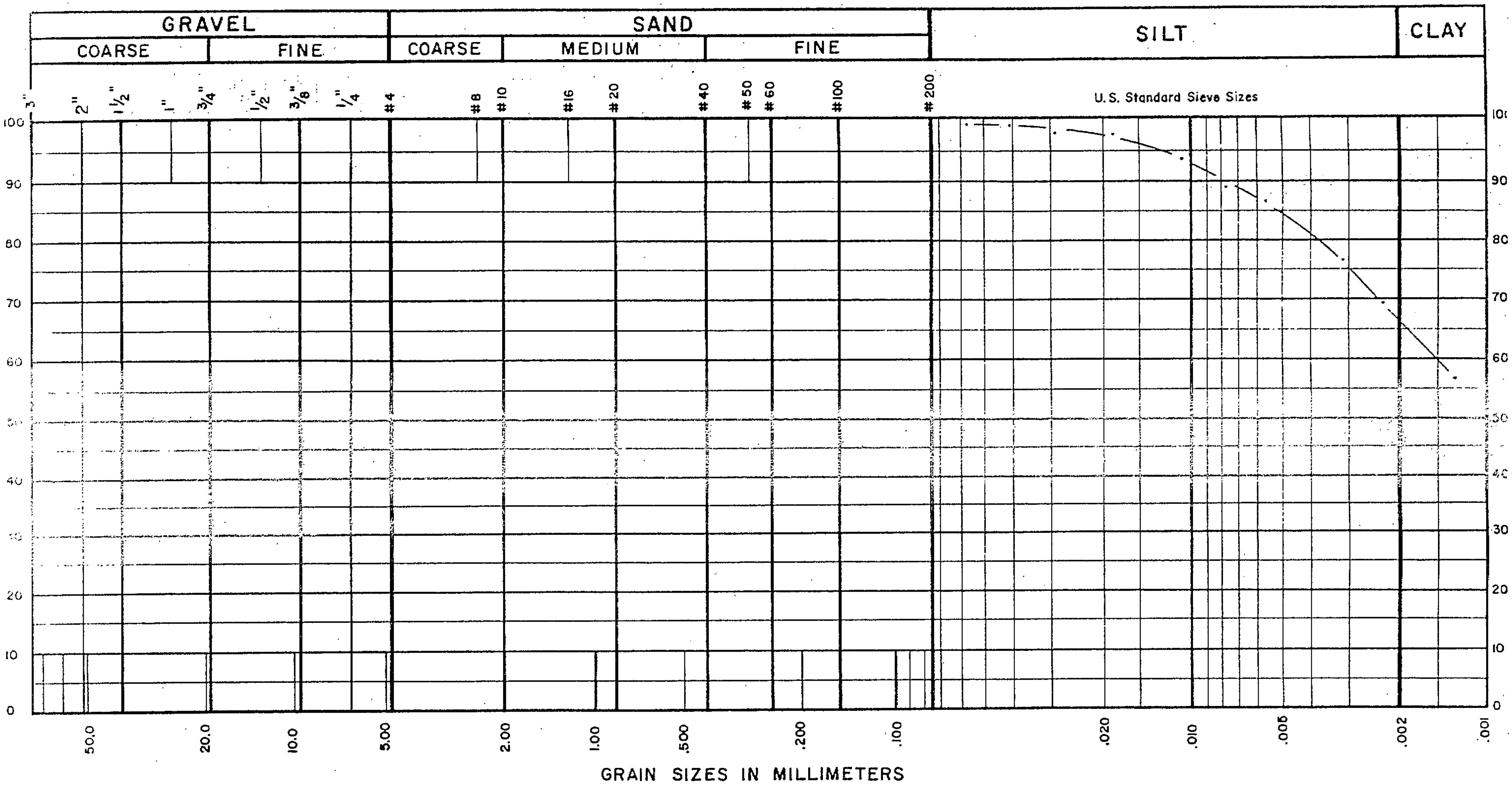
Clay	61.0		%
Silt	39.0		
Sand	TR		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-8
TEST DATE	Dec 17/86 FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



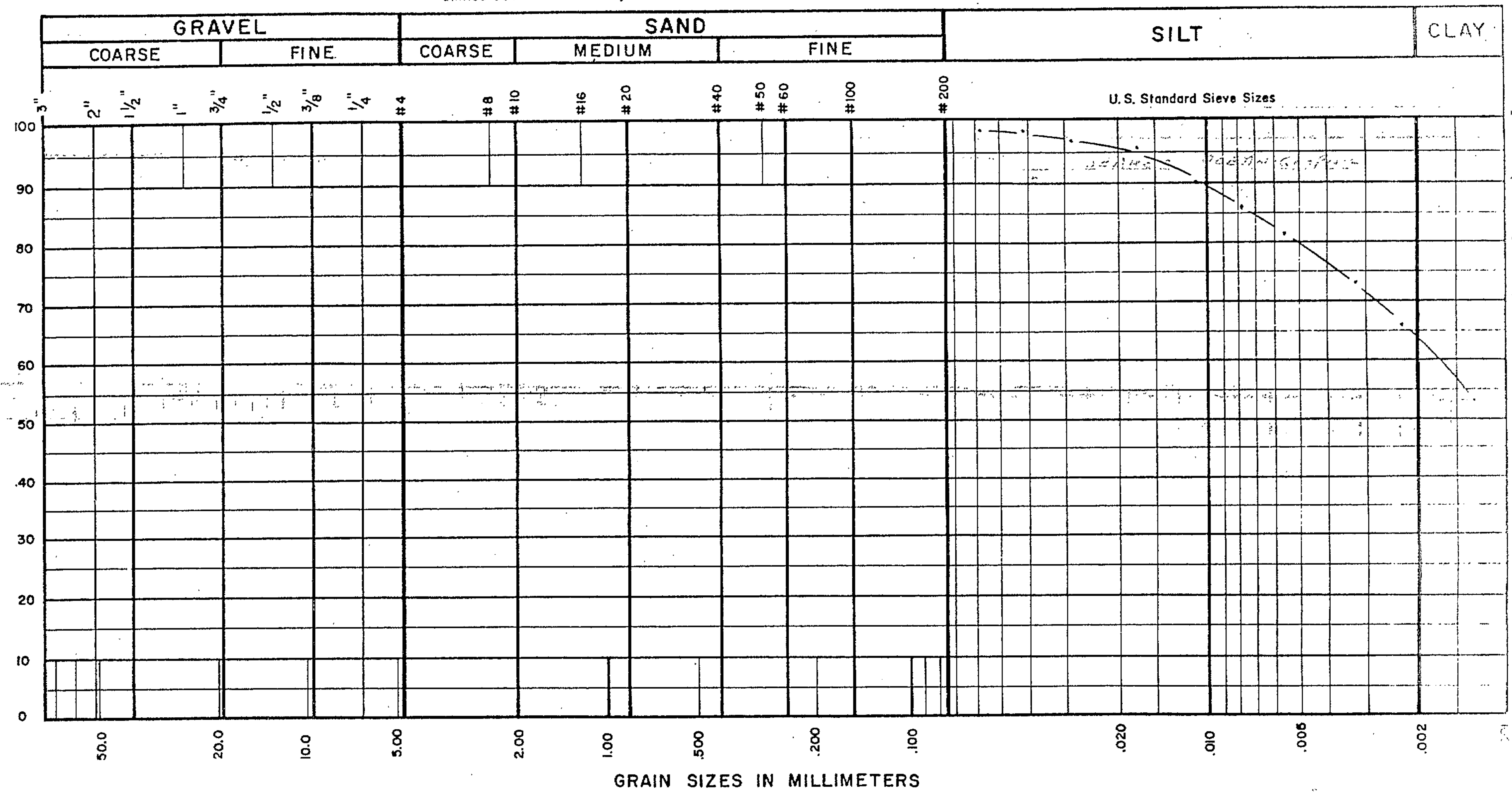
Nat. Water Content			%	Clay	66.5		%
Liquid Limit				Silt	33.5		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification ______________________

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 1-9
TEST DATE
FILE No

THURBER CONSULTANTS LTD. Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	64.0	%
Liquid Limit				Silt	36.0	
Plastic Limit				Sand	TR	
Plastic Index				Gravel		

Classification

CLIENT [illegible]

PROJECT

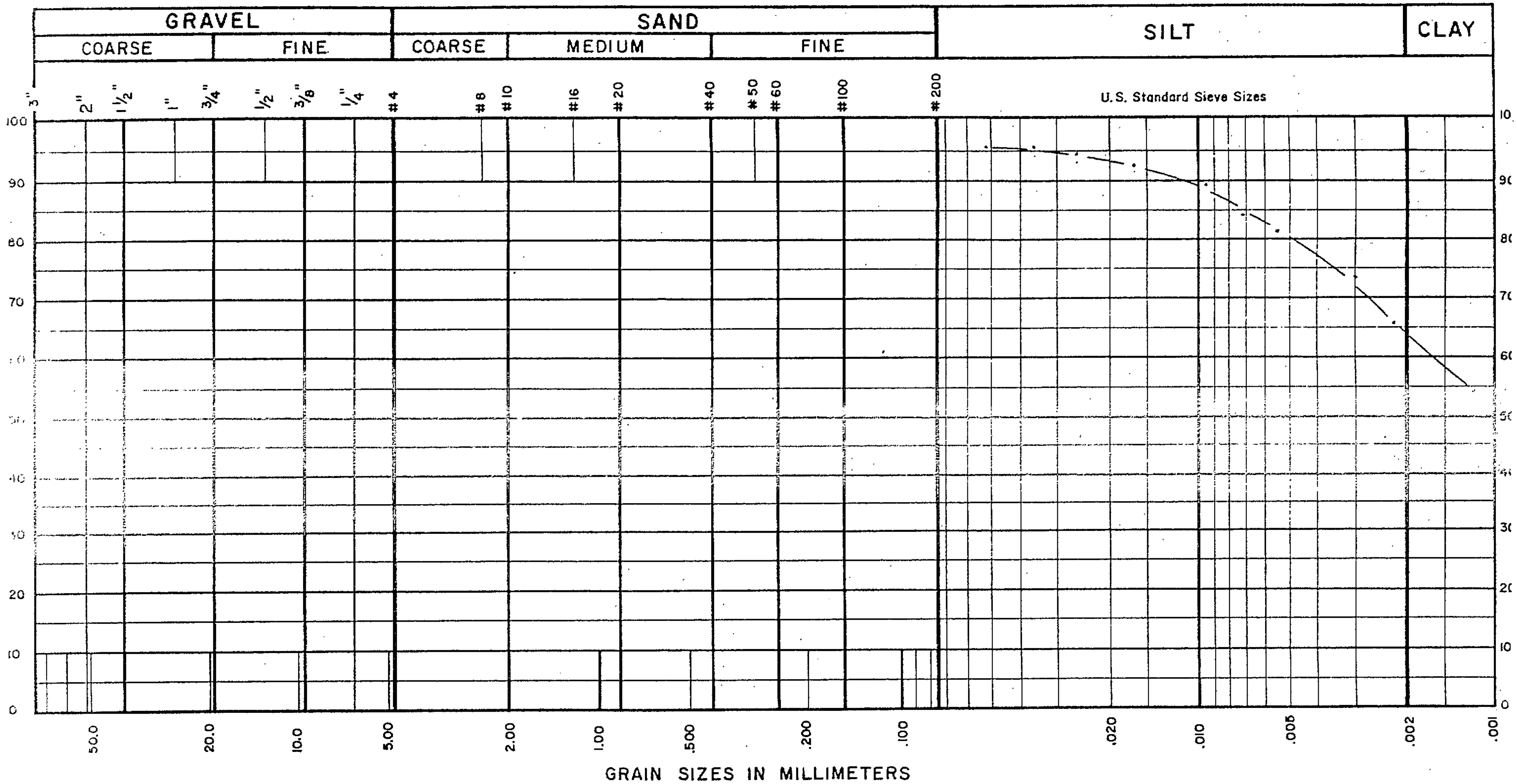
LOCATION

SAMPLE 1-10

TEST DATE Dec 17/86 FILE No.

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	64.0		%
Silt	36.0		
Sand	TR		
Gravel			

Classification

CLIENT Seakem Oceanographic

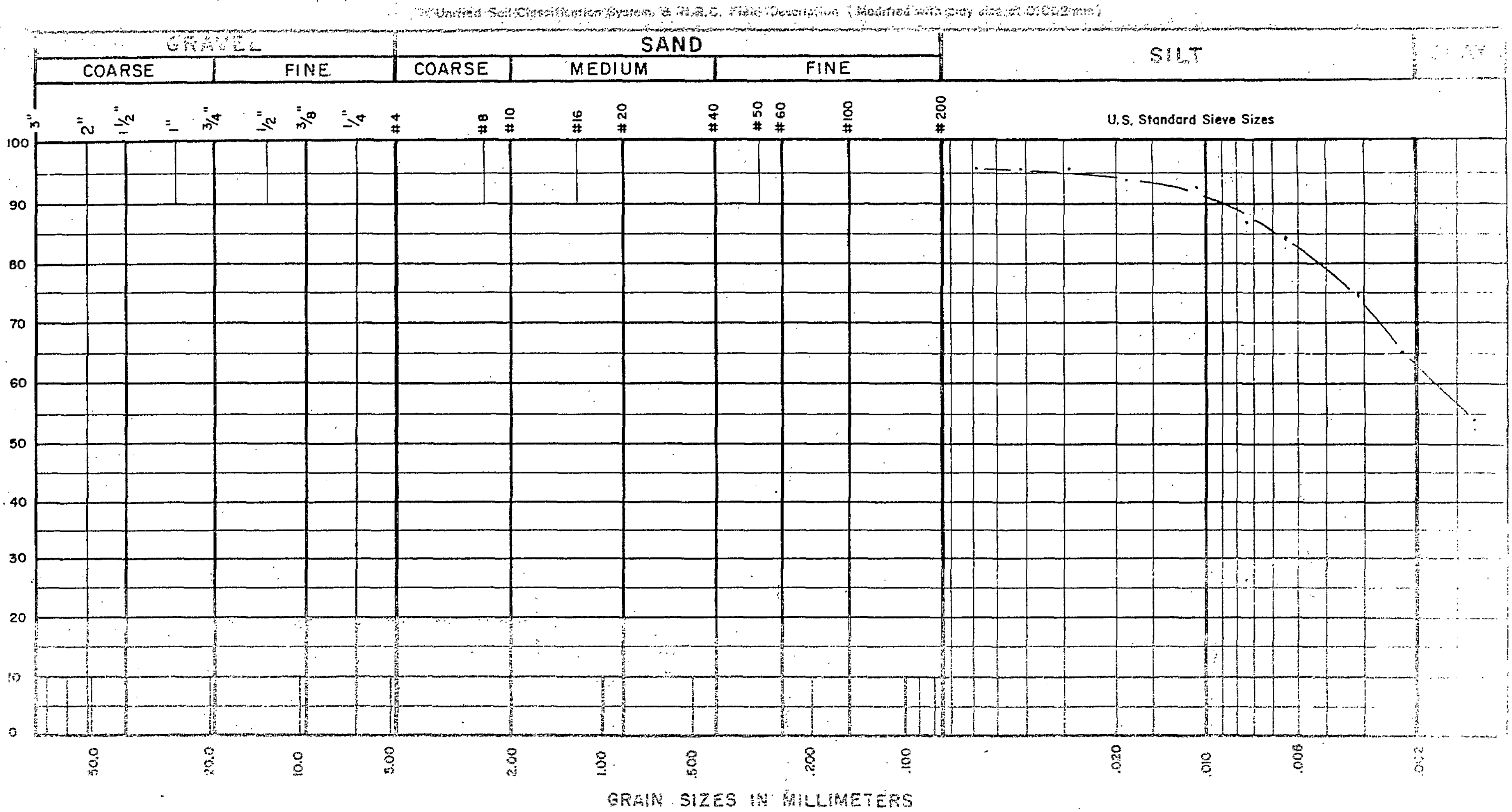
PROJECT

LOCATION

SAMPLE [illegible]

TEST DATE Dec [illegible] FILE No. [illegible]

THURBER CONSULTANTS LTD. Geotechnical Engineers

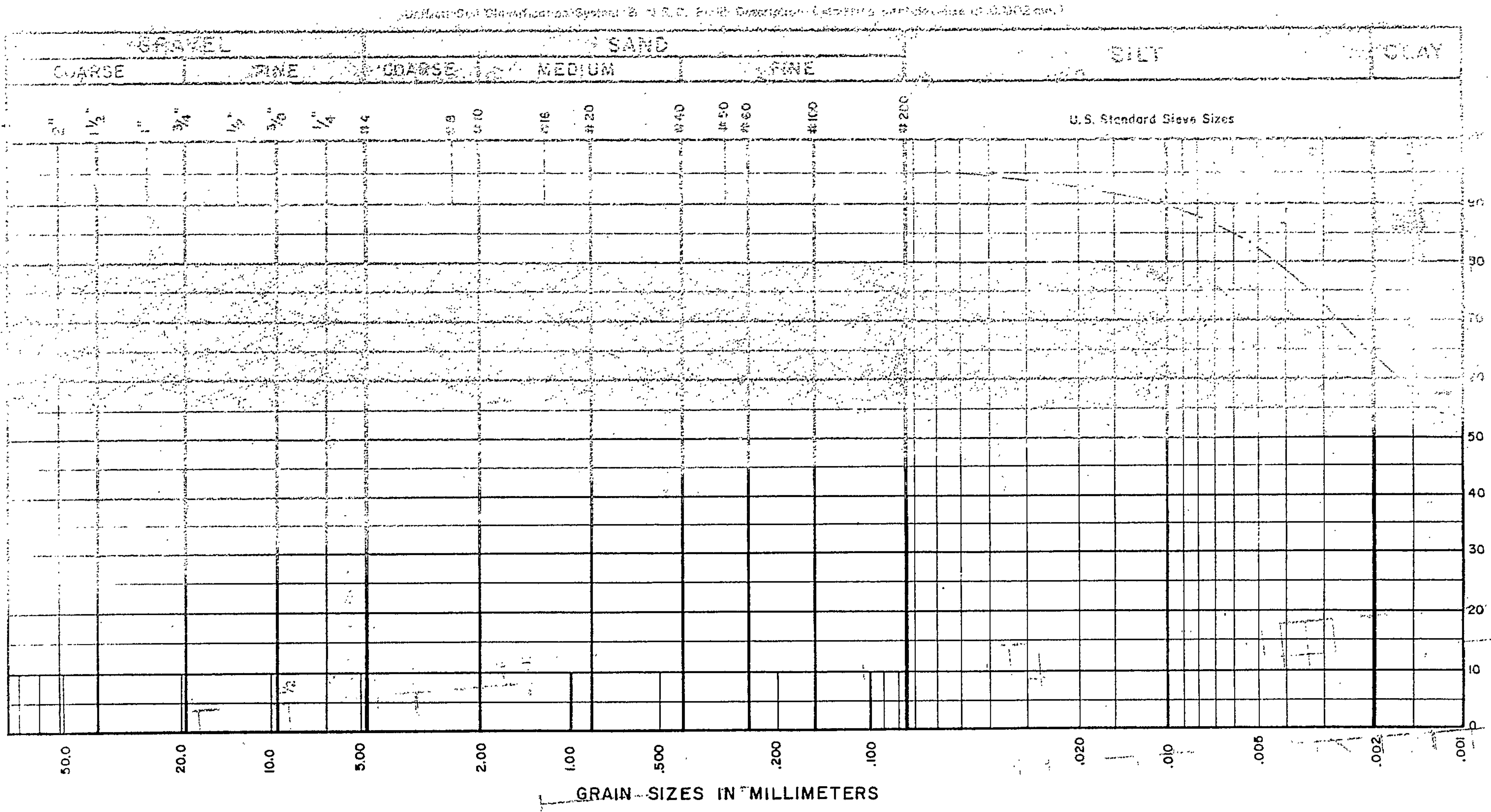


Nat. Water Content			%	Clay	63.0		%
Liquid Limit				Silt	37.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification ______________________________

THURBER CONSULTANTS LTD., Geotechnical Engineers

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-12
TEST DATE	Dec 18/86 — FILE NO [illegible]



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	64.0		%
Silt	36.0		
Sand	TR		
Gravel			

Classification

CLIENT Seakem Oceanography

PROJECT

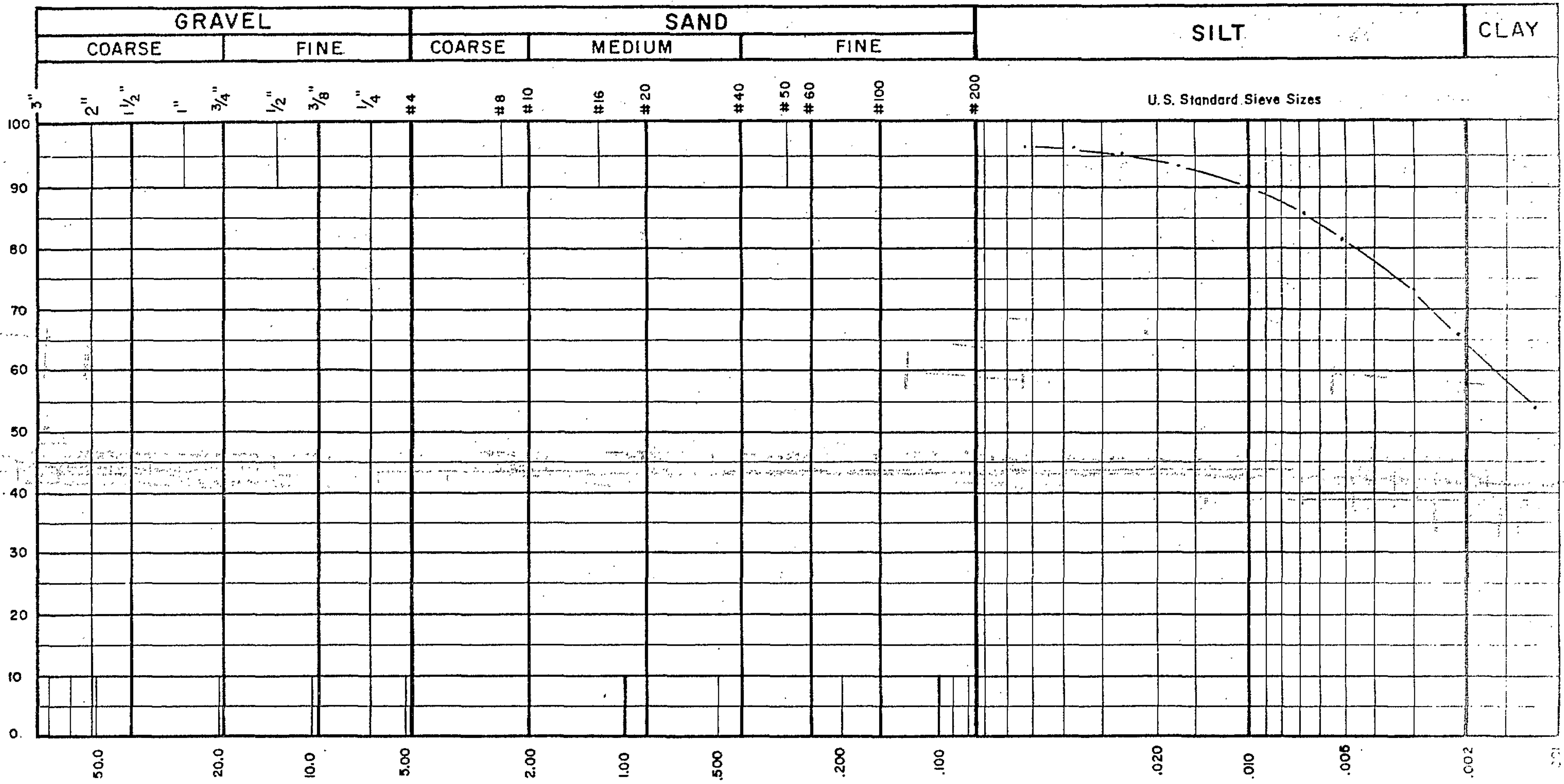
LOCATION

SAMPLE 1-13

TEST DATE Dec 13/8[illegible] FILE N? [illegible]

THURBER CONSULTANTS LTD. Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

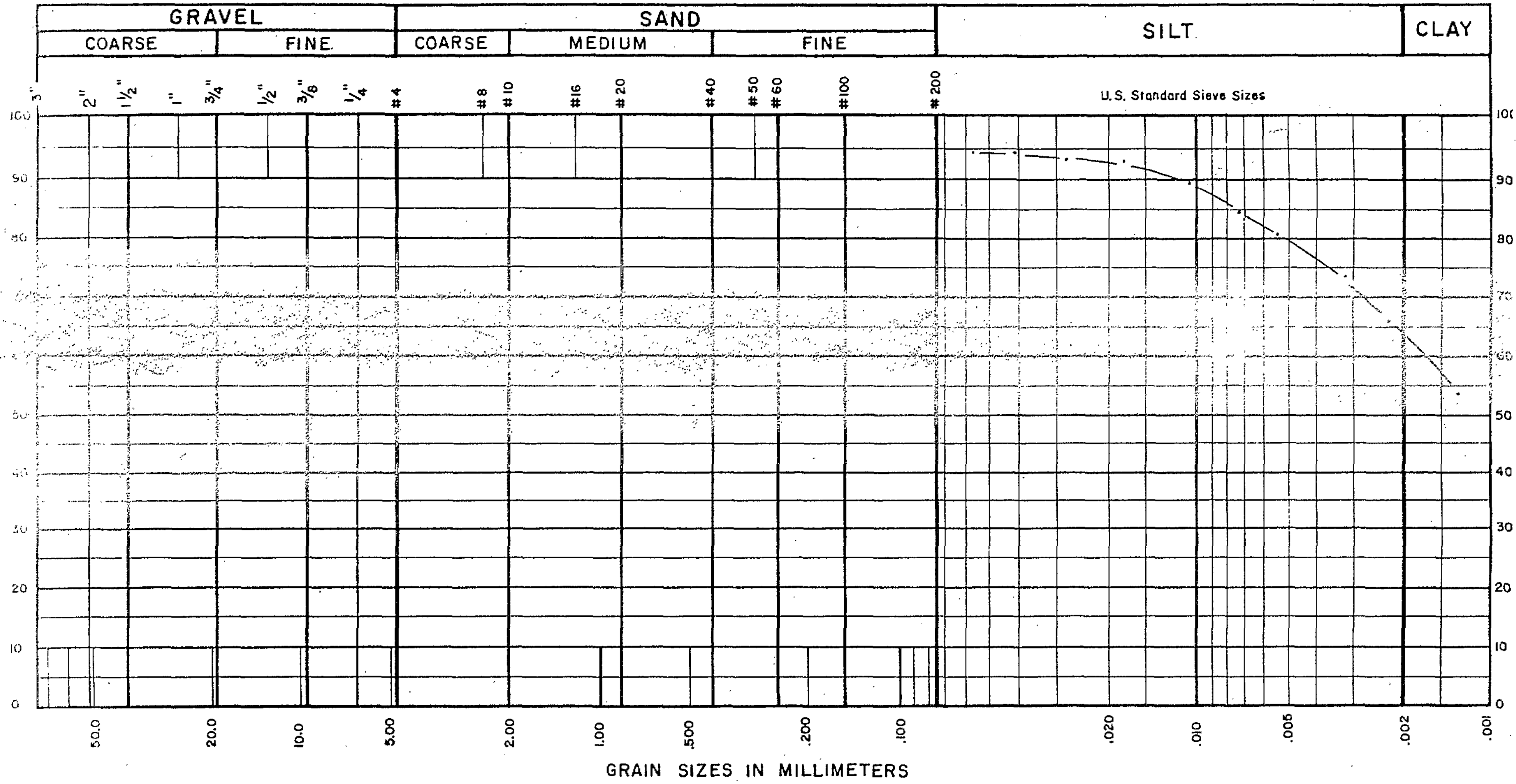
Clay	64.0		%
Silt	36.0		
Sand	TR		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	7-14
TEST DATE	Dec 18/86 — FILE NO 17-[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	64.0		%
Silt	36.0		
Sand	TR		
Gravel			

Classification

CLIENT [illegible]

PROJECT

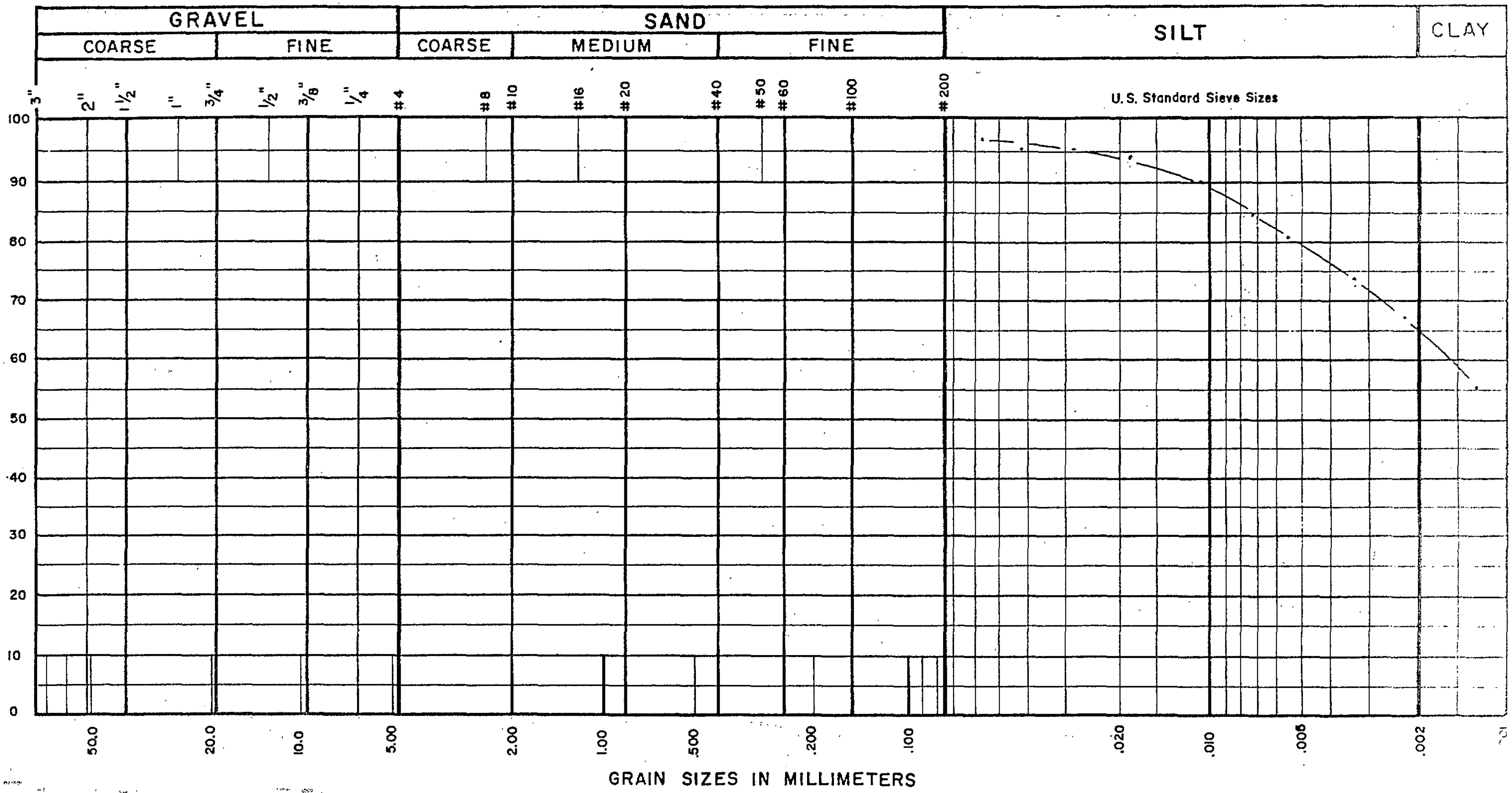
LOCATION

SAMPLE [illegible]

TEST DATE [illegible]   FILE NO [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



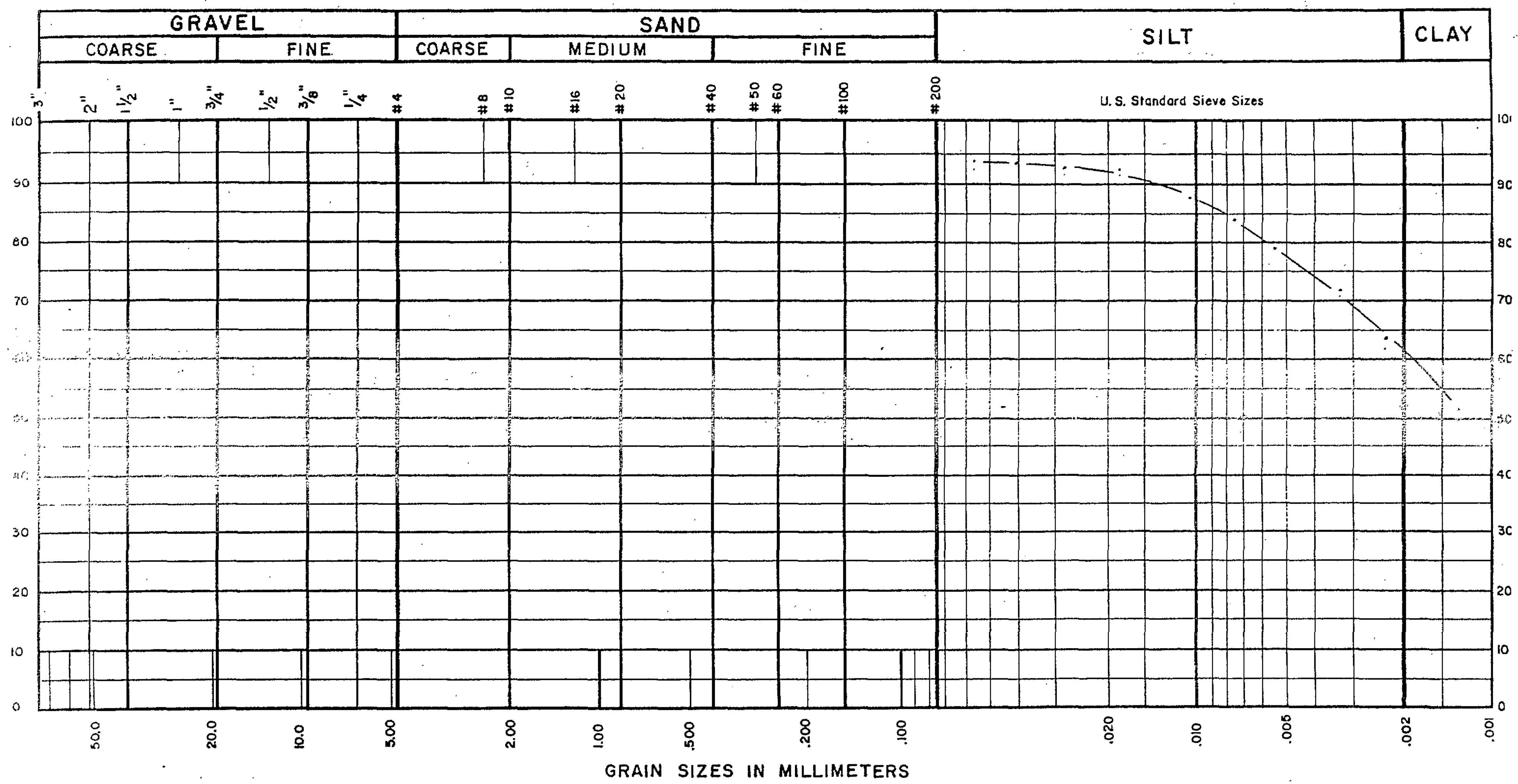
Nat. Water Content			%	Clay	65.0		%
Liquid Limit				Silt	35.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification ______________________

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-16
TEST DATE	Dec 18/86 FILE Nº 19.[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	61.5		%
Silt	38.5		
Sand	TR		
Gravel			

Classification

CLIENT Seakem Oceanographic

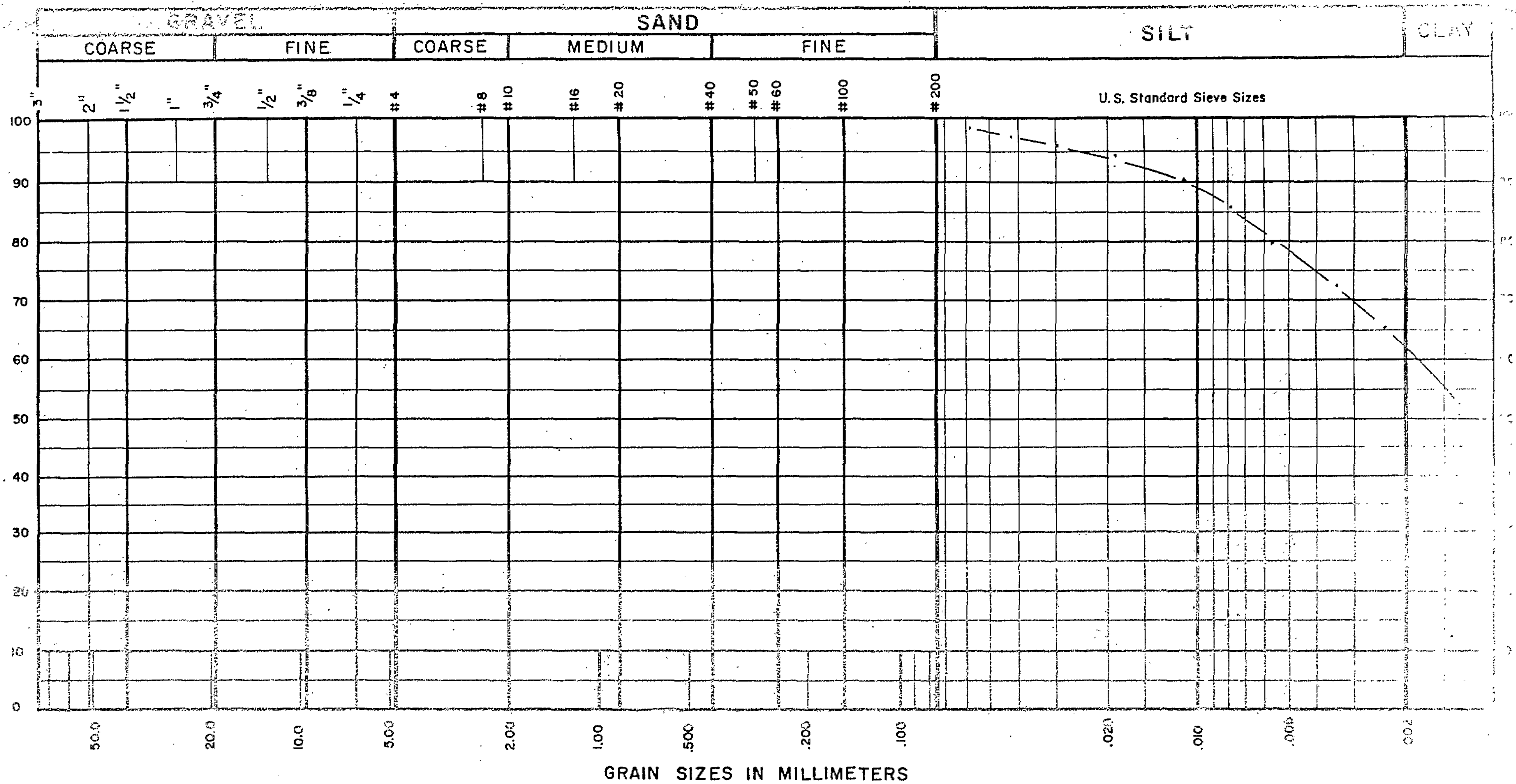
PROJECT

LOCATION

SAMPLE 1-17

TEST DATE Dec 18/80 FILE No. 79-[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers



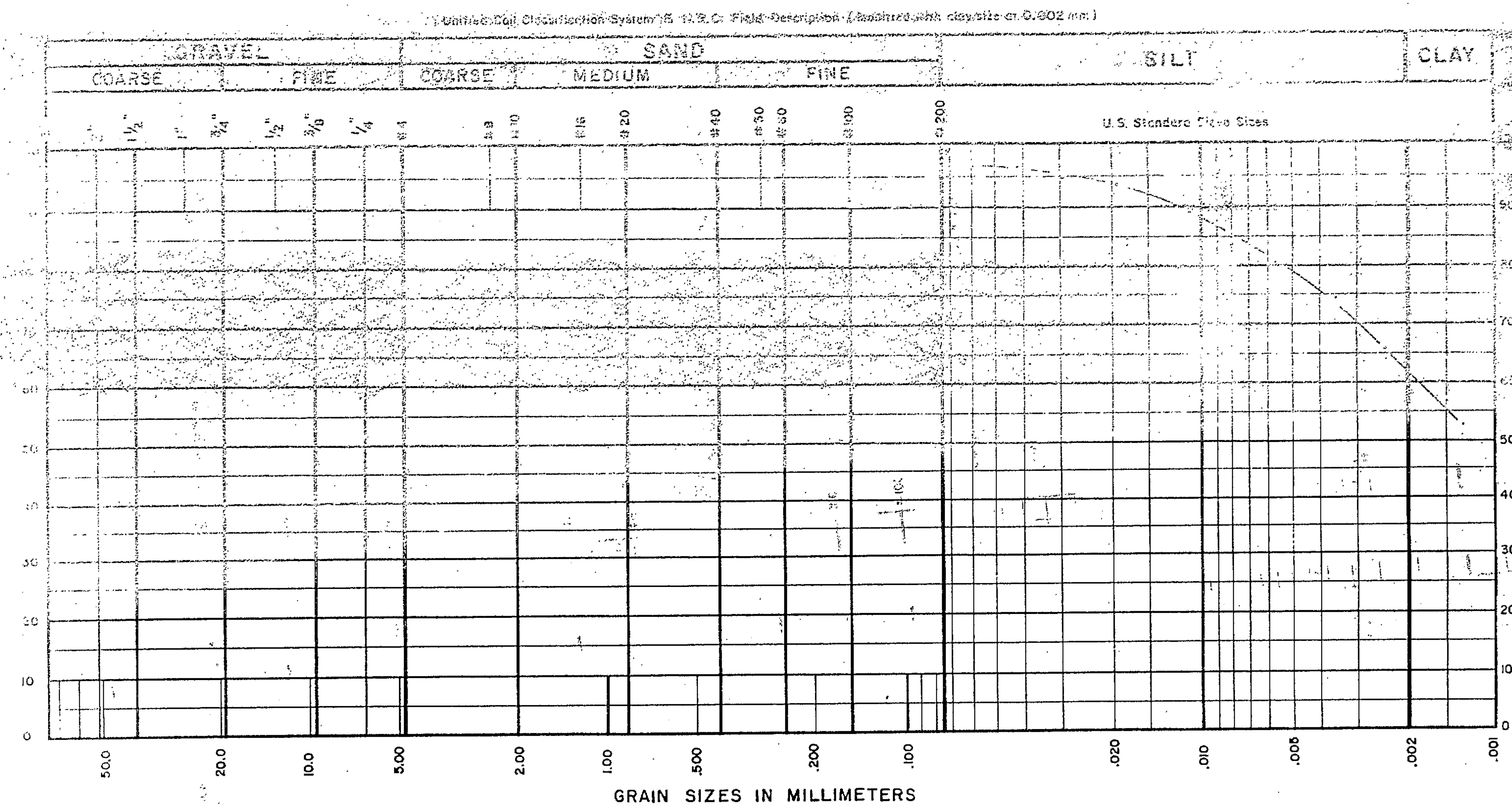
Nat. Water Content		%
Liquid Limit		
Plastic Limit		
Plastic Index		

Clay	62.0	%
Silt	38.0	
Sand	TR	
Gravel		

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	1-1B
TEST DATE	DEC 18/86 FILE No 19 39[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	62.0		%
Silt	38.0		
Sand	TR		
Gravel			

Classification ______________________

CLIENT [illegible]

PROJECT

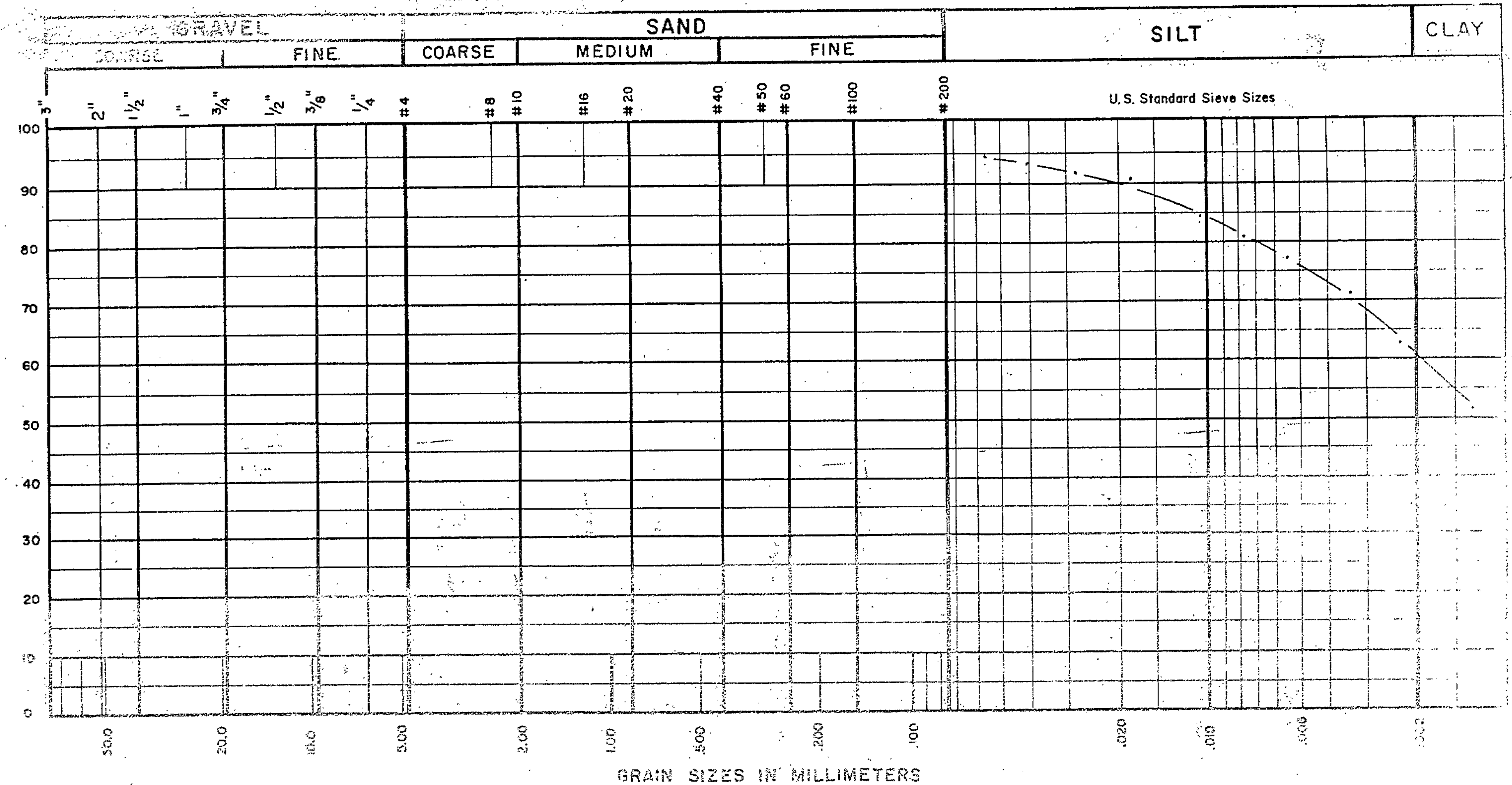
LOCATION

SAMPLE [illegible]

TEST DATE [illegible] FILE No. [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System / Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	60.0		%
Liquid Limit				Silt	40.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification

CLIENT Seakem Oceanography

PROJECT

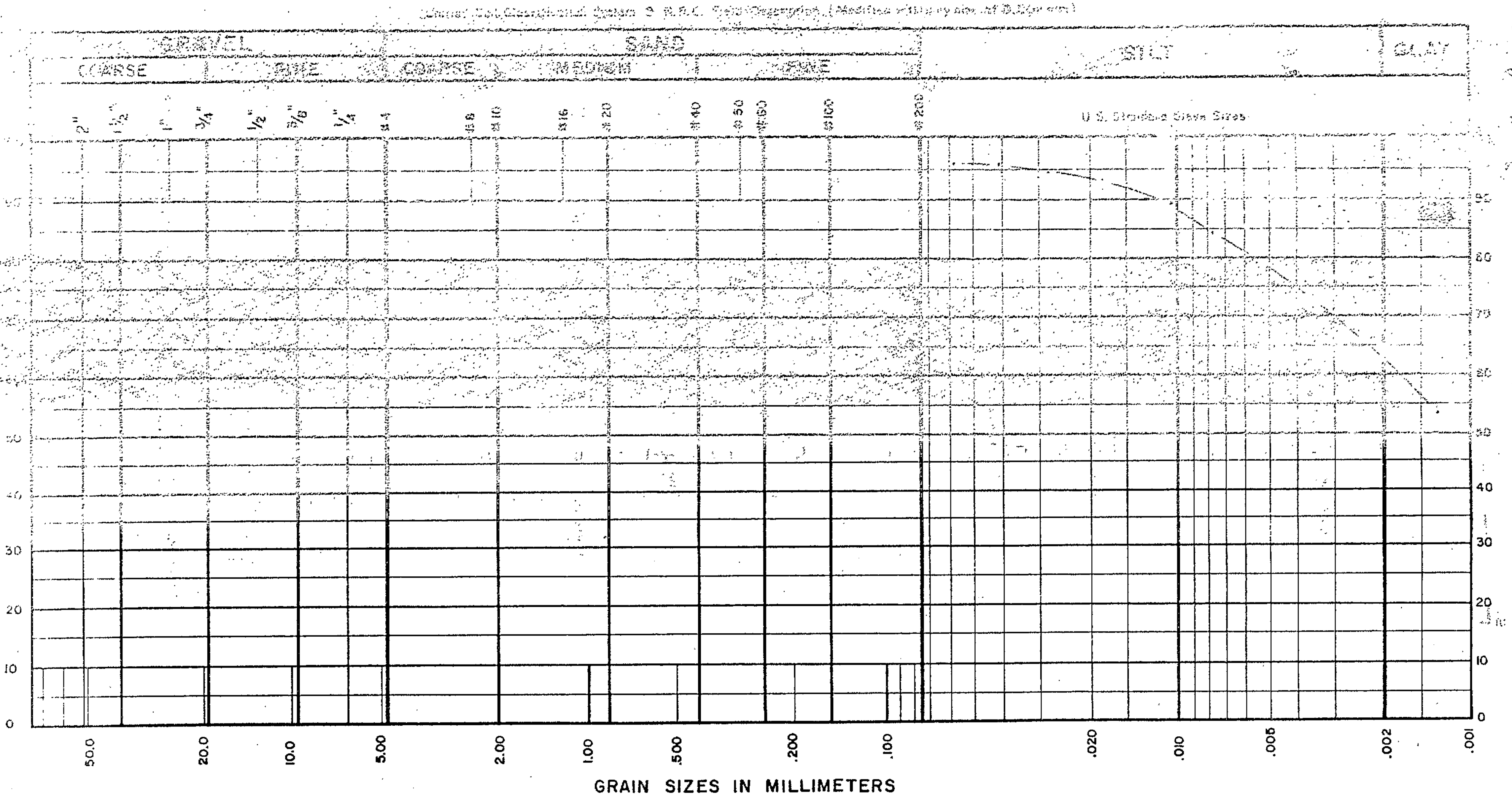
LOCATION

SAMPLE 1-22

TEST DATE 24/12/8_

FILE No.

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	62.5		%
Silt	37.5		
Sand	TR		
Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC

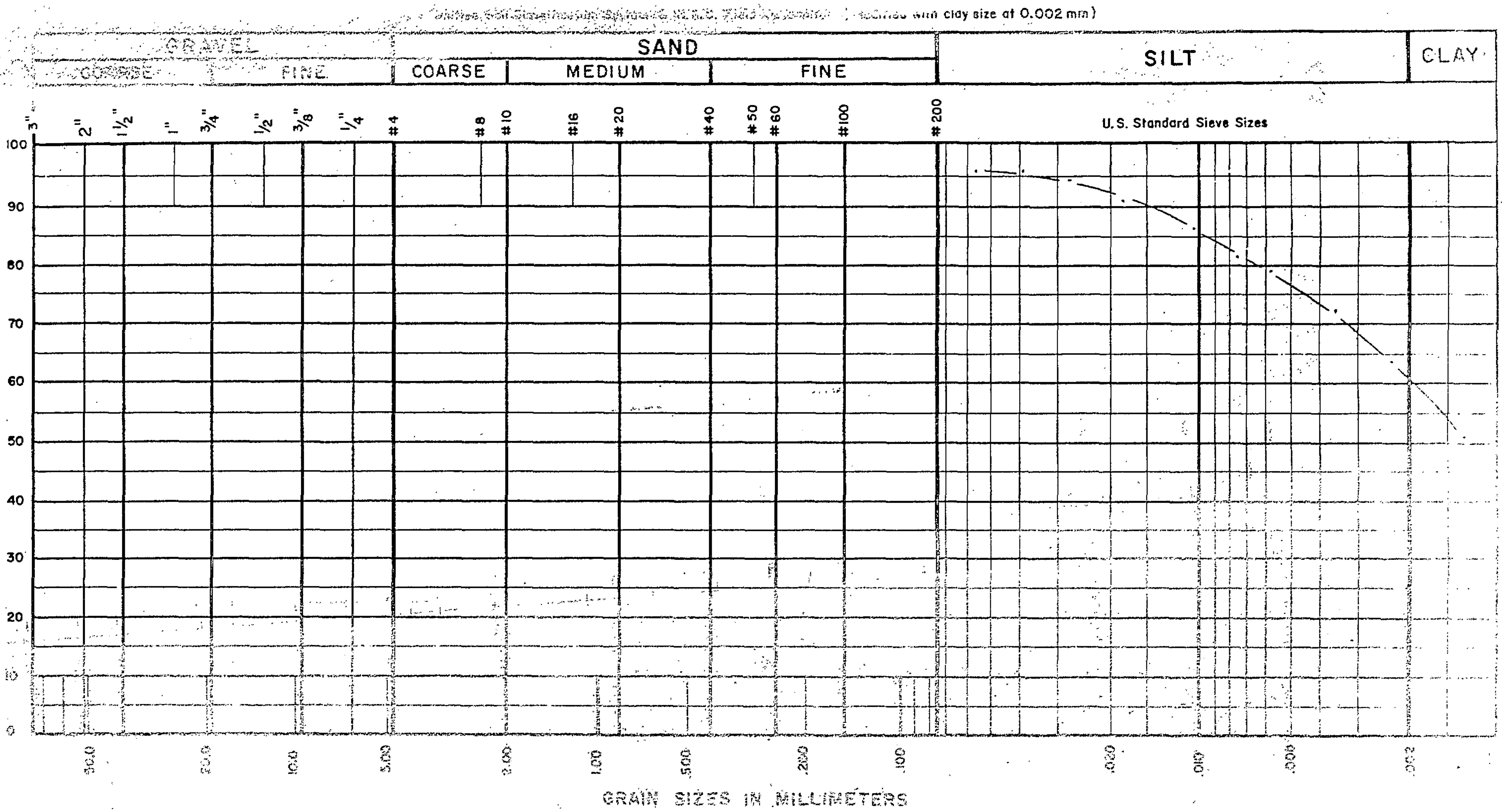
PROJECT

LOCATION

SAMPLE 1-21

TEST DATE Dec 18/86 FILE Nº [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

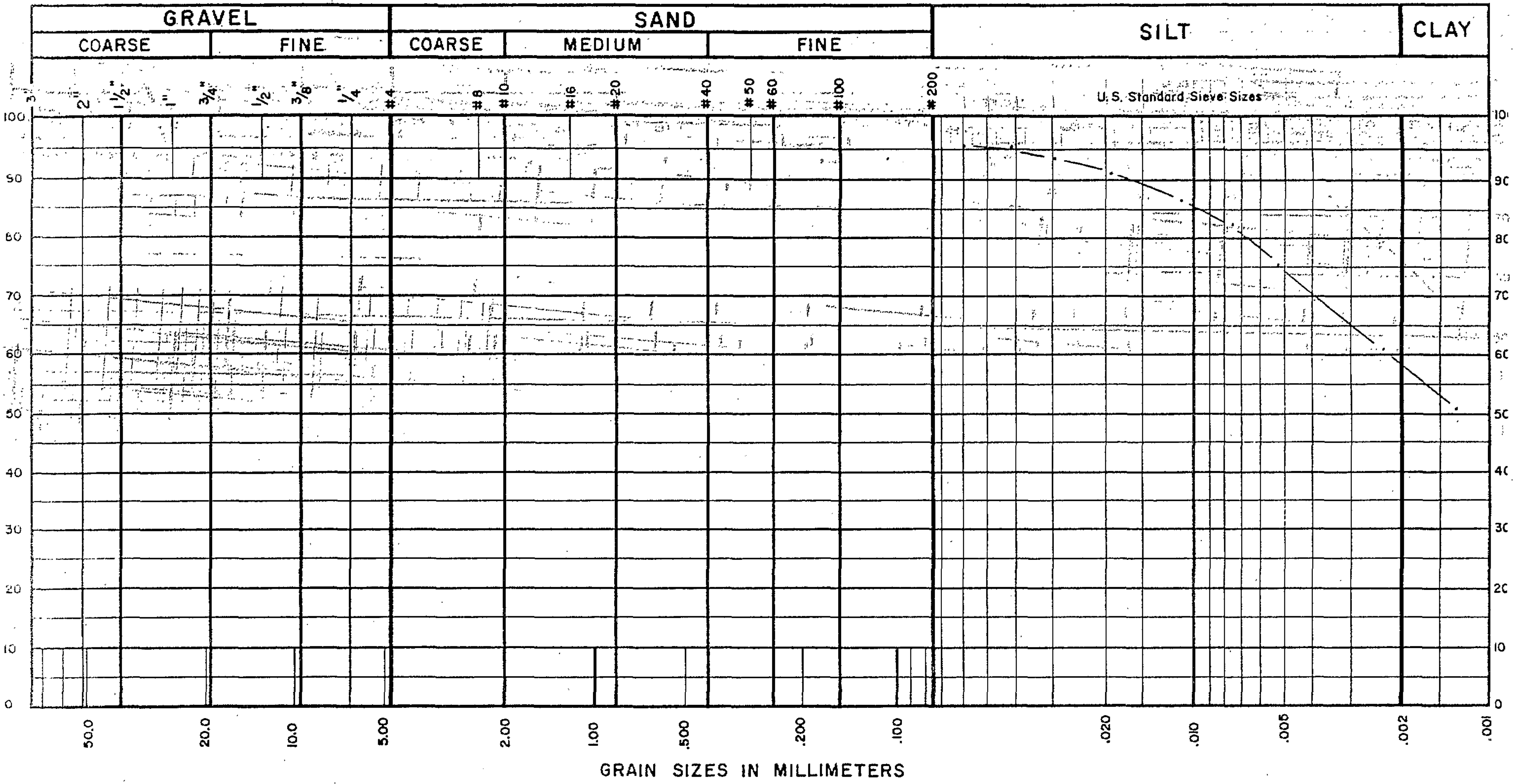
Clay	60.5		%
Silt	39.5		
Sand	Tr.		
Gravel			

Classification

CLIENT SEAKEM [illegible]
PROJECT
LOCATION
SAMPLE 1-2
TEST DATE Dec 18/86 FILE No

THURBER CONSULTANTS LTD. Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



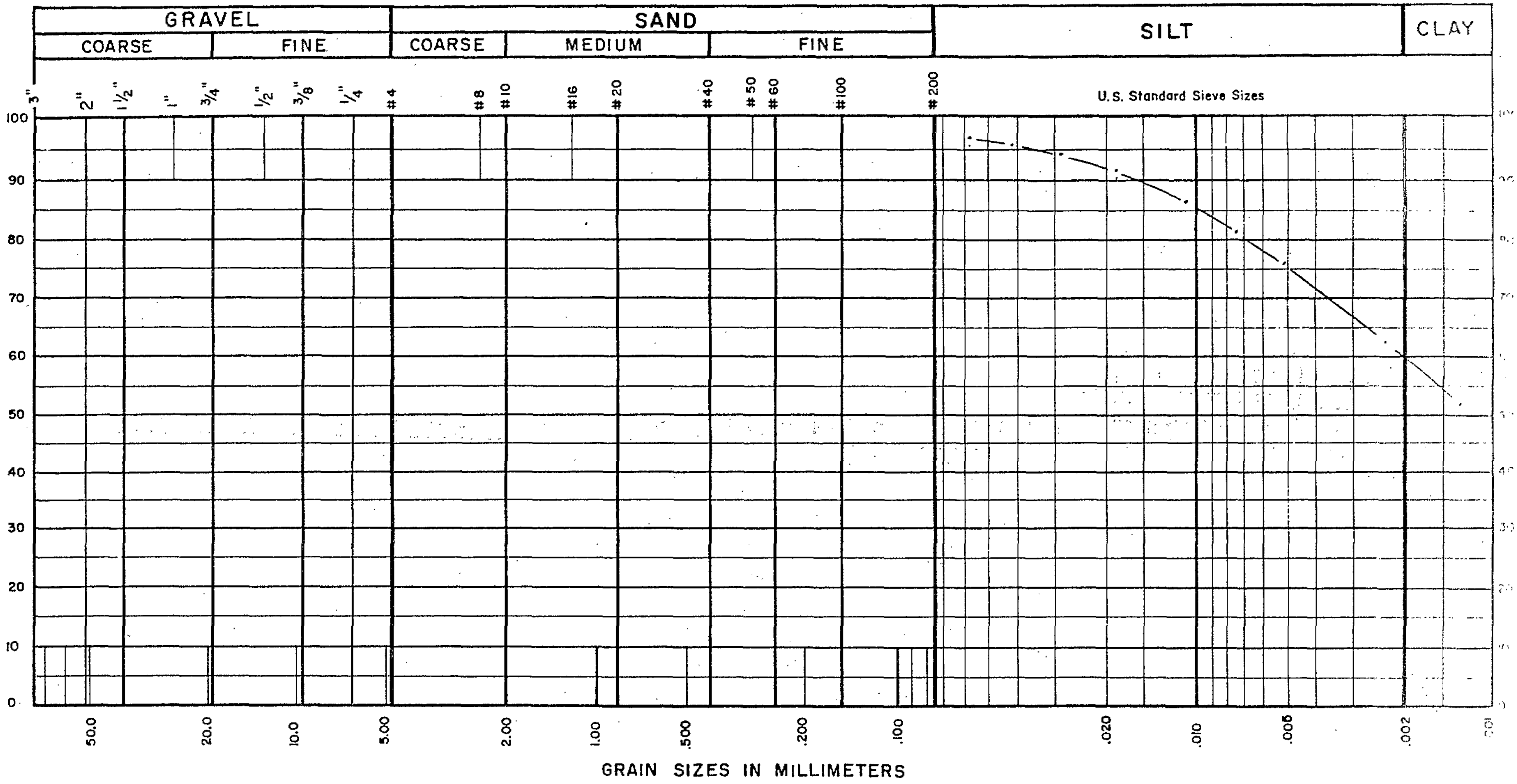
Nat. Water Content	%		Clay	58.0 %
Liquid Limit			Silt	42.0
Plastic Limit			Sand	TR
Plastic Index			Gravel	

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	1-23
TEST DATE	DEC 19/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

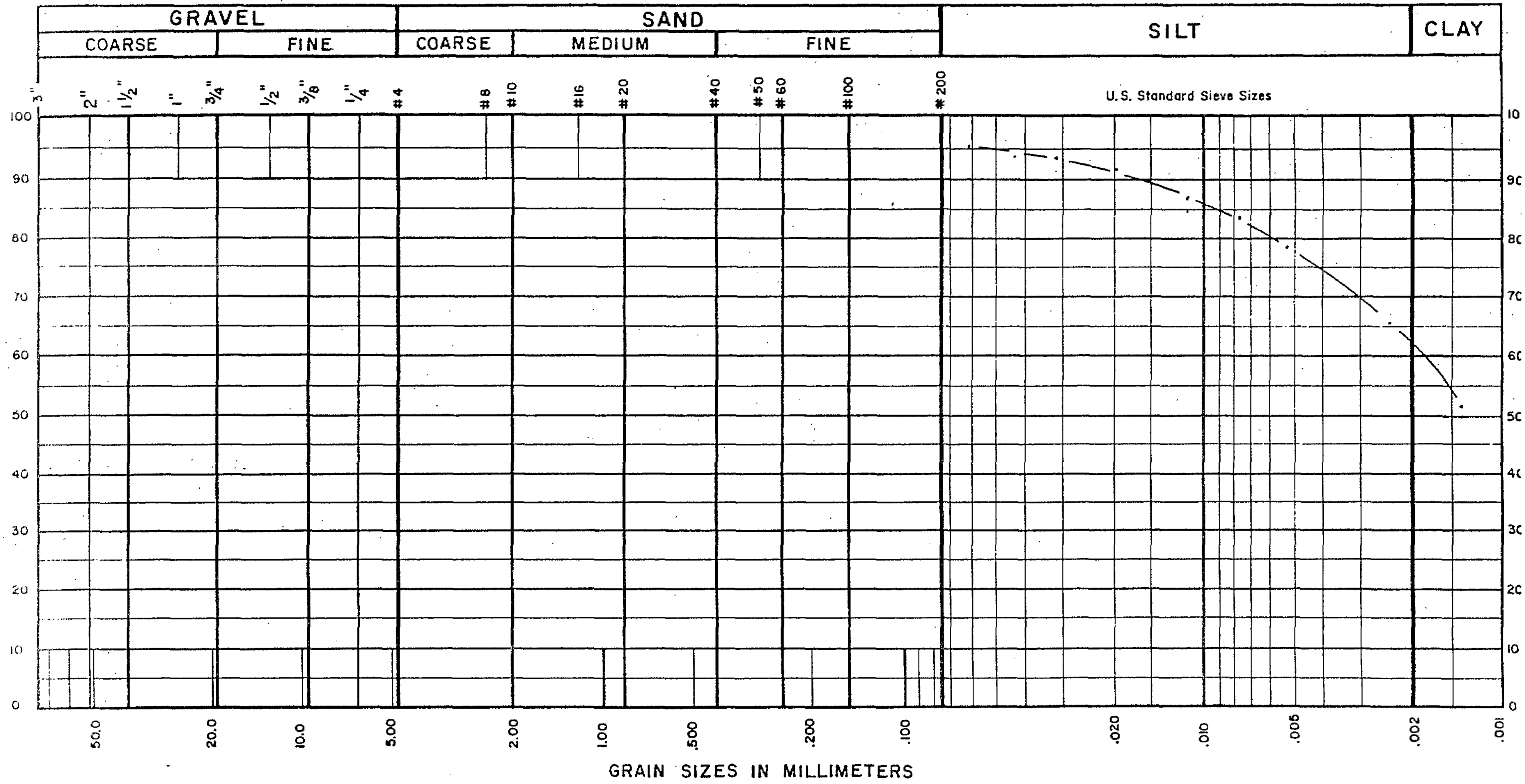
Clay	60.0		%
Silt	40.0		
Sand	TR		
Gravel			

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHICS
PROJECT	
LOCATION	
SAMPLE	1-24
TEST DATE	Dec 19/86 FILE NO 19.[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

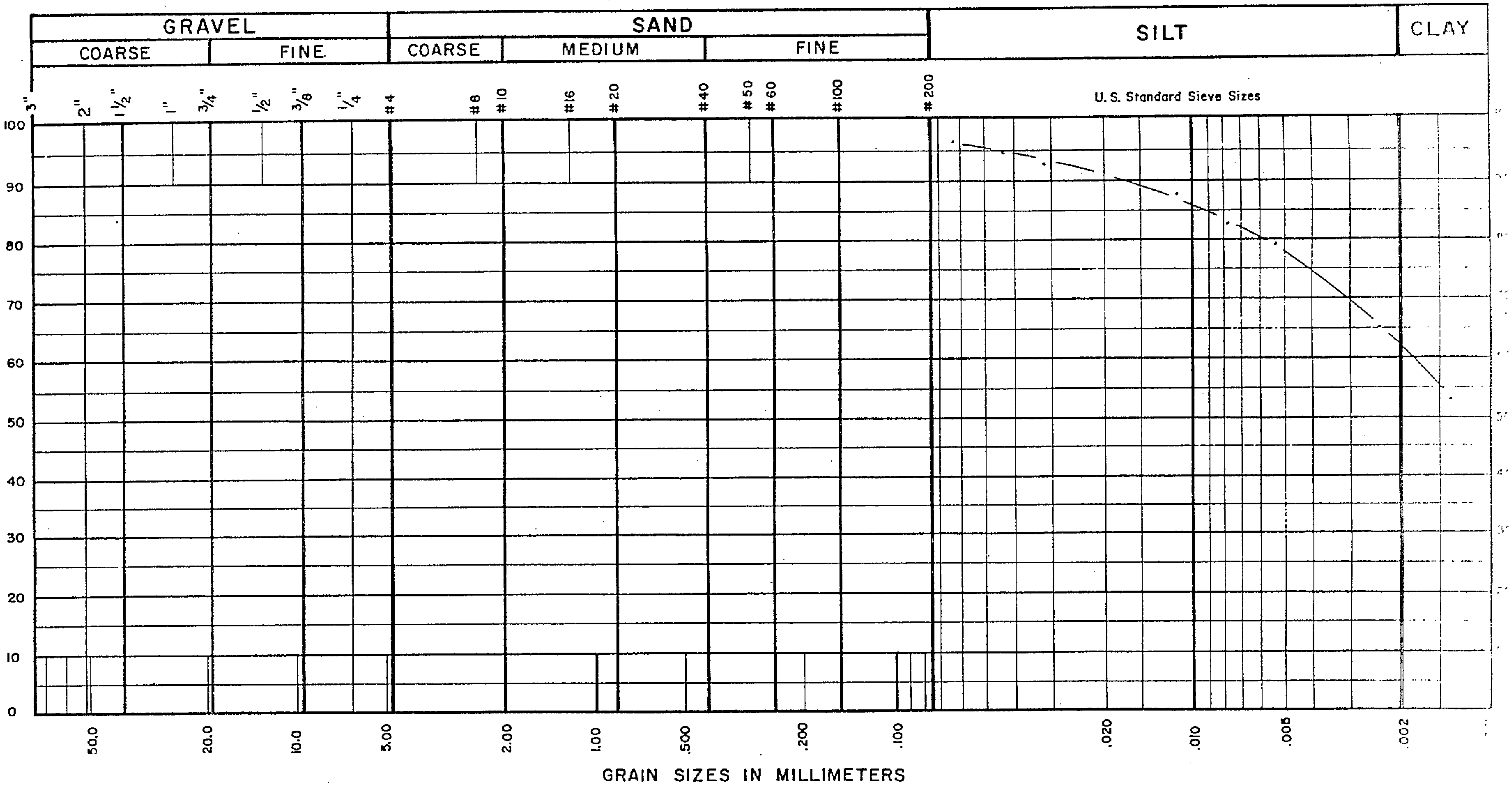
			%
Clay	62.0		
Silt	38.0		
Sand	TR		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-25'
TEST DATE	Dec 19/86 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	62.0		%
Silt	38.0		
Sand	TR		
Gravel			

Classification

CLIENT Seakem Oceanographic

PROJECT

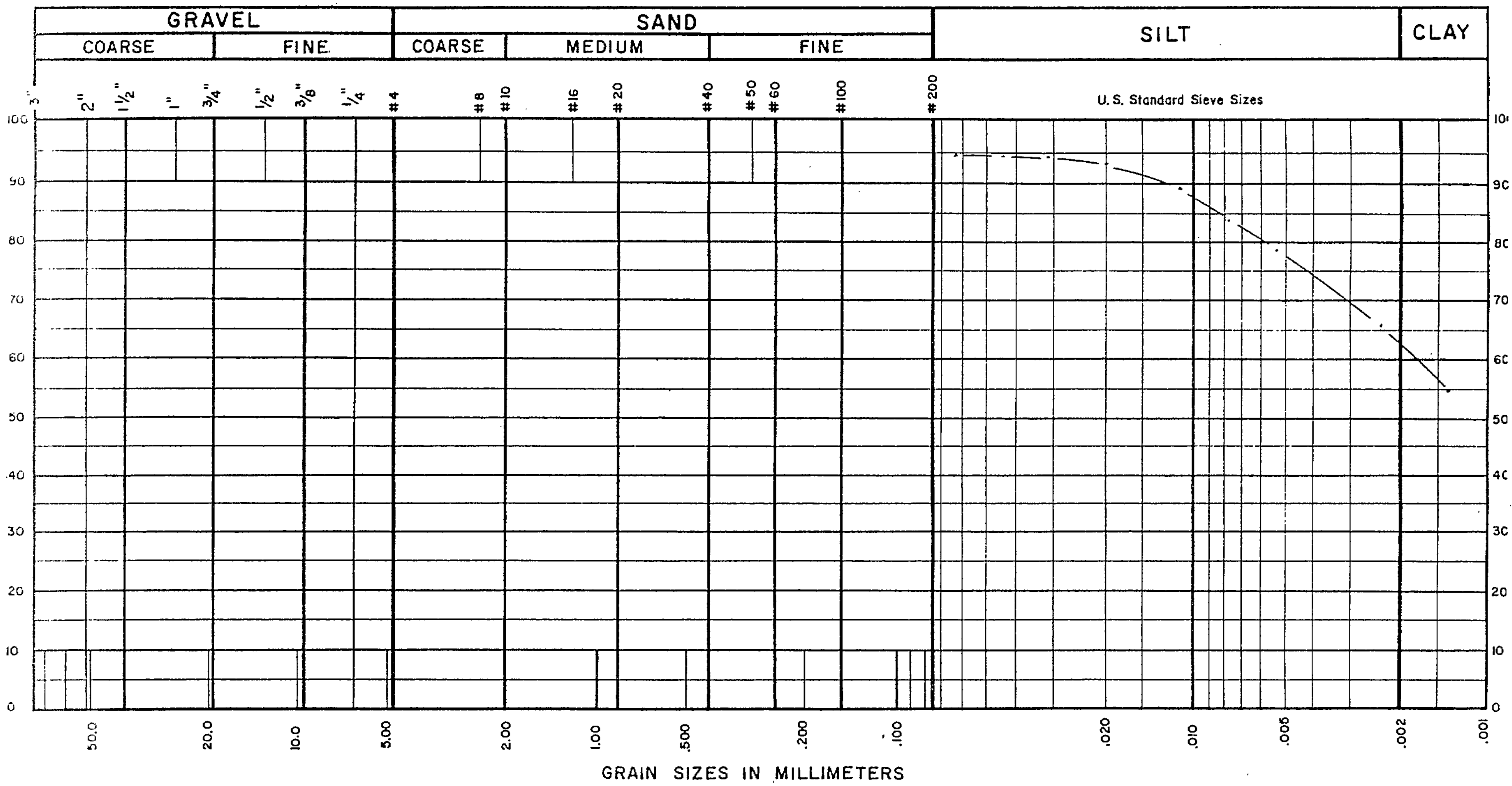
LOCATION

SAMPLE 1-26

TEST DATE Dec 19/86 FILE Nº 19-[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



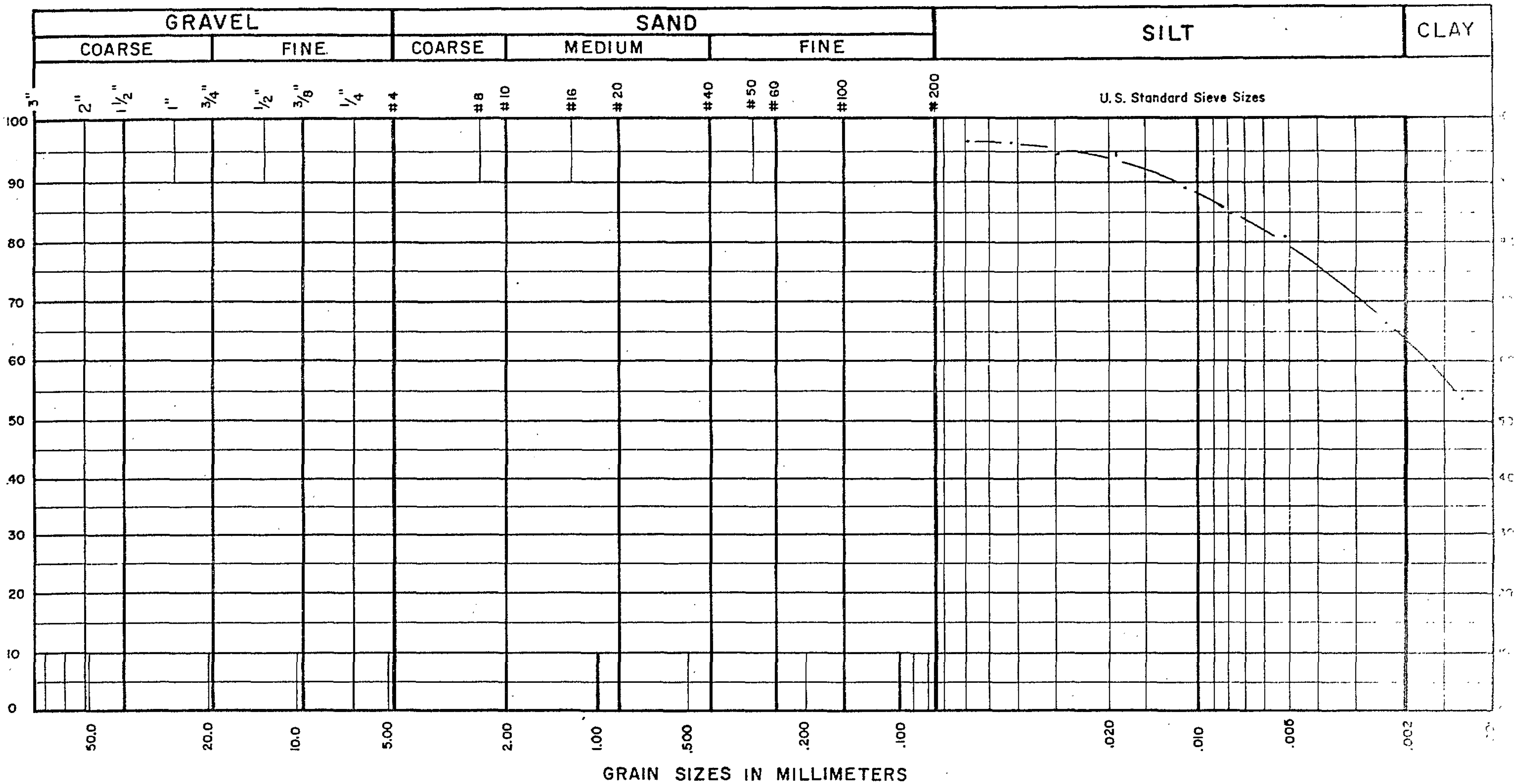
Nat. Water Content			%	Clay	62.5		%
Liquid Limit				Silt	37.5		
Plastic Limit				Sand	Tr		
Plastic Index				Gravel			

Classification ______________________

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	1-27
TEST DATE	Dec 19/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



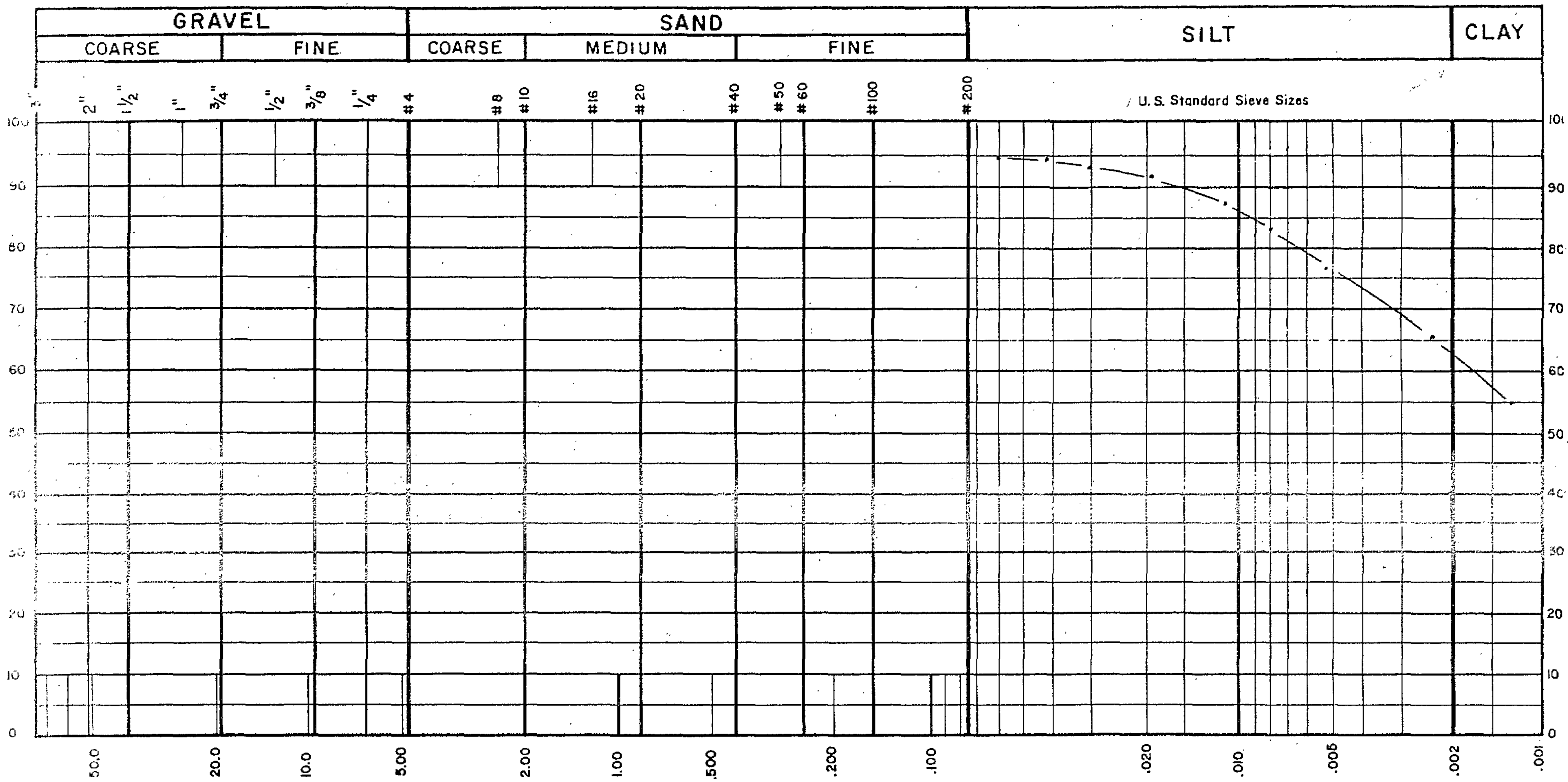
Nat. Water Content			%	Clay	64.0		%
Liquid Limit				Silt	36.0		
Plastic Limit				Sand	TR		
Plastic Index				Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	1-28
TEST DATE	DEC 19/86 FILE No [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



GRAIN SIZES IN MILLIMETERS

			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

			%
Clay	62.5		
Silt	37.5		
Sand	TR		
Gravel			

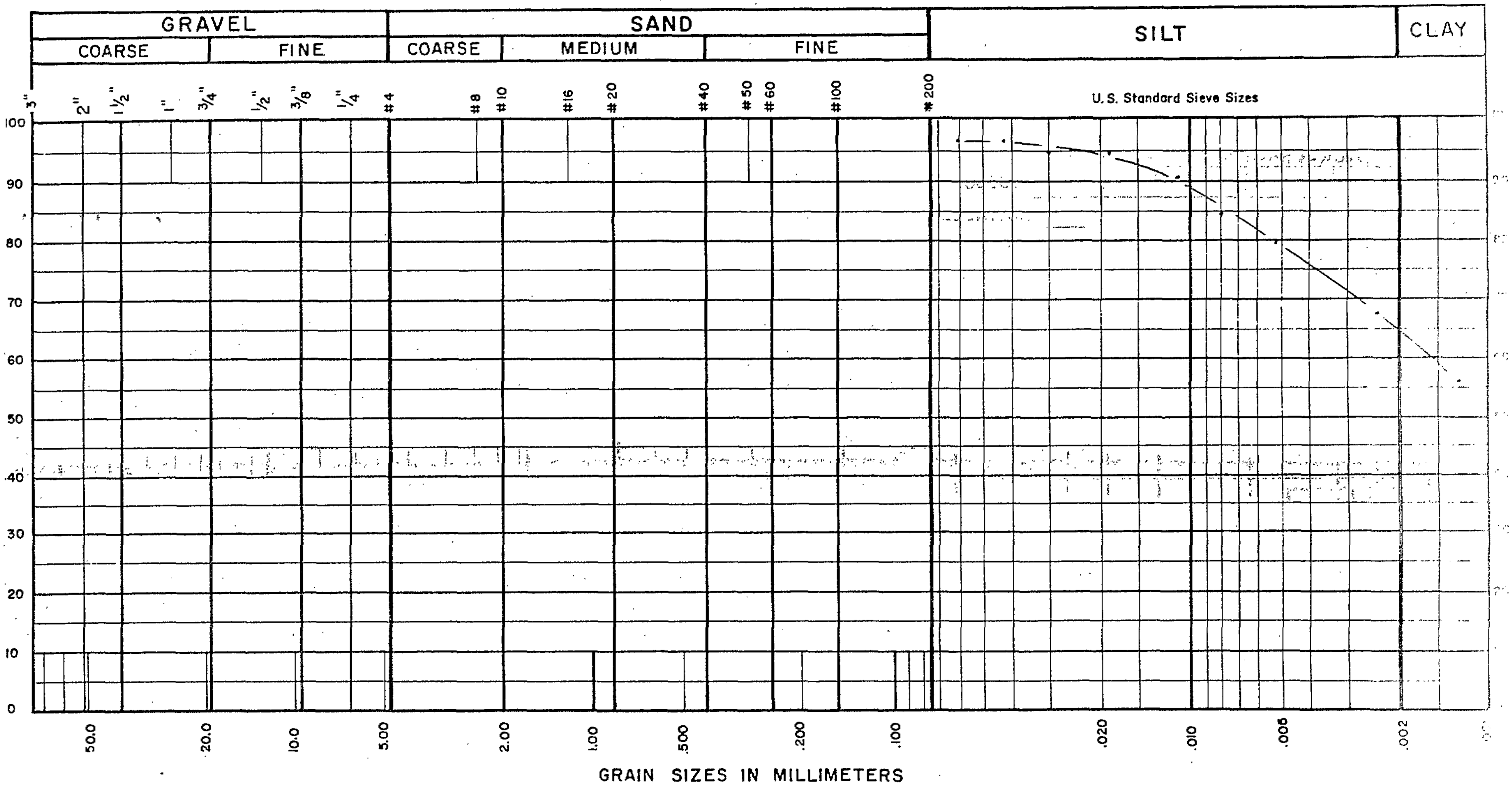
Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	1 - 29
TEST DATE	Dec 19/86

FILE Nº 19-138

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	65.0		%
Silt	35.0		
Sand	TR		
Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC

PROJECT

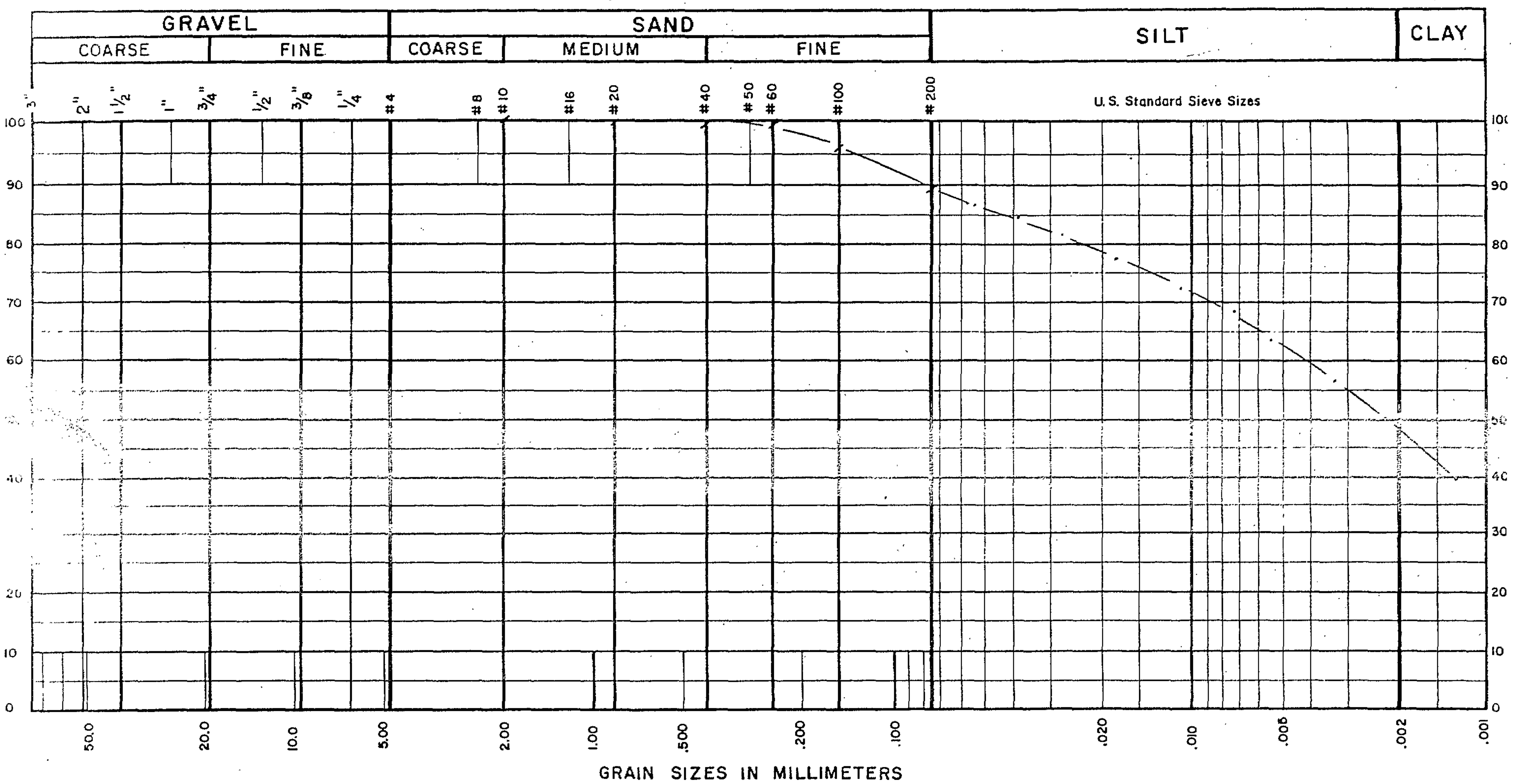
LOCATION

SAMPLE 1 - 30

TEST DATE DEC 19/85 FILE No

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



				%
Nat. Water Content				
Liquid Limit				
Plastic Limit				
Plastic Index				

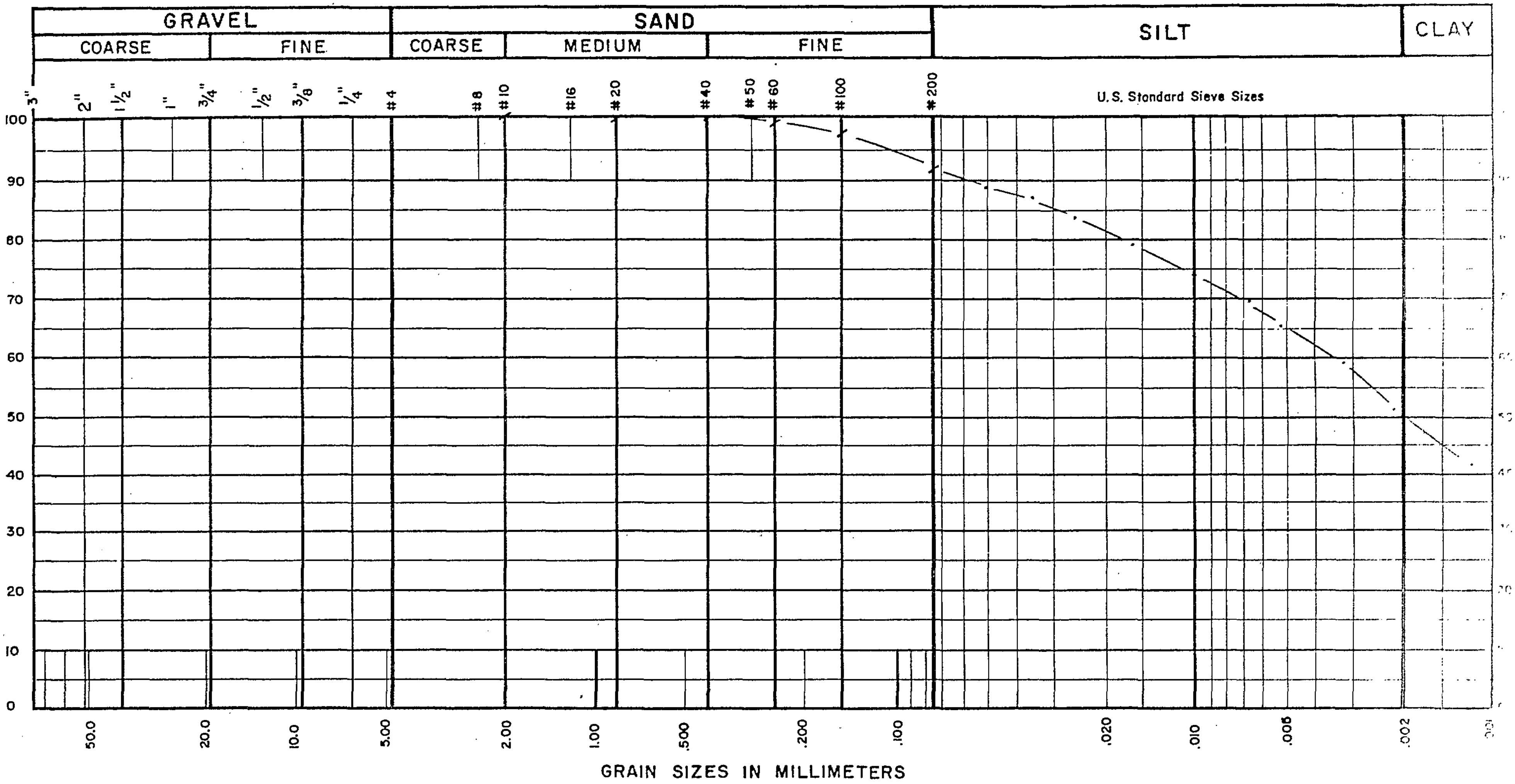
			%
Clay	48.0		
Silt	41.4		
Sand	10.6		
Gravel	—		

Classification ____________________

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 2-1
TEST DATE Dec 23/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



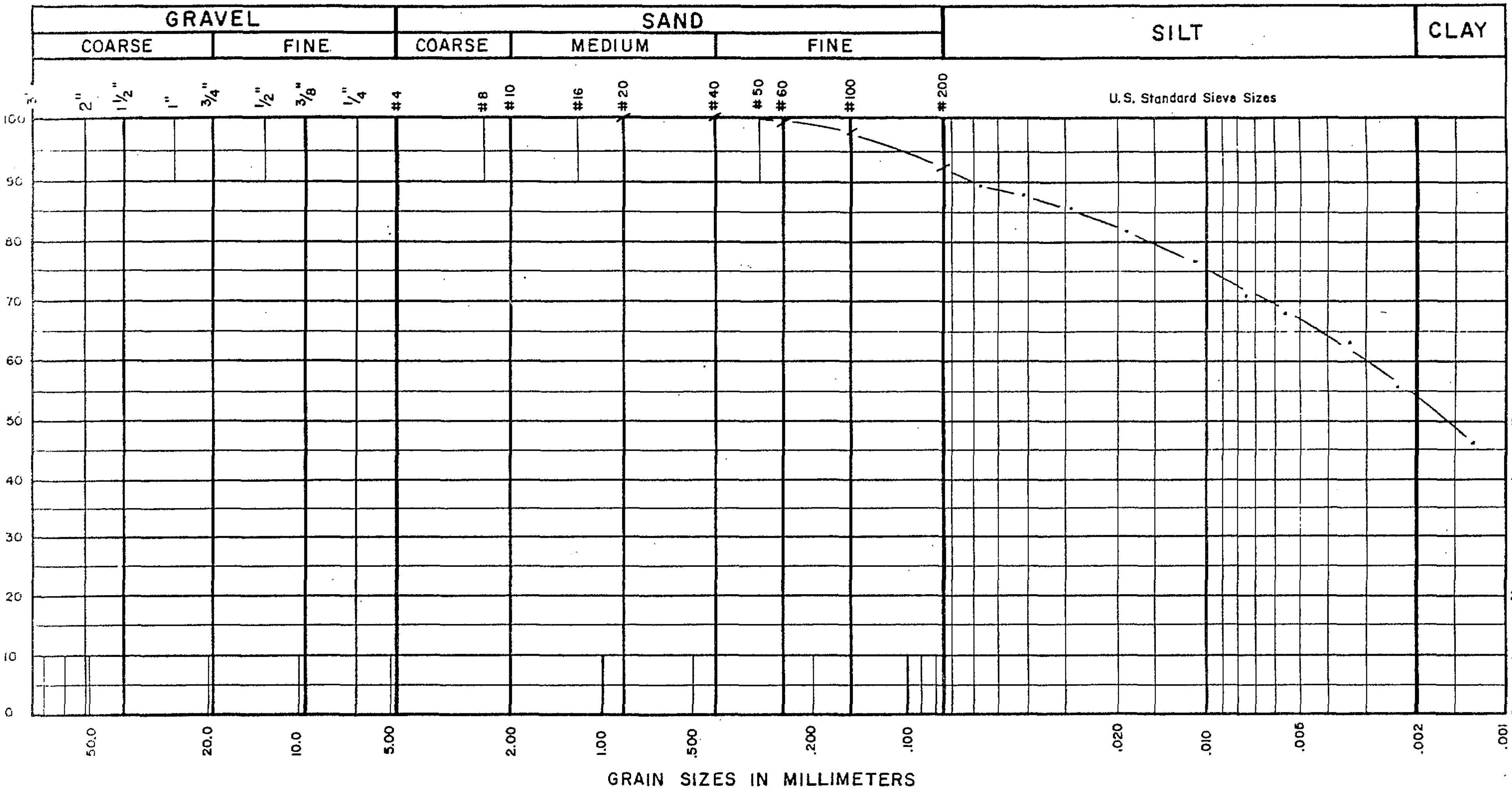
Nat. Water Content	%	Clay	50.0 %
Liquid Limit		Silt	42.0
Plastic Limit		Sand	8.0
Plastic Index		Gravel	

Classification ______

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-3
TEST DATE	Dec 23/86 — FILE No 19-[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

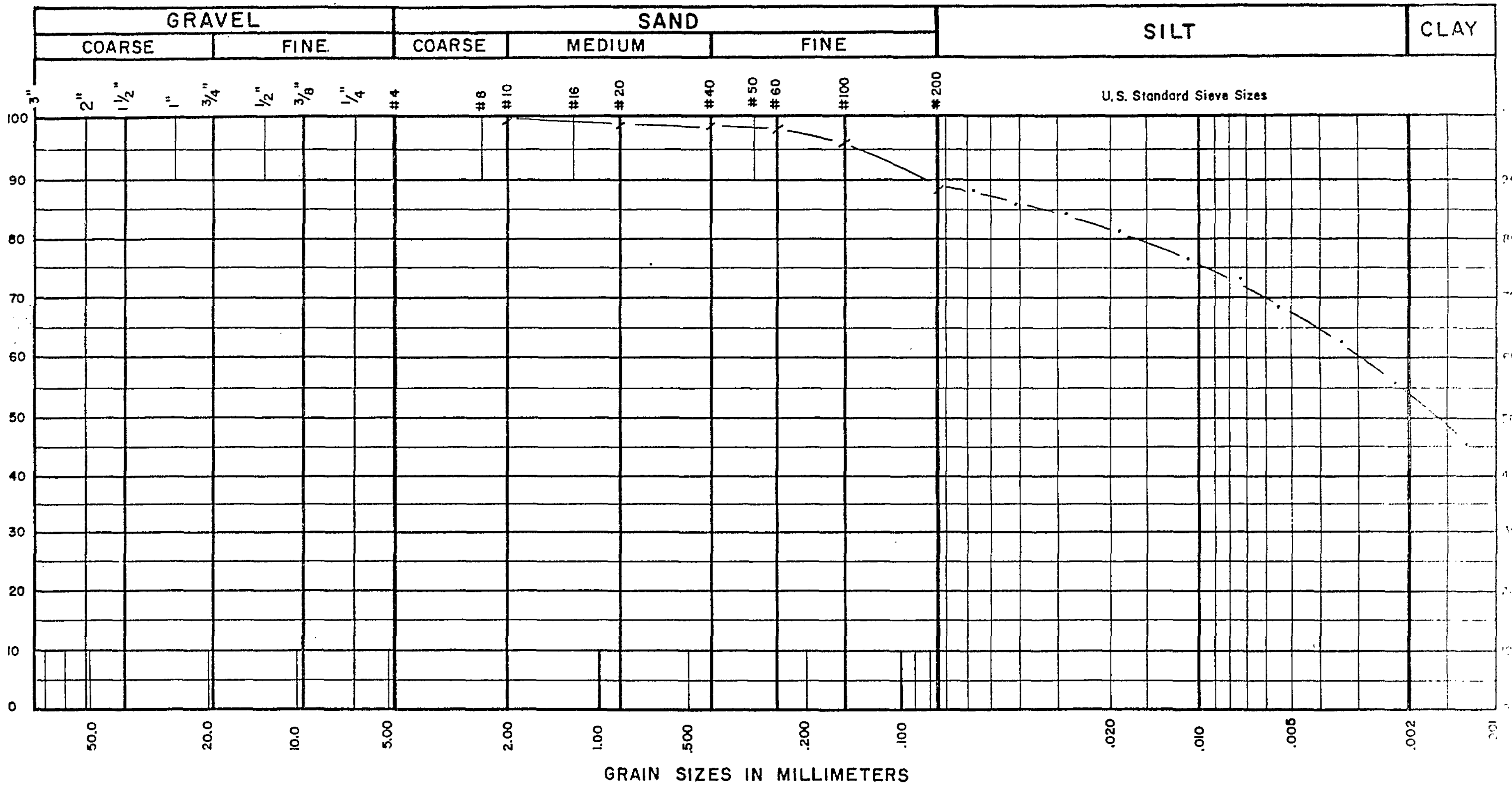
Clay	54.0		%
Silt	38.5		
Sand	7.5		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	2-1
TEST DATE	Dec 23/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)

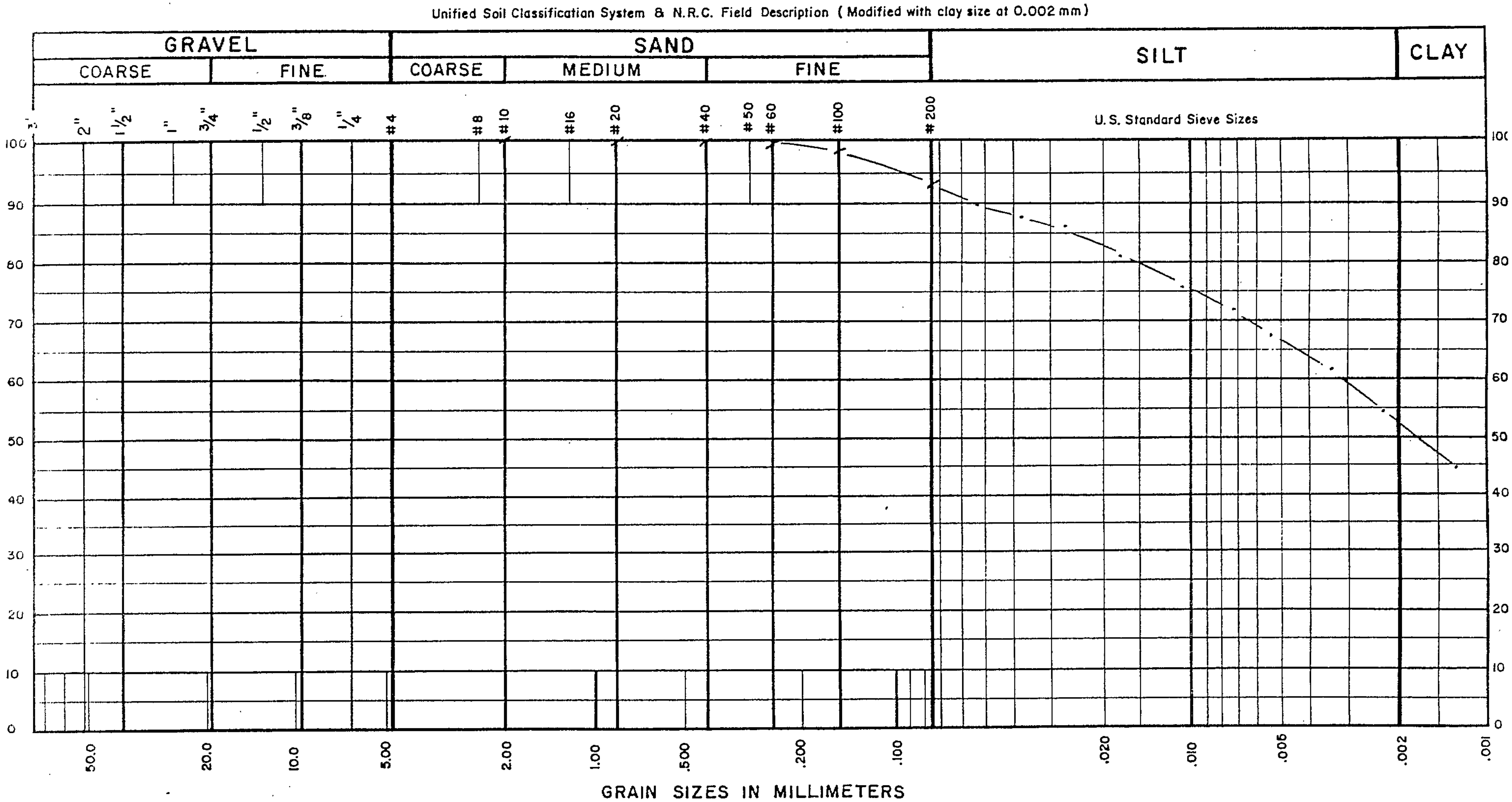


Nat. Water Content			%	Clay	54.0		%
Liquid Limit				Silt	34.0		
Plastic Limit				Sand	12.0		
Plastic Index				Gravel			

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-5
TEST DATE	Dec 23/86 — FILE No [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%	
Liquid Limit				
Plastic Limit				
Plastic Index				

Clay	52.5		%
Silt	40.3		
Sand	7.2		
Gravel			

Classification

CLIENT Seakem Oceanographic

PROJECT

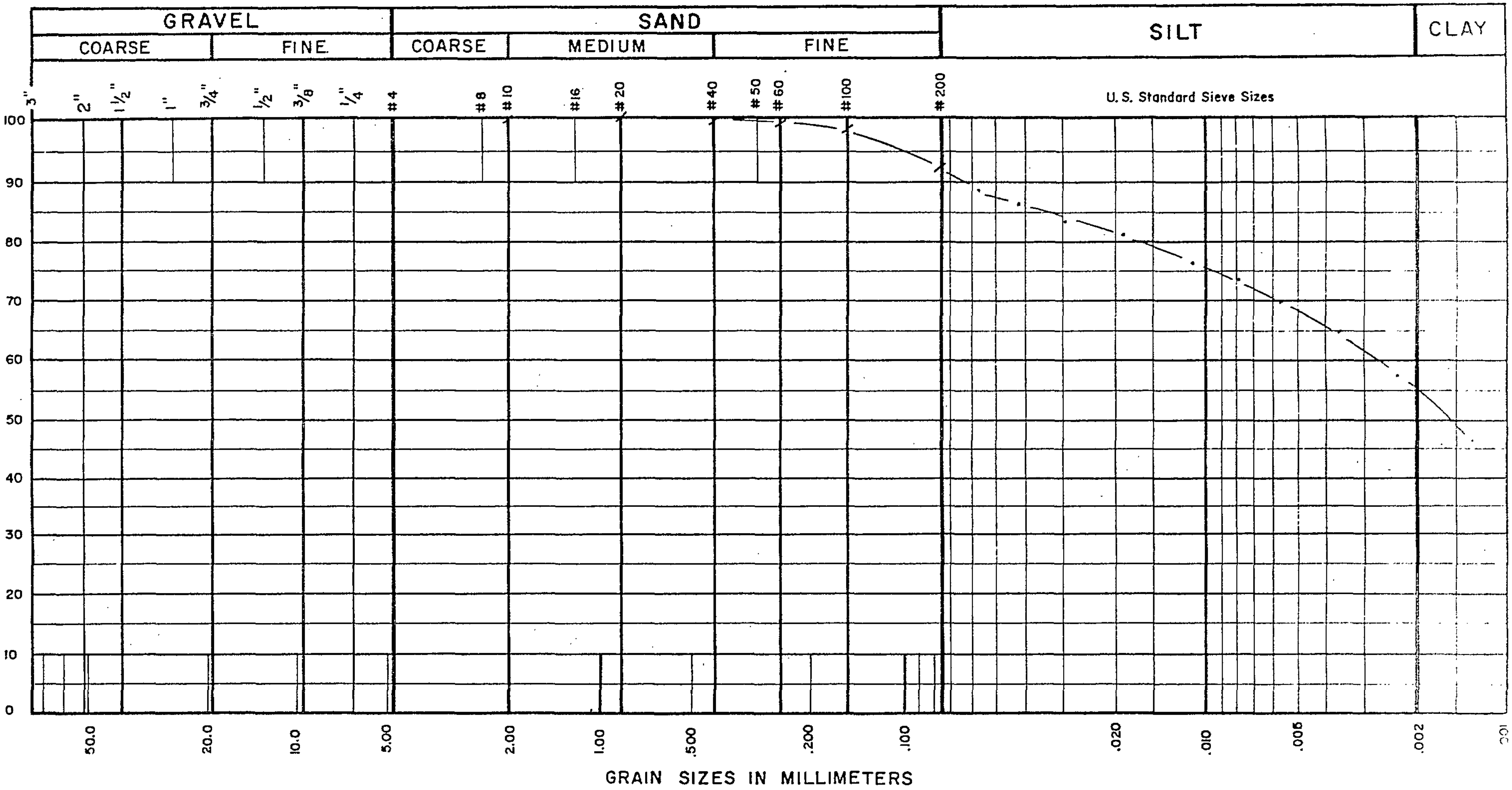
LOCATION

SAMPLE 2 - 6

TEST DATE Dec 23/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

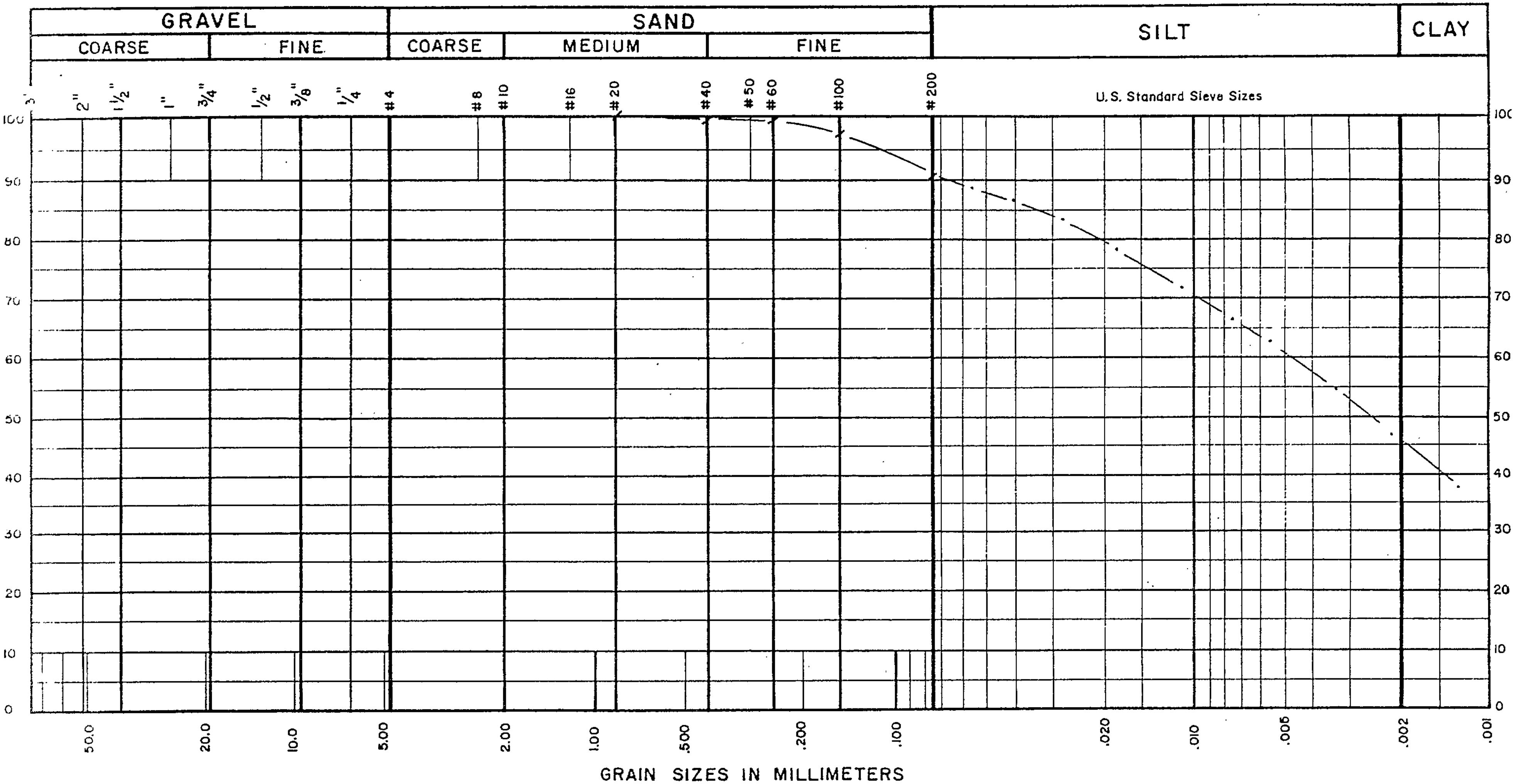
Clay	55.0		%
Silt	37.5		
Sand	7.5		
Gravel	–		

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-7
TEST DATE	DEC 23/86 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

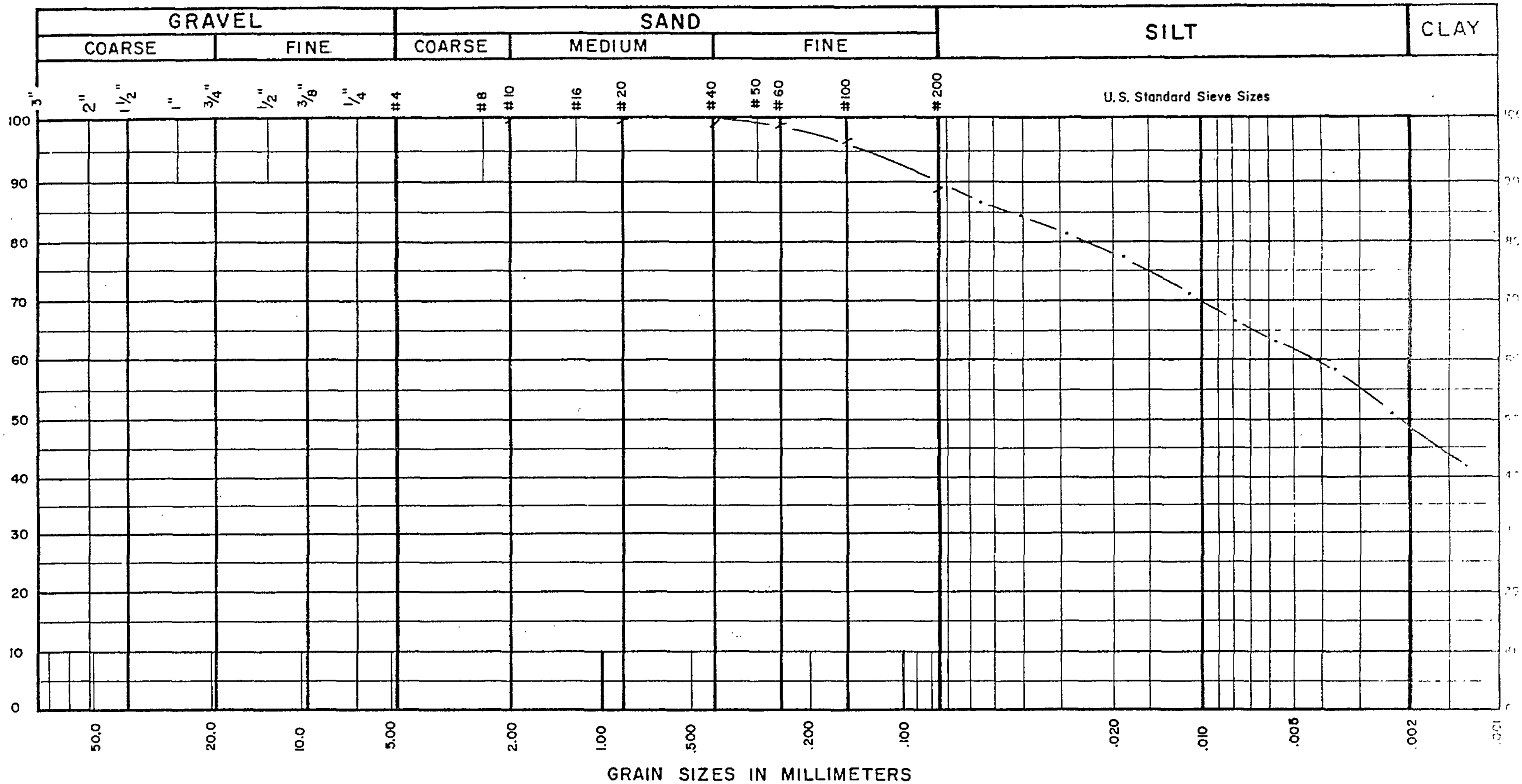
Clay	46.0		%
Silt	44.2		
Sand	9.8		
Gravel	—		

Classification

CLIENT	Seakem Oceanographic		
PROJECT			
LOCATION			
SAMPLE	2 - 2		
TEST DATE	Dec 29/86	FILE Nº	19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



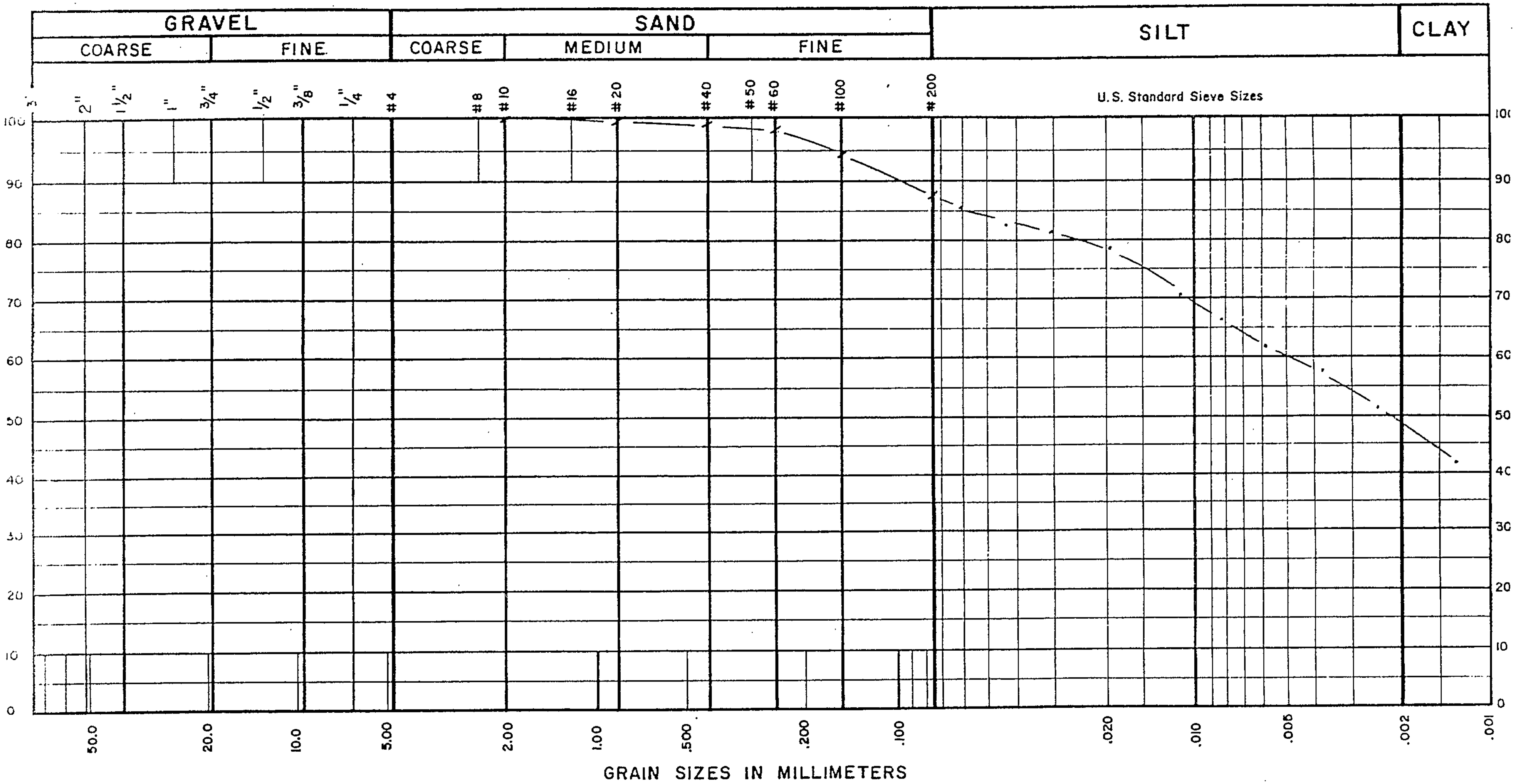
Nat. Water Content	%		Clay	49.0 %
Liquid Limit			Silt	39.9
Plastic Limit			Sand	11.1
Plastic Index			Gravel	

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2 – 8
TEST DATE	DEC 23/86 FILE Nº 19-3910

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	48.0		%
Silt	39.8		
Sand	12.2		
Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC

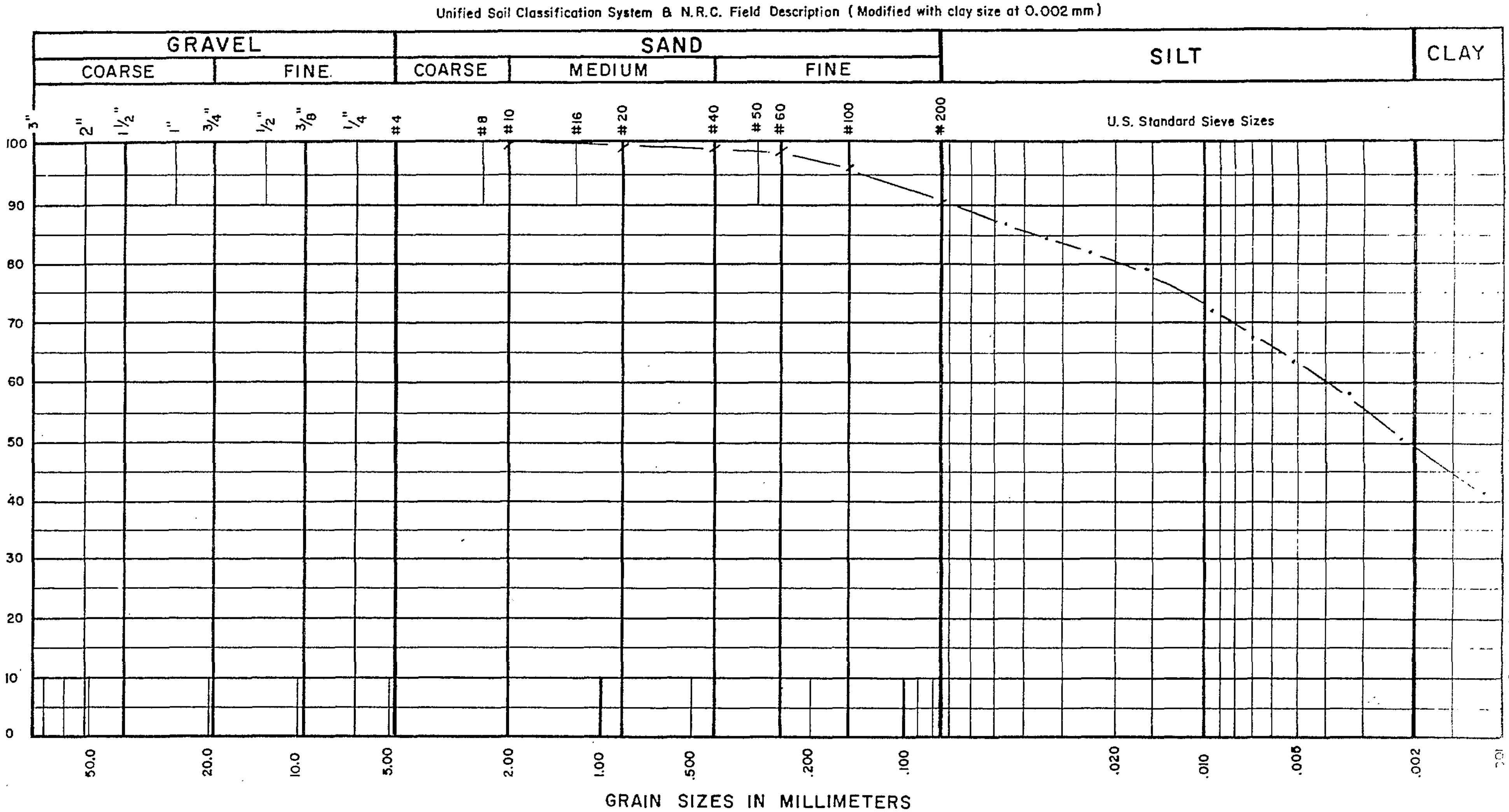
PROJECT

LOCATION

SAMPLE 2-9

TEST DATE Dec 23/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



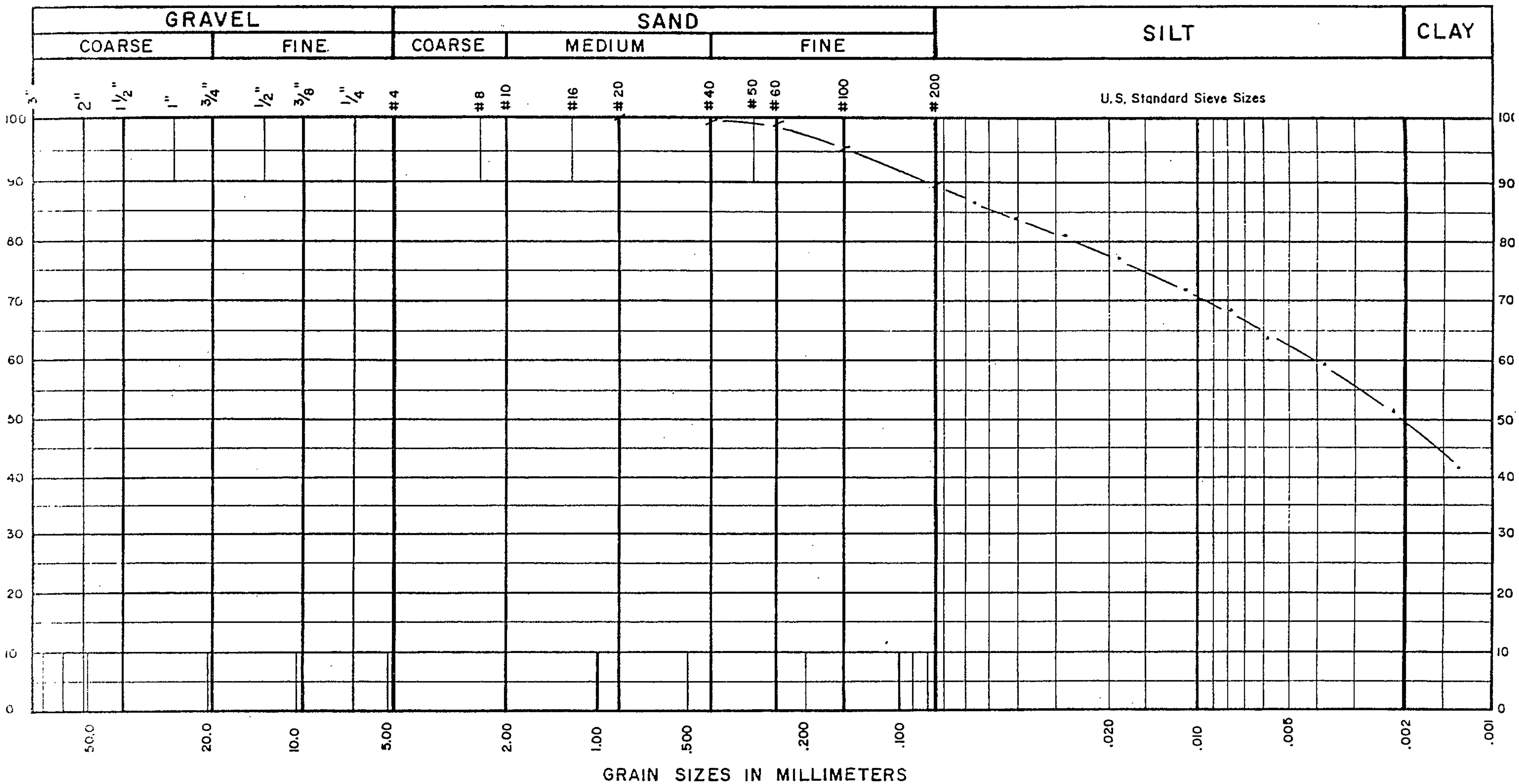
Nat. Water Content			%	Clay	50.0		%
Liquid Limit				Silt	40.1		
Plastic Limit				Sand	9.9		
Plastic Index				Gravel			

Classification

CLIENT Seakem Oceanographic
PROJECT
LOCATION
SAMPLE 2-10
TEST DATE Dec 23/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

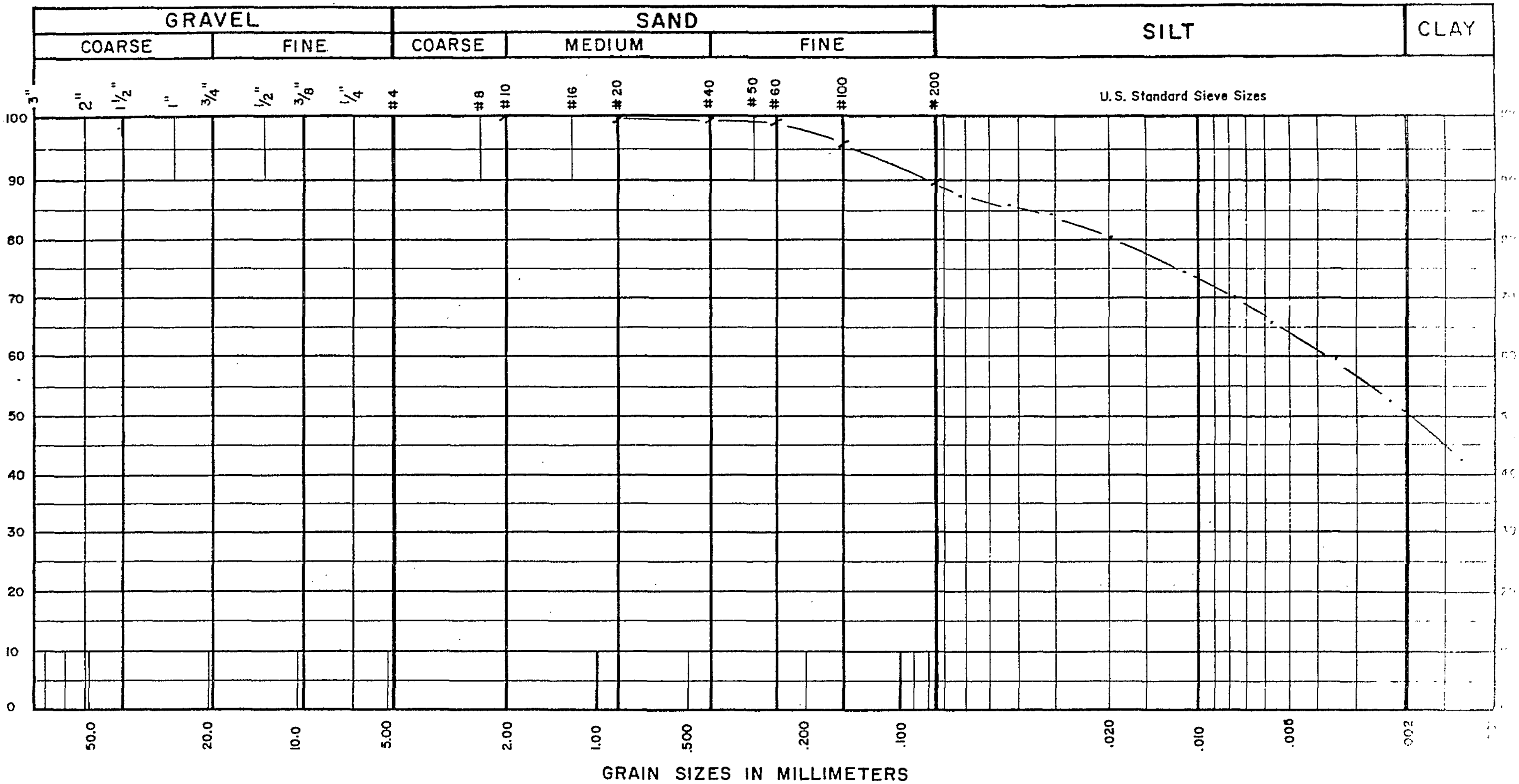
			%
Clay	50.0		
Silt	39.7		
Sand	10.3		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	2-11
TEST DATE	Dec 23/86 FILE NO 19-395.0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content		%
Liquid Limit		
Plastic Limit		
Plastic Index		

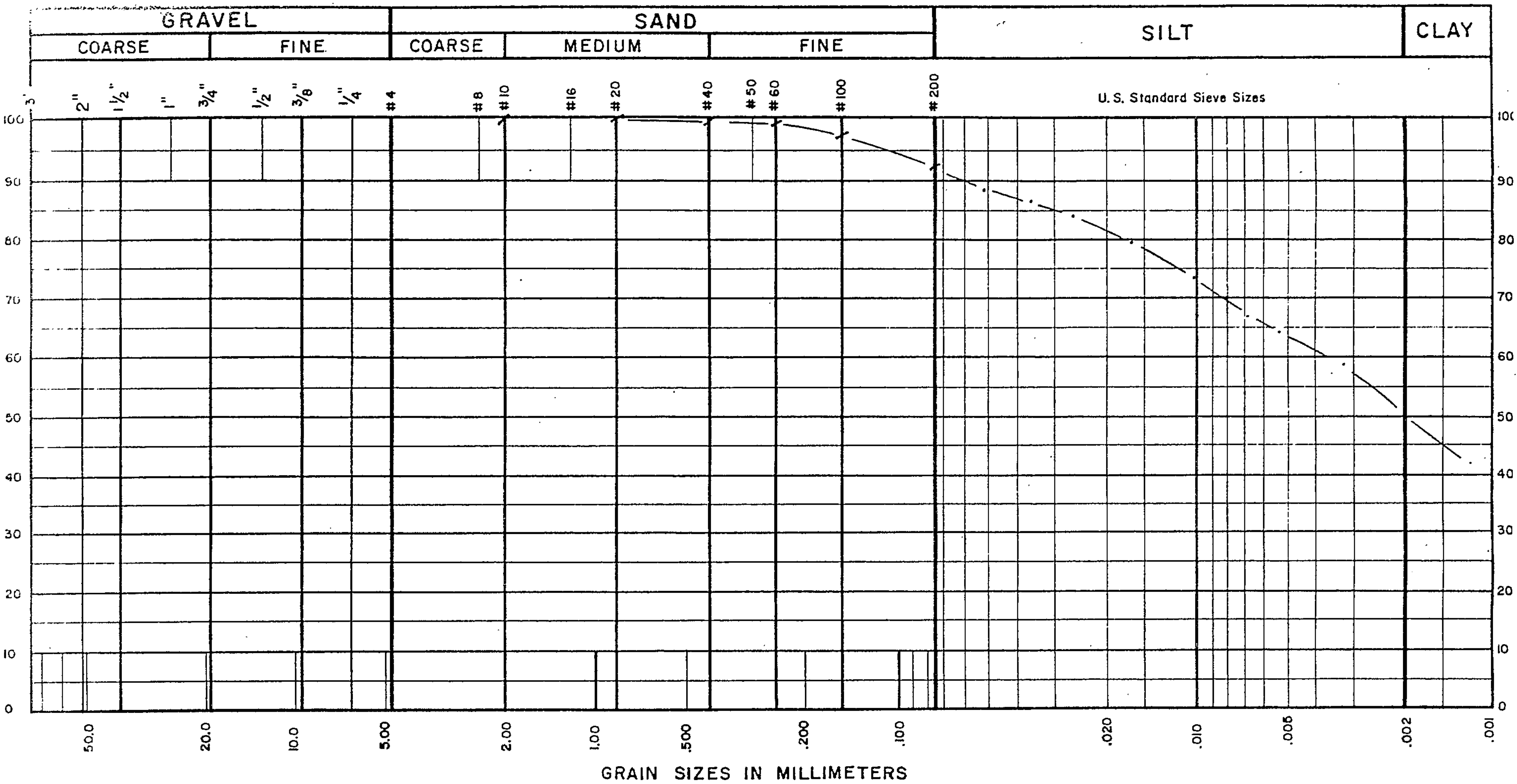
Clay	50.0	%
Silt	39.9	
Sand	10.1	
Gravel		

Classification

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 2 - 12
TEST DATE Dec 29/86 FILE No [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



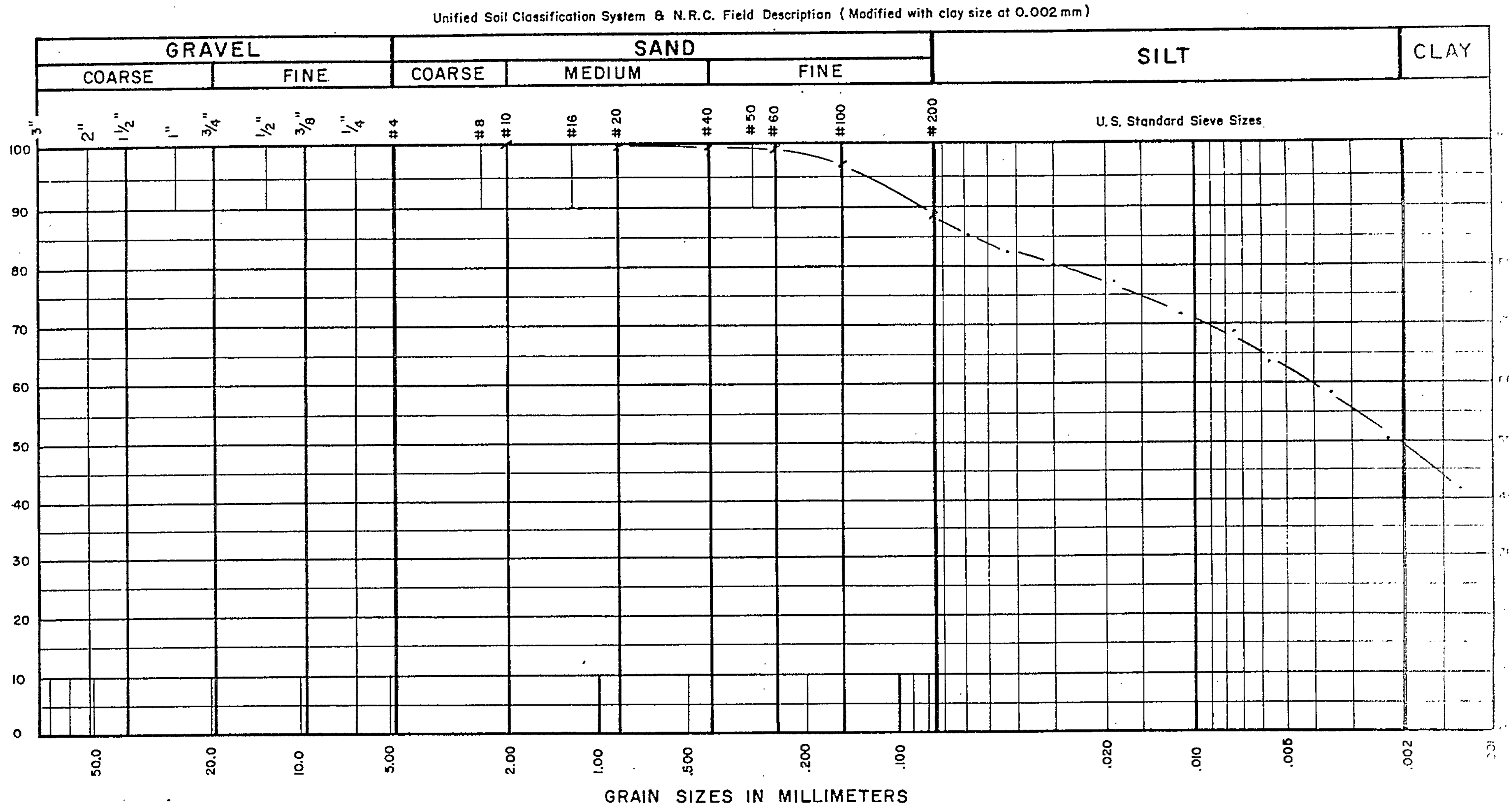
			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

			%
Clay	49.8		
Silt	42.5		
Sand	7.7		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-13
TEST DATE	Dec 29/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	49.0		%
Silt	39.9		
Sand	11.1		
Gravel			

Classification ______

CLIENT SEAKEM OCEANOGRAPHIC

PROJECT

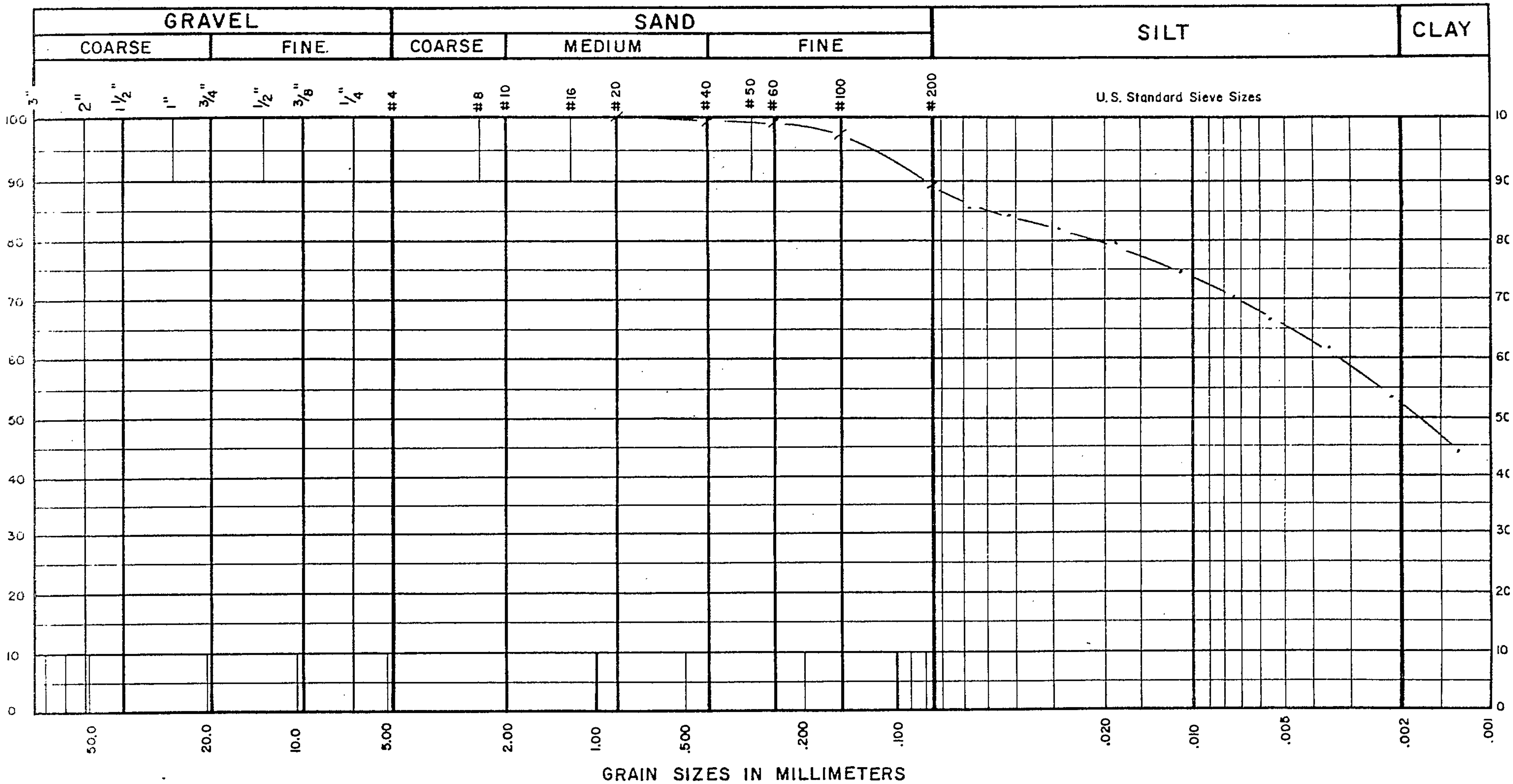
LOCATION

SAMPLE 2-14

TEST DATE Dec 29/86 FILE NO 19.39[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	
Liquid Limit				
Plastic Limit				
Plastic Index				

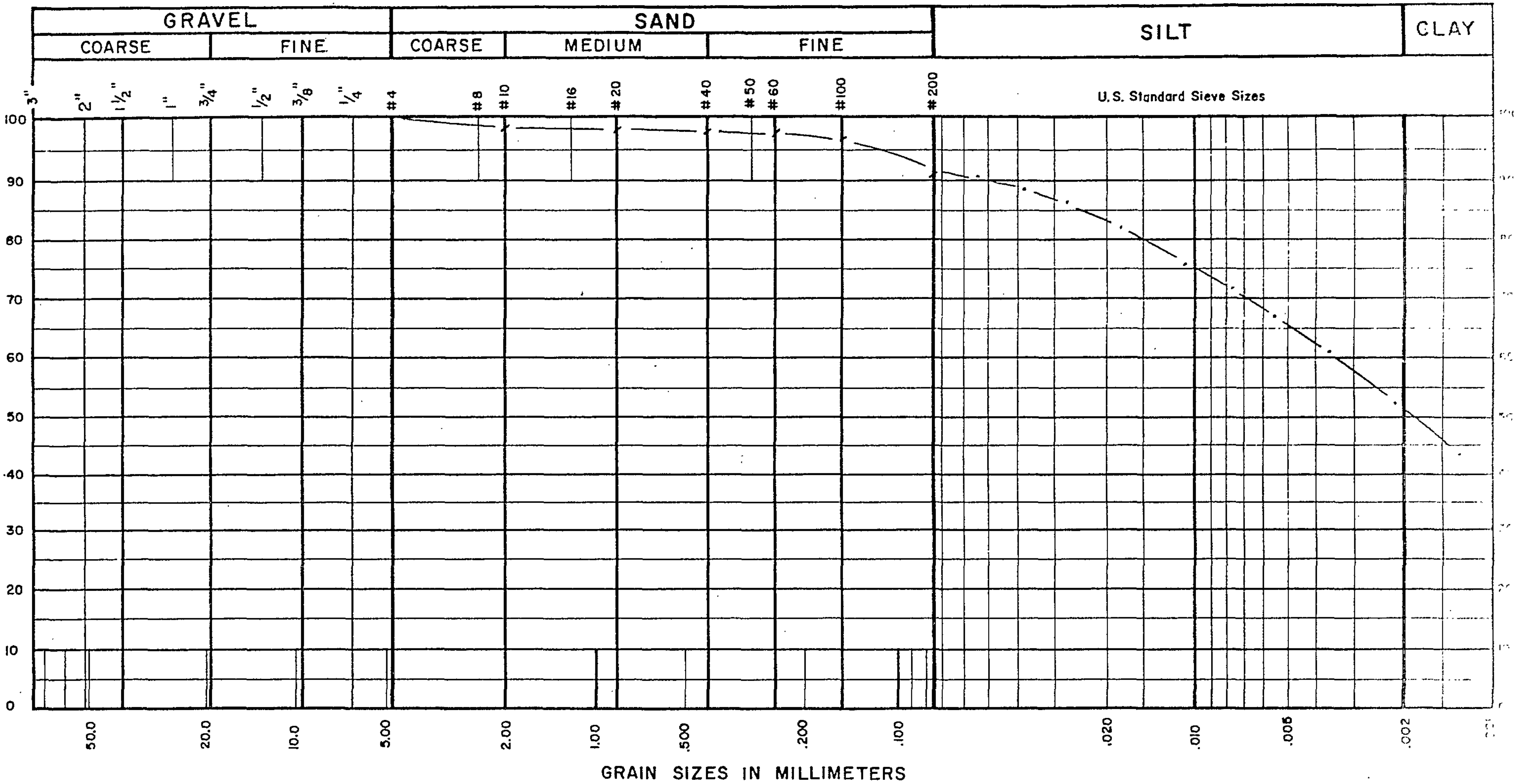
Clay	52.0		%
Silt	37.5		
Sand	10.5		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-15
TEST DATE	Dec 29/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



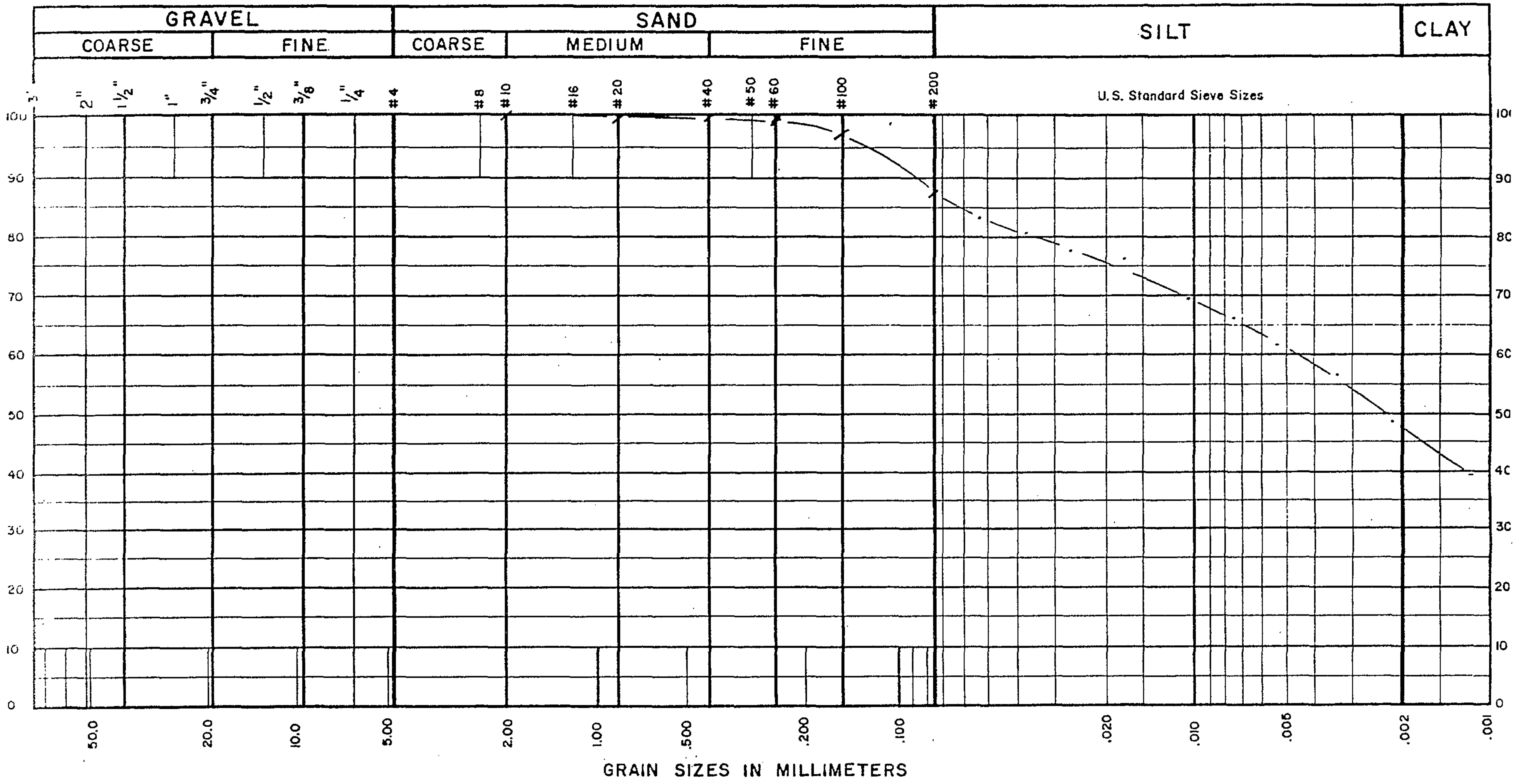
Nat. Water Content			%	Clay	51.0		%
Liquid Limit				Silt	39.9		
Plastic Limit				Sand	9.1		
Plastic Index				Gravel			

Classification ______________________

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	2-17
TEST DATE	Dec 29/86 FILE Nº 19-39[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

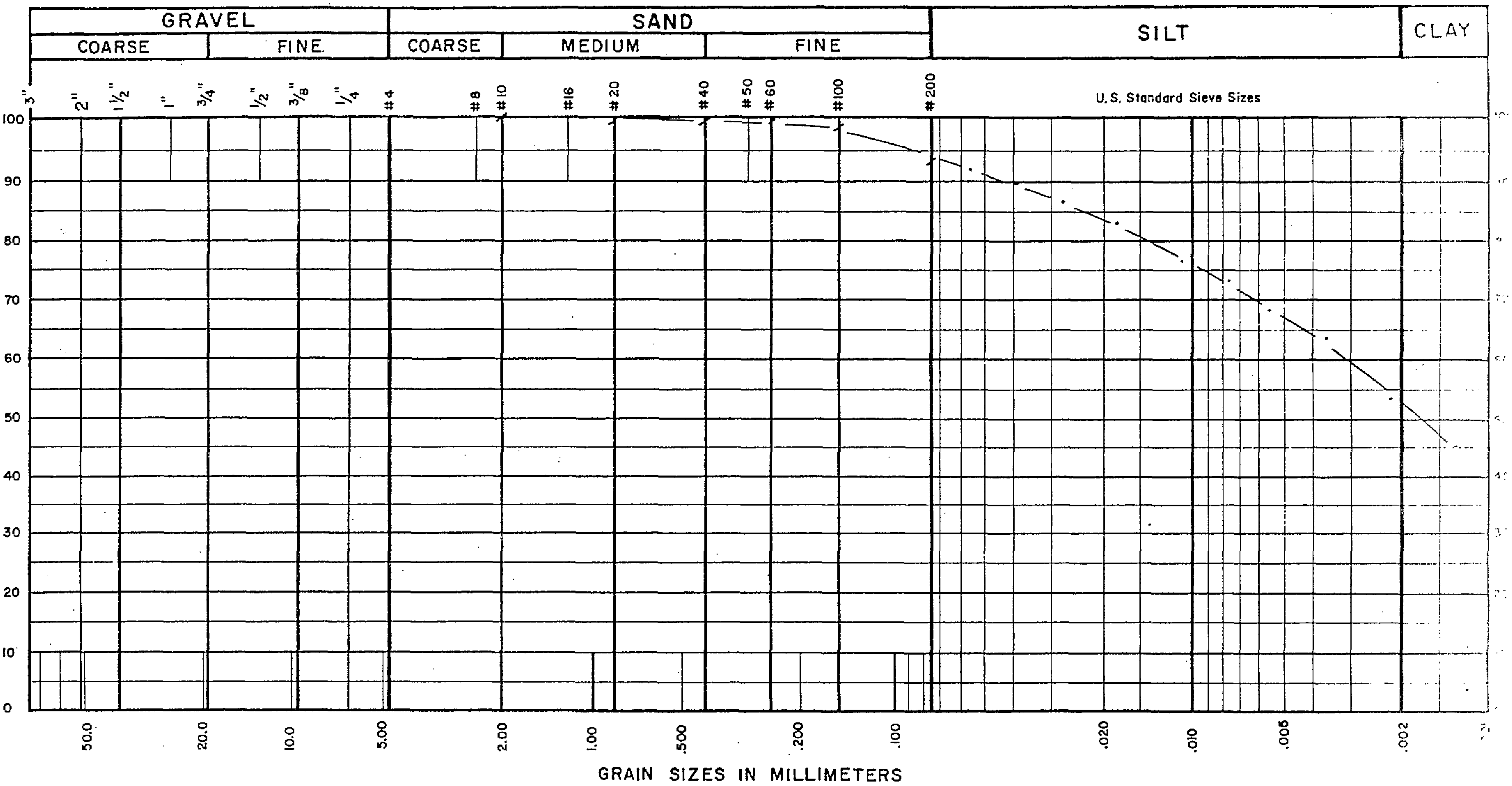
Clay	47.5		%
Silt	40.2		
Sand	12.3		
Gravel			

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2 - 16
TEST DATE	DEC 29/86 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



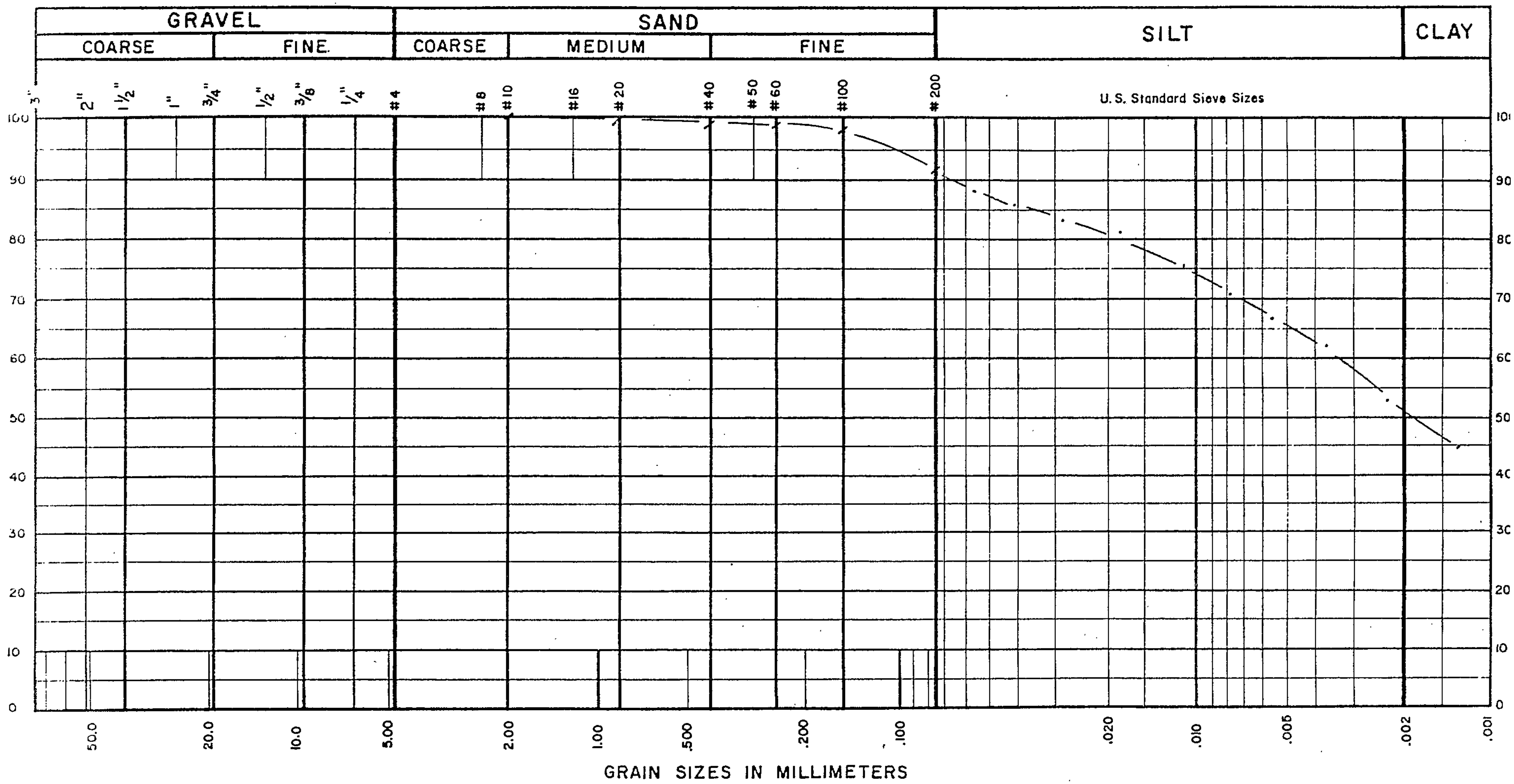
			%					%
Nat. Water Content				Clay	53.0			
Liquid Limit				Silt	40.5			
Plastic Limit				Sand	6.5			
Plastic Index				Gravel				

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-18
TEST DATE	Dec 29/86 FILE No [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

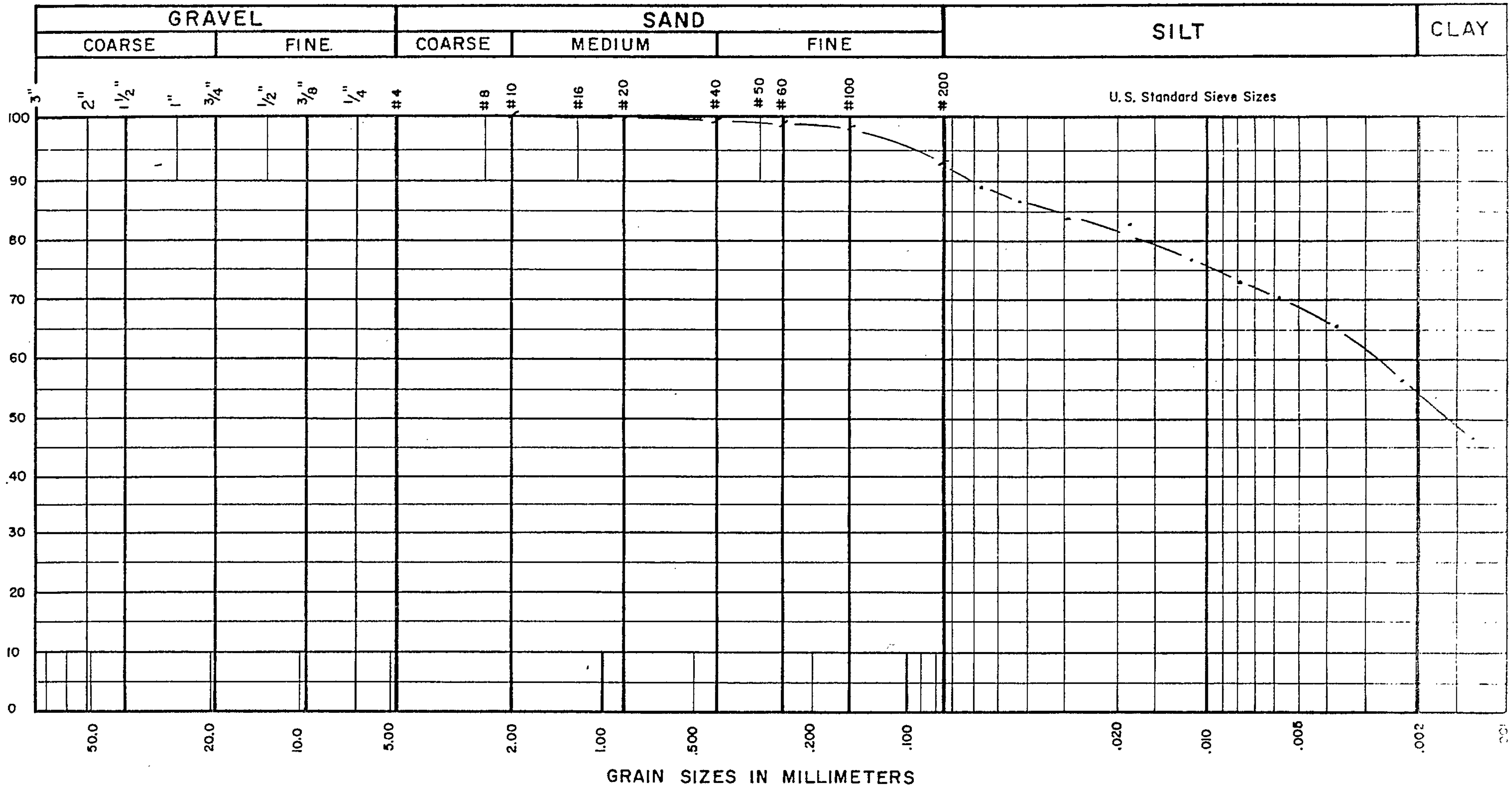
Clay	51.0		%
Silt	40.6		
Sand	8.4		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-19
TEST DATE	DEC 29/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



				%
Nat. Water Content				
Liquid Limit				
Plastic Limit				
Plastic Index				

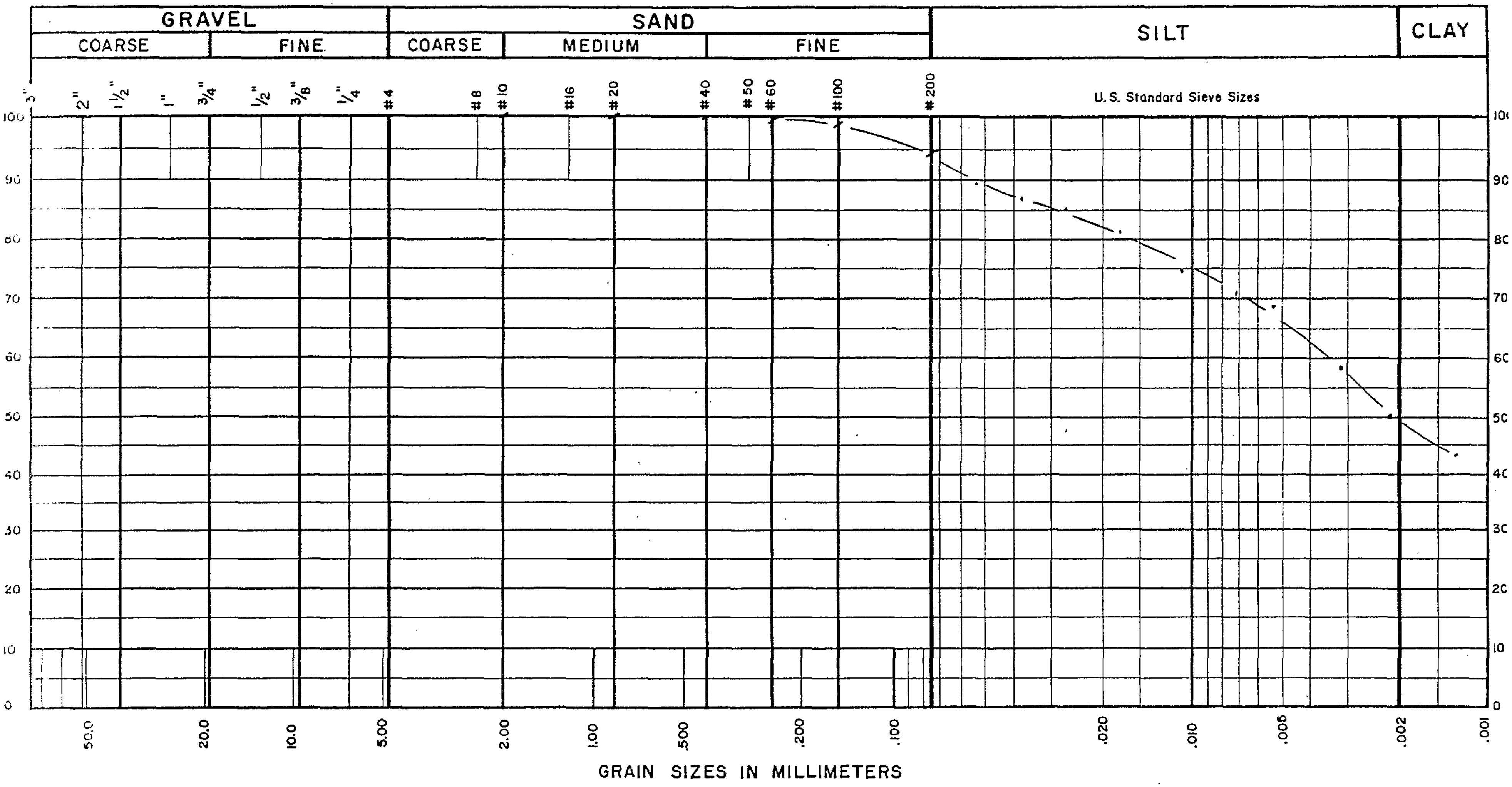
			%
Clay	54.5		
Silt	38.7		
Sand	6.8		
Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 2-20
TEST DATE DEC 29/86 FILE Nº [illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



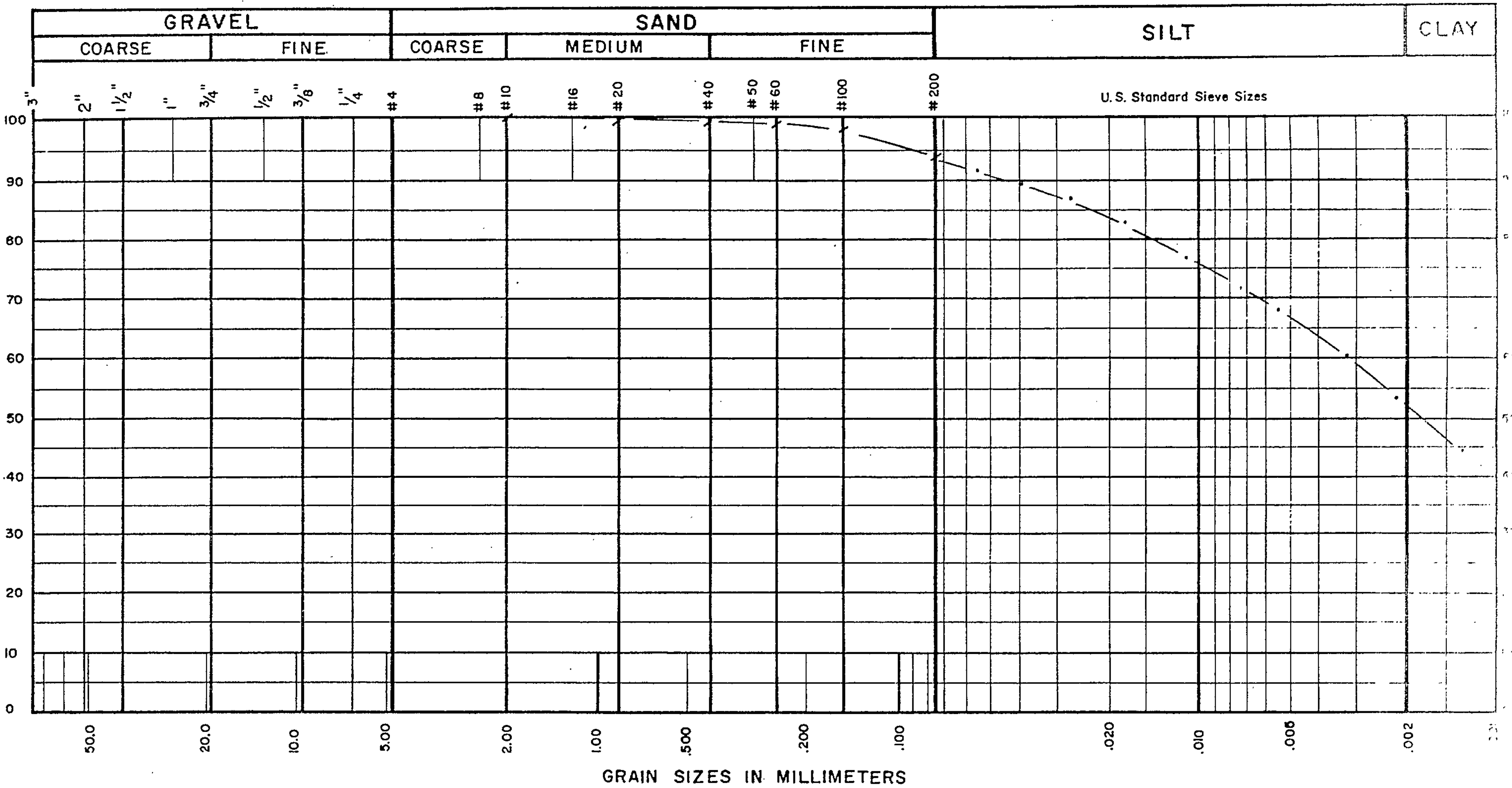
			%		Clay	49.5		%
Nat. Water Content					Silt	45.1		
Liquid Limit					Sand	5.4		
Plastic Limit					Gravel			
Plastic Index								

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	2-21
TEST DATE	Dec 30/86 FILE Nº 19-391-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	52.0		%
Liquid Limit				Silt	42.1		
Plastic Limit				Sand	5.9		
Plastic Index				Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC

PROJECT

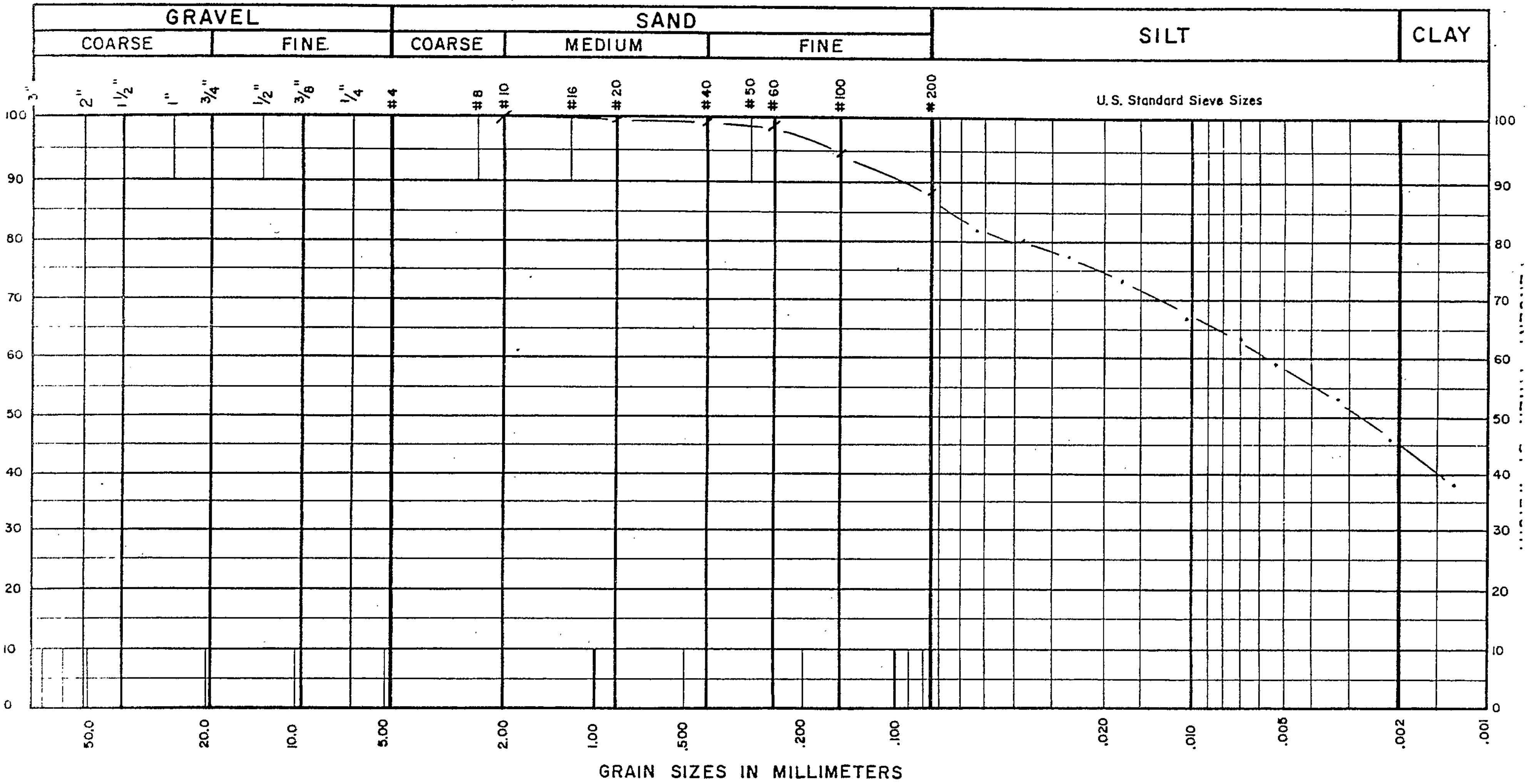
LOCATION

SAMPLE 2-22

TEST DATE Dec 30/86 FILE Nº 17-[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

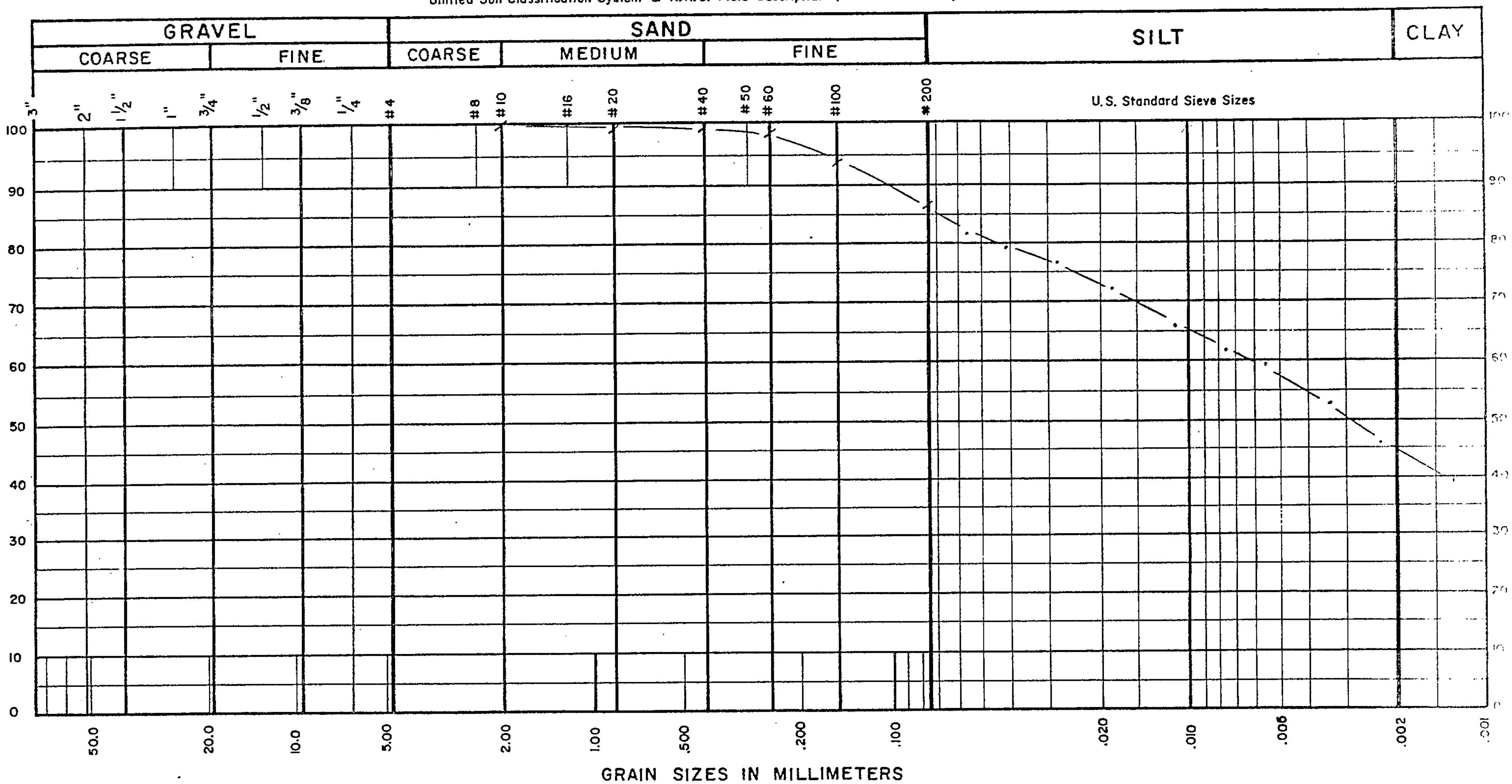
			%
Clay	45.0		
Silt	43.6		
Sand	12.4		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-24
TEST DATE	DEC 30/86 FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



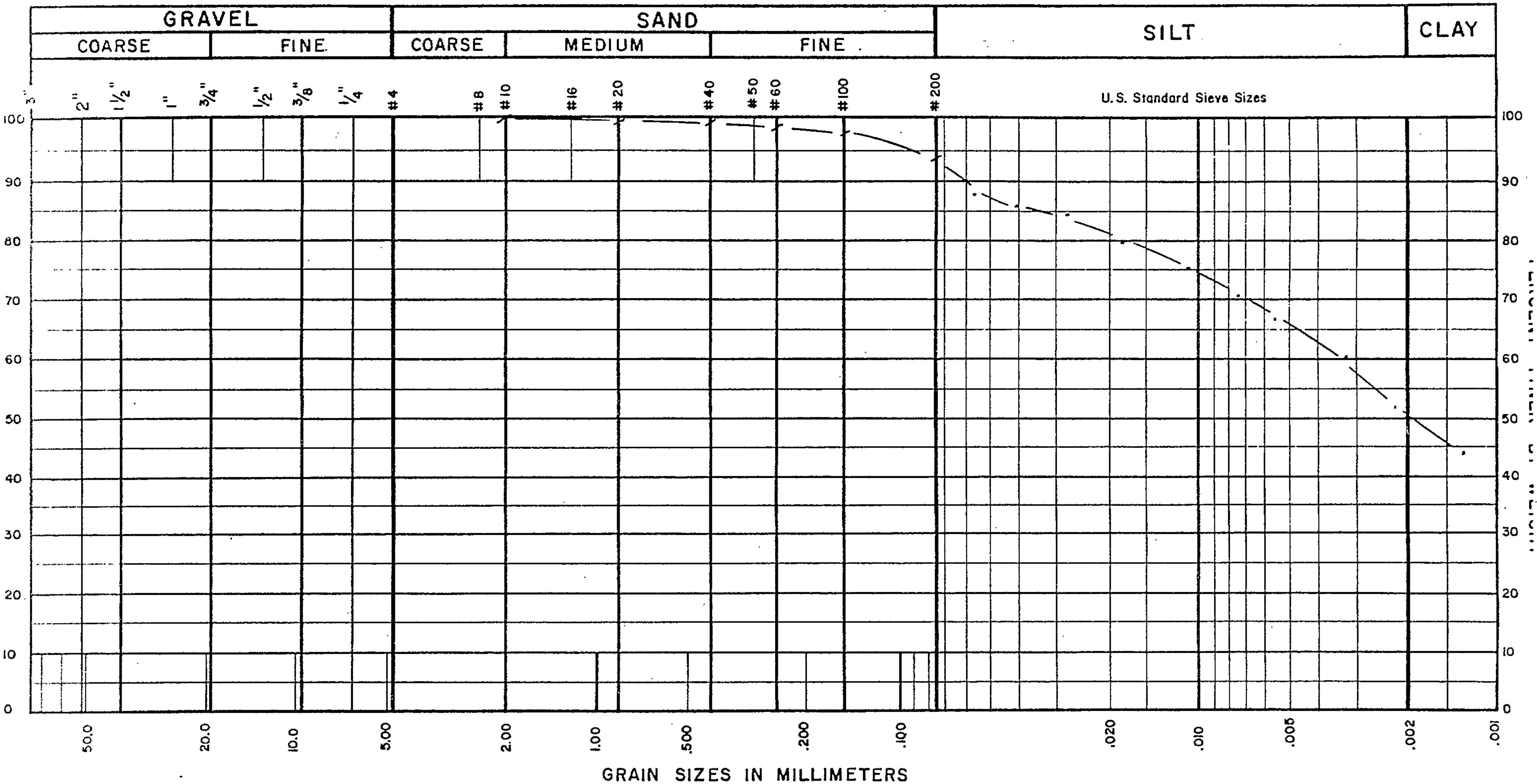
Nat. Water Content	%	Clay	45.0 %
Liquid Limit		Silt	41.7
Plastic Limit		Sand	13.3
Plastic Index		Gravel	

Classification ______

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-25'
TEST DATE	DEC 30/86 FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

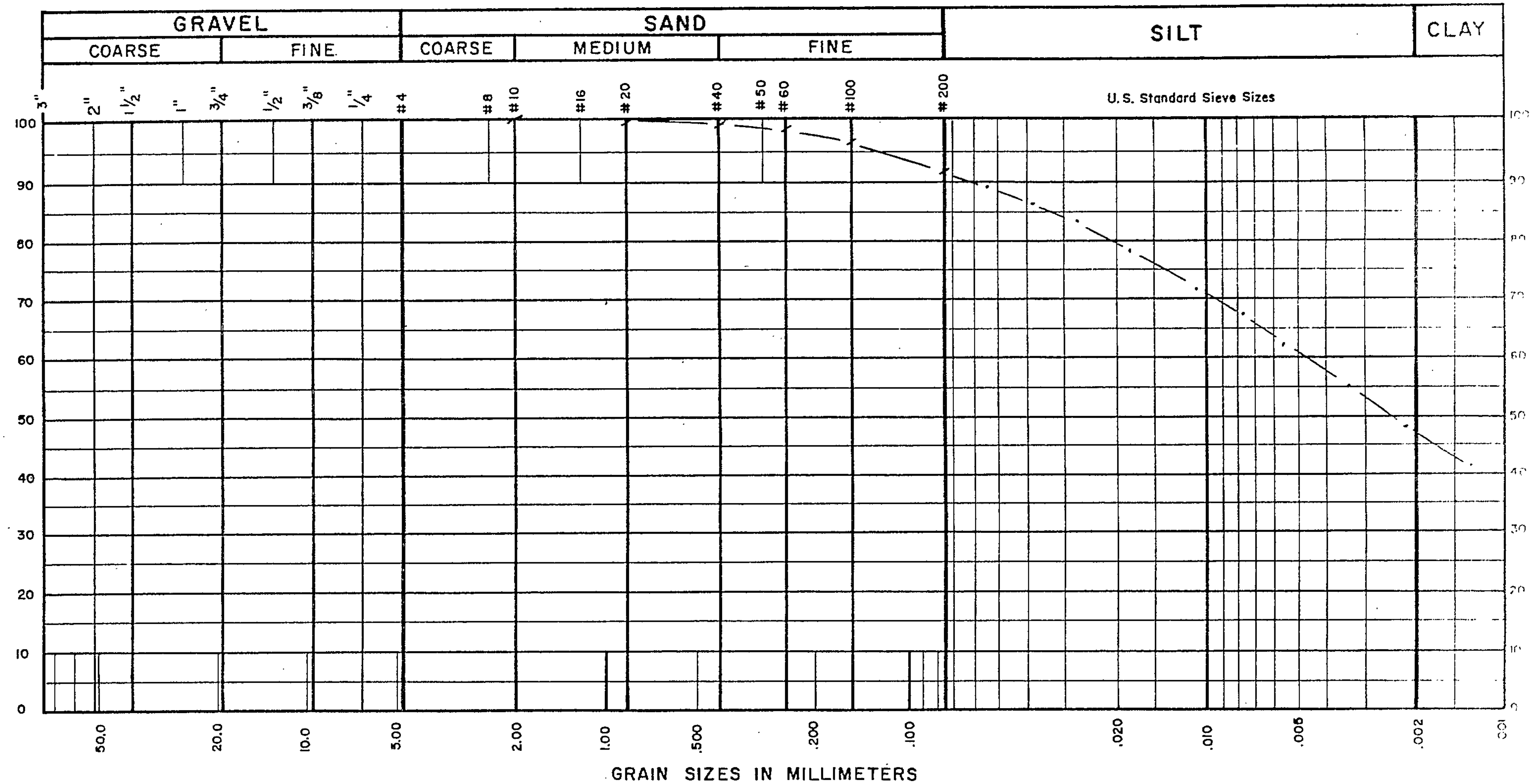
			%
Clay	50.0		
Silt	43.9		
Sand	6.1		
Gravel			

Classification

CLIENT	Seakem Oceanographic
PROJECT	
LOCATION	
SAMPLE	2-23
TEST DATE	Dec 30/86 FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



				%
Nat. Water Content				
Liquid Limit				
Plastic Limit				
Plastic Index				

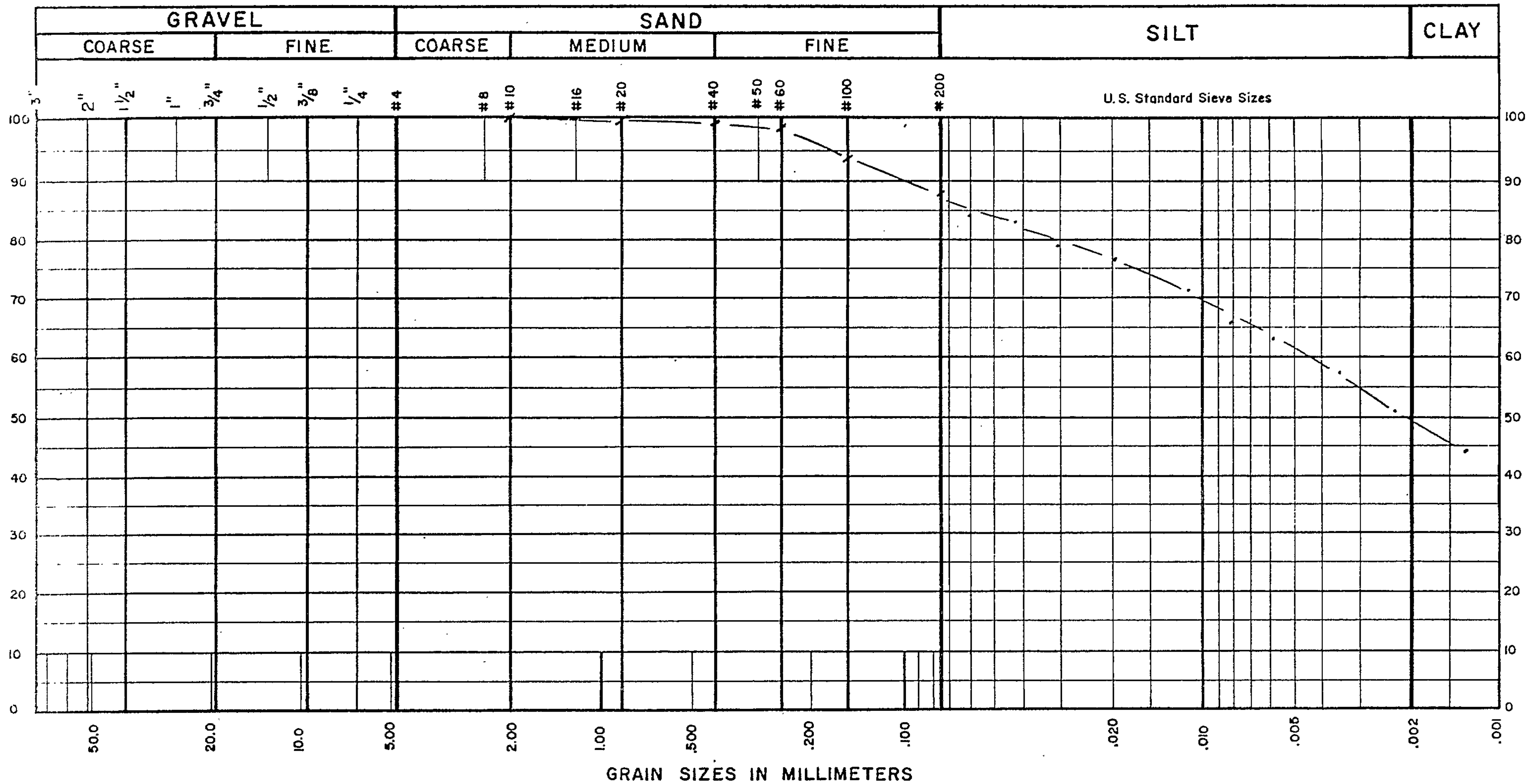
			%
Clay	47.0		
Silt	44.6		
Sand	8.4		
Gravel			

Classification ______________________

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 2-26
TEST DATE DEC 30/86 FILE No 17-395 0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

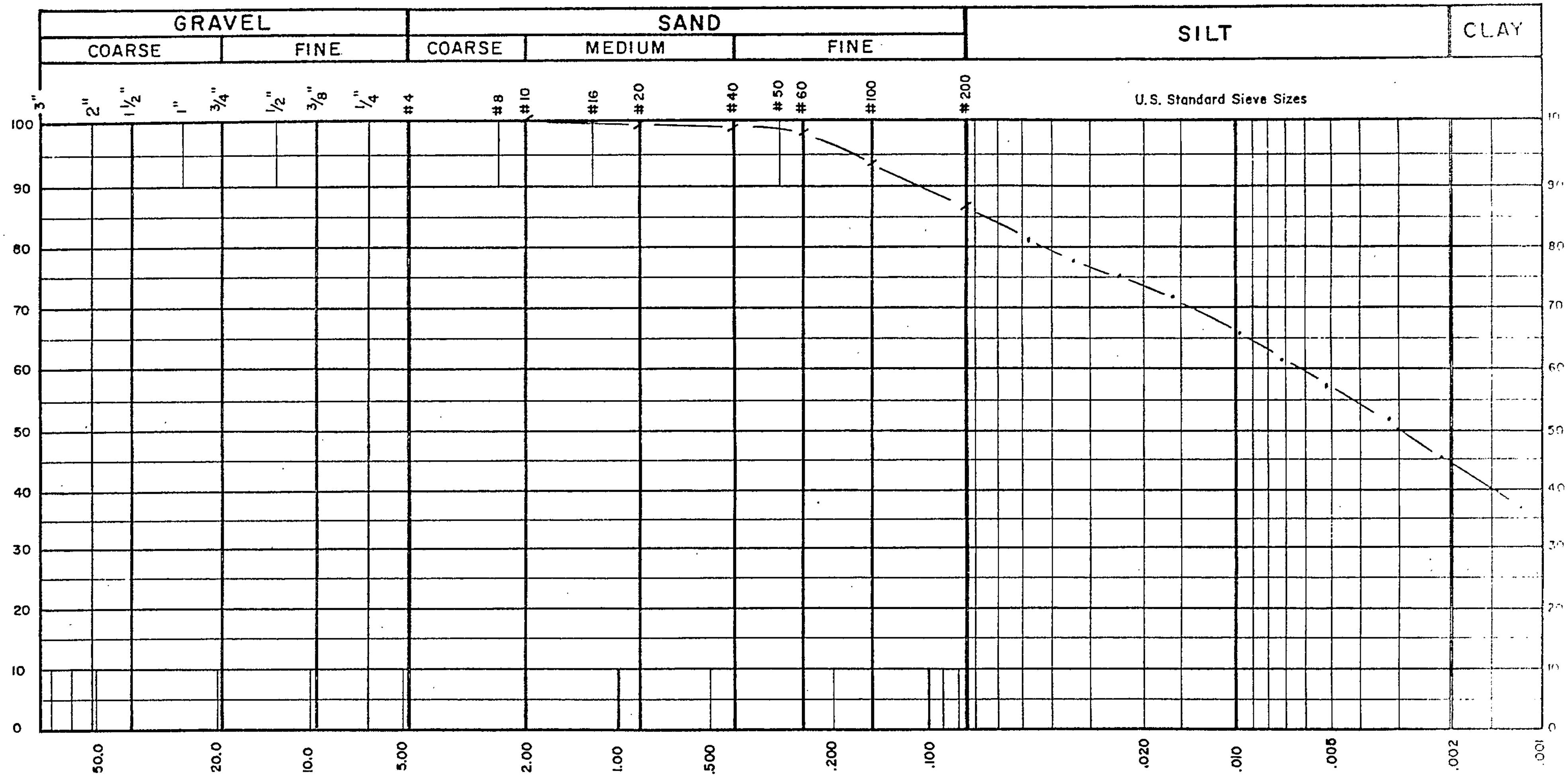
Clay	49.5		%
Silt	38.4		
Sand	12.1		
Gravel			

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-27
TEST DATE	DEC 30/86 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



GRAIN SIZES IN MILLIMETERS

Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

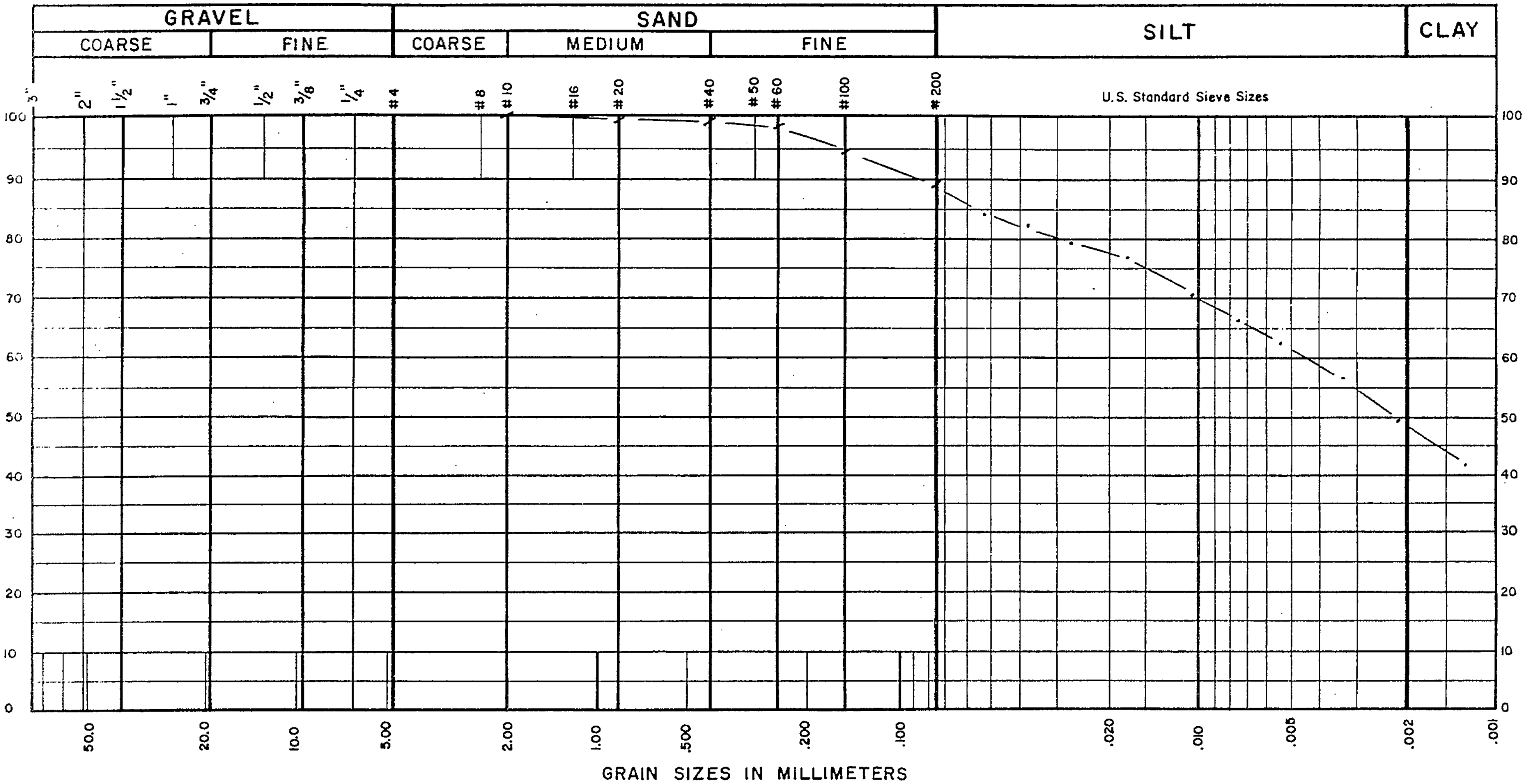
Clay	44.5		%
Silt	42.2		
Sand	13.3		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-28
TEST DATE	DEC 30/86 — FILE Nº 19-3[illegible]

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

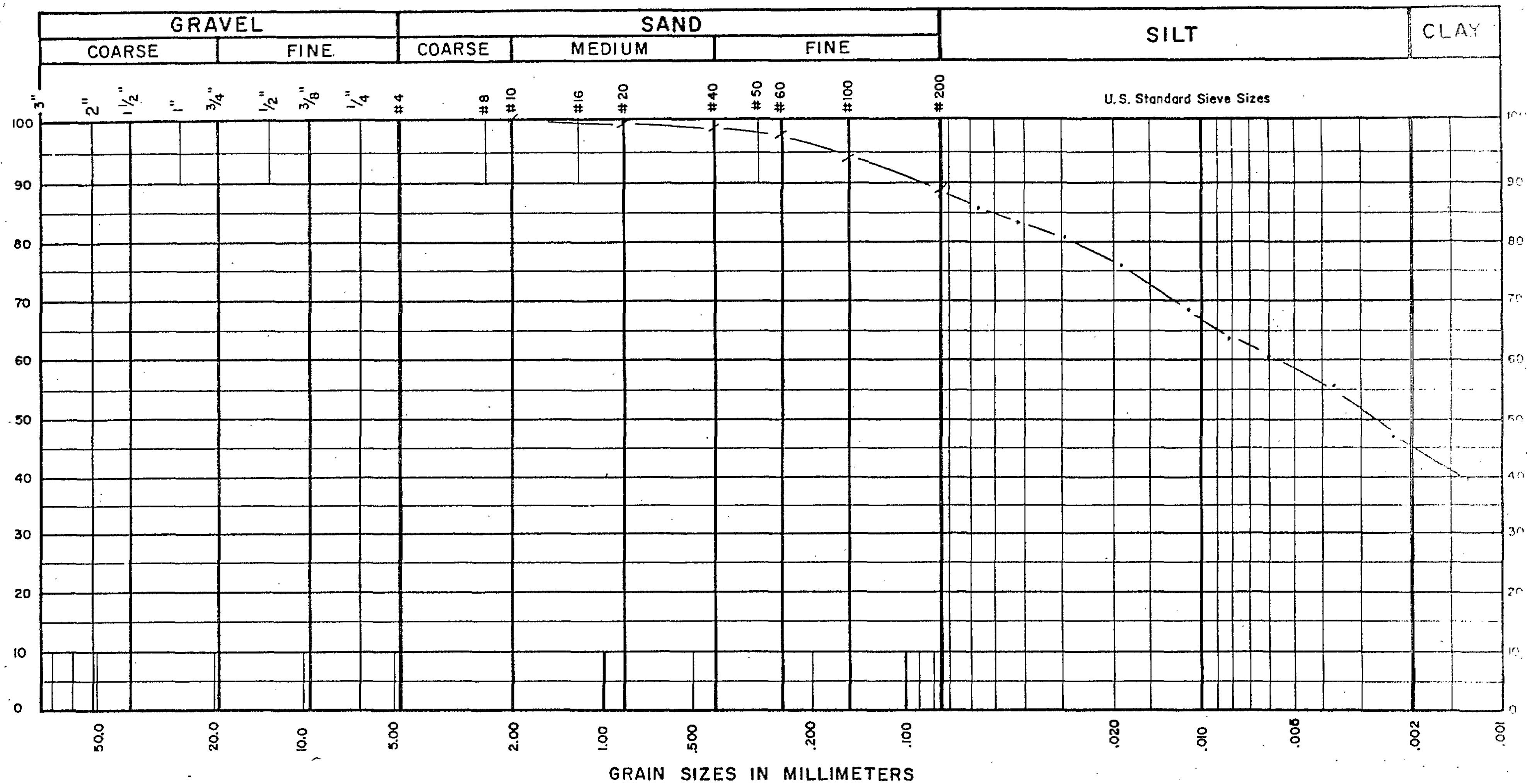
Clay	48.0		%
Silt	41.2		
Sand	10.8		
Gravel			

Classification ______________________

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-29
TEST DATE	DEC 30/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	45.0		%
Liquid Limit				Silt	44.4		
Plastic Limit				Sand	10.6		
Plastic Index				Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	2-30
TEST DATE	Dec 30/86 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers