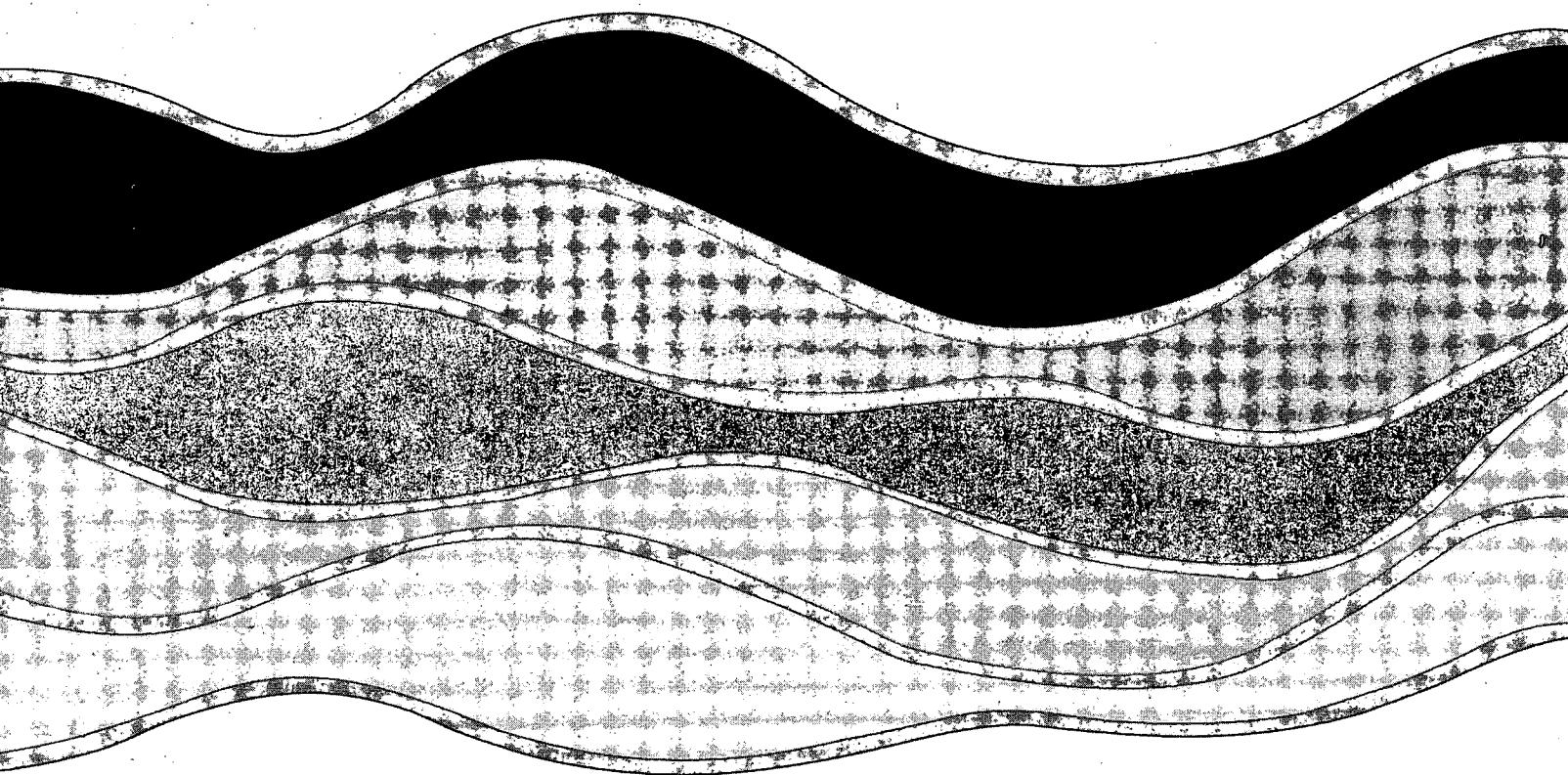
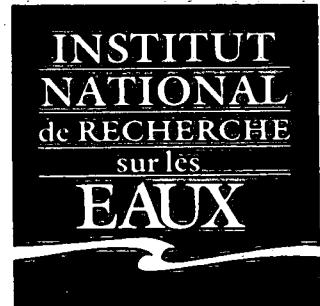
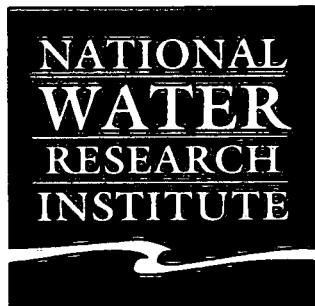
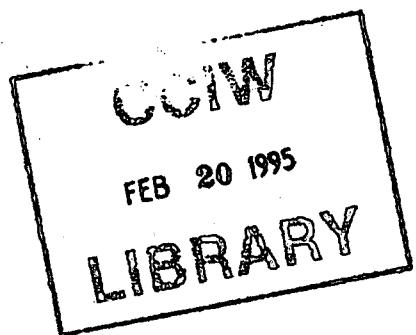


95-03



**RESULTS OF BASELINE GEOTECHNICAL,
CHEMICAL AND BIOLOGICAL TESTS FOR A
PROPOSED *IN-SITU* SEDIMENT CAPPING SITE
IN HAMILTON HARBOUR**

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**RESULTS OF BASELINE GEOTECHNICAL, CHEMICAL AND
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ABSTRACT

Pre-capping investigations at a pre-selected 1-ha capping site in Hamilton Harbour were conducted in order to determine geotechnical properties and trends, geochemical sediment and pore water concentrations, benthic-invertebrate community structure and sediment toxicity.

The sediment at the proposed capping site consists mainly of silt and clay with underlying sand pockets. Natural water content, measured on sediment core subsamples, ranges from 433% to 25%, and mainly decreases with depth. Liquid limits for all cores generally decreases with depth, and ranges from a high of 161% to a low of 28%. Plastic limit values range from a high of 132% to a low of 19%. Undrained shear strength generally increases with depth from 0.06 kPa to 4.86 kPa, except for sand pockets. Most sediments tested are organic clays and silts of medium to high plasticity, with the exception of sand pockets found in some cores.

Geochemical analyses on sediments from the site show that the concentrations of Zn, Cu, Pb, Cr, Ni, Cd, As and Hg exceed the Ontario Ministry of Environment and Energy (MOEE) sediment quality guidelines that identify the "severe effects level". The greatest concentrations of Fe, P, Hg, Ni, Pb, Cr, Zn and As were found at a sediment depth between 6 and 11 cm in all cores. The Zn concentrations are particularly high, being in the range considered to be recoverable as an ore body. The geochemical profiles are remarkably similar for all cores and they, in general, show maximum concentrations for a period between about 1957 and 1973. The sediments over the past 20 years are less contaminated but most concentrations are still seriously elevated. The highest concentrations of metals in sediment pore water are those of Fe and Mn, which are

sensitive to redox potential. The pore-water profiles for Zn, Pb and Cd show, in general, much lower concentrations and no sensitivity to redox potential. Other metals analyzed were close to or below the detection limit.

Based on the 1990 benthic-invertebrate survey and oligochaete bioassays carried out for the entire Harbour, the sediment at the proposed capping site shows high chronic toxicity, which is characteristic for a large part of the Harbour. The results of bioassays from nine stations located within and around the proposed capping site, which were carried out on the chironomid, *Chironomid riparius*, the amphipod, *Hyalella azteca*, the mayfly, *Hexagenia* and the oligochaete worm, *Tubifex tubifex*, are considered to be chronic and sublethal.

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1.0 INTRODUCTION

In-situ capping is a non-removal remedial alternative for contaminated sediments that has been used in Japan (Kikegawa, 1983; Togashi, 1983; Toa Construction, 1990), at sites on the west coast of the U.S.A. (Sumeri et al., 1991), and is being evaluated at several sites in the Great Lakes region. This remedial alternative is in its application both similar and simpler than capping of contaminated dredged material, which has been used extensively in pilot-scale and full-scale projects since the late 1970s by the U.S. Army Corps of Engineers (Palermo, 1991a). Experience has been obtained from a number of capping projects under a variety of field conditions. Both fine-grained and sandy sediments have been found to be effective capping materials. Laboratory tests with highly mobile chemical tracers (Brannon et al., 1985) and results of long-term field monitoring at existing capping sites (Sumeri et al., 1991) have shown that a relatively thin layer of sand or silt (10-20 cm) can effectively isolate sediment contaminants from the overlying water column. Contaminants effectively immobilized below caps include: metals and metalloids (As, Cd, Cu, Pb, Zn), polynuclear aromatic hydrocarbons (benzo(a)pyrene and structurally similar PAHs), polychlorinated biphenyls (Aroclor 1242, Aroclor 1254, Aroclor 1260), pesticides, and pulp mill wastes (Sumeri et al., 1991). Caps are typically made thicker (30-60 cm) in order to isolate sediment contaminants from the benthic organisms burrowing in the cap.

In-situ capping requires the placing of a layer of clean (i.e. acceptable for unrestricted open-water placement) material over contaminated sediments to prevent contaminants from entering the water column and to provide a clean substrate for benthic invertebrates. In-situ capping is probably the lowest-cost sediment remediation alternative. Procedures for cap placement and cap monitoring are fairly well established, using principally the

experience obtained from capping of contaminated dredged material (Palermo, 1991b).

1.1 Hamilton Harbour Pilot-Scale Demonstration

In the past four years, various technical aspects of in-situ capping have been studied at the National Water Research Institute (Zeman and Graham, 1991; Zeman, 1992; Graham and Zeman, 1992; Zeman et al., 1992). The results of a feasibility study (Zeman, 1994) indicated the suitability of this technique for a site in the Harbour where bottom sediments are of intermediate to high acute toxicity, as determined by bioassays using the zooplankter *Daphnia magna* (Hamilton Harbour RAP Team, 1989). It is proposed to carry out a pilot-size demonstration of the effectiveness of in-situ capping of contaminated sediments at a 100 m x 100 m area in site-specific conditions of the Harbour.

1.2 Scope of Pre-Capping Site Investigation

The first part of the monitoring, i.e. the pre-capping stage, was carried out in 1993/94 at the site selected for the demonstration of the sediment capping in Hamilton Harbour. The second part of the monitoring will be carried out over three years following the placement of the cap material at the selected location. The site conditions determined during the pre-capping investigations are presented in the following sections of this report.

The physical pre-capping monitoring included a detailed bathymetry of the proposed capping site, a side-scan survey of the site (McQuest Marine Sciences Ltd., 1994; Rukavina et al., 1994), and sediment coring for geotechnical and sedimentological testing (particle size distribution, natural water content, Atterberg limits, fall-cone shear strength, and primary and secondary consolidation).

The chemical pre-capping monitoring included determination of sediment geochemistry (concentrations of major and trace elements in sediment cores) and determination of metal concentrations in sediment pore water, which was collected in-situ using peepers (Rosa and Azcue, 1993).

The biological monitoring included the determination of benthic invertebrate community structure and sediment toxicity with four different species: the chironomid, *Chironomus riparius*, the amphipod, *Hyalella azteca*, the mayfly, *Hexagenia*, and the oligochaete worm, *Tubifex tubifex*.

2.0 BROAD AREA PHYSICAL MEASUREMENTS

2.1 Bathymetry of Capping Site Area

Detailed bathymetry of the general area of the proposed capping site was carried out on May 10, 1993 by the Canadian Hydrographic Service, Department of Fisheries & Oceans, Burlington, Ont. The digital sounding records have been plotted as a map using UTM (NAD 1927) coordinates (Figure 1) and cross sections (Figures 2.1 to 2.10) in order to obtain information on the bottom topography. Sounding depth in metres is referred to IGLD 1985. The depth across the site ranges from about 11.8 m IGLD in the northwest corner to about 16.5 m IGLD in the southeast corner of the site. The maximum slope of the site, represented approximately by the gradient of the line between the northwest corner and the southeast corner of the site (Figure 1), is about 1.9°. The cross sections (Figures 2.1 to 2.10) show the boundaries of the capping site and the water depth of 15 m as measured at the time of the survey.

2.2 Side-Scan Sonar Survey of Capping Site Area

A detailed side-scan sonar survey of Hamilton Harbour was conducted in November 1993 (McQuest Marine Sciences Ltd., 1994;

Rukavina et al., 1994). The interpreted results show that the harbour floor has been extensively disturbed by human activities (i.e. by anchor scours, dredging and dumping). Areas most affected by sediment disturbance occur from the central portion of the harbour southward to the docking areas. No surficial sediment disturbance has been detected in the general vicinity of the proposed capping site.

3.0 GEOTECHNICAL AND SEDIMENTOLOGICAL CONDITIONS

3.1 Field and Laboratory Methods

In October 1993, six sediment cores were taken at the location of a proposed subaqueous capping site in Hamilton Harbour. The perimeter and centre areas of the site were sampled (Figure 3). A modified (Kajak-Briulehurst) corer with a 3-in. (7.6-cm) plastic liner was used for sediment coring. After sampling, the cores were sealed and stored in cold storage until testing was conducted. Each core was drained of surface water and split into two halves with a circle saw. Before testing was conducted, photographs were taken of both halves. One half was used for testing shear strength, natural water content, and particle size at 5 cm intervals. The other half was sub-sampled at three or four separate locations throughout the core for Atterberg limits and put back into cold storage. Specimens for consolidation tests were subsampled from a large (0.5 m x 0.5 m x 0.5 m) box core that was collected from a location shown on Figure 3. The dimensions of the two cylindrical specimens tested in consolidation tests were approximately 150 mm in diameter and 50 mm high (Golder Associates Ltd., 1994).

Undrained shear strength was determined by the fall-cone test (Hansbo, 1957). Natural water content was measured in accordance with ASTM standard D2216. Atterberg limits were determined in accordance with ASTM standards D423-66 and D424-59. Particle size distribution was determined using the sieve and sedigraph method of the NWRI Sedimentology Laboratory (Duncan and LaHaie, 1979). The

in-house program SPECS was used to merge together the electronic information created by the sedigraph, with the hand recorded sieve weights. The sieve weights were entered into the SPECS program to create .ADD files for merging with .DAT files created by the sedigraph. Another in-house program, SIZMERGE, used the .ADD and .DAT files to calculate gravel, sand, silt, and clay content for each sample. Sediment primary and secondary consolidation behaviour was tested in a large oedometer standard consolidation test and a large oedometer creep test. Details on the methodology of consolidation testing, carried out in accordance with current ASTM standards where applicable, are provided in an unpublished report (Golder Associates Ltd., 1994).

3.2 Results

The results of laboratory geotechnical testing are plotted in geotechnical core logs (Figures 4.1 to 4.6) and numerical values are presented in Tables 1 to 4.

3.2.1 Length of sediment cores

All cores reached a depth of between 55 to 70 cm, with the exception of Core 1 which sampled down to a full length of 100 cm.

3.2.2 Sediment texture

Sediment size distributions varied considerably with depth, especially in Cores 3 and 5 (Figures 4.4 and 4.6). Some general trends, however, were still detectable. Out of 76 samples, gravel was only detected in two samples; one gravel sized particle in Core 1 at 80-85 cm (Figure 4.1), and one clinker in Core 4 at 15-20 cm weighing 0.17 grams (Figure 4.5).

Generally, the sand content found throughout each core was less than 20%, except for the three noted sand pockets: Core 1 below 95 cm (63.3%, Figure 4.1), Core 3 below 40 cm (82.4%, Figure 4.4), and Core 5 below 50 cm (43.5%, Figure 4.6). From these

findings, it is quite likely that all cores would have contained areas of high sand content between 50 and 100 cm, if each core had sampled to a depth of 1 m. As sand pockets were found at different depths, they are apparently discontinuous. Similar sand pockets at different depths occur in other cores outside the proposed capping area (N. Rukavina, personal communication).

Silt content for all the cores ranged from a low of 23% to a high of 60%, except for the mentioned sand pockets, which had lower percentages (Figures 4.4 and 4.6). Clay content normally ranged from 31% to 71%, also excluding the sand pockets. Depths of high silt content (greater than about 40%) generally ranged between 35 and 60 cm. Depths of high clay percentages (greater than 50%) were generally between 10 and 35 cm. Between 0 and 10 cm, silt and clay content were found to be roughly equal, though there was generally more clay.

3.2.3 Natural water content, w

All cores showed a general expected decrease of the natural water content, w, with depth, except for Core 2X (Figure 4.3). Core 1 had a high of 433% at its surface, and a low of 25% at 100-105 cm at its sand pocket (Figure 4.1). Core 3 also had w values of 25% at its sand pocket below 50 cm (Figure 4.4), and the sand pocket in Core 5, below 60 cm, was 47% (Figure 4.6). These measurements were the lowest recorded for all six cores. All cores had a w value of at least 370% (Core 2) at the surface, and a high of 480% (Core 2X).

No consistent decrease existed in w values with depth, although this was the general trend. Every core had a mean increase in w values between 20 and 30 cm, although w values in Core 2 were approximately constant with depth (Figure 4.2). This trend in Core 2 likely reflects a general increase of clay content with depth. All cores have w values of greater than 200% above 60 cm, with the exception of Cores 3 and 5, which fall below 200% at 40-45 cm (Figures 4.4 and 4.6). The remaining cores from 15 to 60 cm have the w values between 200 and 300%.

3.2.4 Atterberg limits

The liquid limit and plastic limit (LL and PL respectively) values were also irregular. The LL values in Cores 2 and 2X increased slightly with depth. The LL values in all cores ranged from a high of 161% (Core 4 at 40 cm) to a low of 28% (Core 1 at 100 cm - at sand pocket). The PL values were also irregular except for Core 4 where values increased with depth. The ranges were from a high of 132% (Core 1 at 50 cm) to a low of 19% (Core 1 at 100 cm - at sand pocket). The plasticity index, PI, does not seem to follow any pattern for any cores except for Core 1, where it decreased with depth (Figure 4.1). The range was from 104% (Core 2 at 50 cm) to 9% (Core 1 at 100 cm - at sand pocket) as shown in Figure 4.1. A subsample at 49 cm in Core 3 was too sandy to produce an accurate value (Figure 4.4). The liquidity index, LI, for all cores generally decreased with depth. The range was from a high of 6.95 (Core 4 surface) to a low of 1.55 (Core 1, 100 cm - at sand pocket, Figure 4.1).

3.2.5 Undrained shear strength, s_u

The sediments occurring at the site are predominantly of very soft consistency, i.e. s_u is lower than 12 kPa. The s_u values for all cores except Cores 3 and 5 remained below 5 kPa (Figures 4.4 and 4.6). All cores had s_u values below 1 kPa above 30 cm depth. Core 3 increased from 3 kPa at 40 cm, to 32 kPa at 45 cm, at its sand pocket (Figure 4.4). In the same manner, Core 5 increased from 1 kPa at 50 cm, to 12 kPa at 55 cm, where another sand pocket exists (Figure 4.6).

3.2.6 Large-oedometer consolidation testing

The natural water content value, w , obtained for the standard test and creep test specimens were 228 % and 197 % respectively, and this difference may reflect natural variability. The initial void ratio, e , values are 6.320 and 5.641 for the standard test and the creep test respectively. Measured specific gravity values, G_s ,

were 2.50 and 2.53 for the standard test and the creep test respectively.

The compression index, C_c , determined from the standard oedometer test is 2.2. The C_c value from the creep test results, taken as the straight line from end of saturation (2 kPa stress) to 10 kPa stress is 1.4. The reason(s) for the difference in the C_c values between these two tests is not known.

The interpreted coefficient of consolidation, c_v , from the standard test results decreases from about $10^3 \text{ cm}^2/\text{s}$ to $10^4 \text{ cm}^2/\text{s}$. The c_v values could not be reliably interpreted from the creep test results and, therefore, the same values as for the standard test are used.

The interpreted values for the coefficient of volume compressibility, m_v , for the standard test range from 10^{-2} to 10^{-4} kPa^{-1} as the stress increases. The interpreted values of m_v for the 5 kPa and 10 kPa stresses are similar for the standard and creep tests.

The interpreted values of the coefficient of permeability, k , for the standard test range from about 10^{-4} cm/s at a stress of 5 kPa to about 10^{-8} cm/s at a stress of 320 kPa.

The secondary compression index, C_s , expressed as the change in void ratio, e , over a log cycle of time, was interpreted from the straight-line portion of the dial deflection (or void ratio) vs. log time plots obtained for the 5 kPa and 10 kPa stresses in the creep test. The results of this interpretation are 0.32 at 5 kPa and 0.62 at 10 kPa. Using the value of the initial void ratio, $e_0 = 5.641$, the corresponding values of the coefficient of secondary consolidation, C_s , are 4.82 % and 9.34 % respectively. These C_s values are within the range of expected values based on high initial water content values. The secondary compressibility is "very high to extremely high" according to the classification proposed by Mesri (1973).

3.2.7 Sediment classification

Using the results of the particle size tests (Section 3.2.2) and the results of the Atterberg limit tests (Section 3.2.4), it is possible to classify the sediment at the site (Figures 5.1 to 5.3).

The first classification is a ternary particle-size classification consisting of ten classes proposed by Shepard (1954), where class limits are defined by 20, 50 and 75 percentiles of each size component. As shown in Figure 5.1, the surficial sediments (depths 0-5 cm and 20-25 cm) in all six cores are silty clays to clay silts (classes 9 and 7 respectively). Discontinuous sandy pockets or lenses at 40-45 cm and 50-55 cm depths are clayey sand and sand (classes 5 and 1 respectively).

The results of particle-size testing have been plotted using the phi-notation widely used by sedimentologists and the mean ϕ (phi) size as an indicator of sediment texture (Figure 5.2). Comparing the ϕ values to the Wentworth Scale (Royse, 1970), samples with ϕ greater than 8.0 are clays and those with ϕ greater than 7 are very fine silts. Only two samples shown in Figure 5.2 have lower values: $\phi = 5.5$ (medium silt) in Core 5 at the depth interval 50-55 cm; and $\phi = 2.8$ (fine sand) in Core 3 at the depth of 40-45 cm.

According to the Universal Soil Classification (Terzaghi and Peck, 1968), most samples fall in the group of organic clays of medium to high plasticity (OH), some to the group of silts of medium to high plasticity (MH), and the coarser pockets or lenses in Cores 3 and 5 (the depth interval of 40-45 cm and 50-55 cm respectively) to the group of clayey sands or sand-clay mixtures (SC). The resulting plot is shown in Figure 5.3.

4.0 SEDIMENT GEOCHEMISTRY AND METAL CONCENTRATIONS IN SEDIMENT PORE WATER

4.1 Materials and Methods

4.1.1 Sediment coring and sediment pore water sampling

Sediment cores were collected in October 1993 at five sampling stations located near the four corners and the centre of the site (Figure 6). A modified K-B corer with a 3-in. (7.6-cm) plastic liner was used for the sediment coring. Obtained sediment cores were up to 60 cm long and consisted of fine-grained, dark grey sediment with increasing content of sand towards the bottom of the cores. Each core was subsampled vertically into 1-cm sections down to 30 cm depth. The bottom 59 to 60 cm section was also collected where available. Each subsample was collected into a glass jar prewashed with 5% HNO₃, and distilled water.

Sediment pore water was collected in-situ using peepers. The peepers were inserted into the sediment by a diver at two sampling stations close to those used for the sediment coring (Figure 6). After three weeks of equilibrating the sediment pore water with deoxygenated distilled water in the peeper chambers, the peepers were recovered by the diver and the sediment pore water was collected immediately upon the retrieval of the peepers. The preparation of the peepers and collection of the sediment pore water from the peepers followed the procedures described by Rosa and Azcue (1993).

4.1.2 Analytical methods

Major elements (Si, Al, Ca, Fe, K, Mg, Mn, Na, P and Ti) in the sediment samples were determined by an ICP-AES with a multi-channel Jarell-Ash Atomcomp 1100 after fusion of 0.1 g of the sample with 0.8 g of Spectroflux 100B (4:1 lithium meta- and tetraborate) in a graphite crucible at 950° C for 15 to 20 minutes. The fusion mixture was dissolved in 10% HNO₃. Trace elements (V, Cr, Co, Ni, Cu, Zn, Cd, Sn and Pb) were determined by the ICP-AES after

sediment extraction by aqua regia following the method described by McLaren (1981). Mercury was determined by cold vapor atomic absorption spectrometry after digestion of sediment samples with hot HNO₃:HCl (1:1) mixture following the procedure described by the U.S. Environmental Protection Agency (1981a). Arsenic was determined by atomic absorption spectrometry after extraction of sediment samples with hot HNO₃:HCl (1:3) mixture and hydride generation following the method described by the U.S. Environmental Protection Agency (1981b).

Trace elements in sediment pore water samples which were acidified by 0.1 mL of ultra pure conc. HNO₃, were determined by ICP-AES.

Quality assurance/quality control was carried out by using different sediment and soil standards and replicates of the sediment samples (one replicate for a group of five samples). Standards and replicates were used in the analysis of the sediment pore water.

4.2 Results and Discussion

The concentrations of major and trace elements in sediment cores are given in Table 5. The concentrations of Zn, Cu, Pb, Cr, Ni, Cd, As and Hg exceeded the severe effects level given in the Ontario Ministry of the Environment and Energy sediment guidelines in most samples. Generally, the greatest concentrations of Fe, P, Hg, Ni, Pb, Cr, Zn and As were found between the sediment depth of 6 and 11 cm in all cores (Figure 7). The concentration profiles of the major and trace elements in the five sediment cores suggested deposition of similar material within the area of the proposed demonstration site. Assuming a sedimentation rate of about 3 mm per year, the greatest input of Fe, P, Hg, Ni, Pb, Cr, Zn and As to the site occurred between 1957 and 1973. The results indicated a burial of the contaminated sediments by less contaminated material over the past 20 years. However, the concentrations of the trace elements remain considerably elevated in the surface 6 cm of the

sediment at the site. The concentrations of Zn in the sediment cores were over 6,000 $\mu\text{g/g}$ (i.e., 0.6% Zn) which is considered a sufficient quantity for recovering Zn from an ore body.

The concentrations of trace elements in sediment pore water are shown in Table 6. From the analyzed trace elements, Fe, Mn, Pb, Cd and Zn occurred in greater concentrations than the others. The concentration profiles of Fe, Mn, Pb, Cd and Zn in the sediment pore water and in the water above the sediment/water interface are shown in Figure 8. The sediment pore water was sampled in August 1993 when the bottom water at the sampling site was anoxic. The objective was to obtain results for the scenario where the capped contaminated sediments remain anoxic during the whole year. The determination of concentrations of trace elements in sediment pore water during the period of oxygenated bottom waters at the site will be carried out in the near future. The anoxic conditions during the sediment pore water sampling in August 1993 are the reason for high concentrations of Fe and Mn in the pore water collected from the topmost sediment layer. With the exception of Pb and Zn, the other trace elements in the sediment pore water were close to or at the detection limit of the analytical method.

5.0 INVERTEBRATE COMMUNITY STRUCTURE AND SEDIMENT TOXICITY

5.1 Materials and Methods

Samples for estimation of invertebrate community structure and toxicity were taken from nine stations (Figure 9) in the fall of 1993 to provide background pre-treatment conditions. Six of the sites are in the capping site (treatment) and three outside (control). These sites should be re-sampled periodically after treatment to assess the biological effects of the capping layer.

5.1.1 Sediment sampling

Samples for the identification and enumeration of benthic invertebrates were taken by inserting five 10-cm long plexiglass tubes (ID 5.5 cm) into sediment taken with a 25 x 25 cm mini box core. Each core tube was considered to be a replicate sample unit and was removed from the box core and the contents placed into a plastic bag and kept cool until sieved. The contents of each bag were sieved through a 250 μm mesh in the field as quickly as possible after sampling. If sieving could not be done in the field, 4% formalin was added to the bag and the replicate samples were stored at 4° C and sieved as soon as possible thereafter. After sieving, the samples were placed in plastic vials (50 ml) and preserved with 4% formalin. After 24 h the formalin was replaced by ethanol.

5.1.2 Laboratory procedures

Samples were sorted with a low power stereo microscope and identified to species or genus level where possible. As required (Chironomidae and Oligochaeta) slide mounts were made for high power microscopic identification. Appropriate identification guides were used and type specimens of all identified specimens were submitted to experts for confirmation.

A mini-ponar sampler was used to obtain five replicate field samples of sediment for laboratory bioassays with four species of invertebrates. Each replicate sample was placed in a plastic bag and held at 4° C until tests could be conducted.

Tests were conducted, in sets of six to seven, over a period of approximately six months. A clean control sediment from the Canadian Wildlife Bird Sanctuary, Long Point, Lake Erie was also tested with each set of samples to provide biological quality assurance. Complete details of the culture of organisms and conditions for each toxicity test with *C. riparius* and *T. tubifex* are described elsewhere (Reynoldson et al. 1991, Day et al. 1994, Reynoldson et al. 1994). Culture of *H. azteca* was conducted according to the procedure described in Borgmann et al. (1989). Eggs of the mayfly, *Hexagenia* spp. (both *H. limbata* and *H. rigida*), were collected during late June and July in 1991 according to the method of Hanes and Ciberowski (1992) and organisms were cultured using the procedure of Bedard et al. (1992). Tests with *H. azteca*, *C. riparius* and *T. tubifex* were conducted in 250 mL glass beakers containing 60 to 100 mL of sieved (500 µm mesh), homogenized sediment with approximately 100 to 140 ml of overlying carbon-filtered, dechlorinated and aerated Lake Ontario water (pH 7.8 to 8.3, conductivity 439 to 578 µohms/cm, hardness 119 to 137 mg/l). Tests with the mayfly, *Hexagenia* were conducted in 1 l glass jars with 150 ml of test sediment and 850 ml overlying water. The sediment was allowed to settle for 24 h prior to addition of the test organisms. Tests were initiated with the random addition of 15 organisms per beaker for *H. azteca* and *C. riparius*, 10 organisms per jar for *Hexagenia* spp. and 4 organisms per beaker for *T. tubifex*. Juveniles of *H. azteca* were 3 to 7 d old at test initiation; *C. riparius* larvae were first instars and were approximately 3 d post-oviposition; *Hexagenia* nymphs were 1.5 to 2 months old (approximately 5 to 10 mg wet weight) and *T. tubifex* adults were 8 to 9 weeks old. Tests were conducted at 23±1° C with a 16 1:8 d photoperiod. Tests were static with the periodic addition of distilled water to replace water lost during

evaporation. Each beaker was covered with a plastic petri dish with a central hole for aeration using a Pasteur pipette and air line. Dissolved oxygen concentrations and pH were measured at the beginning, middle and end of each exposure period. Tests were terminated after 10 d for *C. riparius*, 21 d for *Hexagenia* and 28 d for *H. azteca* and *T. tubifex* by passing the sediment samples through a 500 μm mesh sieve. Sediment from the *T. tubifex* test was passed through an additional 250 μm mesh sieve at test completion. Endpoints measured in the tests were survival and growth for *C. riparius*, *Hexagenia* spp. and *H. azteca* and for *T. tubifex* survival and production of cocoons and young. Mean dry weights of *H. azteca*, *C. riparius* and *Hexagenia* spp. were determined after drying the surviving animals from each treatment replicate as a group to a constant weight in a drying oven (60° C).

5.2 Results and Discussion

From a 1990 benthic-invertebrate survey of the entire harbour (Reynoldson, unpublished data), sediment-toxicity conditions at the capping site can be compared with those existing in other areas of the harbour. Based on bioassays using the oligochaete worm (*T. tubifex*) reproduction, three sediment categories in the Harbour have been defined (Figure 10). These designations are based upon a comparison of the results from the Harbour with 168 reference sites sampled in the Great Lakes (Reynoldson and Day 1994). There is an area where sediments are acutely toxic, as indicated by mortality of adults in the area of Randle Reef (2 sites). A large part of the Harbour including the capping demonstration site shows high chronic toxicity where two of the test endpoints (cocoons and young produced) are below the expected level based on reference sites. The remainder of the harbour shows low chronic (one endpoint fails) or no toxicity (all endpoints meet criteria). The distribution of sediment categories follows a general pattern of sediment toxicity delineated in a survey using 62 locations in the Harbour and the (acute) sediment toxicity to the zooplankter *Daphnia magna*. This

survey, which was carried out in February 1989, also established that more toxic sediments were in the central and southern portion of the Harbour (Hamilton Harbour RAP Team, 1989, Fig. 12).

The community structure data from 1990 show the 50 sites sampled to be dominated by the presence of oligochaetes (99% of the fauna). The capping site is typical of much of the Harbour and the community is responding mainly to anoxia. As a result of the anoxia, it is difficult to isolate effects on the benthic community associated with sediment toxicity alone.

Results of the 1993 bioassays from the nine locations in and around the capping site are shown in Figures 11 to 14. Each graph shows the mean of five replicates with standard deviation. The solid line is the level of acceptability based on comparisons with the control sediment from Long Point. Means of endpoints for any sediment which are below the solid line indicate a problem with sediment. Only three sites (Nos. 7,8 and 9) show toxicity to the chironomid *C. riparius* (Fig. 11), due mainly to reductions in growth. One site (No. 2) showed a reduction in survival of the amphipod *H. azteca*, and four sites (Nos. 1,7,8 and 9) showed reduced growth (Fig. 12). Survival of the mayfly *Hexagenia* (Fig. 13) was not reduced in any sediments but its growth was shown to be reduced at seven sites (Nos. 2,3,5,6,7,8 and 9). Reproduction of *T. tubifex* was significantly reduced at all sites. In general, the results of the four bioassays are considered to be chronic and sublethal.

6.0 CONCLUSIONS

New information has been obtained on geotechnical, sedimentological, geochemical and biological conditions that exist at the proposed capping site. Detailed bathymetry of the general site area revealed that the site is located on a gentle slope with the maximum gradient of about 1.9°. The depth across the site ranges from about 11.8 m IGLD at the northwest corner to about 16.5 m IGLD at the southwest corner. The side scan sonar survey did not detect any appreciable disturbance of the sediment surface.

The results of geotechnical and sedimentological testing carried out on six sediment cores and on one large box core are in agreement with the existing knowledge of harbour sediments and their properties. The sediments are typically silty clays to clay silts with the occurrence of thin (several cm thick) discontinuous layers of coarser material that were detected in all cores at different depth below the surface. The origin of these "sand pockets", which are known to occur in other areas of the harbour, is unknown. All cores show a general decrease of natural water content with depth, with values in the order of 400 % near the sediment-water interface. Considerably lower water content values were measured within the coarser irregular sand layers. Based on the Atterberg test results, most sediments are organic clays and silts of medium to high plasticity (groups OH and MH), except for the sand pockets that fall within the group of clayey sands (SC). The shear strength values of fine-grained sediments are typically below 5 kPa, except for appreciably higher s_u values measured within coarser "sand pockets" in Cores 3 and 5 (Table 4).

The concentrations of many metals exceeded the severe effects level given in the Ontario Ministry of the Environment sediment guidelines. The greatest inputs of these metals into the sediment were considered to have occurred between 1957 and 1973, using an estimated sedimentation rate of 3 mm per year. The main trace

elements appearing in sediment pore water were Fe, Mn, Pb, Cd, and Zn, sampled during anoxic conditions, which is considered to be responsible for high Fe and Mn readings.

Based on the 1990 benthic-invertebrate survey and oligochaete bioassays carried out for the entire Harbour, the sediment at the proposed capping site shows high chronic toxicity, which is characteristic for a large part of the Harbour (Fig. 10). The results of bioassays from nine stations located within and around the proposed capping site, which were carried out on the chironomid, *Chironomid riparius*, the amphipod, *Hyalella azteca*, the mayfly, *Hexagenia* and the oligochaete worm, *Tubifex tubifex* (Figs. 11 to 14), are considered to be chronic and sublethal.

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TABLE 1

CORE (cm)	GRAVEL PERCENT	SAND PERCENT	SILT PERCENT	CLAY PERCENT	TOTAL PERCENT
CORE 1					
0- 5		9.0	45.2	45.8	100.0
5-10		7.6	38.6	53.9	100.0
10-15		9.0	37.4	53.7	100.0
15-20		12.2	34.8	53.0	100.0
20-25		5.2	30.5	64.4	100.0
25-30		6.7	28.2	65.1	100.0
30-35		10.0	24.7	65.3	100.0
35-40		3.8	38.3	57.9	100.0
40-45		10.4	41.6	48.0	100.0
45-50		20.2	42.4	37.4	100.0
50-55		9.8	44.1	46.1	100.0
55-60		7.9	43.6	48.5	100.0
60-65		8.7	37.4	53.9	100.0
65-70		9.0	37.2	53.8	100.0
70-75		12.2	41.9	45.9	100.0
75-80		4.1	50.9	45.0	100.0
80-85	0.23	7.1	39.5	53.2	100.0
85-90		11.7	23.8	64.4	100.0
90-95		8.0	32.7	59.3	100.0
95-100		63.3	10.1	26.6	100.0
CORE 2					
0- 5		5.1	40.5	54.5	100.0
5-10		27.7	23.7	48.6	100.0
10-15		11.7	23.8	64.4	100.0
15-20		18.3	21.6	60.1	100.0
20-25		2.4	28.1	69.5	100.0
25-30		4.3	29.7	65.9	100.0
30-35		4.3	31.6	64.0	100.0
35-40		3.1	52.6	44.4	100.0
40-45		9.3	59.0	31.8	100.0
45-50		8.3	54.8	37.0	100.0
50-55		8.2	56.3	35.5	100.0
CORE 2X					
0- 5		7.7	43.1	49.1	99.9
5-10		18.8	30.3	50.9	100.0
10-15		10.6	27.8	61.6	100.0
15-20		5.8	26.3	67.9	100.0
20-25		8.0	24.6	67.4	100.0
25-30		2.8	26.8	70.4	100.0
30-35		1.7	27.6	70.8	100.0
35-40		8.0	47.7	44.3	100.0
40-45		4.6	54.6	40.8	100.0
45-50		5.4	60.6	34.1	100.0
50-55		5.9	59.9	34.2	100.0

CORE 3

0- 5	3.0	47.6	49.5	100.1
5-10	5.3	48.5	46.2	100.0
10-15	11.2	35.9	52.9	100.0
15-20	4.0	30.8	65.2	100.0
20-25	4.7	33.4	61.9	100.0
25-30	4.2	32.6	63.2	100.0
30-35	7.3	30.0	62.7	100.0
35-40	14.3	47.3	38.4	100.0
40-45	82.4	4.9	12.6	99.9
45-50	56.6	32.8	10.6	100.0

CORE 4

0- 5	8.8	53.6	37.6	100.0
5-10	7.3	45.1	47.6	100.0
10-15	9.6	35.9	54.5	100.0
15-20	3.90	35.0	52.6	100.0
20-25	3.6	26.4	70.0	100.0
25-30	6.5	36.0	57.4	99.9
30-35	14.6	52.1	33.3	100.0
35-40	5.7	52.0	42.4	100.1
40-45	8.8	49.6	41.6	100.0
45-50	9.3	48.3	42.4	100.0
50-55	9.6	40.0	50.5	100.1
55-60	7.5	47.4	45.1	100.0
60-65	7.8	42.8	49.4	100.0

CORE 5

0- 5	4.4	40.8	54.8	100.0
5-10	9.0	31.8	59.2	100.0
10-15	3.8	28.7	67.4	99.9
15-20	3.3	44.2	52.5	100.0
20-25	4.3	50.6	45.1	100.0
25-30	5.2	51.2	43.6	100.0
30-35	4.5	43.4	52.2	100.1
35-40	4.4	45.1	50.5	100.0
40-45	7.1	42.3	50.6	100.0
45-50	6.0	38.2	55.8	100.0
50-55	43.5	19.4	37.1	100.0

TABLE 2

CORE 1				CORE 2			
DEPTH TAKEN (cm)	NAT. WATER CONT. (w)(%)	MEAN NAT. WATER CONT. (w)(%)		DEPTH TAKEN (cm)	NAT. WATER CONT. (w)(%)	MEAN NAT. WATER CONT. (w)(%)	
TOP	430.28			TOP	378.32		
TOP	436.37	433.33		TOP	363.43	370.87	
0- 5	358.95	358.95		0- 5	381.92	381.92	
5-10	355.27			5-10	364.30		
5-10	256.10	305.68		5-10	267.15	315.72	
10-15	245.87			10-15	283.64		
10-15	227.20	236.54		10-15	191.79	237.71	
15-20	223.10			15-20	211.54		
15-20	199.65	211.38		15-20	224.09	217.82	
20-25	157.70			20-25	224.18		
20-25	249.43	203.56		20-25	207.51	215.85	
25-30	263.17			25-30	203.42		
25-30	264.90	264.03		25-30	228.64	216.03	
30-35	249.80			30-35	211.41		
30-35	233.34	241.57		30-35	211.88	211.65	
35-40	238.45			35-40	214.63		
35-40	258.15	248.30		35-40	235.73	225.18	
40-45	245.74			40-45	236.94		
40-45	288.08	266.91		40-45	256.05	246.49	
45-50	288.00			45-50	261.93		
45-50	259.32	273.66		45-50	243.84	252.88	
50-55	255.02			50-55	244.55		
50-55	229.36	242.19		50-55	238.01	241.28	
55-60	225.48			55-60	236.51		
55-60	219.24	222.36		55-60	229.01	232.76	
60-65	206.91			60-65	220.40	220.40	
60-65	183.93	195.42					
65-70	193.85						
65-70	180.78	187.31					
70-75	177.38						
70-75	171.11	174.25					
75-80	168.10						
75-80	156.11	162.11					
80-85	150.80						
80-85	147.17	148.99					
85-90	142.54						
85-90	140.03	141.29					
90-95	142.21						
90-95	136.31	139.26					
95-100	134.32						
95-100	41.68	88.00					
100-105	24.66	24.66					

CORE 2X			CORE 3		
	MEAN			MEAN	
DEPTH TAKEN (cm)	NAT. WATER CONT. (w)(%)	NAT. WATER CONT. (w)(%)	DEPTH TAKEN (cm)	NAT. WATER CONT. (w)(%)	NAT. WATER CONT. (w)(%)
TOP	497.68		TOP	425.54	
TOP	461.10	479.39	TOP	448.38	436.96
0- 5	322.77	322.77	0- 5	415.18	415.18
5-10	319.95		5-10	399.25	
5-10	271.30	295.62	5-10	338.45	368.85
10-15	275.66		10-15	366.46	
10-15	204.97	240.31	10-15	260.45	313.46
15-20	214.39		15-20	259.58	
15-20	241.97	228.18	15-20	219.24	239.41
20-25	245.63		20-25	229.27	
20-25	209.36	227.50	20-25	229.77	229.52
25-30	215.28		25-30	231.33	
25-30	260.92	238.10	25-30	240.78	236.05
30-35	240.66		30-35	244.63	
30-35	215.79	228.22	30-35	207.97	226.30
35-40	220.06		35-40	226.48	
35-40	203.32	211.69	35-40	229.52	228.00
40-45	198.91		40-45	231.48	
40-45	221.68	210.29	40-45	43.24	137.36
45-50	246.68		45-50	60.24	
45-50	258.79	252.73	45-50	27.44	43.84
50-55	268.17		50-55	26.03	
50-55	256.63	262.40	50-55	22.26	24.15
55-60	253.97		55-60	24.63	24.63
55-60	246.43	250.20			
60-65	245.48	245.48			

CORE 4			CORE 5		
DEPTH TAKEN (cm)	NAT. WATER (w)(%)	MEAN NAT. WATER (w)(%)	DEPTH TAKEN (cm)	NAT. WATER (w)(%)	MEAN NAT. WATER (w)(%)
TOP	380.33		TOP	397.76	
TOP	387.47	383.90	TOP	404.17	400.97
0- 5	363.46	363.46	0- 5	365.29	365.29
5-10	334.70		5-10	354.89	
5-10	298.94	316.82	5-10	232.44	293.67
10-15	336.49		10-15	240.31	
10-15	236.65	286.57	10-15	262.25	251.28
15-20	228.08		15-20	254.04	
15-20	239.72	233.90	15-20	236.57	245.30
20-25	234.55		20-25	248.48	
20-25	247.87	241.21	20-25	285.13	266.81
25-30	260.02		25-30	285.65	
25-30	213.55	236.78	25-30	241.92	263.78
30-35	219.05		30-35	239.53	
30-35	244.99	232.02	30-35	220.98	230.26
35-40	258.57		35-40	212.42	
35-40	256.26	257.42	35-40	193.22	202.82
40-45	251.27		40-45	188.62	
40-45	245.71	248.49	40-45	177.16	182.89
45-50	242.18		45-50	171.10	
45-50	235.70	238.94	45-50	154.59	162.84
50-55	229.37		50-55	148.60	
50-55	206.41	217.89	50-55	135.52	142.06
55-60	218.80		55-60	148.17	
55-60	200.82	209.81	55-60	93.26	120.71
60-65	198.34		60-65	47.29	47.29
60-65	193.20	195.77			
65-70	190.84				
65-70	185.99	188.41			
70-75	188.99	188.99			

TABLE 3
Atterberg Limits Test Results for Cores 1 to 5

DEPTH (cm)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	NATURAL WATER (%)	PLAST- ICITY INDEX (%)	LIQUID- ITY INDEX
CORE 1					
0	107.48	55.54	358.95	51.94	5.84
50	154.32	132.07	257.17	22.25	5.62
100	28.2	19.17	33.17	9.03	1.55
CORE 2					
0	111.25	57.80	372.68	53.45	5.89
25	112.66	63.67	205.47	48.98	2.89
50	171.28	66.86	240.92	104.42	1.67
CORE 2X					
0	111.93	50.55	322.77	61.38	4.44
30	134.73	100.18	250.79	34.56	4.36
50	167.11	87.23	263.48	79.88	2.21
CORE 3					
0	113.45	57.94	415.18	55.52	6.43
30	134.43	70.87	242.71	63.56	2.70
40	93.97	25.68	230.50	68.29	3.00
49 ¹	-----	-----	-----	-----	-----
CORE 4					
0	99.82	55.54	363.46	44.29	6.95
40	160.61	94.49	253.77	66.13	2.41
65	135.15	100.94	192.02	34.21	2.66
CORE 5					
0	110.47	47.38	365.29	63.09	5.04
30	149.01	76.95	240.72	72.06	2.27
50	104.21	52.60	151.59	51.61	1.92

¹ non-plastic

TABLE 4
Shear Strength (Fall Cone), kPa

Core	1	2	3	4	5	2X
Depth (cm)						
0	0.06	0.06	0.06	0.06	0.06	0.06
2	0.07	0.11	0.07	0.09	0.09	0.11
5	0.10	0.17	0.09	0.11	0.19	0.13
10	0.22	0.27	0.25	0.17	0.20	0.27
15	0.25	0.20	0.25	0.23	0.74	0.22
20	0.19	0.27	0.41	0.36	0.58	0.38
25	0.34	0.32	0.38	0.74	0.74	0.81
30	0.68	0.58	0.91	0.95	1.08	0.93
35	0.82	0.98	0.68	1.07	0.98	1.16
40	0.65	0.68	3.48	0.98	1.27	1.16
45	0.81	1.55	32.10	1.11	1.40	1.11
50	0.87	1.07	32.70 ¹	1.16	1.40	1.16
55	1.11	1.63		1.63	11.92	1.40
60	1.63			1.63		
65	1.22			1.72		
70	1.47					
75	1.22					
80	1.81					
85	1.92					
90	1.63					
95	1.63					
100	4.86					

¹ depth is 49 cm.

TABLE 5
Concentrations of Major and Trace Elements in Sediment Cores

Station No.	Depth cm	SiO ₂ %	TiO ₂ %	Al ₂ O ₃ %	Fe ₂ O ₃ %	MnO %	MgO %	CaO %	Na ₂ O %	K ₂ O %	P ₂ O ₅ %
M 1	0-1	42.61	0.54	9.81	9.98	0.31	2.12	9.33	0.54	2.08	0.94
M 1	1-2	41.28	0.55	9.95	10.13	0.34	2.17	9.69	0.5	2.08	1.01
M 1	2-3	41.2	0.54	9.67	10.42	0.35	2.12	9.87	0.55	2.06	1.1
M 1	3-4	40.72	0.53	9.58	11.16	0.37	2.08	9.6	0.46	2.06	1.2
M 1	4-5	40.48	0.55	10.02	12.79	0.41	2.12	7.9	0.51	2.1	1.41
M 1	5-6	42.96	0.57	10.56	14.71	0.39	2.18	5.13	0.55	2.42	1.23
M 1	6-7	42.36	0.58	10.79	15.92	0.4	2.21	4.76	0.57	2.31	1.34
M 1	7-8	42.04	0.6	10.85	16.28	0.4	2.26	4.71	0.6	2.32	1.17
M 1	8-9	41.47	0.57	10.59	16.03	0.39	2.16	4.51	0.53	2.24	1.51
M 1	9-10	41.94	0.59	10.51	16.32	0.4	2.18	4.7	0.59	2.22	1.43
M 1	10-11	43.57	0.6	10.58	14.88	0.37	2.2	5.28	0.67	2.26	1.41
M 1	11-12	45.78	0.61	10.94	12.47	0.28	2.22	6.38	0.8	2.21	1.27
M 1	12-13	46.07	0.63	11.93	13.01	0.27	2.23	5.48	0.54	2.5	0.98
M 1	13-14	45.79	0.63	12.05	12.7	0.26	2.22	5.5	0.62	2.52	0.96
M 1	14-15	45.73	0.64	12.14	12.23	0.24	2.26	5.87	0.58	2.62	0.77
M 1	15-16	46.69	0.63	11.54	11.52	0.22	2.2	6.3	0.58	2.57	0.7
M 1	16-17	48.4	0.62	11.45	10.39	0.21	2.16	7.09	0.88	2.34	0.65
M 1	17-18	50.98	0.58	11.42	9.97	0.2	1.96	5.92	1	2.38	0.67
M 1	18-19	47.51	0.68	12.58	11.12	0.21	2.27	4.71	0.57	2.71	0.54
M 1	19-20	47.71	0.69	12.67	9.83	0.19	2.31	5.43	0.76	2.71	0.46
M 1	20-21	48.6	0.69	12.92	9.27	0.19	2.31	5.6	0.57	2.68	0.51
M 1	21-22	48.95	0.71	13.39	8.65	0.17	2.41	5.22	0.62	2.76	0.48
M 1	22-23	48.36	0.71	13.24	8.69	0.19	2.39	5.18	0.6	2.86	0.55
M 1	23-24	48.24	0.7	13.5	9.17	0.19	2.37	4.45	0.57	2.8	0.47
M 1	24-25	49.68	0.69	13.74	8.46	0.18	2.39	4.45	0.56	2.92	0.44
M 1	25-26	50.1	0.76	14.41	7.82	0.16	2.57	4.11	0.51	2.98	0.29
M 1	26-27	50.72	0.76	14.57	7.7	0.16	2.6	3.31	0.49	3.07	0.31
M 1	27-28	51.11	0.77	14.89	7.5	0.15	2.62	2.94	0.5	3.2	0.27
M 1	28-29	52.5	0.8	15.62	7.51	0.14	2.69	2.26	0.57	3.31	0.28
M 1	29-30	52.73	0.8	15.74	7.44	0.14	2.68	2.2	0.58	3.32	0.24
M 1	60	58.2	0.43	8.48	2.47	0.08	1.23	13.17	1.82	1.8	0.1

Station No.	Depth cm	Hg ng/g	V ug/g	Cr ug/g	Co ug/g	Ni ug/g	Cu ug/g	Zn ug/g	Cd ug/g	Sn ug/g	Pb ug/g	As ug/g
M 1	0-1	403	37	162	15	62	111	2466	6.4	160	288	10
M 1	1-2	416	39	164	14	62	113	2453	6.2	169	287	10
M 1	2-3	422	40	174	14	66	114	2846	6	171	304	11
M 1	3-4	497	42	195	14	68	123	3173	8.5	210	350	10
M 1	4-5	621	48	244	16	80	195	4636	10.6	219	447	18
M 1	5-6	836	45	320	17	88	166	5744	14	200	567	30
M 1	6-7	857	44	342	17	86	159	5612	15.4	189	595	15
M 1	7-8	907	44	361	17	91	167	5840	15.7	194	628	31
M 1	8-9	882	43	343	17	87	159	5498	14.9	174	606	19
M 1	9-10	1168	38	309	16	82	147	5191	14.8	141	564	28
M 1	10-11	683	35	254	15	78	126	4040	13.2	120	492	18
M 1	11-12	409	33	199	14	73	114	2911	11.8	93	392	16
M 1	12-13	472	38	174	16	75	128	2347	14.1	83	315	16
M 1	13-14	509	37	149	16	75	129	2053	13.7	77	279	10
M 1	14-15	522	36	129	16	73	130	1984	12.9	88	264	14
M 1	15-16	497	35	103	15	69	124	1840	13.6	66	236	13
M 1	16-17	409	32	85	13	61	111	1629	12.4	42	203	11
M 1	17-18	587	30	73	12	58	106	1556	11.7	48	195	10
M 1	18-19	684	34	78	15	64	131	1700	12.9	60	239	12
M 1	19-20	832	33	69	15	58	120	1599	10.8	45	218	10
M 1	20-21	757	34	64	14	54	115	1517	8.9	49	209	<5
M 1	21-22	789	34	56	15	50	103	1387	7.4	32	200	9
M 1	22-23	704	35	53	15	47	97	1326	5.7	35	180	9
M 1	23-24	725	35	52	15	48	98	981	2.9	37	144	<5
M 1	24-25	715	35	52	16	39	87	479	0.9	36	95	<5
M 1	25-26	533	36	47	16	38	66	326	0.9	27	72	<5
M 1	26-27	533	36	49	15	40	61	301	1.5	<20	70	<5
M 1	27-28	416	37	48	15	41	61	289	0.7	31	70	<5
M 1	28-29	341	35	45	15	39	54	264	1.7	<20	67	<5
M 1	29-30	299	36	46	15	42	53	255	1	20	58	<5
M 1	60	5	12	11	4	7	7	25	<0.2	<20	<2	<5

Station	Depth	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5
No.	cm	%	%	%	%	%	%	%	%	%	%
M 2	0-1	40.2	0.56	10.16	10.46	0.33	2.21	9.54	0.47	2.1	0.81
M 2	1-2	39.55	0.54	9.86	10.63	0.35	2.16	9.84	0.39	2.14	0.85
M 2	2-3	38.32	0.52	9.54	11.03	0.36	2.09	9.72	0.35	2.08	1
M 2	3-4	37.97	0.53	9.58	11.68	0.37	2.09	10.01	0.36	1.94	1.01
M 2	4-5	38.86	0.56	10.04	12.35	0.39	2.01	9.47	0.43	2.26	1.12
M 2	5-6	39	0.56	10.14	13.83	0.44	2.03	8.13	0.44	2.24	1.39
M 2	6-7	40.27	0.65	10.64	16.33	0.45	2.1	5.43	0.5	2.49	1.29
M 2	7-8	39.81	0.73	10.57	17.02	0.44	2.08	4.74	0.51	2.44	1.31
M 2	8-9	39.73	0.59	10.73	16.99	0.43	2.09	4.41	0.47	2.53	1.26
M 2	9-10	40.07	0.59	10.6	17.48	0.43	2.04	4.43	0.55	2.42	1.38
M 2	10-11	40.34	0.59	10.55	16.36	0.4	2.19	4.81	0.6	2.47	1.23
M 2	11-12	43.52	0.62	11.05	14.27	0.33	2.1	5.27	0.68	2.58	1.01
M 2	12-13	41.88	0.62	11.26	14.12	0.32	2.1	5.69	0.65	2.6	1
M 2	13-14	46.96	0.67	11.33	11.11	0.24	2.15	6.56	0.89	2.72	0.72
M 2	14-15	43.63	0.64	11.95	13.63	0.3	2.16	5.43	0.61	2.75	0.86
M 2	15-16	42.08	0.64	12.14	15.23	0.37	2.13	4.54	0.47	2.79	1.02
M 2	16-17	41.71	0.64	12.39	15.82	0.38	2.14	3.96	0.41	2.86	0.94
M 2	17-18	41.69	0.64	12.31	14.54	0.32	2.08	4.26	0.4	2.82	1.1
M 2	18-19	43.17	0.68	12.44	13.43	0.29	2.17	4.99	0.52	2.84	0.89
M 2	19-20	43.07	0.67	12.25	13.72	0.3	2.19	6.08	0.54	2.82	0.83
M 2	20-21	42.8	0.67	12.57	13.18	0.28	2.23	6.46	0.53	2.84	0.79
M 2	21-22	44.73	0.65	11.73	12.83	0.28	2.08	6.04	0.68	2.61	0.81
M 2	22-23	43.89	0.63	11.73	14.91	0.33	1.94	4.13	0.55	2.63	0.66
M 2	23-24	42.94	0.66	12.31	15.37	0.33	2.17	3.79	0.48	2.73	0.62
M 2	24-25	43.67	0.68	12.53	14.33	0.29	2.25	4.05	0.45	2.82	0.59
M 2	25-26	46.45	0.81	13.08	11.78	0.23	2.19	4.65	0.54	3.01	0.49
M 2	26-27	46.09	0.71	13.23	10.67	0.22	2.32	4.96	0.56	3.01	0.41
M 2	27-28	46.43	0.72	13.16	9.97	0.2	2.24	5.55	0.58	2.98	0.42
M 2	28-29	46.75	0.72	13.33	9.47	0.19	2.38	5.39	0.53	3.19	0.49
M 2	29-30	47.49	0.73	13.37	9.42	0.19	2.26	5.42	0.54	3.09	0.48

Station No.	Depth cm	Hg ng/g	V ug/g	Cr ug/g	Co ug/g	Ni ug/g	Cu ug/g	Zn ug/g	Cd ug/g	Sn ug/g	Pb ug/g	As ug/g
M 2	0-1	459	38	155	14	59	115	2184	6	164	274	<5
M 2	1-2	980	41	168	15	66	119	2400	7.2	176	298	14
M 2	2-3	533	42	187	15	69	124	2721	7.9	221	333	14
M 2	3-4	555	45	198	16	73	127	2994	7.9	240	364	14
M 2	4-5	619	46	207	16	74	136	3370	9.3	251	392	20
M 2	5-6	821	49	256	17	85	164	4846	10.9	242	477	23
M 2	6-7	1013	48	344	17	95	177	6173	15.4	221	618	27
M 2	7-8	1013	42	333	16	84	156	5481	14	198	580	23
M 2	8-9	1035	47	391	18	96	181	6186	16.5	207	681	30
M 2	9-10	1131	43	360	17	89	163	5775	16.5	182	635	29
M 2	10-11	1237	40	321	16	88	149	5329	16.3	142	598	16
M 2	11-12	533	36	270	15	80	133	4010	13.8	114	526	17
M 2	12-13	537	36	326	16	83	149	4211	15.6	140	601	8
M 2	13-14	379	34	161	15	67	111	2398	10.3	100	323	6
M 2	14-15	495	37	195	17	83	138	3145	13.3	121	450	18
M 2	15-16	484	40	222	18	85	139	2928	14.9	124	421	17
M 2	16-17	421	41	249	18	88	144	2930	15.5	122	427	24
M 2	17-18	474	41	197	18	88	143	2309	14.9	114	320	25
M 2	18-19	421	39	159	18	82	140	2052	14.3	96	285	20
M 2	19-20	453	40	138	17	79	145	2130	14.6	65	286	19
M 2	20-21	400	39	132	18	75	135	1995	13.5	72	276	10
M 2	21-22	442	36	110	16	69	136	1994	13.3	73	253	15
M 2	22-23	632	37	105	16	79	156	2331	18.3	67	280	13
M 2	23-24	653	37	104	17	79	164	2335	18.8	70	284	20
M 2	24-25	653	37	100	16	73	155	2193	16.8	78	290	19
M 2	25-26	674	38	85	17	71	142	1841	14.4	39	260	5
M 2	26-27	653	36	76	16	64	131	1758	12.3	59	239	<5
M 2	27-28	695	36	68	16	56	120	1593	11.6	57	223	11
M 2	28-29	726	37	64	16	52	115	1550	9.2	39	224	8
M 2	29-30	716	38	63	16	54	115	1620	8.2	44	235	9

Station	Depth	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
No.	cm	%	%	%	%	%	%	%	%	%	%
M 3	0-1	40.36	0.56	10.03	10.41	0.32	2.02	9.01	0.53	2.24	0.93
M 3	1-2	40.1	0.55	9.9	10.74	0.34	2	9	0.49	2.32	0.97
M 3	2-3	40.42	0.56	10	10.3	0.35	2.03	9.14	0.51	2.31	0.94
M 3	3-4	40.07	0.56	9.95	10.78	0.35	2.01	9.05	0.5	2.34	1.01
M 3	4-5	39.69	0.57	9.87	10.63	0.36	2	9.25	0.51	2.27	1.06
M 3	5-6	39.32	0.56	9.92	11.73	0.4	2.02	9.44	0.49	2.24	1.35
M 3	6-7	39.15	0.54	9.84	12.84	0.42	1.96	7.76	0.49	2.3	1.58
M 3	7-8	40.63	0.58	10.57	14.94	0.41	2.04	5.47	0.52	2.53	1.33
M 3	8-9	41.29	0.59	10.84	16.01	0.42	2.07	4.59	0.54	2.63	1.34
M 3	9-10	41.25	0.6	11	16.55	0.41	2.08	4.34	0.5	2.54	1.33
M 3	10-11	41.54	0.58	10.61	16.39	0.4	2	4.11	0.52	2.49	1.49
M 3	11-12	41.02	0.59	10.4	16.45	0.4	2.13	4.06	0.62	2.47	1.47
M 3	12-13	40.91	0.58	10.26	16.72	0.41	2.1	4.16	0.55	2.46	1.61
M 3	13-14	41.69	0.58	10.23	15.7	0.39	1.95	4.52	0.6	2.43	1.83
M 3	14-15	43.16	0.61	10.85	13.81	0.32	2.02	5.07	0.6	2.61	1.45
M 3	15-16	44.28	0.64	11.78	13.91	0.3	2.11	5.09	0.56	2.76	1.18
M 3	16-17	44.98	0.66	12.16	13.39	0.27	2.13	4.91	0.52	2.94	1.06
M 3	17-18	45.23	0.66	12.09	12.94	0.25	2.14	5.29	0.57	2.98	0.98
M 3	18-19	45.65	0.66	12.12	12.73	0.24	2.14	5.46	0.57	2.91	0.88
M 3	19-20	45.87	0.67	11.97	12.49	0.24	2.1	5.42	0.63	2.87	0.87
M 3	20-21	47.16	0.65	11.73	12.22	0.24	1.99	4.64	0.7	2.75	0.89
M 3	21-22	48.52	0.72	13.05	10.36	0.19	2.21	4.66	0.62	3.06	0.49
M 3	22-23	48.86	0.71	12.76	10.1	0.2	2.2	5.19	0.66	3.04	0.61
M 3	23-24	48.04	0.73	12.79	9.21	0.2	2.18	5.12	0.63	3.01	0.61
M 3	24-25	49.12	0.73	13.26	9.01	0.19	2.26	4.95	0.6	3.14	0.53
M 3	25-26	48.42	0.71	13.28	9.23	0.19	2.22	4.28	0.57	3.12	0.56
M 3	26-27	47.63	0.68	13.28	9.72	0.19	2.42	3.99	0.51	2.91	0.59
M 3	27-28	47.78	0.71	13.58	9.23	0.16	2.26	4.73	0.57	2.95	0.37
M 3	28-29	50.23	0.75	14.35	7.96	0.16	2.37	3.38	0.57	3.19	0.32
M 3	29-30	50.01	0.75	14.72	8.4	0.16	2.35	3.26	0.53	3.11	0.35

Station No.	Depth cm	Hg ng/g	V ug/g	Cr ug/g	Co ug/g	Ni ug/g	Cu ug/g	Zn ug/g	Cd ug/g	Sn ug/g	Pb ug/g	As ug/g
M 3 0-1	453	39	167	14	63	112	2525	6.8	176	293	7	
M 3 1-2	432	39	165	15	62	111	2486	6.1	162	287	10	
M 3 2-3	442	39	160	14	63	109	2430	6.8	158	283	<5	
M 3 3-4	442	38	160	14	62	109	2400	5.7	148	282	15	
M 3 4-5	453	38	167	15	64	113	2561	6.6	164	296	10	
M 3 5-6	558	42	197	15	73	124	3163	8.2	197	352	12	
M 3 6-7	695	49	251	16	85	152	4699	10.6	234	455	15	
M 3 7-8	884	48	312	17	91	170	5913	14.4	204	566	24	
M 3 8-9	958	45	336	16	88	167	5905	15.6	185	597	24	
M 3 9-10	979	46	367	17	93	170	6094	16.4	209	654	17	
M 3 10-11	1101	40	327	16	83	161	5377	13.7	153	597	40	
M 3 11-12	1202	40	328	16	88	159	5613	15.8	133	616	43	
M 3 12-13	1242	41	326	16	90	158	5607	17.2	120	616	48	
M 3 13-14	828	38	274	16	88	140	4441	13.2	105	540	37	
M 3 14-15	535	37	221	16	80	131	3271	12.7	103	448	38	
M 3 15-16	556	39	184	16	78	136	2592	13.3	82	355	43	
M 3 16-17	525	42	170	18	82	149	2473	14.4	88	339	37	
M 3 17-18	495	38	144	17	77	140	2196	13.5	63	303	41	
M 3 18-19	505	38	116	16	71	139	2139	14.2	53	285	32	
M 3 19-20	535	36	106	16	71	139	2045	14.6	46	275	34	
M 3 20-21	616	33	88	15	67	130	1920	12.6	37	251	40	
M 3 21-22	646	35	76	16	60	124	1715	10.9	34	238	33	
M 3 22-23	697	34	73	15	58	122	1663	10.4	33	234	33	
M 3 23-24	667	34	63	15	51	110	1449	7.5	20	215	20	
M 3 24-25	697	37	63	16	53	113	1536	7.6	<20	221	31	
M 3 25-26	677	37	59	17	51	105	1365	4.4	40	188	30	
M 3 26-27	727	37	60	17	48	111	743	1.6	43	142	29	
M 3 27-28	566	35	55	15	40	79	519	1.4	<20	106	21	
M 3 28-29	444	36	54	16	41	67	483	0.5	25	94	23	
M 3 29-30	444	35	56	16	43	71	508	0.6	22	102	22	

Station	Depth	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
No.	cm	%	%	%	%	%	%	%	%	%	%
M 4	0-1	42.78	0.57	9.7	10.33	0.34	2.01	8.77	0.72	2.04	1.27
M 4	1-2	43.45	0.56	9.61	10.08	0.32	1.99	9.01	0.69	2.12	1.16
M 4	2-3	42.7	0.56	9.79	9.69	0.31	2.02	9.15	0.65	2.16	1.11
M 4	3-4	43.73	0.55	9.46	9.9	0.32	1.96	9.04	0.66	2.04	1.14
M 4	4-5	43.66	0.54	9.11	10.27	0.33	1.94	9.11	0.67	2.02	1.32
M 4	5-6	43.54	0.54	9.29	10.65	0.34	1.93	8.96	0.65	2.03	1.43
M 4	6-7	43.01	0.59	10.03	12.75	0.37	2.04	7.55	0.69	2.42	1.57
M 4	7-8	44.17	0.6	10.33	14.81	0.37	2.05	5.01	0.69	2.49	1.8
M 4	8-9	44.52	0.61	10.28	15.14	0.36	2	4.67	0.75	2.49	1.85
M 4	9-10	44.27	0.62	10.3	14.05	0.33	1.98	4.83	0.73	2.49	1.79
M 4	10-11	45.79	0.65	11.61	12.08	0.24	2.09	5.44	0.66	2.75	1.17
M 4	11-12	47.22	0.67	11.94	11.77	0.23	2.13	5.74	0.72	2.73	1.03
M 4	12-13	47.57	0.66	11.69	11.25	0.22	2.05	5.36	0.77	2.75	0.98
M 4	13-14	49.74	0.7	12.28	10.79	0.22	2.12	4.5	0.78	2.81	0.93
M 4	14-15	50.07	0.72	12.67	9.74	0.21	2.18	4.84	0.8	2.77	0.76
M 4	15-16	49.6	0.75	13.87	9.58	0.2	2.25	3.79	0.65	2.96	0.53
M 4	16-17	51.86	0.8	14.95	8.4	0.15	2.46	2.72	0.7	3.31	0.41
M 4	17-18	52.7	0.82	15.28	7.97	0.14	2.52	2.59	0.69	3.33	0.33
M 4	18-19	51.97	0.8	15.08	7.68	0.14	2.49	2.5	0.68	3.48	0.39
M 4	19-20	52.55	0.81	15.29	7.55	0.13	2.5	2.2	0.65	3.59	0.32
M 4	20-21	54.14	0.84	15.83	7.69	0.13	2.56	2.03	0.68	3.59	0.36
M 4	21-22	54.43	0.83	15.74	7.51	0.12	2.53	1.84	0.73	3.63	0.31
M 4	22-23	54.53	0.82	15.52	7.44	0.12	2.52	2.01	0.73	3.65	0.32
M 4	23-24	54.27	0.81	15.06	7.33	0.12	2.5	2.49	0.79	3.58	0.33
M 4	24-25	52.63	0.77	14.11	6.94	0.12	2.38	3.06	0.78	3.37	0.31
M 4	25-26	52.26	0.75	13.6	6.81	0.12	2.36	3.86	0.81	3.23	0.33
M 4	26-27	52.61	0.75	13.16	6.74	0.12	2.36	5.14	0.89	3.1	0.3
M 4	27-28	50.93	0.71	12.54	6.39	0.12	2.27	5.53	0.82	3.09	0.35
M 4	28-29	51.37	0.7	12.41	6.31	0.12	2.26	5.42	0.84	3.04	0.32
M 4	29-30	52.12	0.73	12.36	6.39	0.12	2.27	5.08	0.85	3.08	0.33

Station No.	Depth cm	Hg ng/g	V ug/g	Cr ug/g	Co ug/g	Ni ug/g	Cu ug/g	Zn ug/g	Cd ug/g	Sn ug/g	Pb ug/g	As ug/g
M 4	0-1	454	37	172	13	62	105	2750	5.7	152	305	25
M 4	1-2	414	37	167	14	64	107	2614	6.5	167	297	33
M 4	2-3	404	36	157	14	59	101	2414	6.5	131	278	29
M 4	3-4	454	38	170	13	64	108	2684	6.6	137	302	35
M 4	4-5	475	39	181	14	68	110	2910	6.9	172	324	27
M 4	5-6	495	40	190	14	70	113	3132	6.2	180	343	31
M 4	6-7	646	41	228	14	74	125	4029	9.5	165	414	38
M 4	7-8	858	41	274	16	84	137	4772	12.6	149	498	42
M 4	8-9	926	37	254	14	81	125	4369	12.8	87	473	46
M 4	9-10	723	35	216	15	81	115	3602	11.6	96	423	40
M 4	10-11	478	35	142	15	74	118	2170	11.3	70	295	28
M 4	11-12	468	35	113	15	72	119	1928	11.2	46	261	35
M 4	12-13	509	34	90	15	69	117	1806	12.1	36	232	33
M 4	13-14	590	34	73	16	67	115	1624	10.3	23	227	39
M 4	14-15	590	35	63	15	59	104	1387	6.7	24	199	36
M 4	15-16	509	36	52	16	49	84	746	3	<20	126	18
M 4	16-17	366	35	48	15	44	63	389	<0.2	24	85	17
M 4	17-18	316	36	49	16	46	60	326	1.3	<20	79	23
M 4	18-19	275	38	50	17	42	59	312	0.2	22	77	21
M 4	19-20	244	39	52	17	47	59	306	<0.2	<20	73	25
M 4	20-21	183	38	48	17	43	53	281	0.7	<20	64	23
M 4	21-22	153	38	44	16	42	50	259	0.8	<20	54	13
M 4	22-23	122	39	44	17	44	50	260	<0.2	<20	48	17
M 4	23-24	81	36	38	15	41	48	225	<0.2	26	39	14
M 4	24-25	71	35	38	15	39	45	217	0.7	<20	36	15
M 4	25-26	71	34	37	15	37	44	221	1.7	<20	33	9
M 4	26-27	61	29	31	13	34	39	190	<0.2	<20	26	12
M 4	27-28	51	28	32	13	33	40	215	<0.2	<20	29	15
M 4	28-29	53	28	31	13	34	39	194	0.5	<20	24	19
M 4	29-30	56	30	34	14	36	41	205	0.9	31	28	12

Station	Depth	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
No.	cm	%	%	%	%	%	%	%	%	%	%
M 5	0-1	41.15	0.58	10.04	10.55	0.33	2.09	9.52	0.59	2.29	1.06
M 5	1-2	41.31	0.59	10.16	10.32	0.33	2.11	9.28	0.57	2.38	1.01
M 5	2-3	41.08	0.58	10.07	10.49	0.35	2.09	9.45	0.56	2.22	1.12
M 5	3-4	40.34	0.57	9.87	11.01	0.36	2.06	9.69	0.55	2.16	1.14
M 5	4-5	40.1	0.55	9.73	10.96	0.36	1.98	9.41	0.5	2.19	1.19
M 5	5-6	39.57	0.56	9.7	11.81	0.38	2.01	9.51	0.54	2.11	1.39
M 5	6-7	40.7	0.59	10.43	15.16	0.41	2.09	6.14	0.54	2.4	1.53
M 5	7-8	41.02	0.59	10.52	16.24	0.41	2.03	4.56	0.57	2.37	1.56
M 5	8-9	41.69	0.65	10.74	16.49	0.39	2.06	4.44	0.59	2.44	1.35
M 5	9-10	42.43	0.6	10.64	15.61	0.38	2.03	4.79	0.66	2.42	1.58
M 5	10-11	44.36	0.63	11.36	13.42	0.29	2.11	5.55	0.79	2.65	1.3
M 5	11-12	44.5	0.66	11.96	13.15	0.27	2.11	5.47	0.66	2.7	1.08
M 5	12-13	44.83	0.67	12.47	12.87	0.25	2.13	5.45	0.58	2.83	0.96
M 5	13-14	44.47	0.67	12.32	12.66	0.24	2.16	5.59	0.56	2.9	0.88
M 5	14-15	44.43	0.66	12.1	12.28	0.23	2.29	6.04	0.6	2.88	0.93
M 5	15-16	49.29	0.63	11.81	10.97	0.22	1.96	5.85	0.89	2.56	0.76
M 5	16-17	45.75	0.67	12.19	13.08	0.24	2.03	4.29	0.64	2.65	0.86
M 5	17-18	46.61	0.69	12.6	11.91	0.22	2.12	4.65	0.62	2.79	0.7
M 5	18-19	48.63	0.73	13.25	10.42	0.2	2.22	4.94	0.68	2.94	0.53
M 5	19-20	47.66	0.71	12.69	9.71	0.2	2.17	5.21	0.68	2.87	0.68
M 5	20-21	49.31	0.75	13.52	9.24	0.18	2.28	5.09	0.65	3.08	0.53
M 5	21-22	49.18	0.75	13.62	9.3	0.19	2.3	4.98	0.62	3.03	0.63
M 5	22-23	47.95	0.73	13.45	9.51	0.19	2.27	4.42	0.56	2.88	0.48
M 5	23-24	47.2	0.73	13.62	9.23	0.18	2.31	4.58	0.53	2.95	0.5
M 5	24-25	49.42	0.78	14.37	8.06	0.16	2.44	4.12	0.55	3.15	0.38
M 5	25-26	50.34	0.79	14.77	7.92	0.16	2.48	3.55	0.55	3.25	0.36
M 5	26-27	50.5	0.78	14.7	7.88	0.16	2.43	3.45	0.55	3.19	0.35
M 5	27-28	49.75	0.78	14.5	7.86	0.16	2.62	3.42	0.54	3.18	0.35
M 5	28-29	51.4	0.8	14.97	7.82	0.15	2.48	2.65	0.55	3.25	0.31
M 5	29-30	50.98	0.85	15.39	7.84	0.14	2.52	2.15	0.53	3.33	0.34

CROSS SECTIONS OF CAPPING AREA

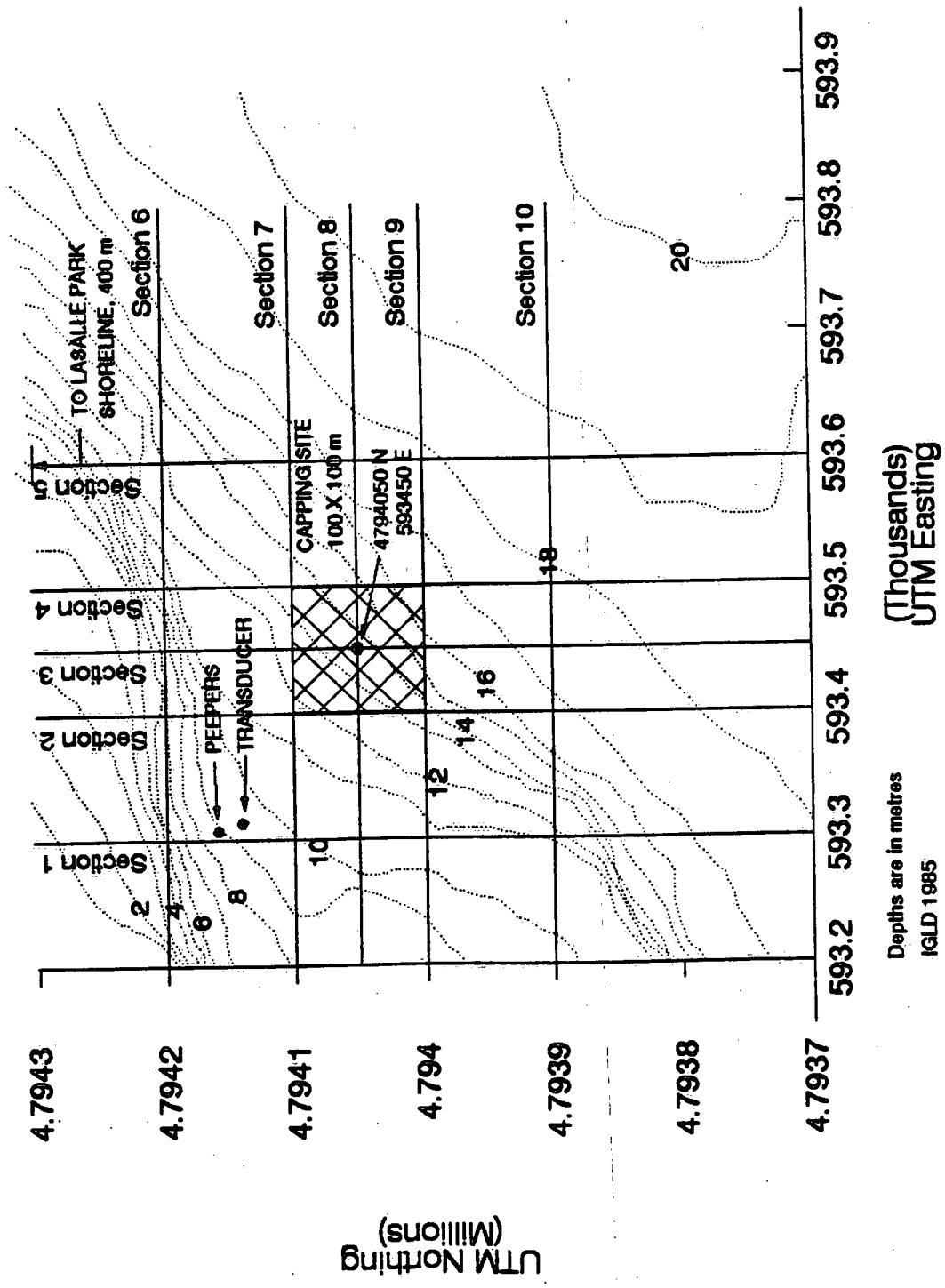


Figure 1

CROSS SECTION 1
593300 EASTING STARTING AT 4794300 NORTHING
MAY 10, 1993

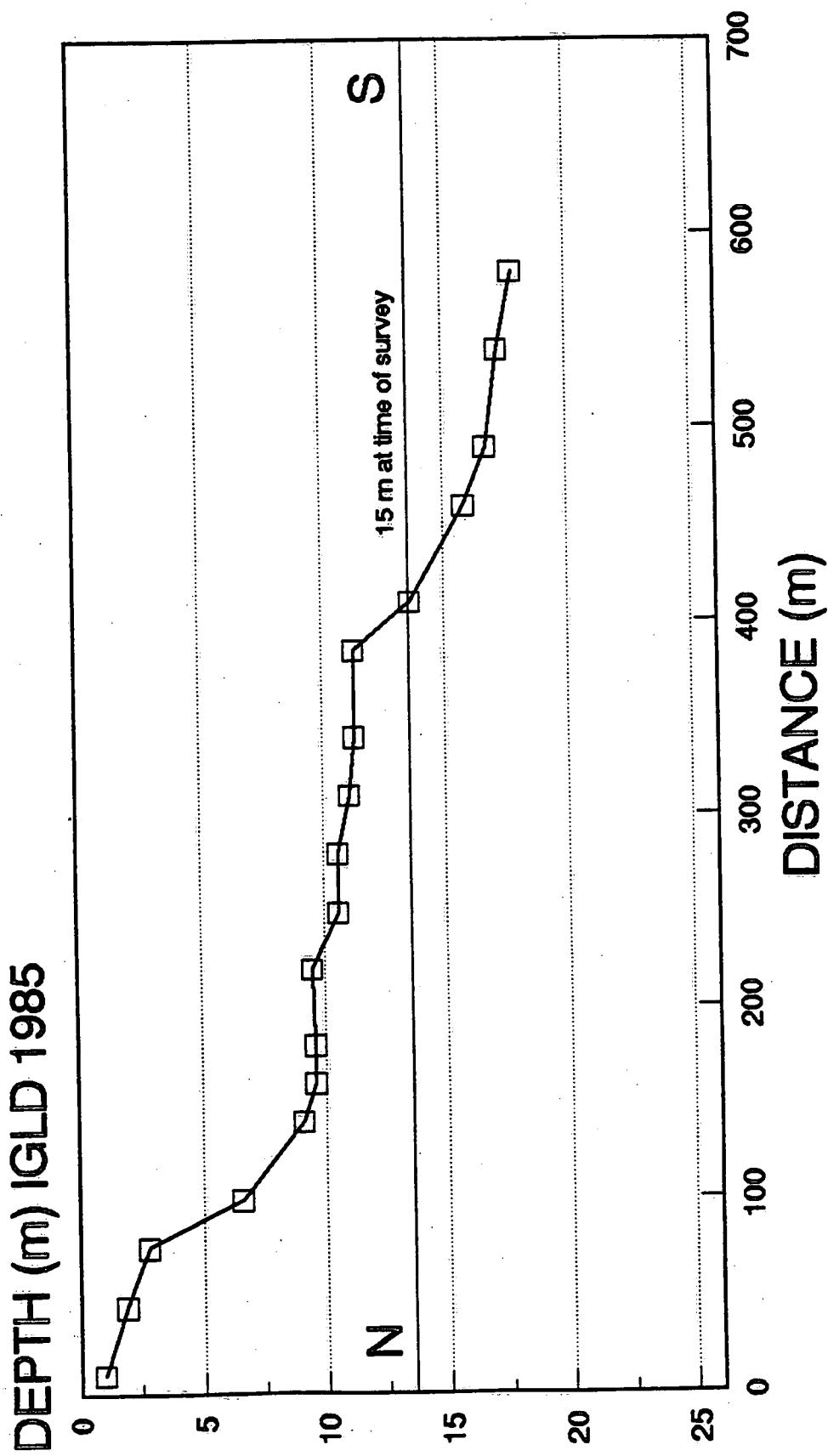


Figure 2.1

CROSS SECTION 2
593400 EASTING STARTING AT 4794300 NORTHING
MAY 10, 1993

DEPTH (m) IGLD 1985

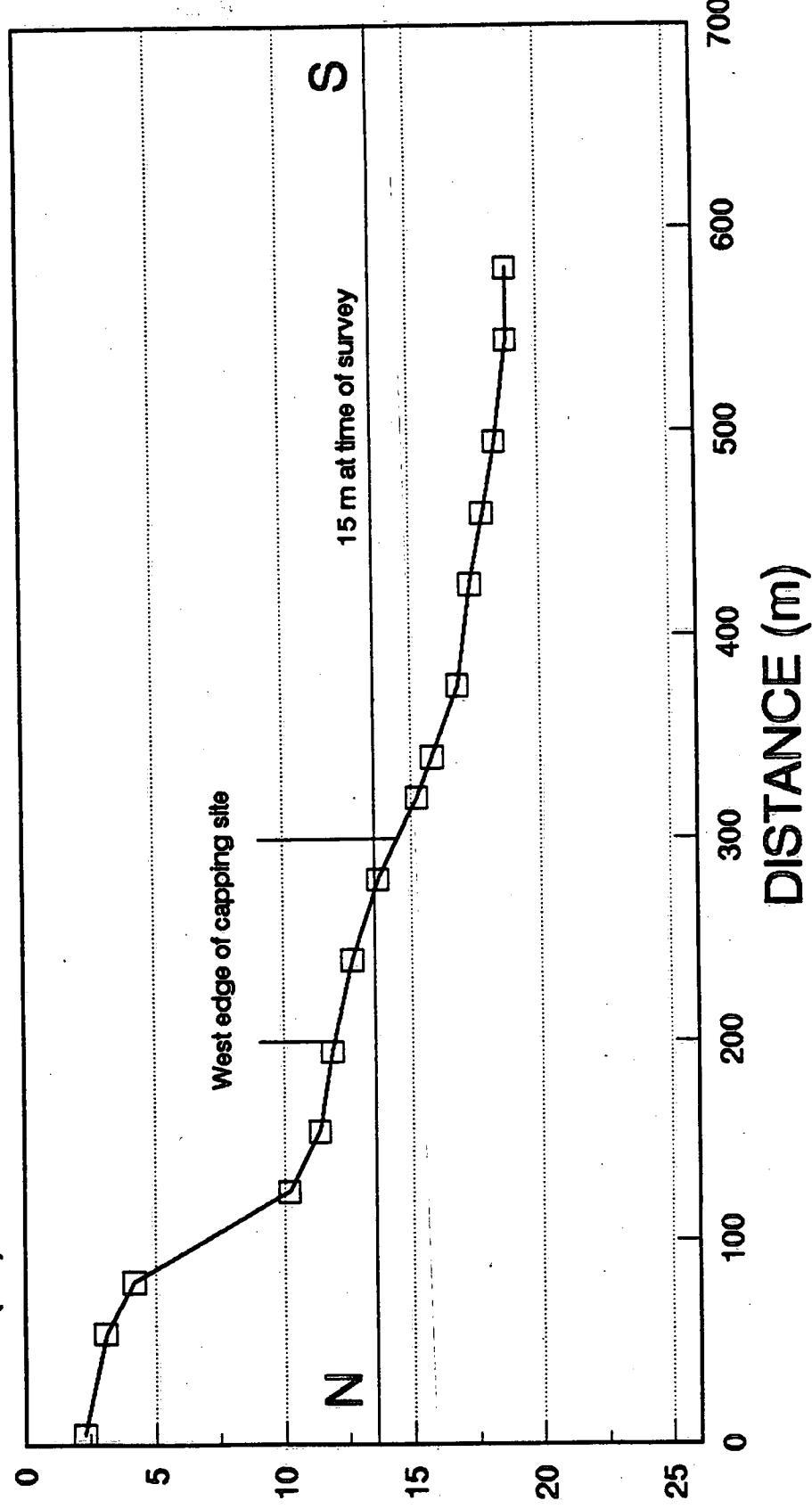


Figure 2.2

CROSS SECTION 3
593450 EASTING STARTING AT 4794300 NORTHING
MAY 10, 1993

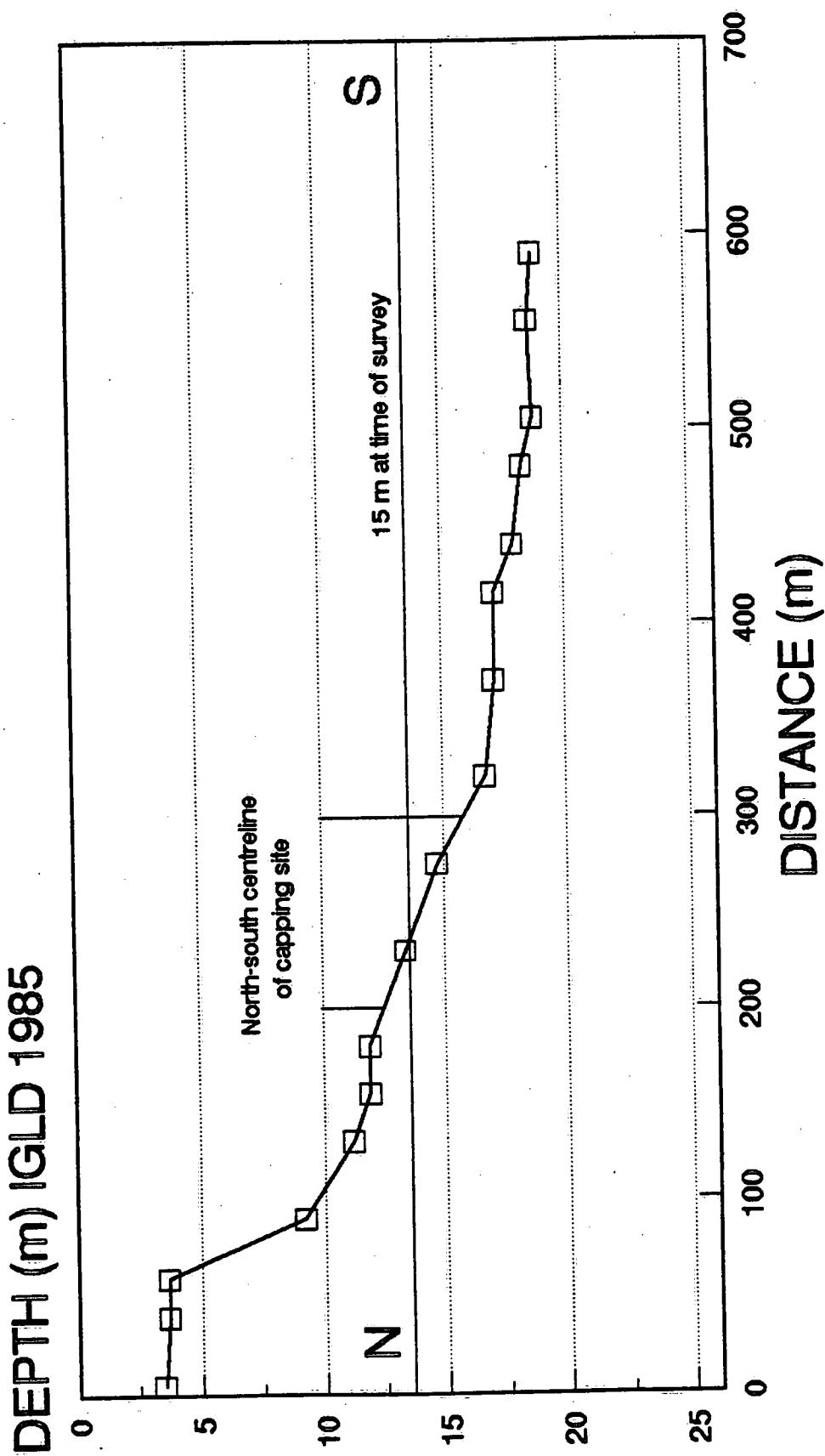


Figure 2.3

CROSS SECTION 4
593500 EASTING STARTING AT 4794300 NORTHING
MAY 10, 1993

DEPTH (m) IGLD 1985

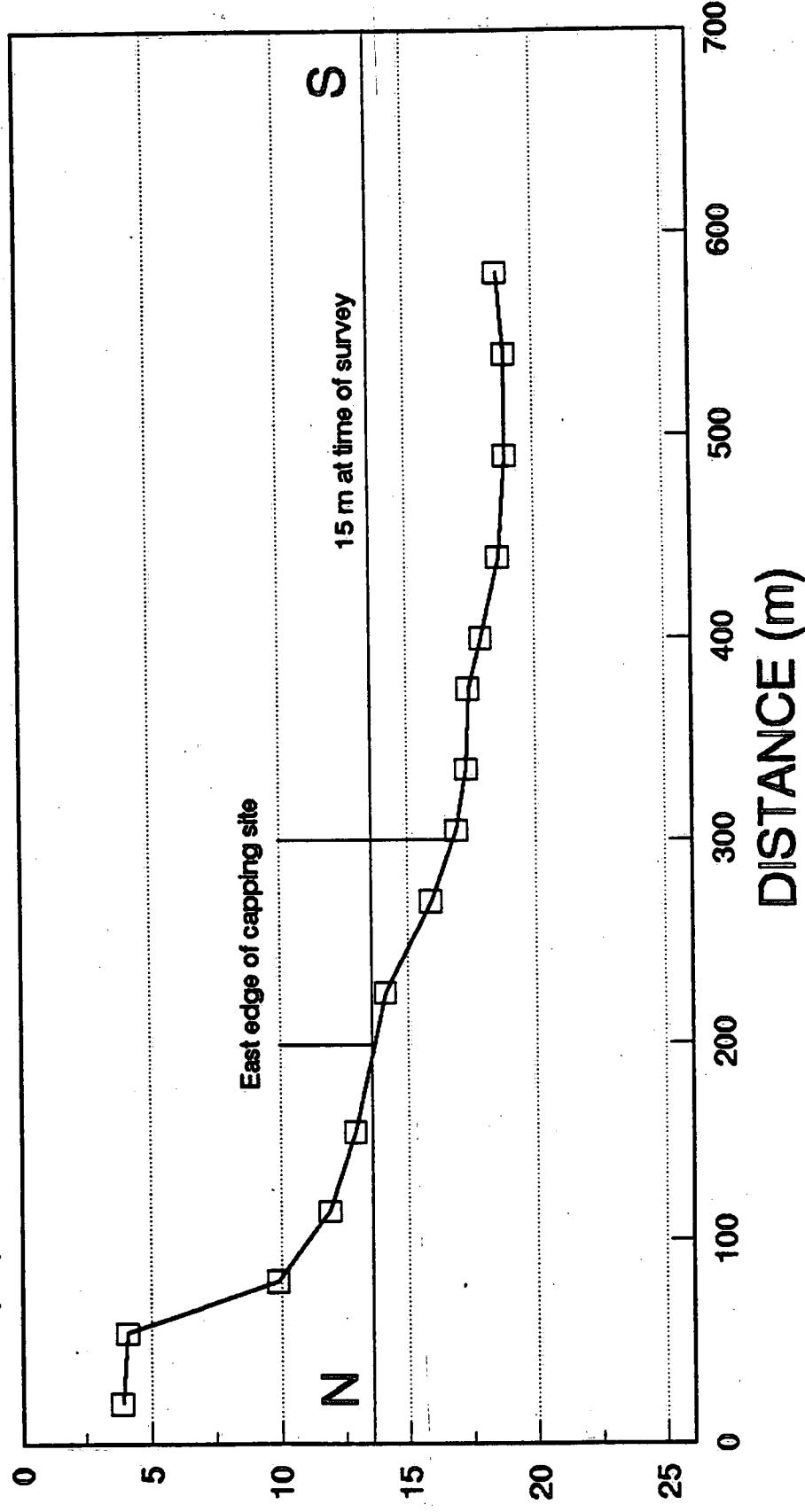


Figure 2.4

CROSS SECTION 5
593600 EASTING STARTING AT 4794300 NORTHING
MAY 10, 1993

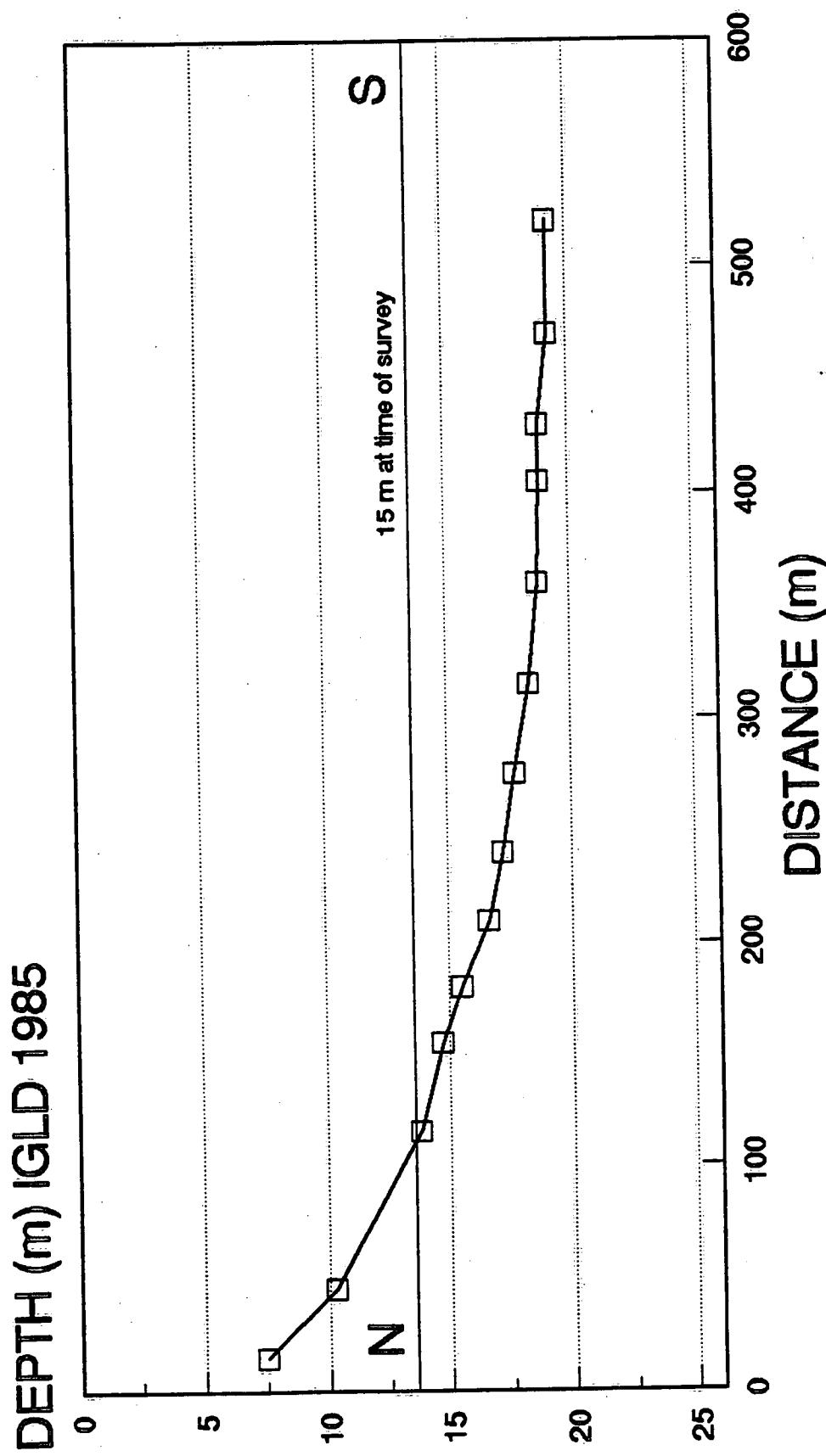


Figure 2.5

CROSS SECTION 6

4794200 NORTHING STARTING AT 593200 EASTING

MAY 10, 1993

DEPTH (m) IGLD 1985

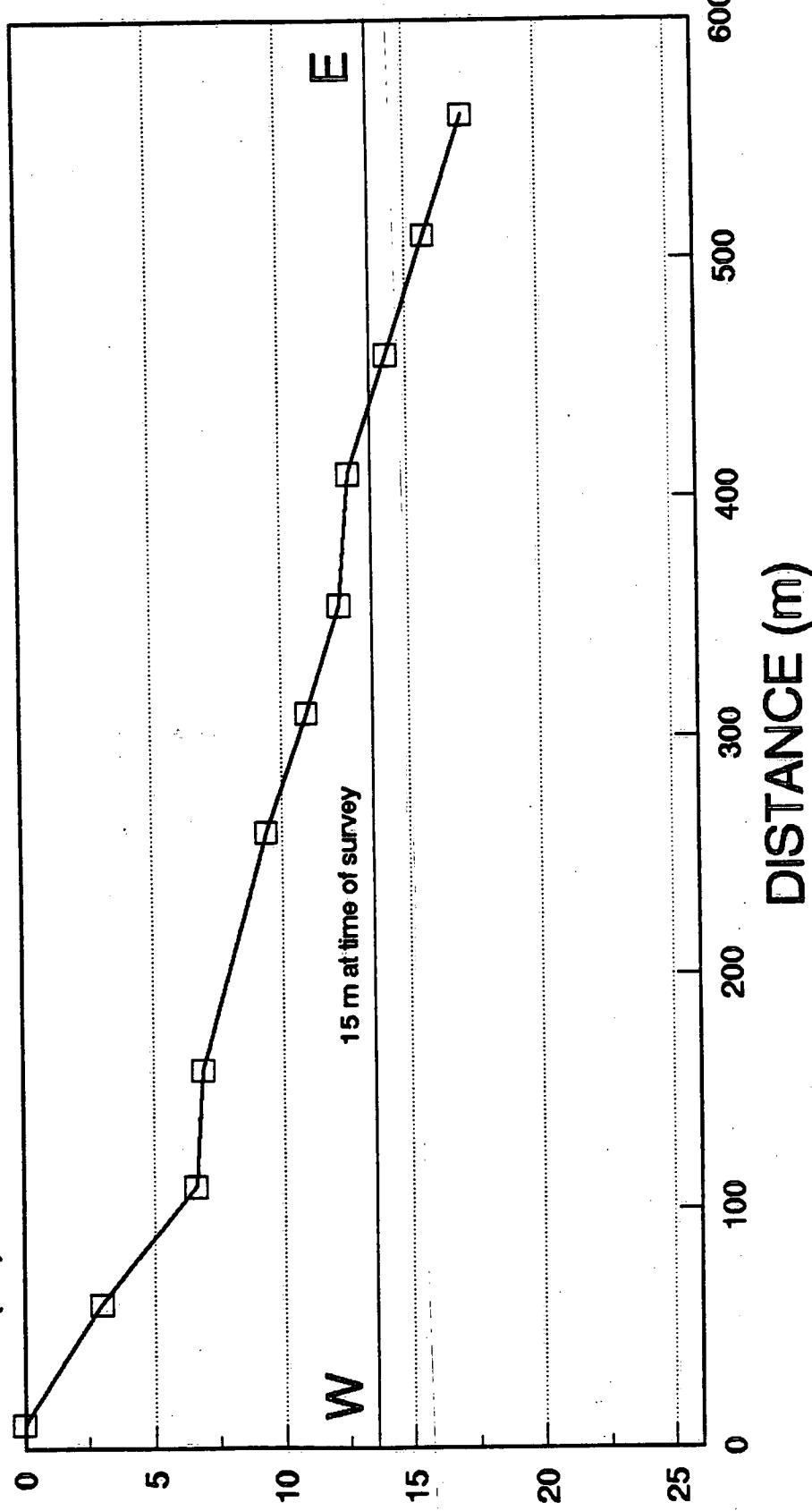


Figure 2.6

CROSS SECTION 7
4794100 NORTHING STARTING AT 593200 EASTING
MAY 10, 1993

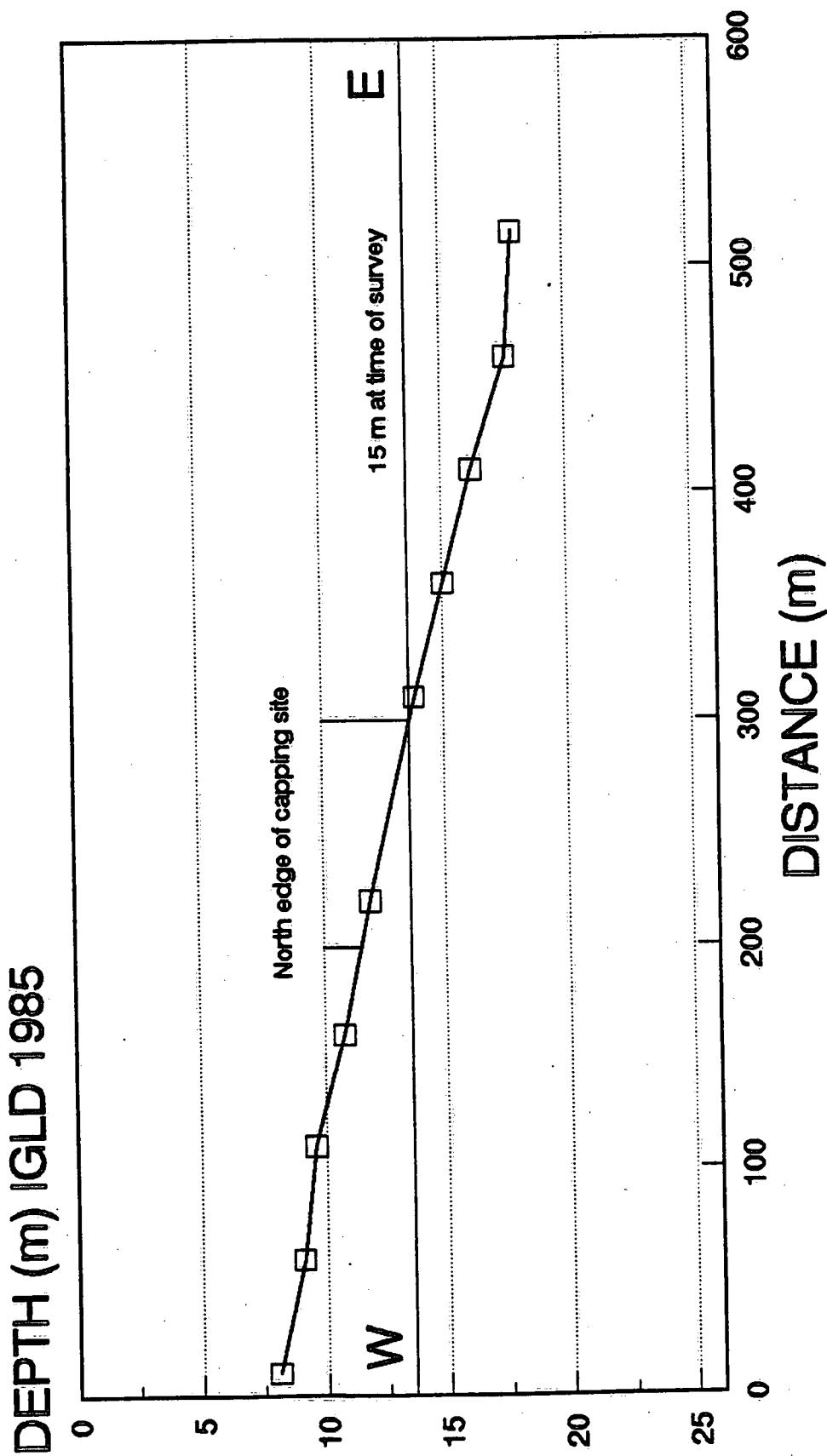


Figure 2.7

CROSS SECTION 8

4794500 NORTHING STARTING AT 593200 EASTING

MAY 10, 1993

DEPTH (m) IGLD 1985

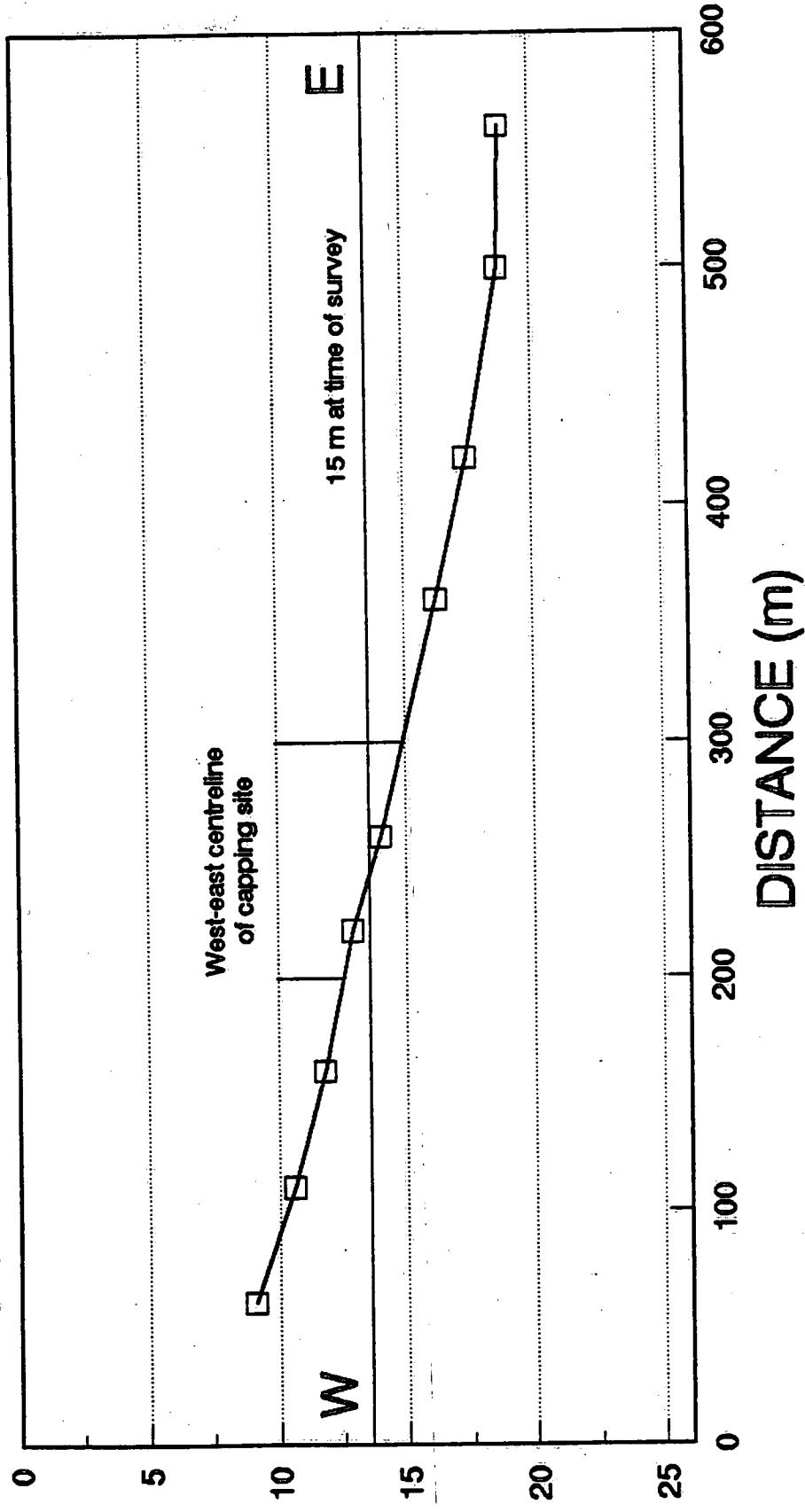


Figure 2.8

CROSS SECTION 9

4794000 NORTHING STARTING AT 593200 EASTING

MAY 10, 1993

DEPTH (m) | GLD 1985

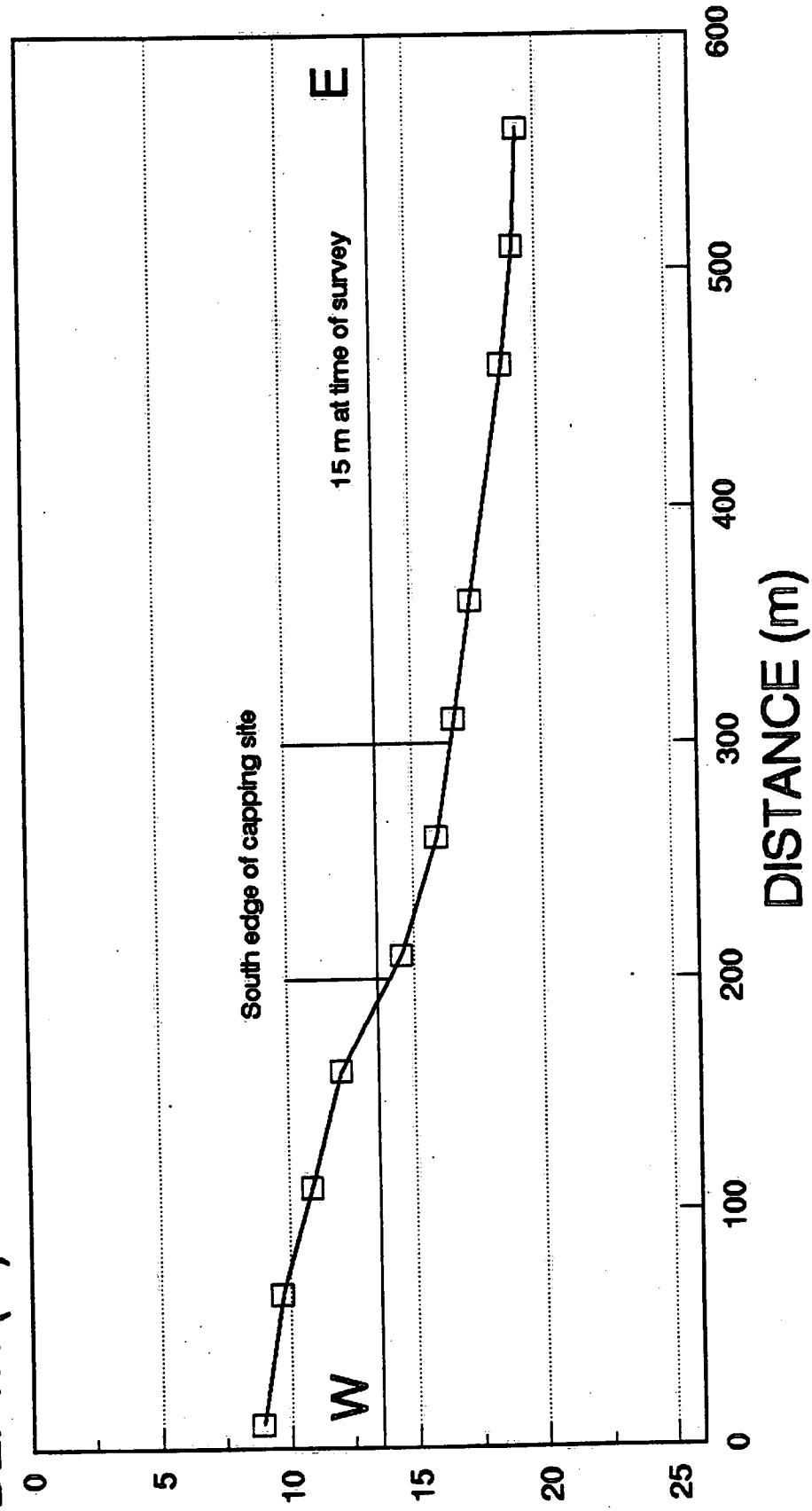


Figure 2.9

CROSS SECTION 10

4793900 NORTHING STARTING AT 593200 EASTING

MAY 10, 1993

DEPTH (m) IGLD 1985

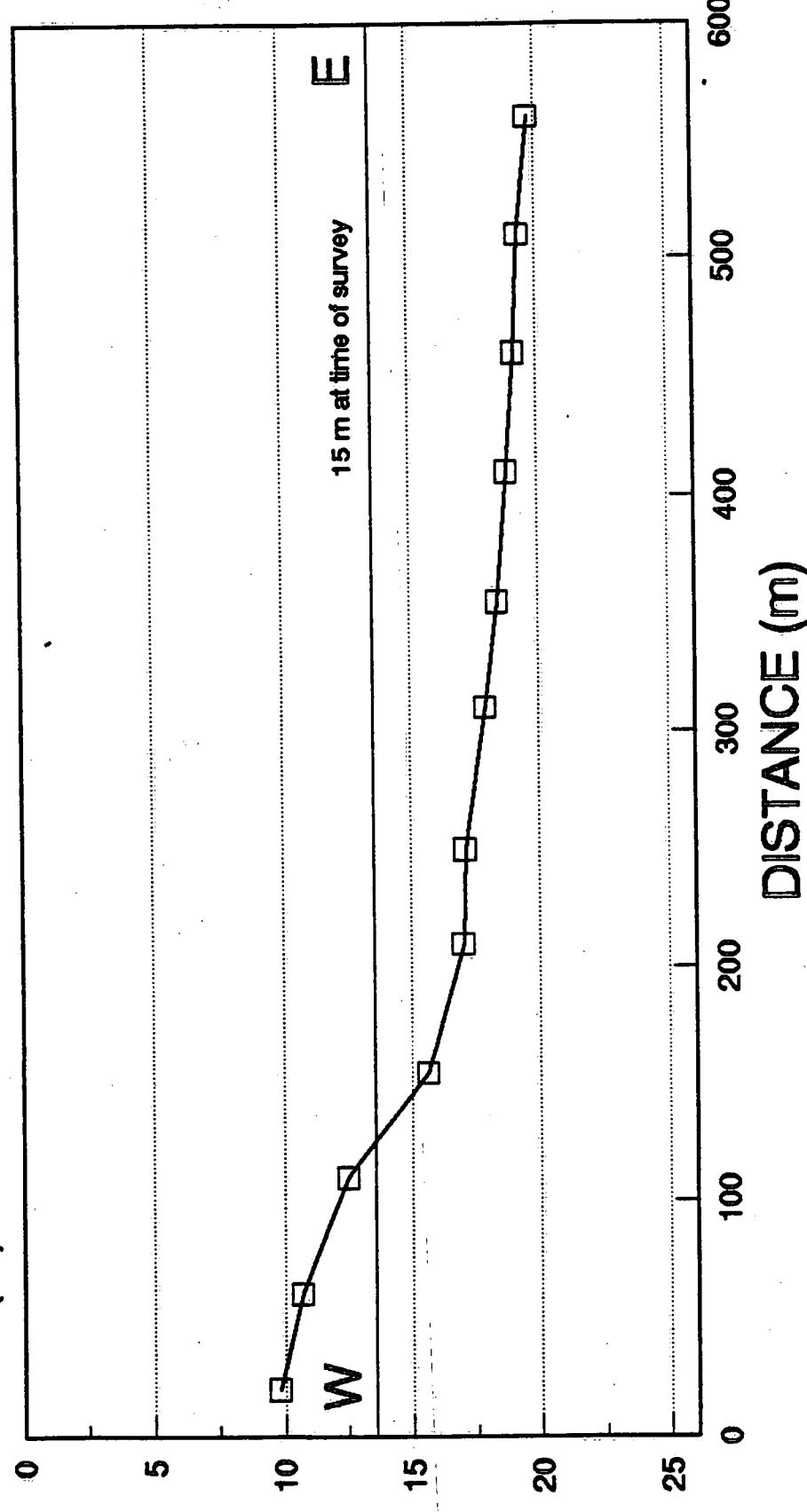
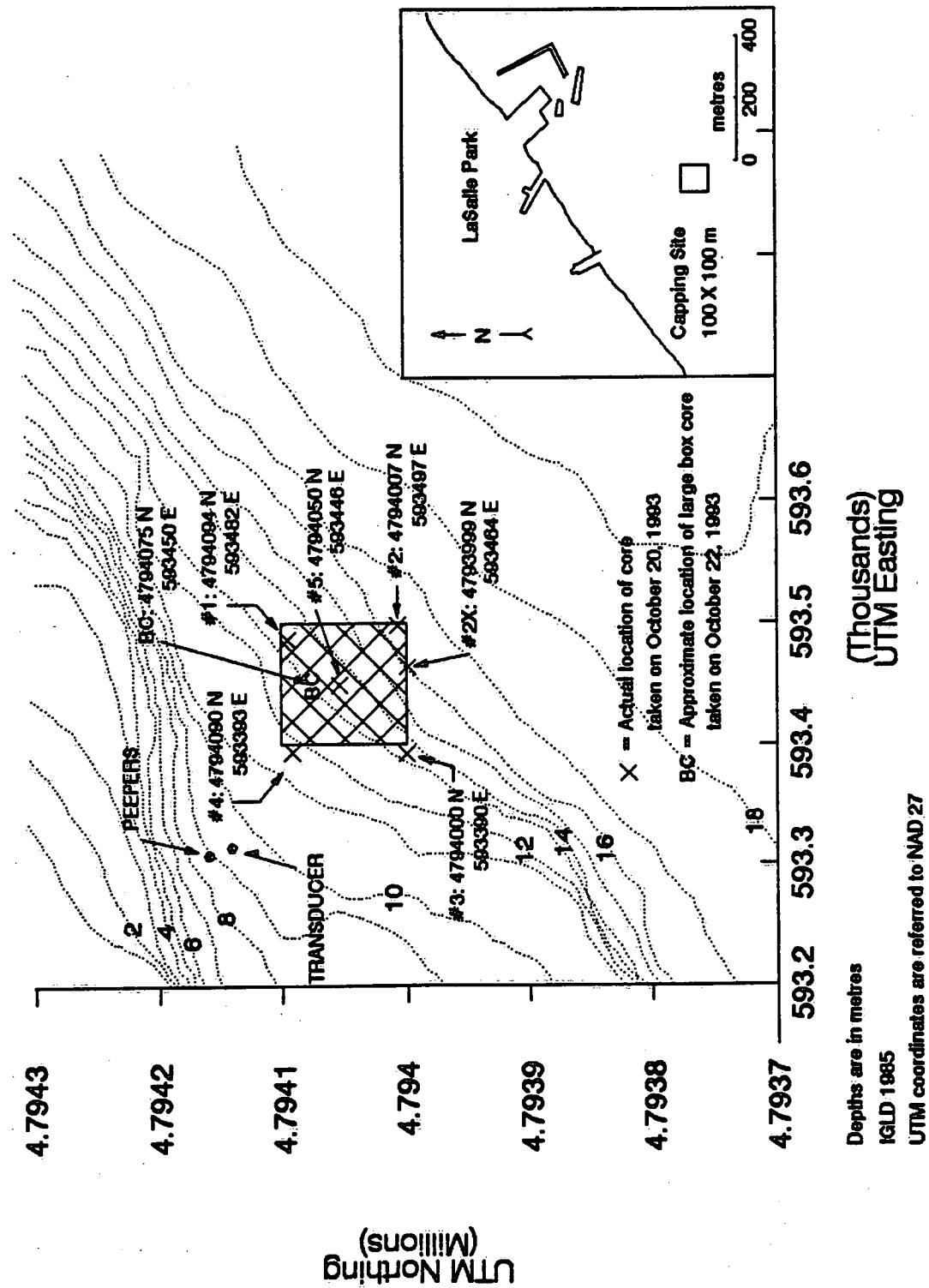


Figure 2.10

**SEDIMENT CORES TAKEN AT PROPOSED CAPPING SITE
SEDIMENT GEOTECHNIQUE**



Depths are in metres
IGLD 1985
UTM coordinates are referred to NAD 27

Figure 3

CORE 1

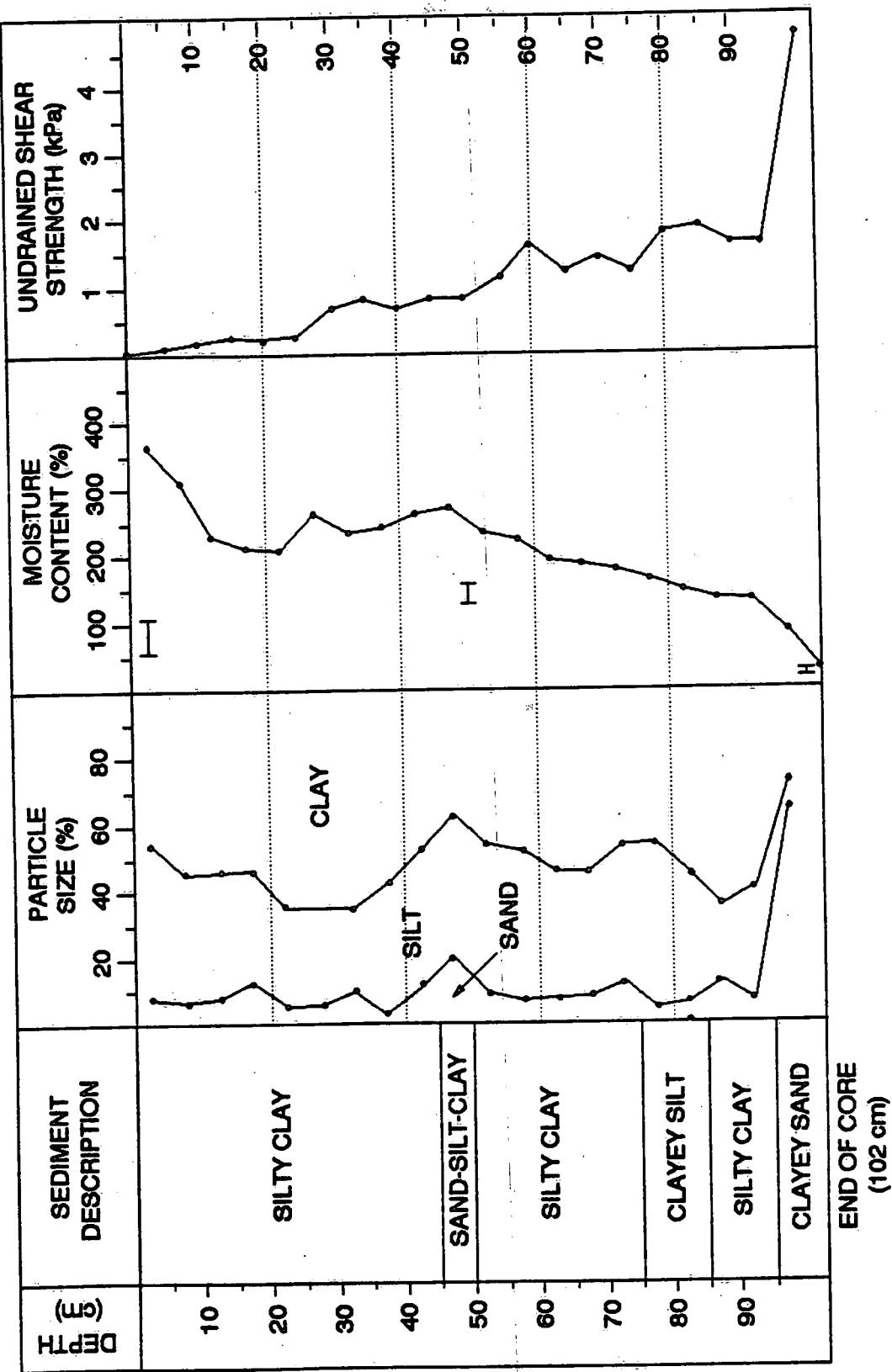


Figure 4.1

CORE 2

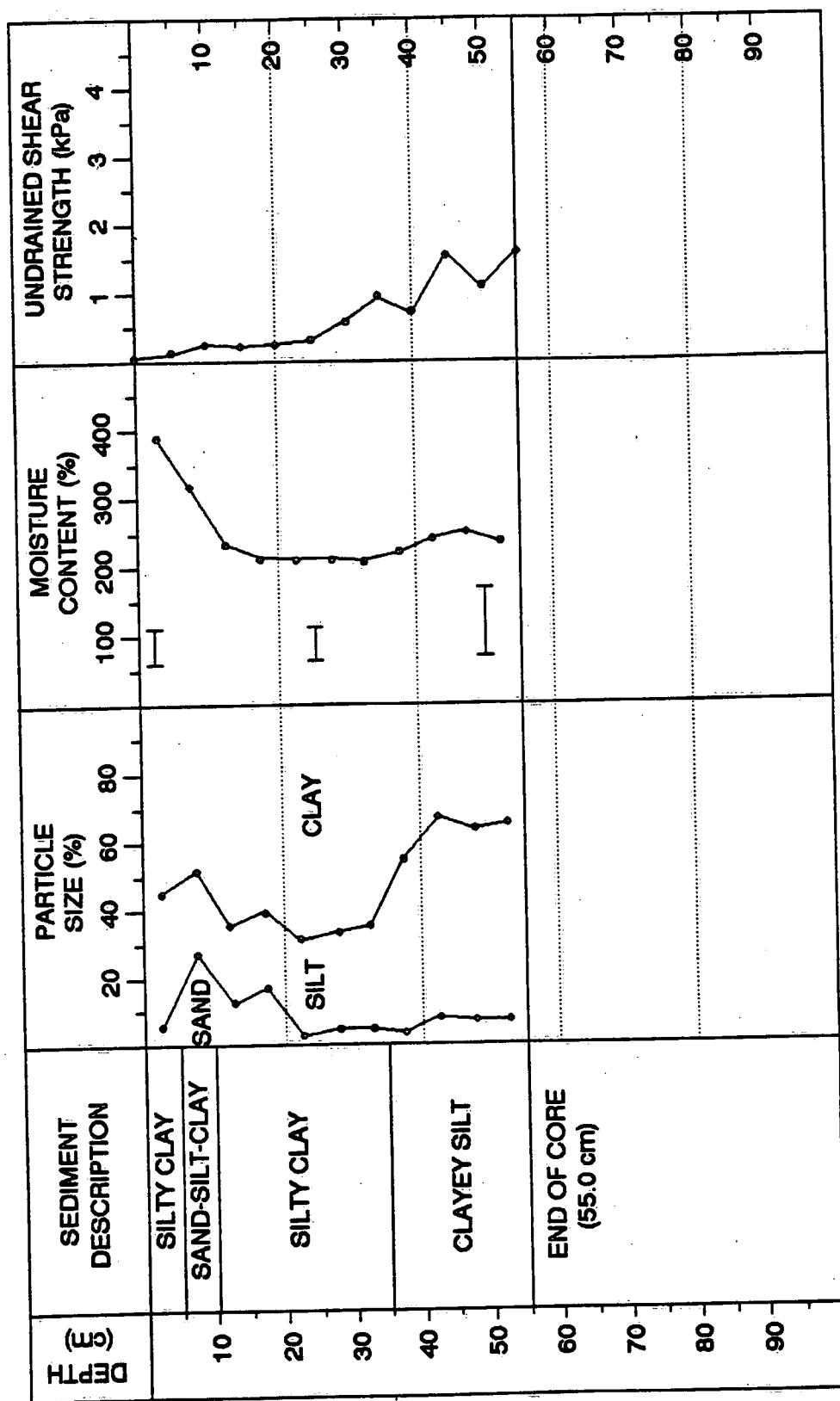


Figure 4.2

CORE 2X

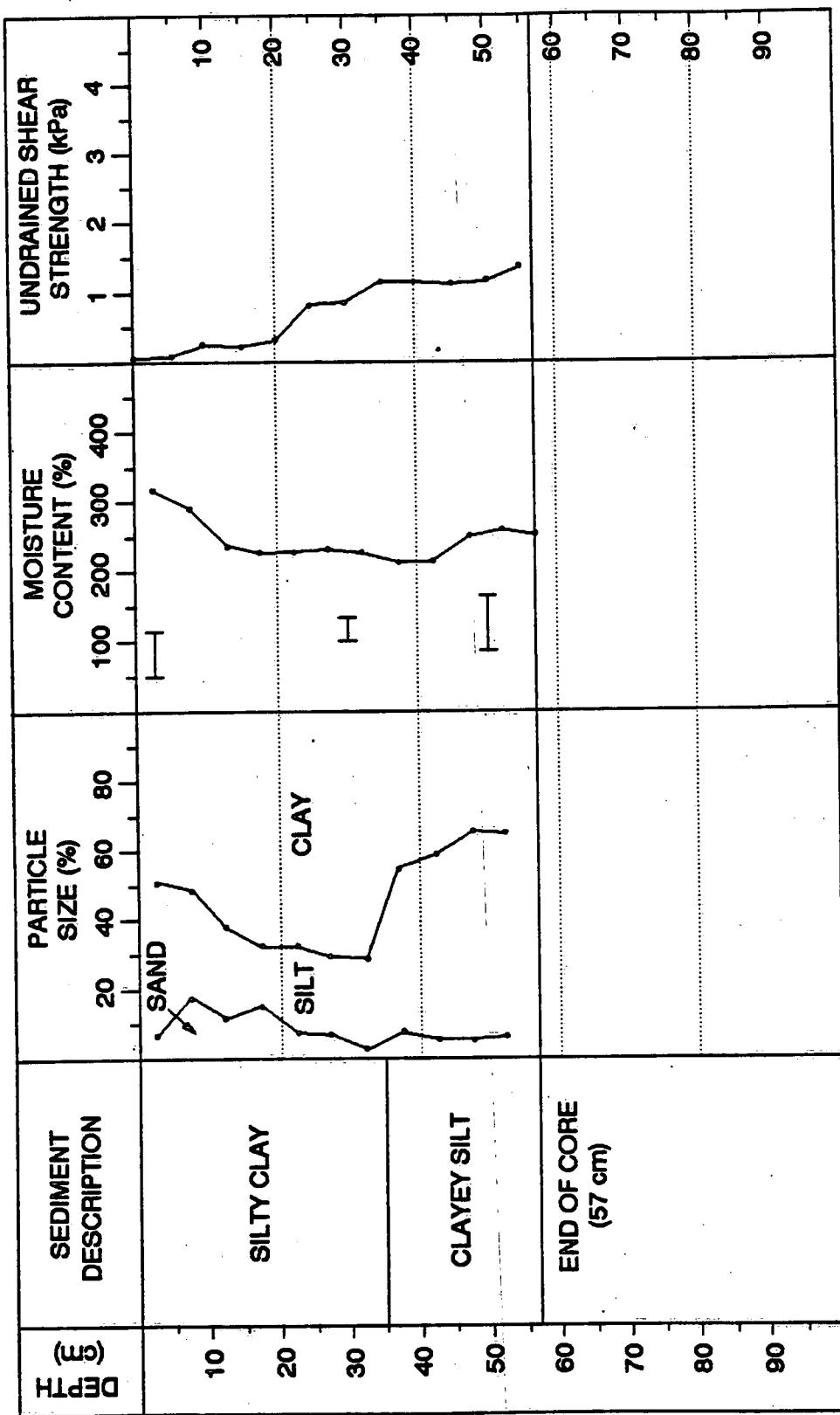


Figure 4.3

CORE 3

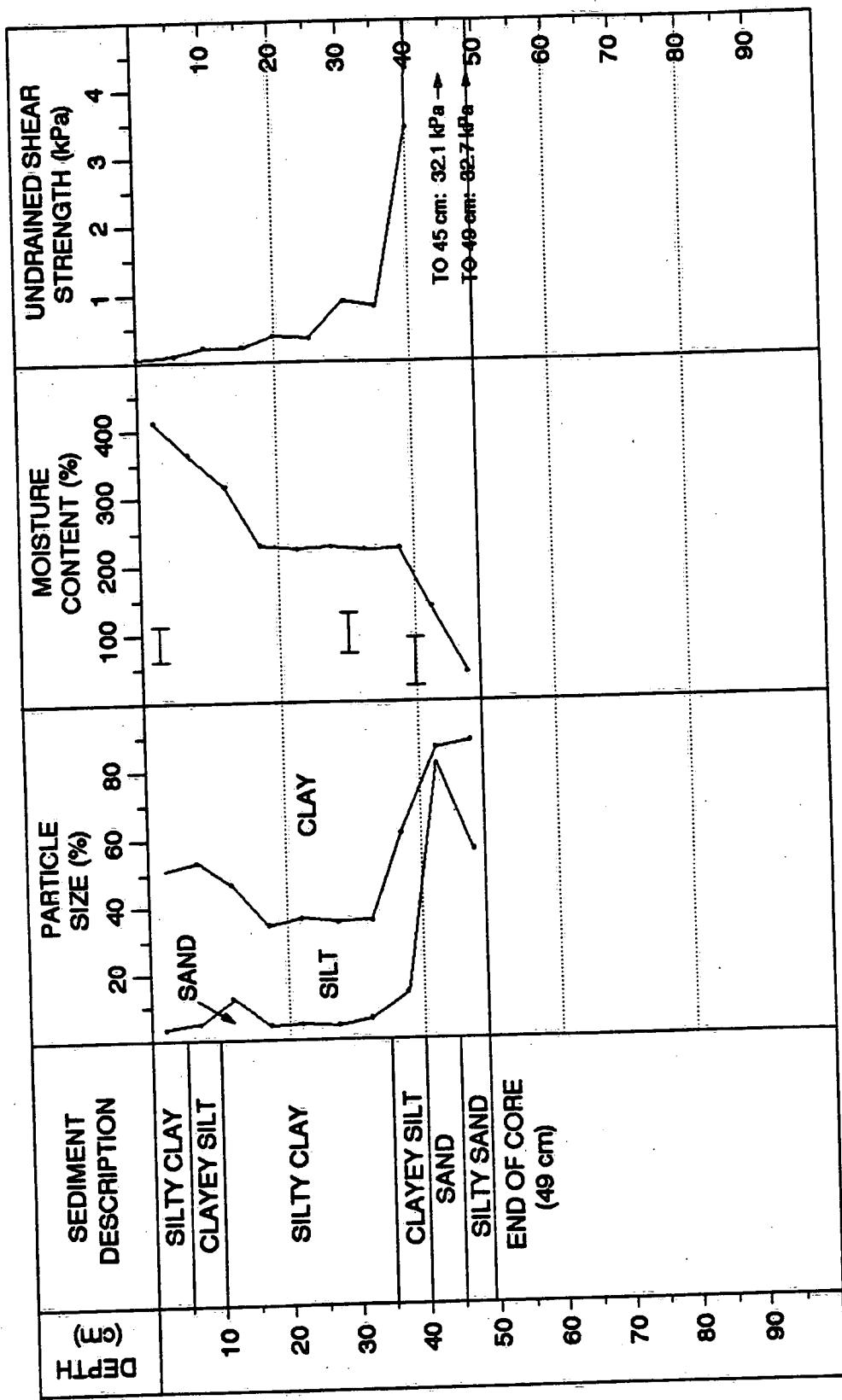


Figure 4.4

CORE 4

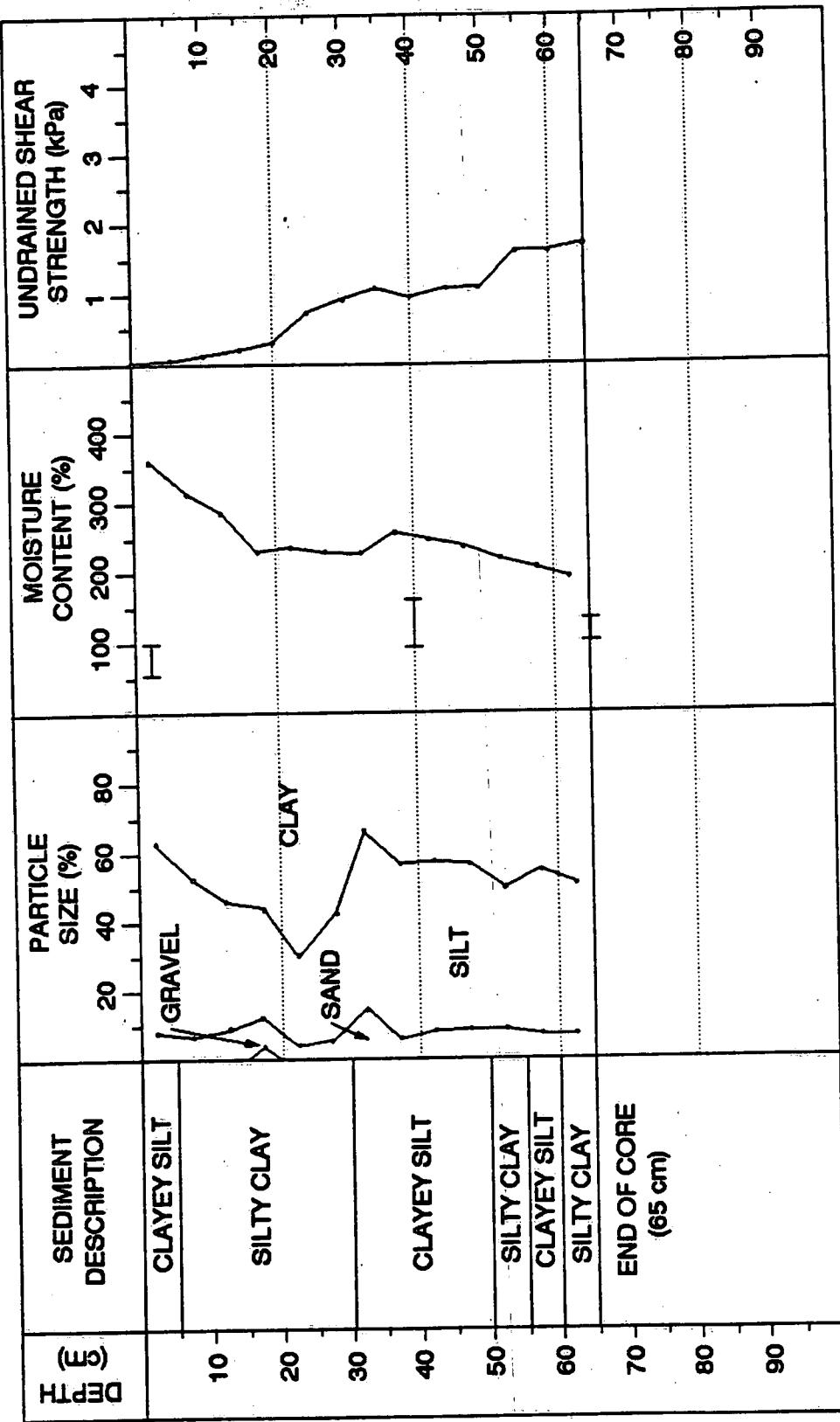


Figure 4.5

CORE 5

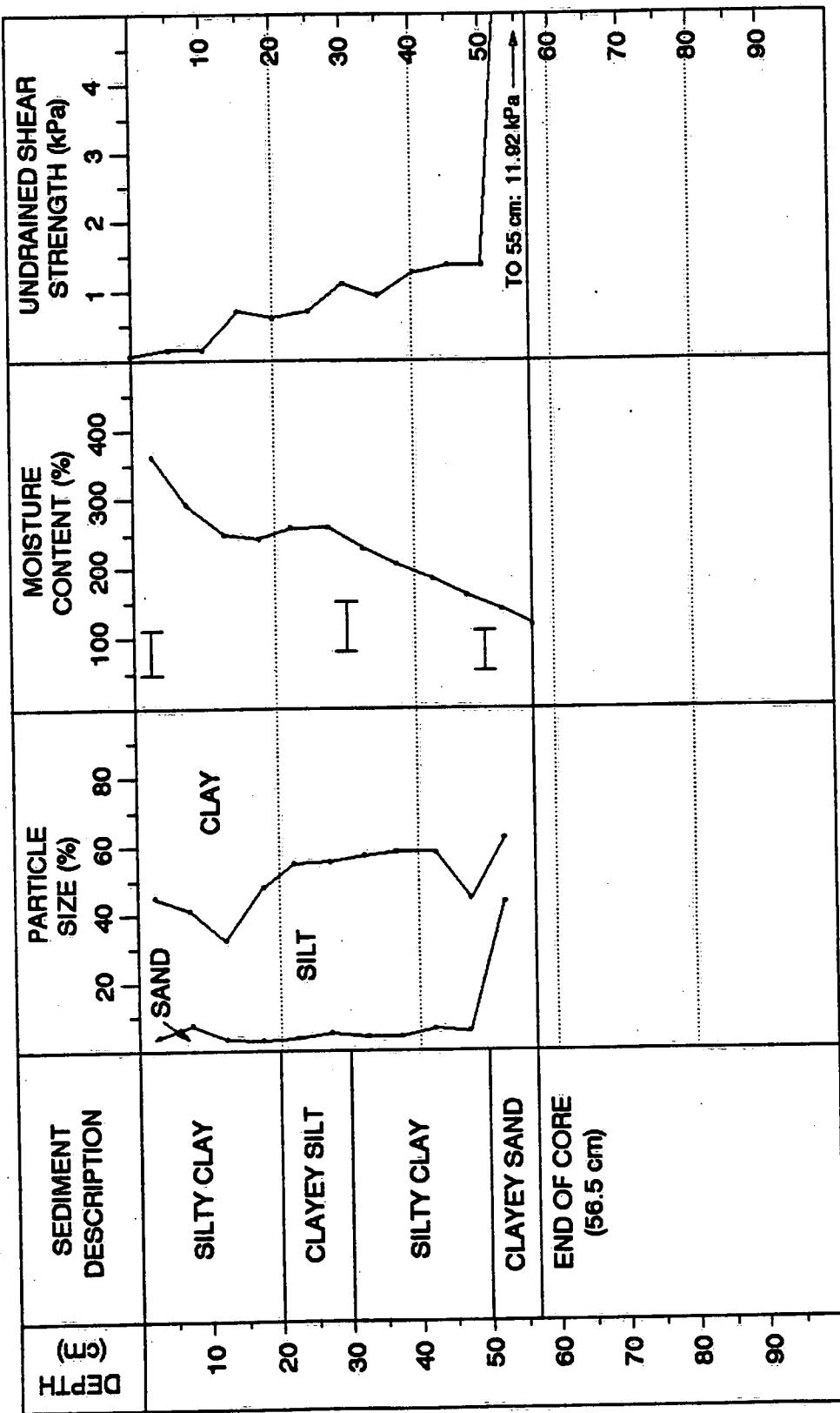


Figure 4.6

SEDIMENT CLASSIFICATION AT CAPPING SITE

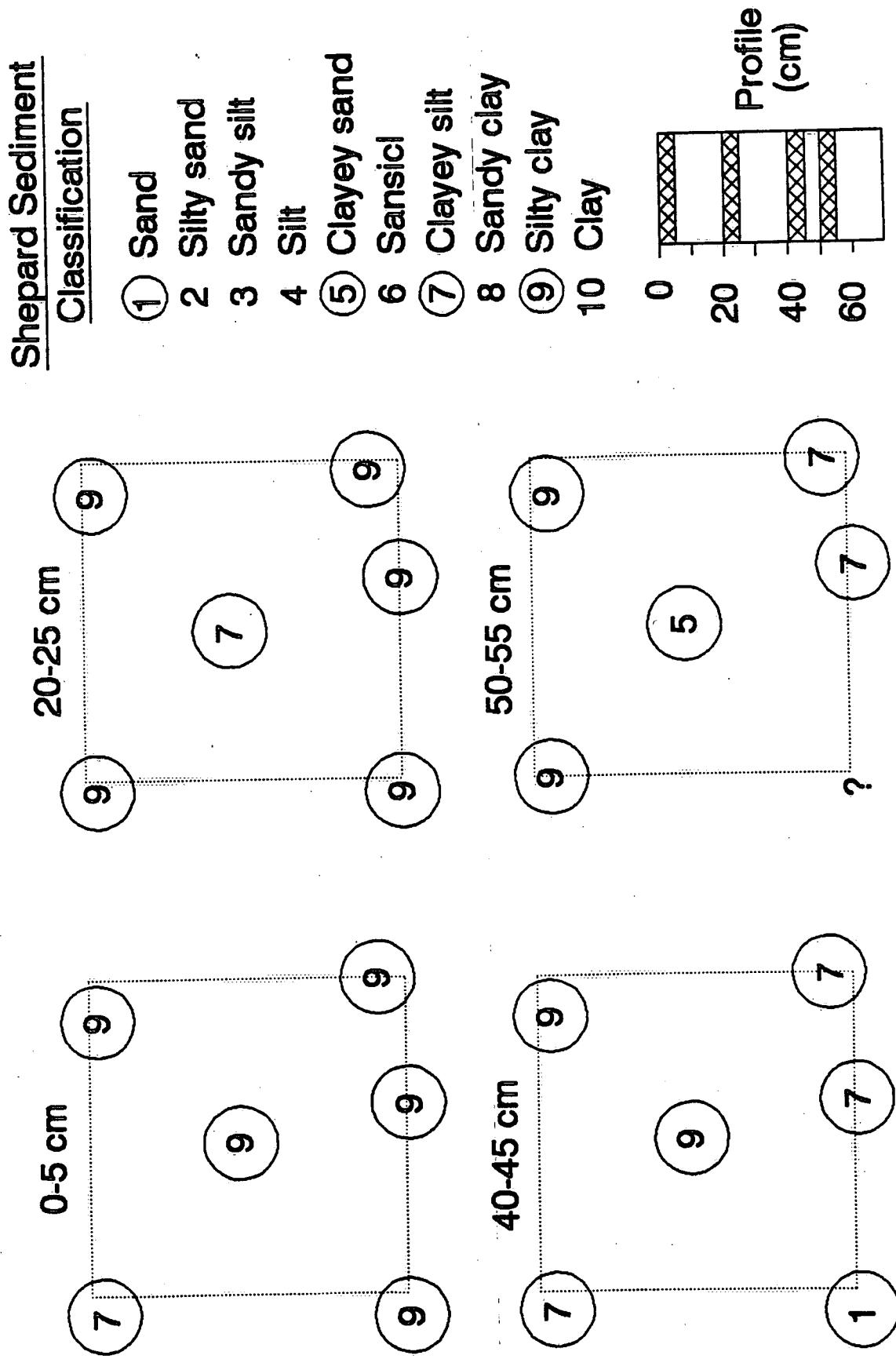


Figure 5.1

SEDIMENT CLASSIFICATION AT CAPPING SITE

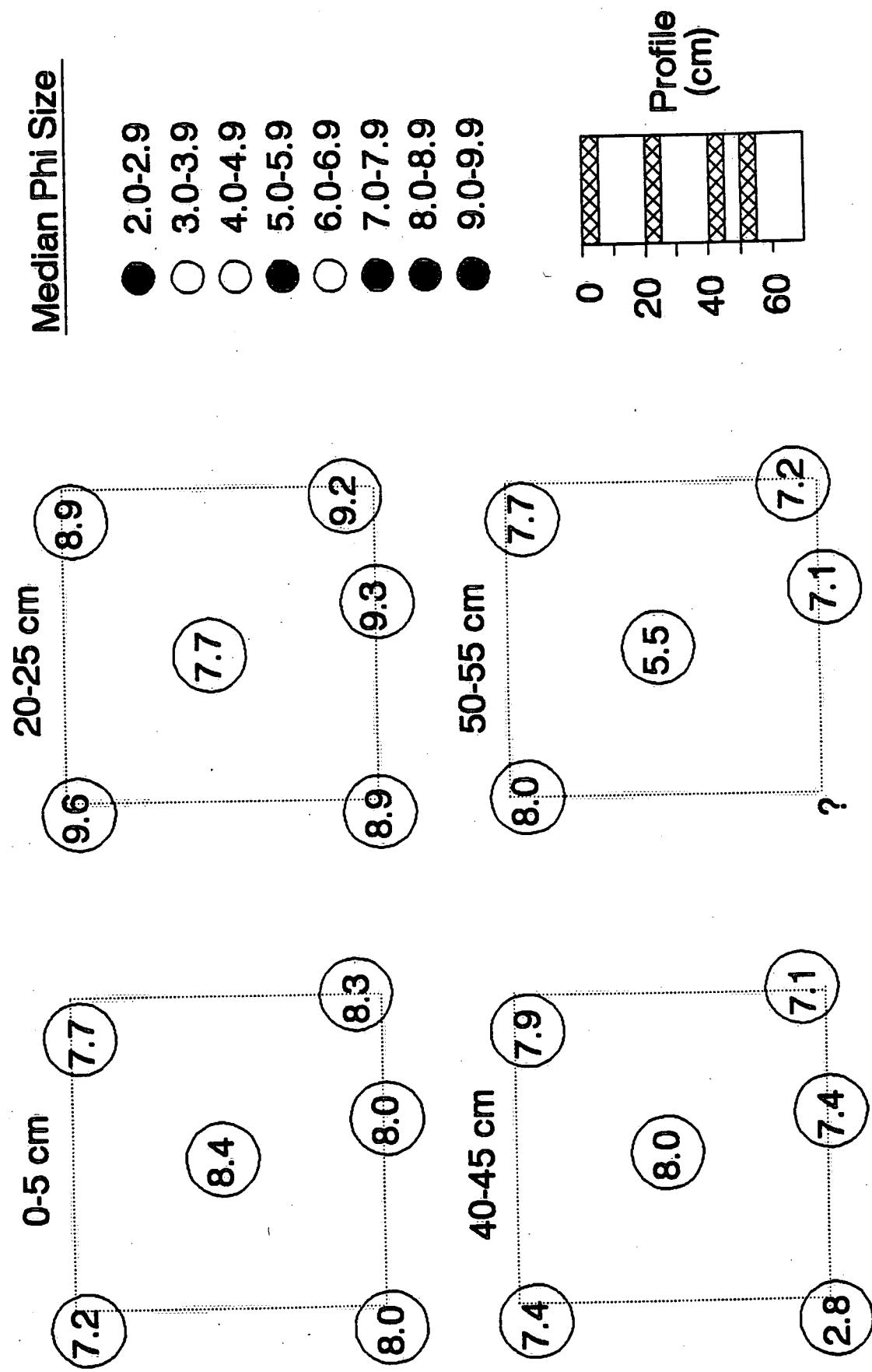


Figure 5.2

SEDIMENT CLASSIFICATION AT CAPPING SITE

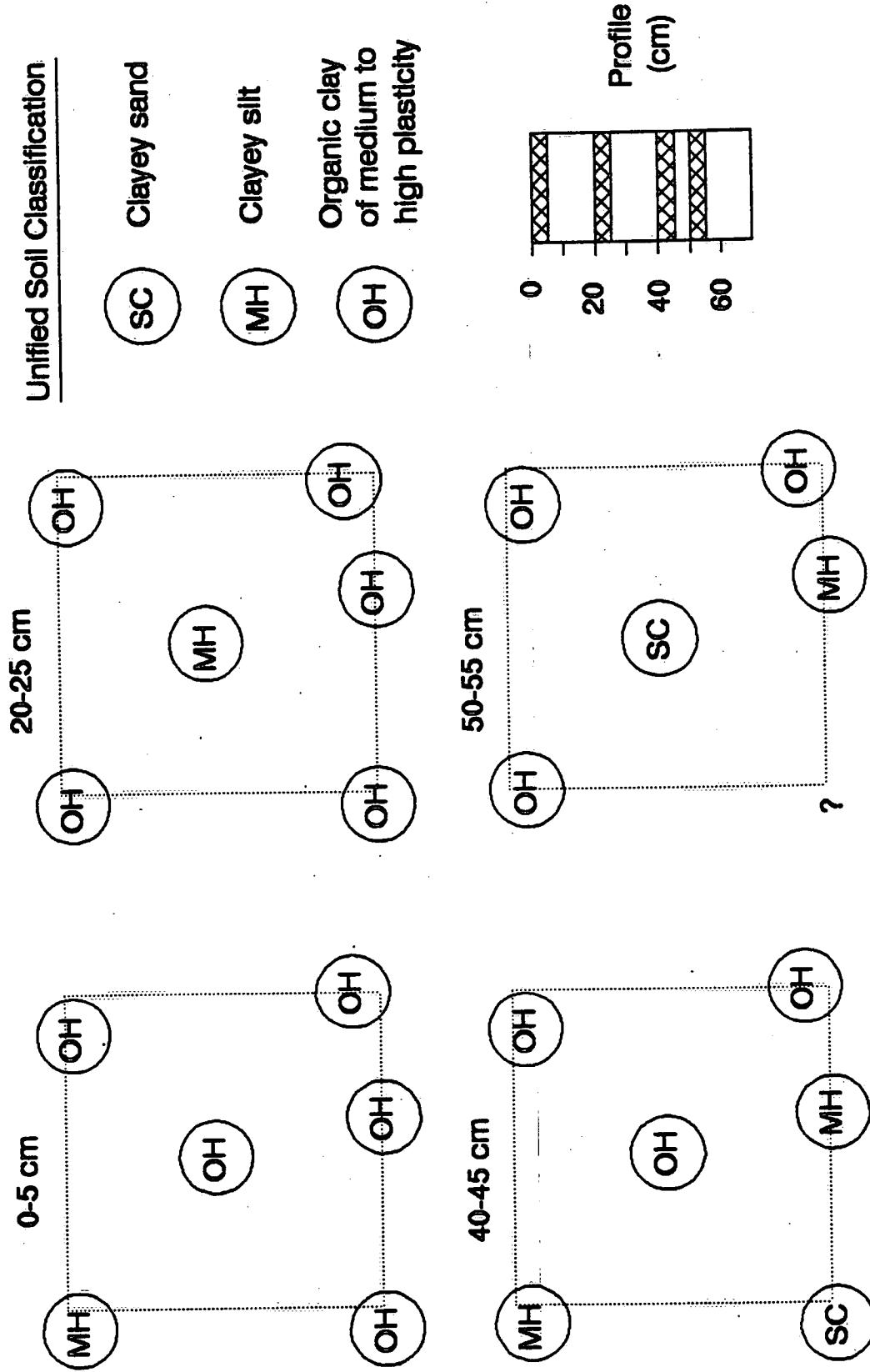


Figure 5.3

**SEDIMENT CORES TAKEN AT PROPOSED CAPPING SITE
SEDIMENT CHEMISTRY**

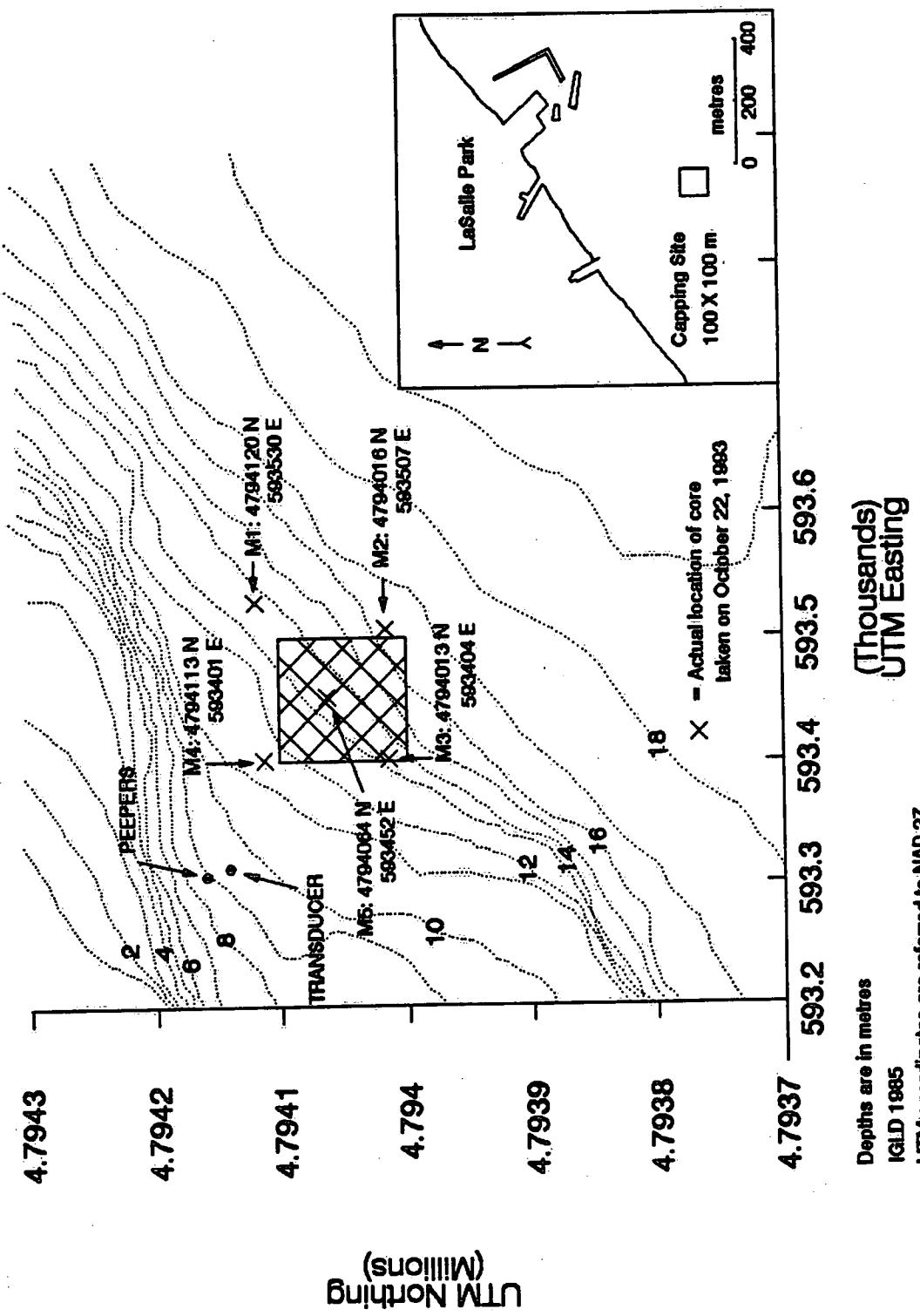
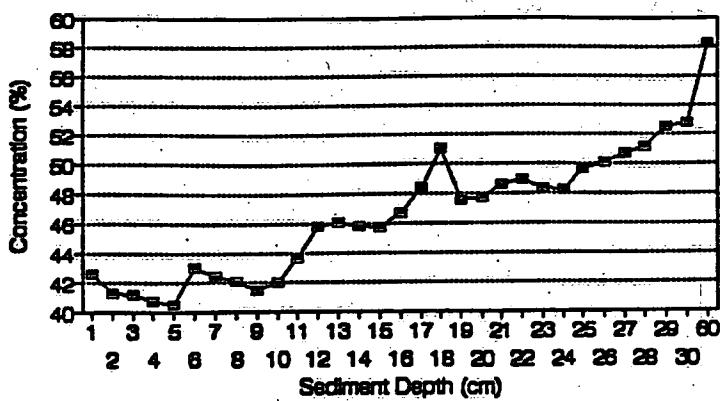


Figure 6

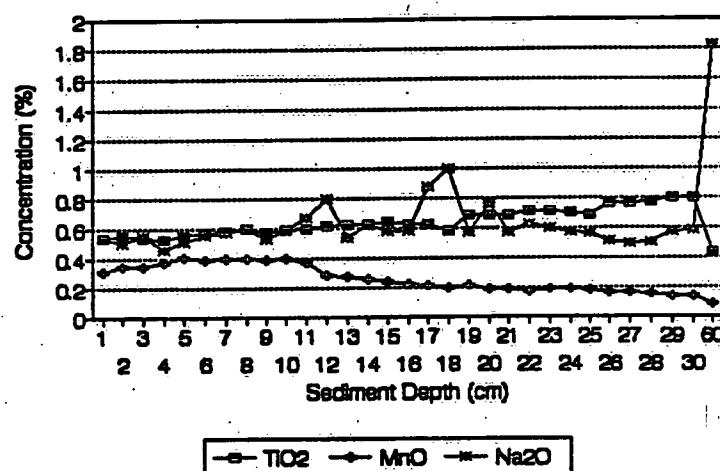
Hamilton Harbour

Core: M 1



Hamilton Harbour

Core: M 1



Hamilton Harbour

Core: M 1

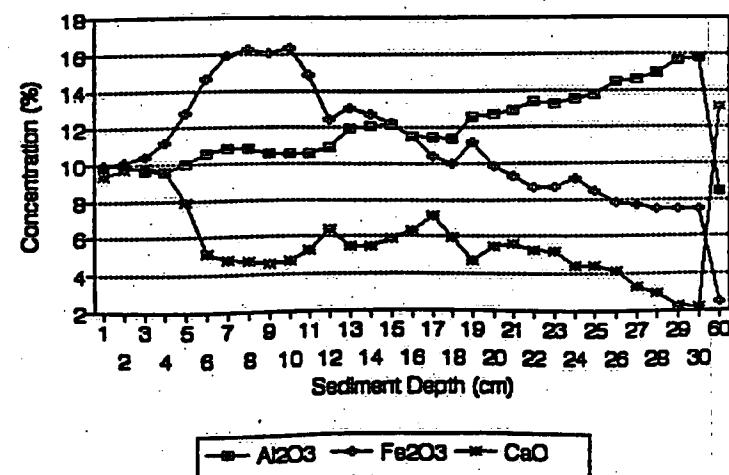
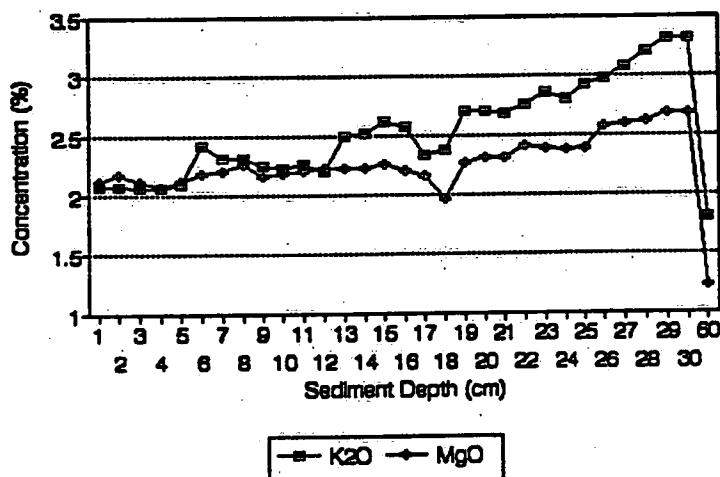


Figure 7.1

Hamilton Harbour

Core: M 1



Hamilton Harbour

Core: M 1

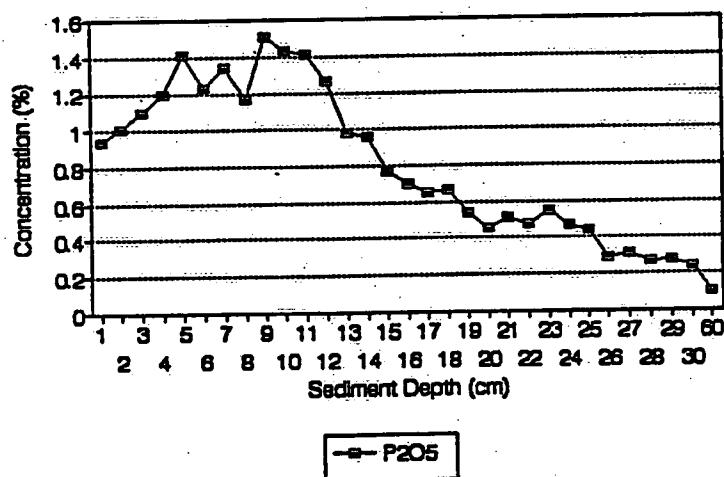
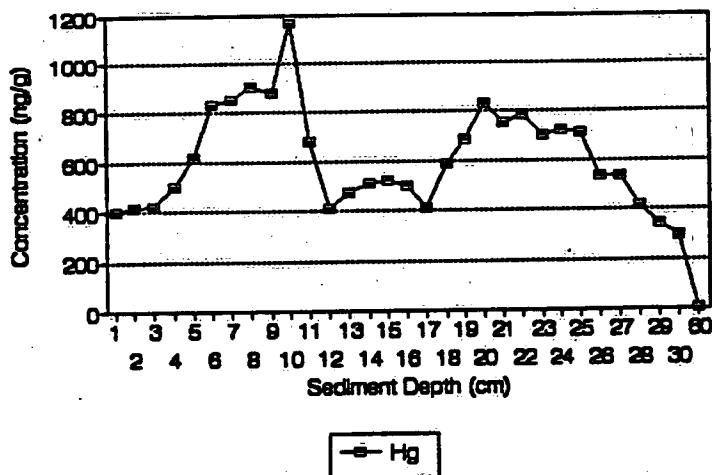
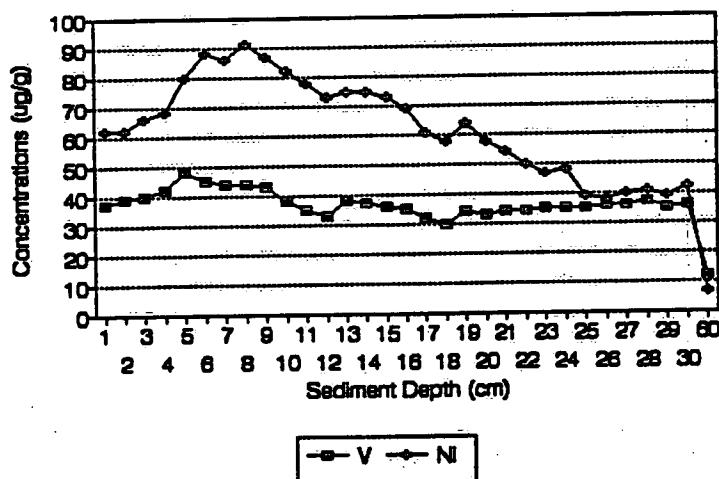


Figure 7.2

Hamilton Harbour
Core: M 1



Hamilton Harbour
Core: M 1



Hamilton Harbour
Core: M 1

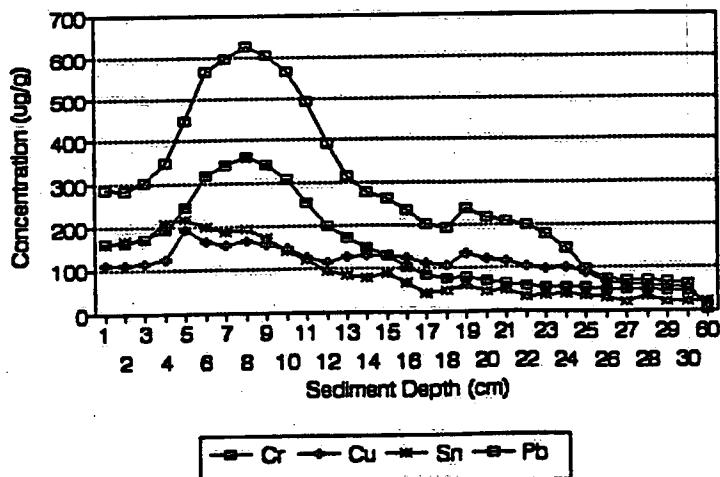
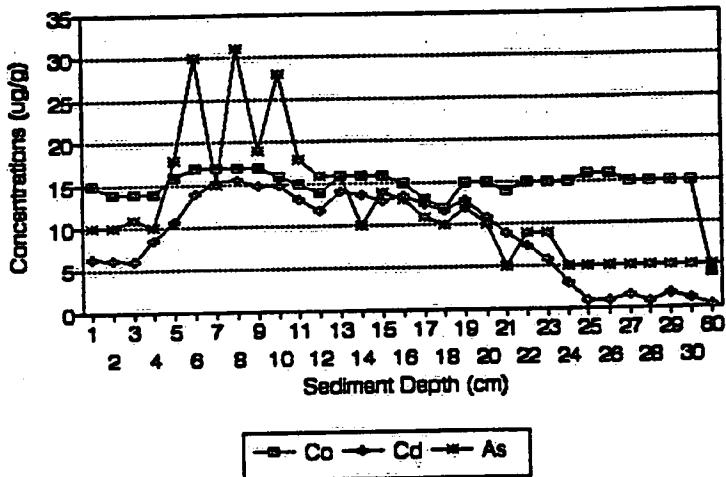


Figure 7.3

Hamilton Harbour

Core: M 1



Hamilton Harbour

Core: M 1

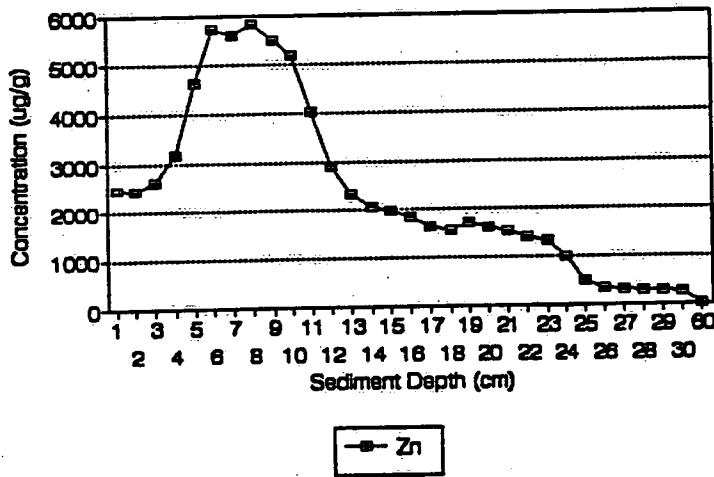
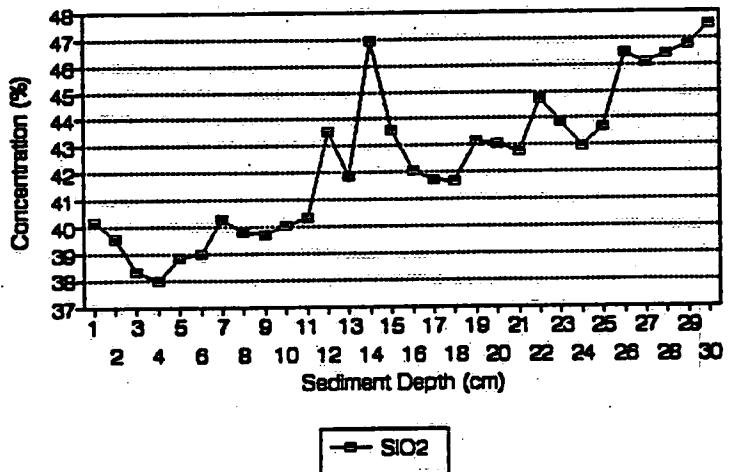
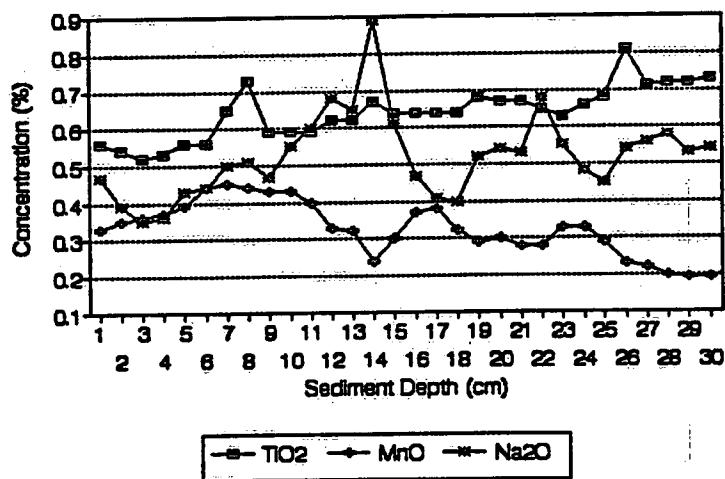


Figure 7.4

Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2

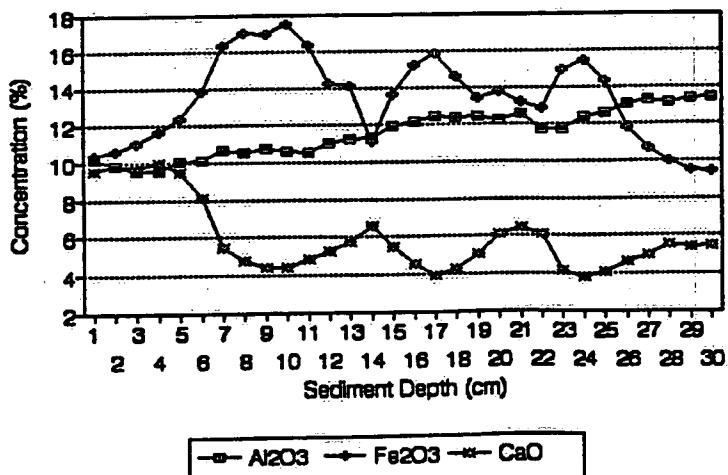
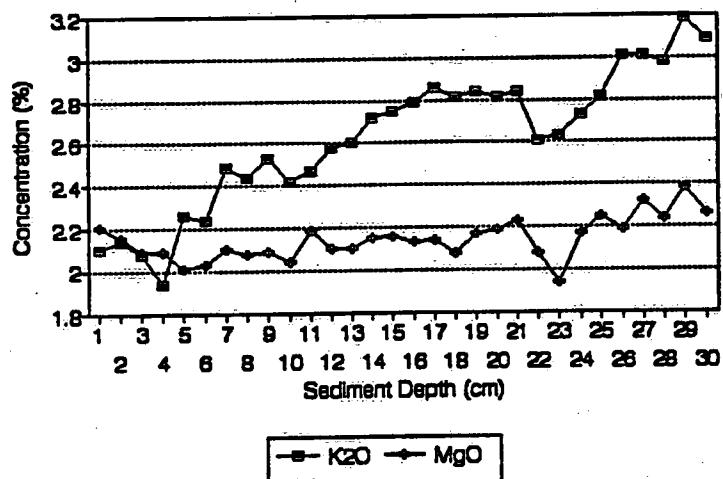


Figure 7.5

Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2

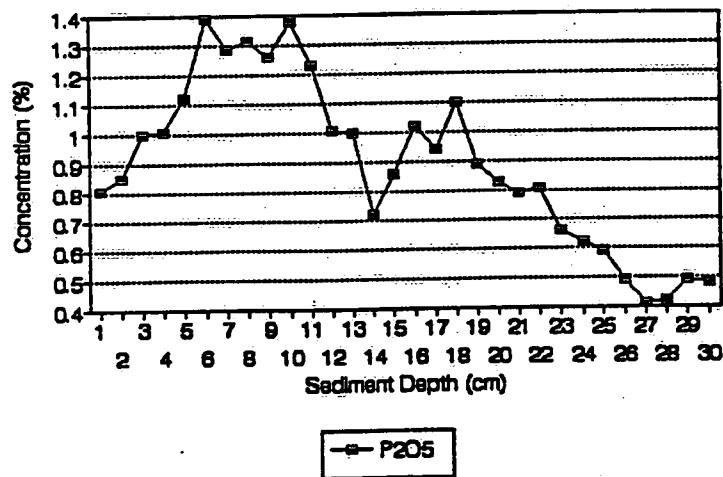
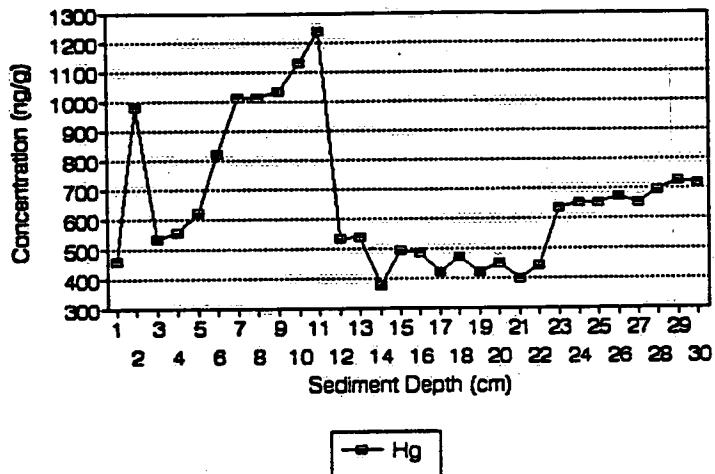
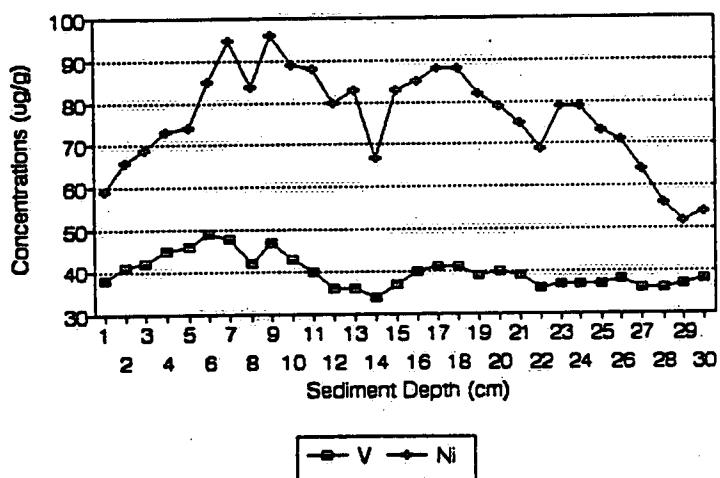


Figure 7.6

Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2

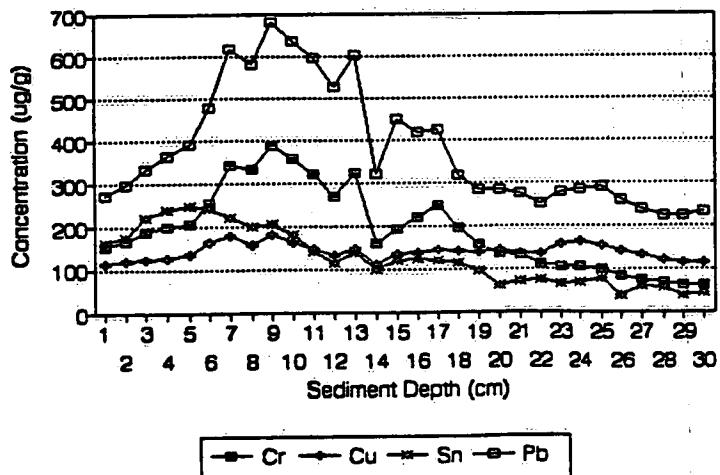
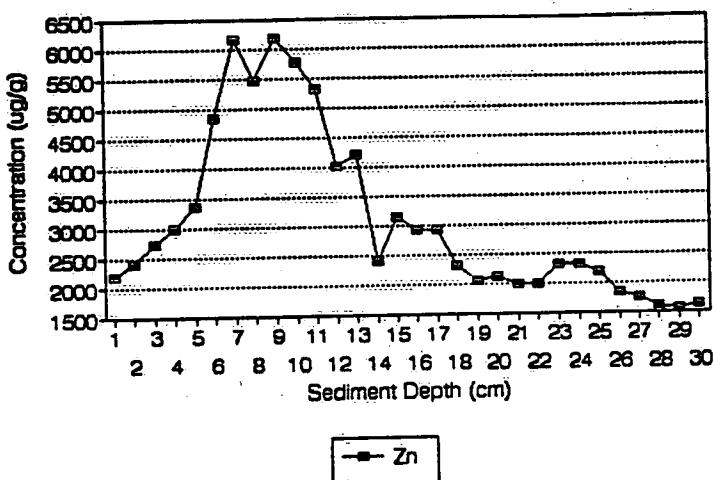


Figure 7.7

Hamilton Harbour
Core: M 2



Hamilton Harbour
Core: M 2

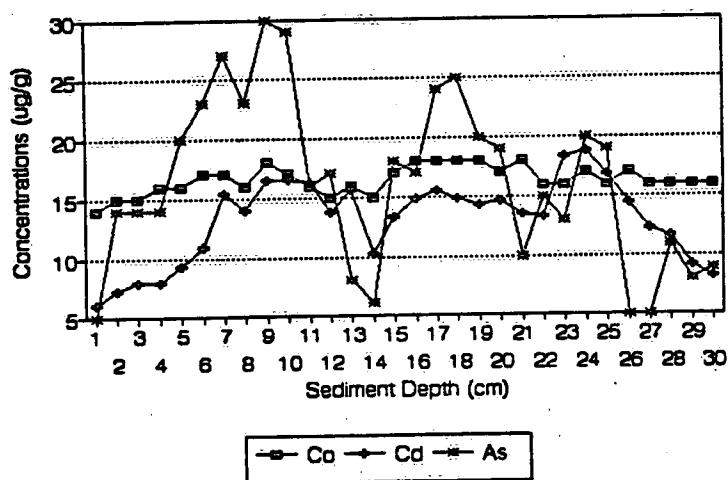
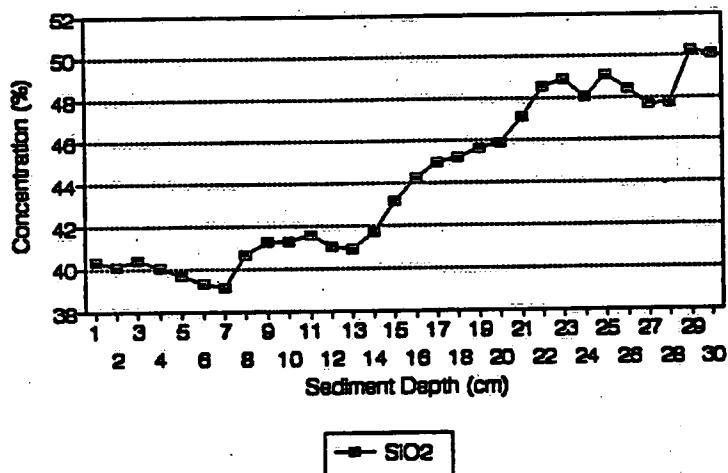
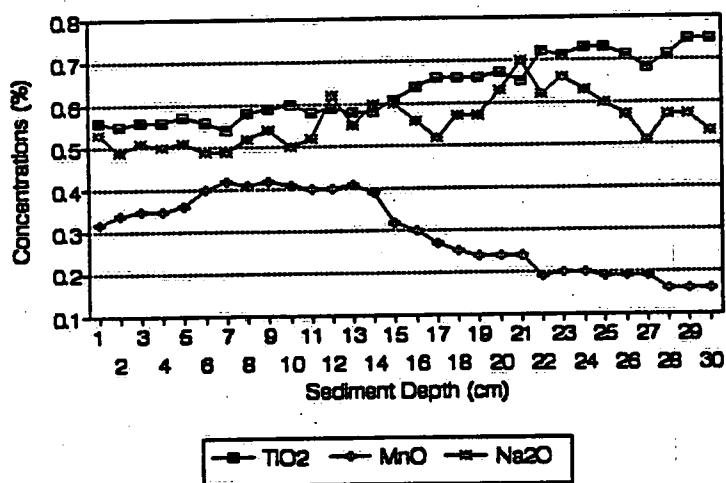


Figure 7.8

Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3

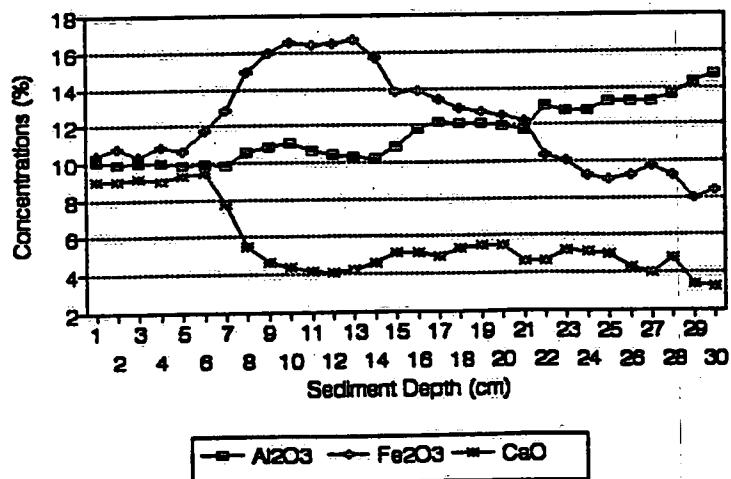
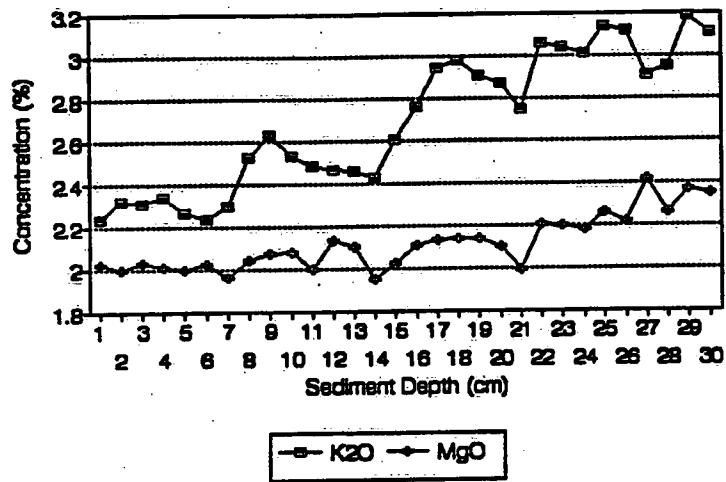


Figure 7.9

Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3

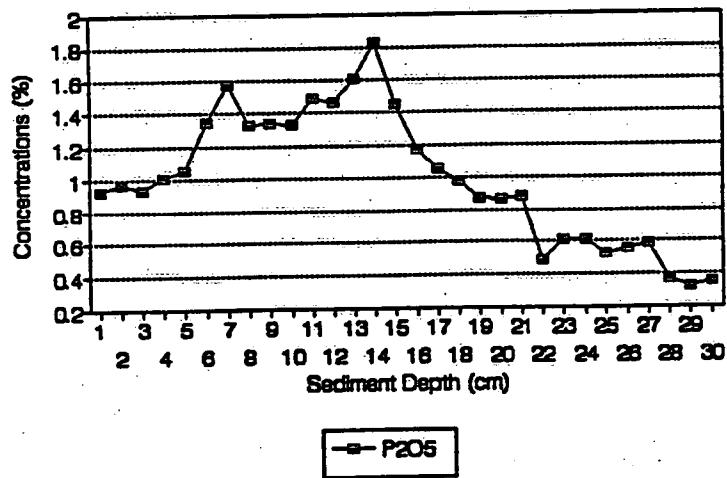
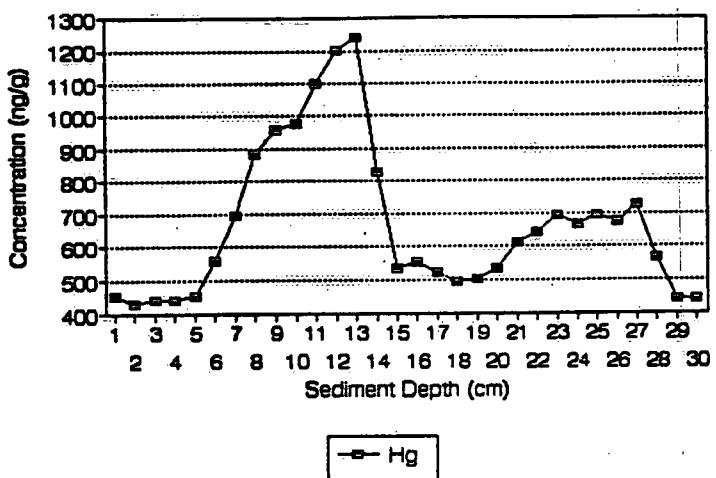
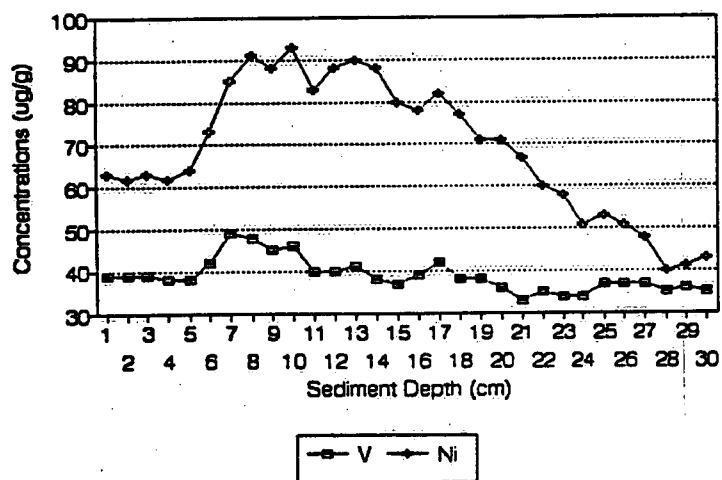


Figure 7.10

Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3

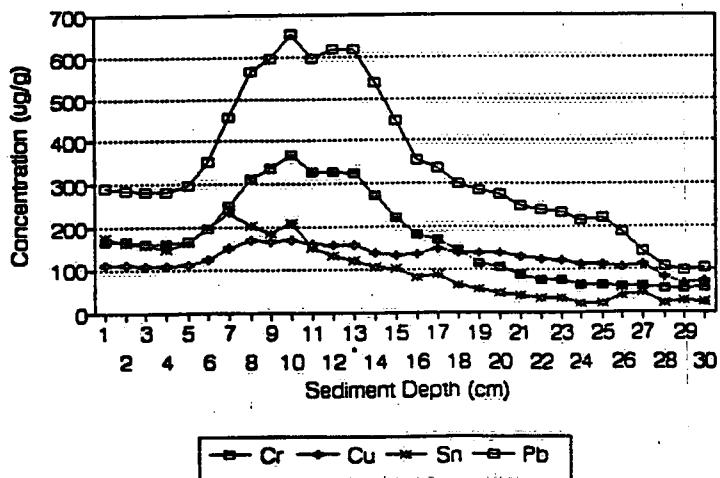
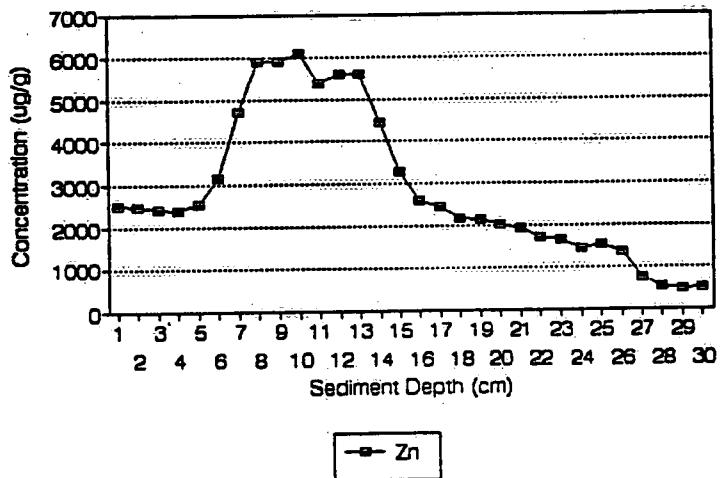


Figure 7.11

Hamilton Harbour
Core: M 3



Hamilton Harbour
Core: M 3

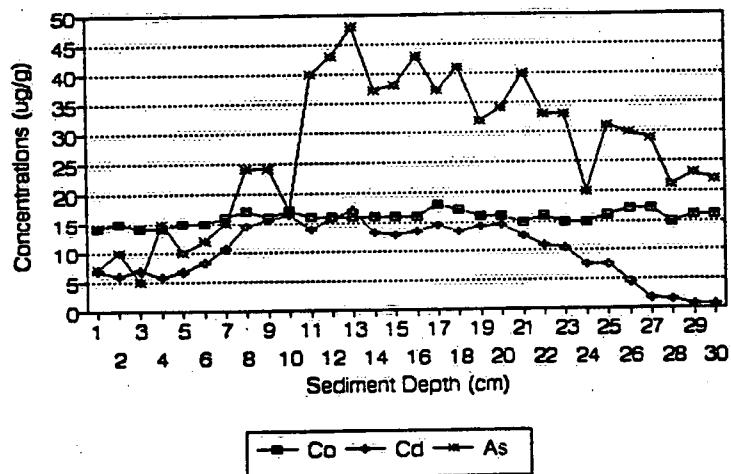
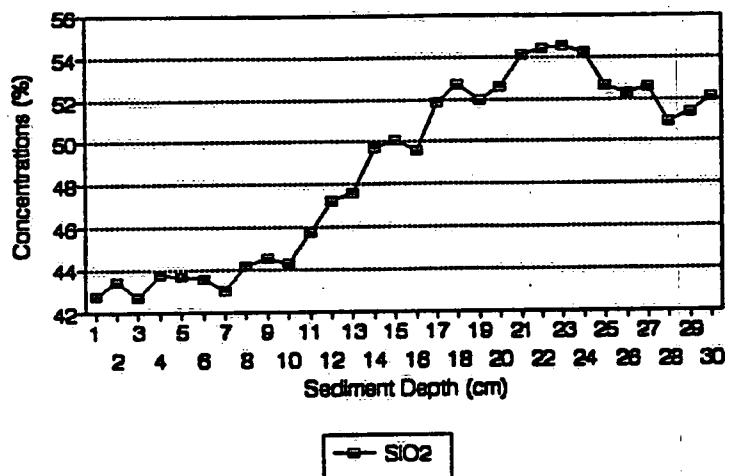


Figure 7.12

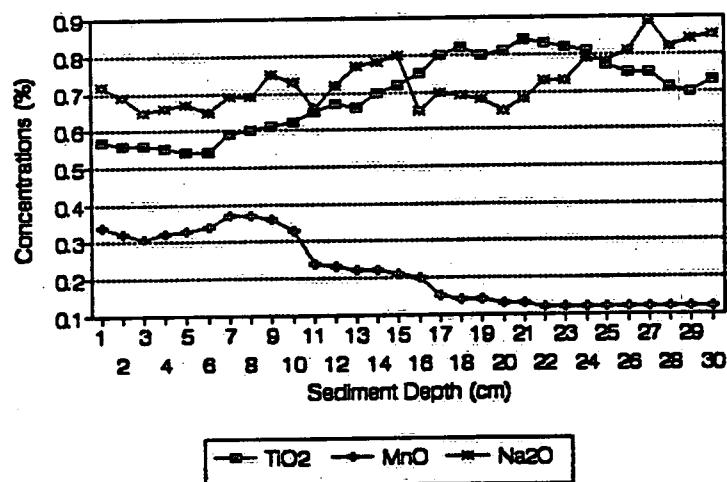
Hamilton Harbour

Core: M 4



Hamilton Harbour

Core: M 4



Hamilton Harbour

Core: M 4

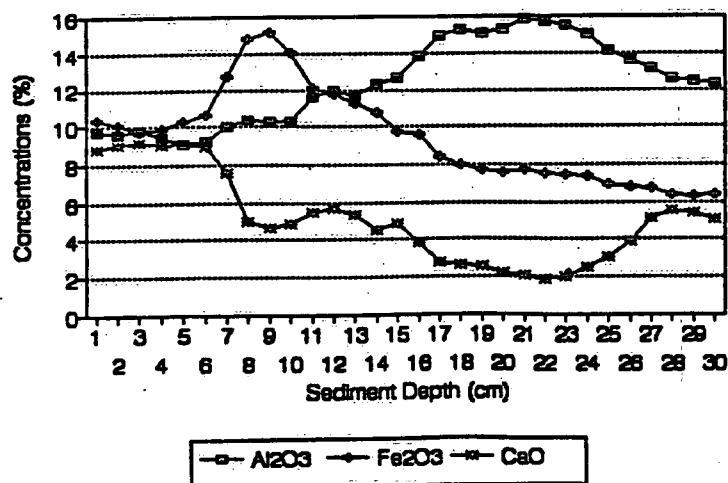
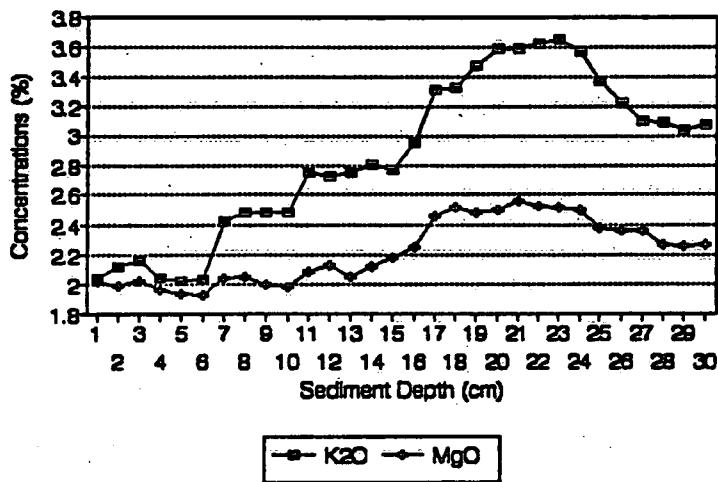


Figure 7.13

Hamilton Harbour Core: M 4



Hamilton Harbour Core: M 4

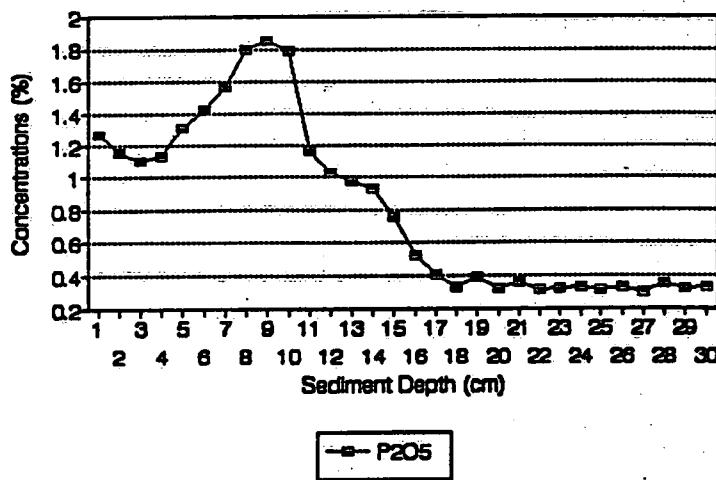
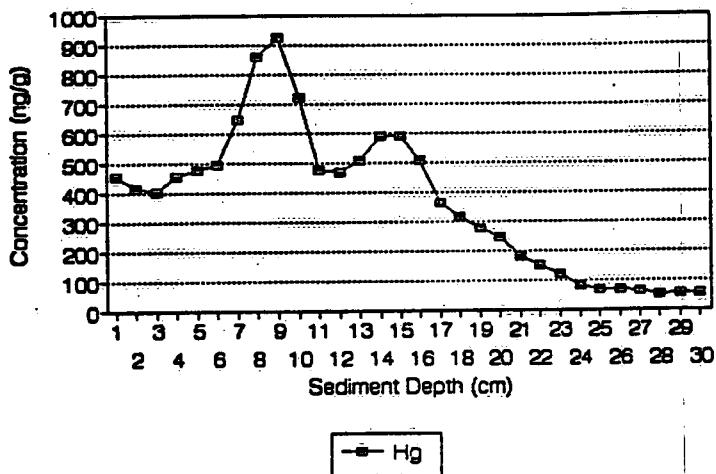
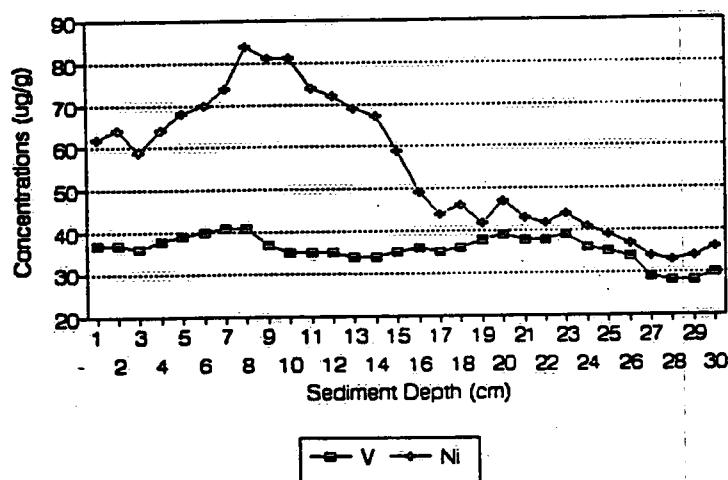


Figure 7.14

Hamilton Harbour
Core: M 4



Hamilton Harbour
Core: M 4



Hamilton Harbour
Core: M 4

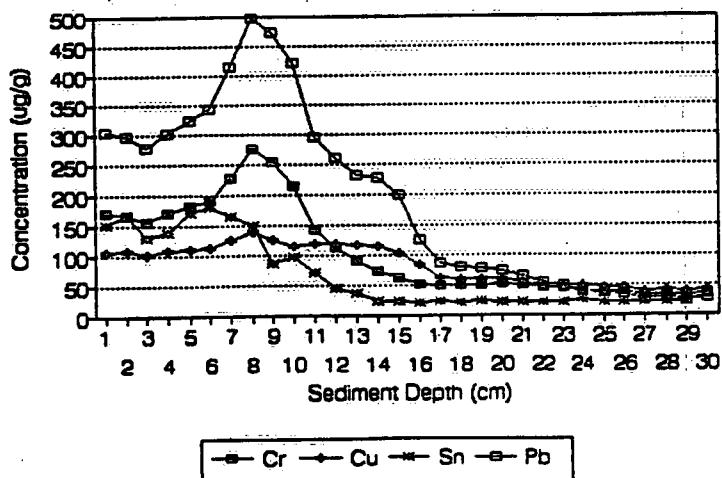
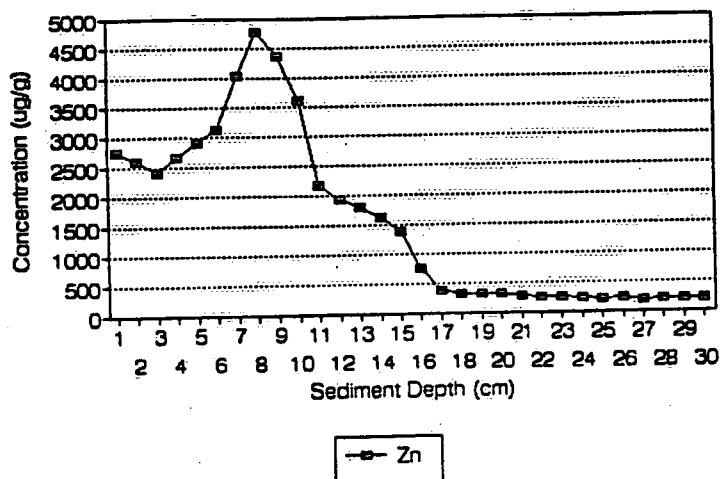


Figure 7.15

Hamilton Harbour Core: M 4



Hamilton Harbour Core: M 4

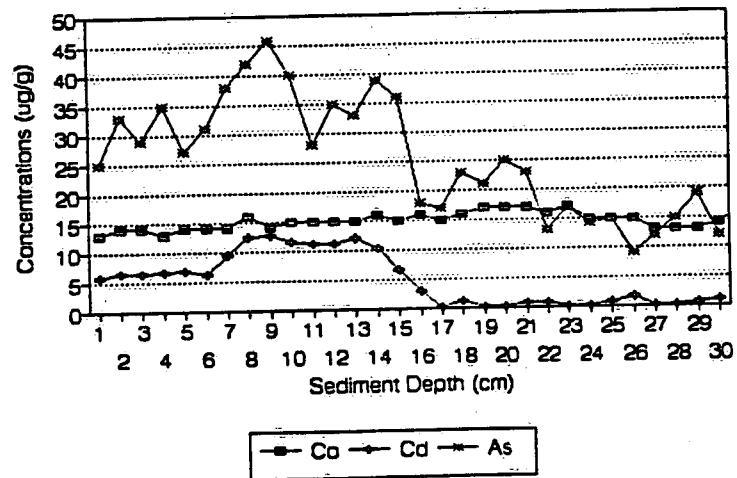
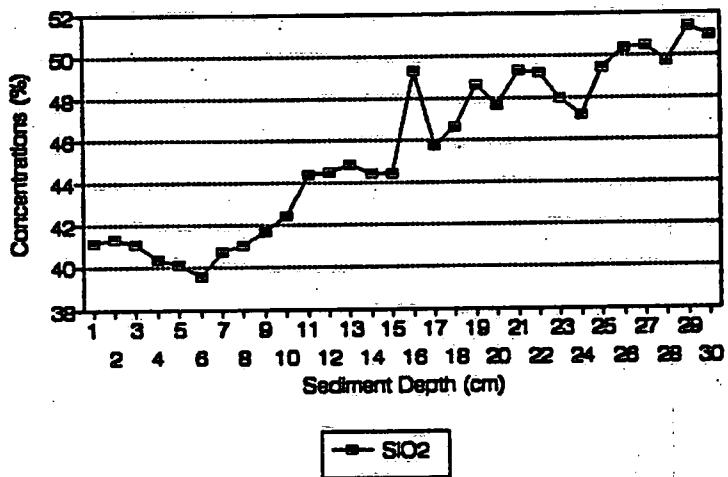
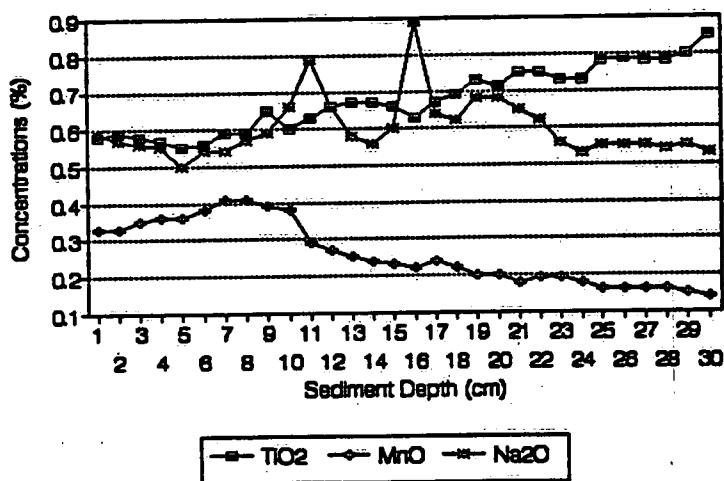


Figure 7.16

Hamilton Harbour
Core: M 5



Hamilton Harbour
Core: M 5



Hamilton Harbour
Core: M 5

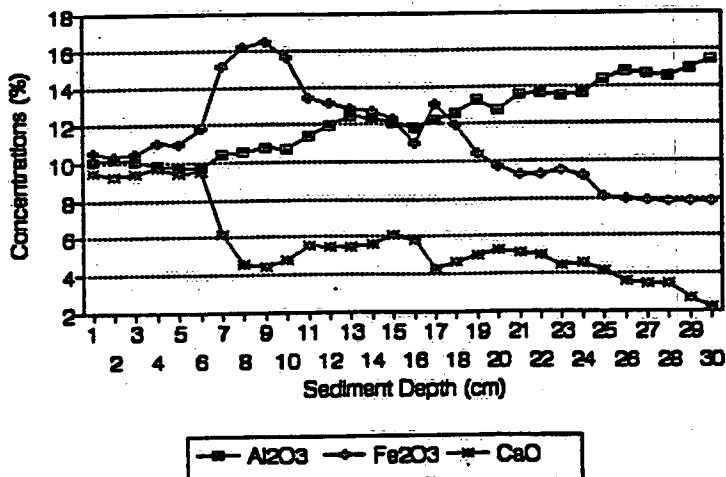
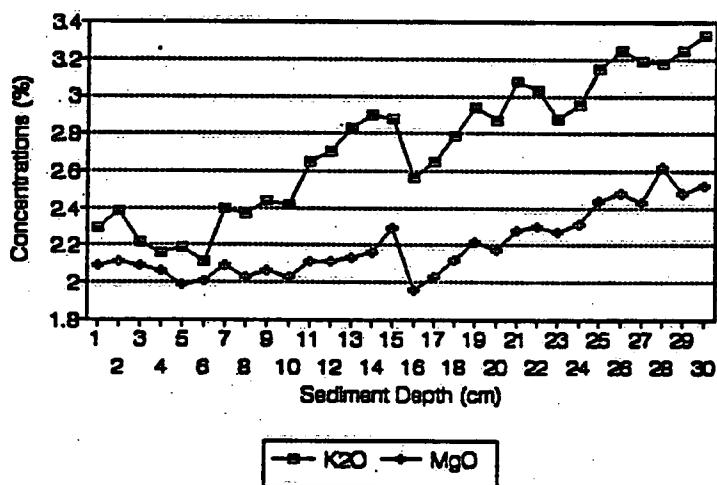


Figure 7.17

Hamilton Harbour
Core: M 5



Hamilton Harbour
Core: M 5

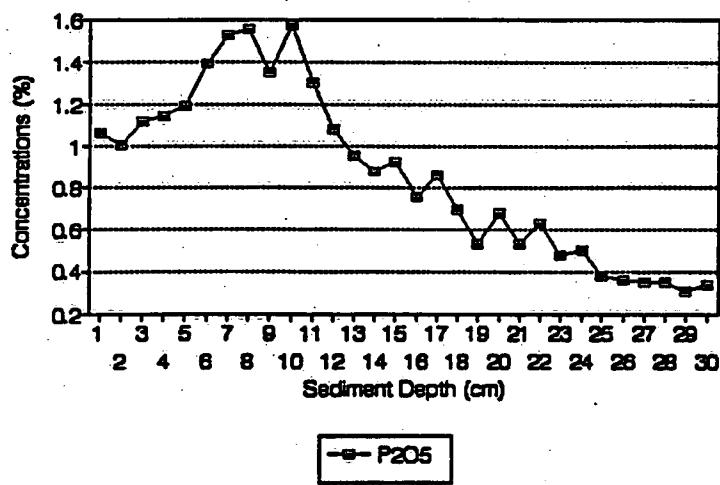
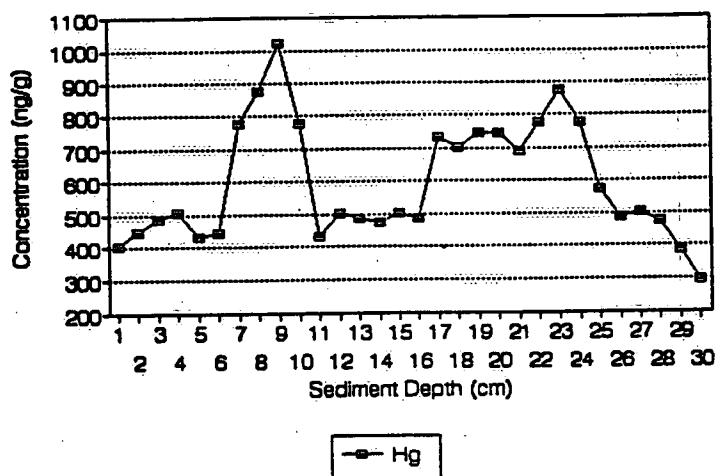


Figure 7.18

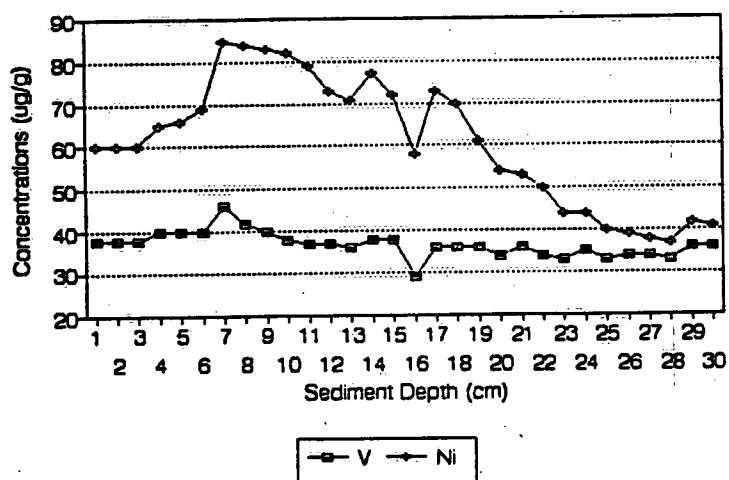
Hamilton Harbour

Core: M 5



Hamilton Harbour

Core: M 5



Hamilton Harbour

Core: M 5

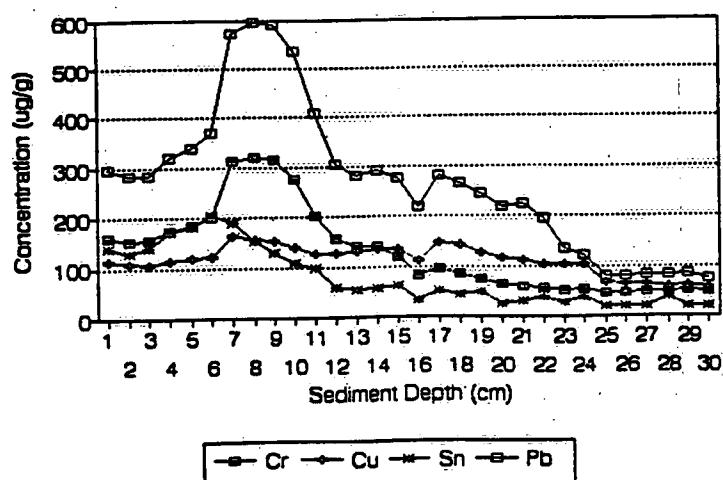
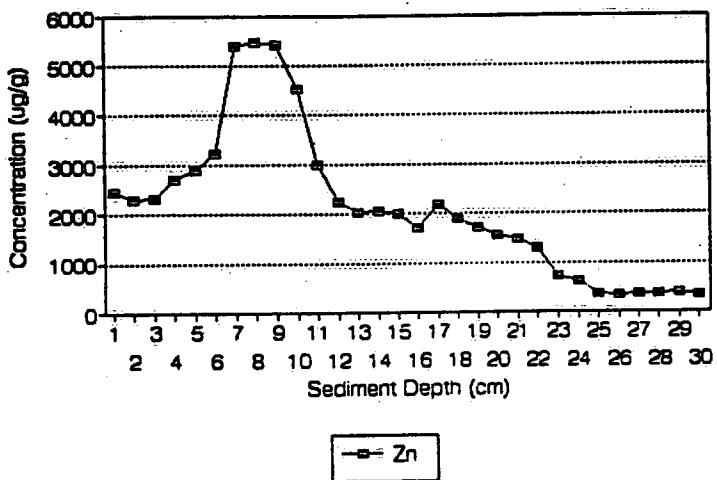


Figure 7.19

Hamilton Harbour Core: M 5



Hamilton Harbour Core: M 5

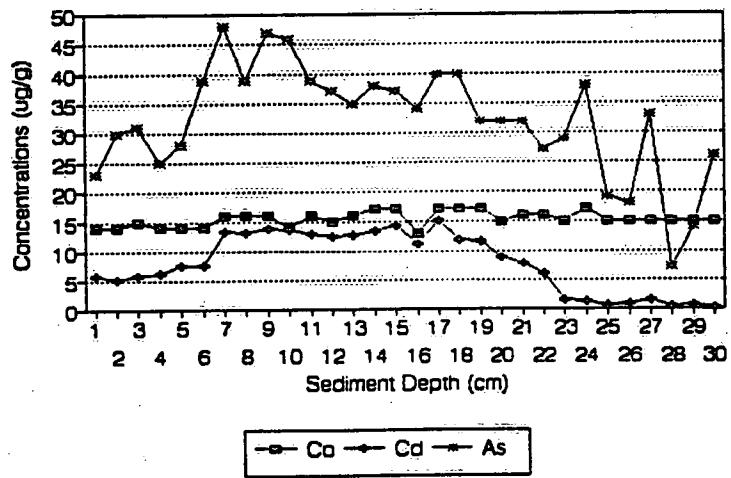


Figure 7.20

Hamilton Harbour

Sediment Pore Water

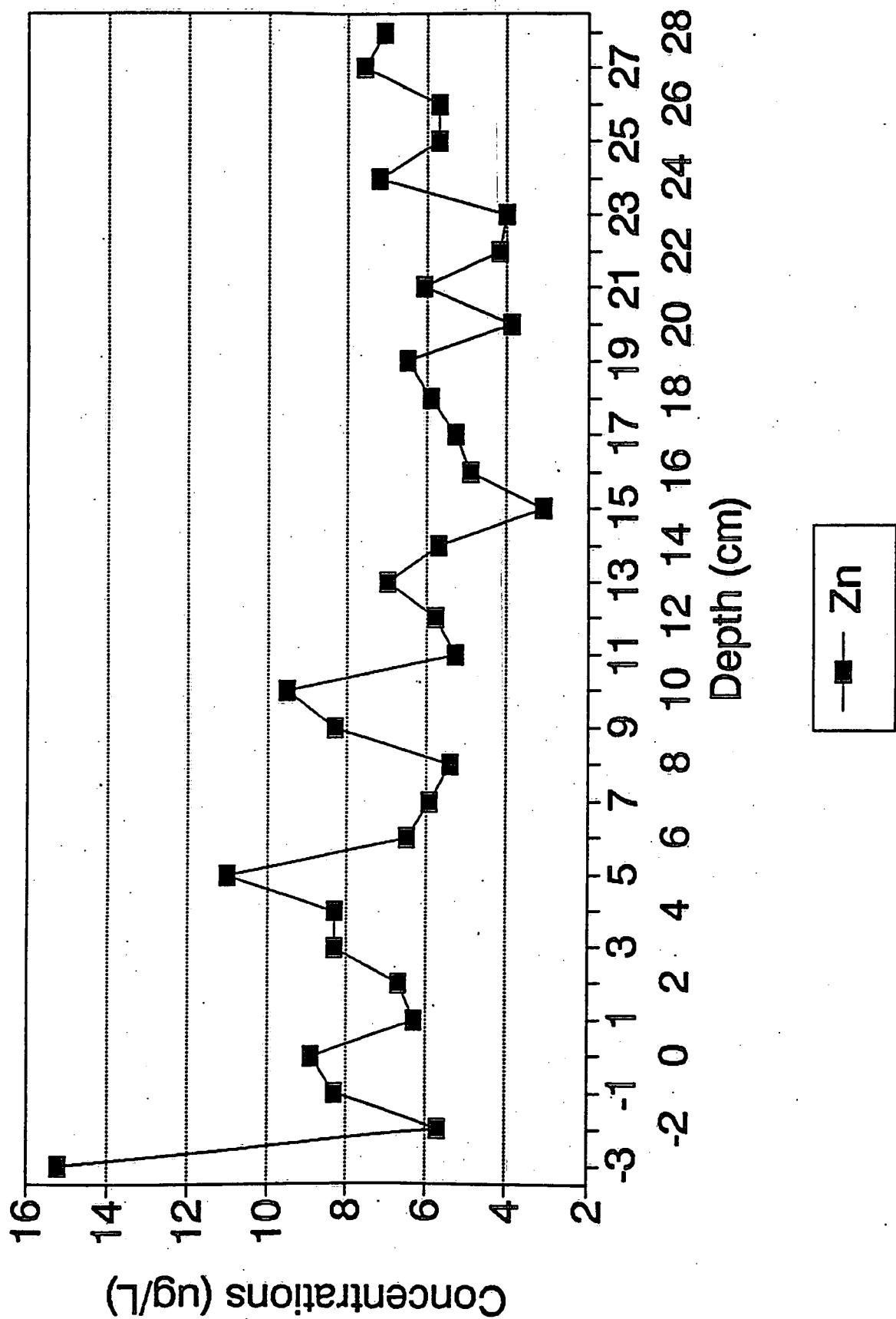


Figure 8.1

Hamilton Harbour

Sediment Pore Water

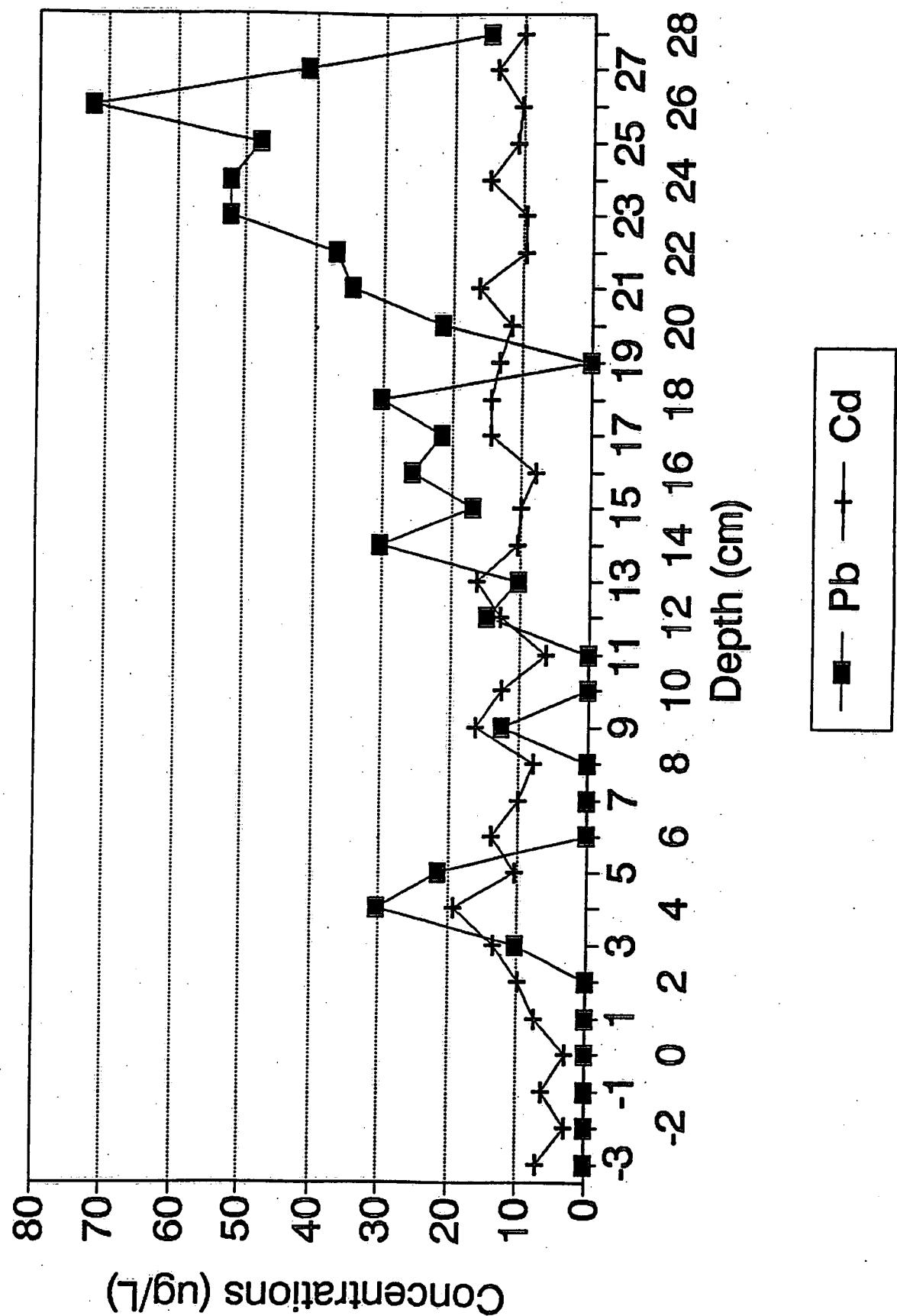


Figure 8.2

Hamilton Harbour

Sediment Pore Water

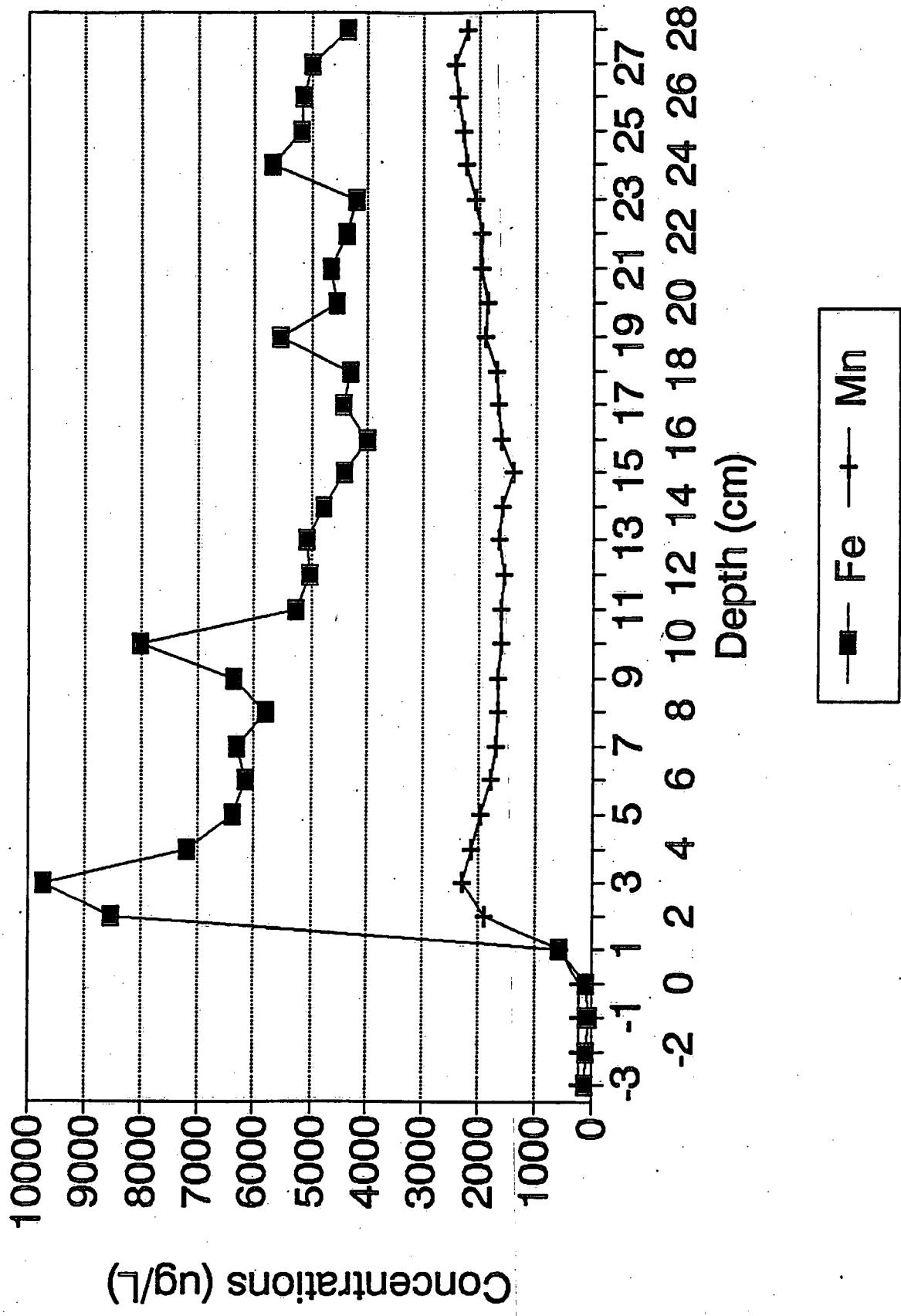


Figure 8.3

GRAB SAMPLES TAKEN AROUND PROPOSED CAPPING SITE
SEDIMENT TOXICITY

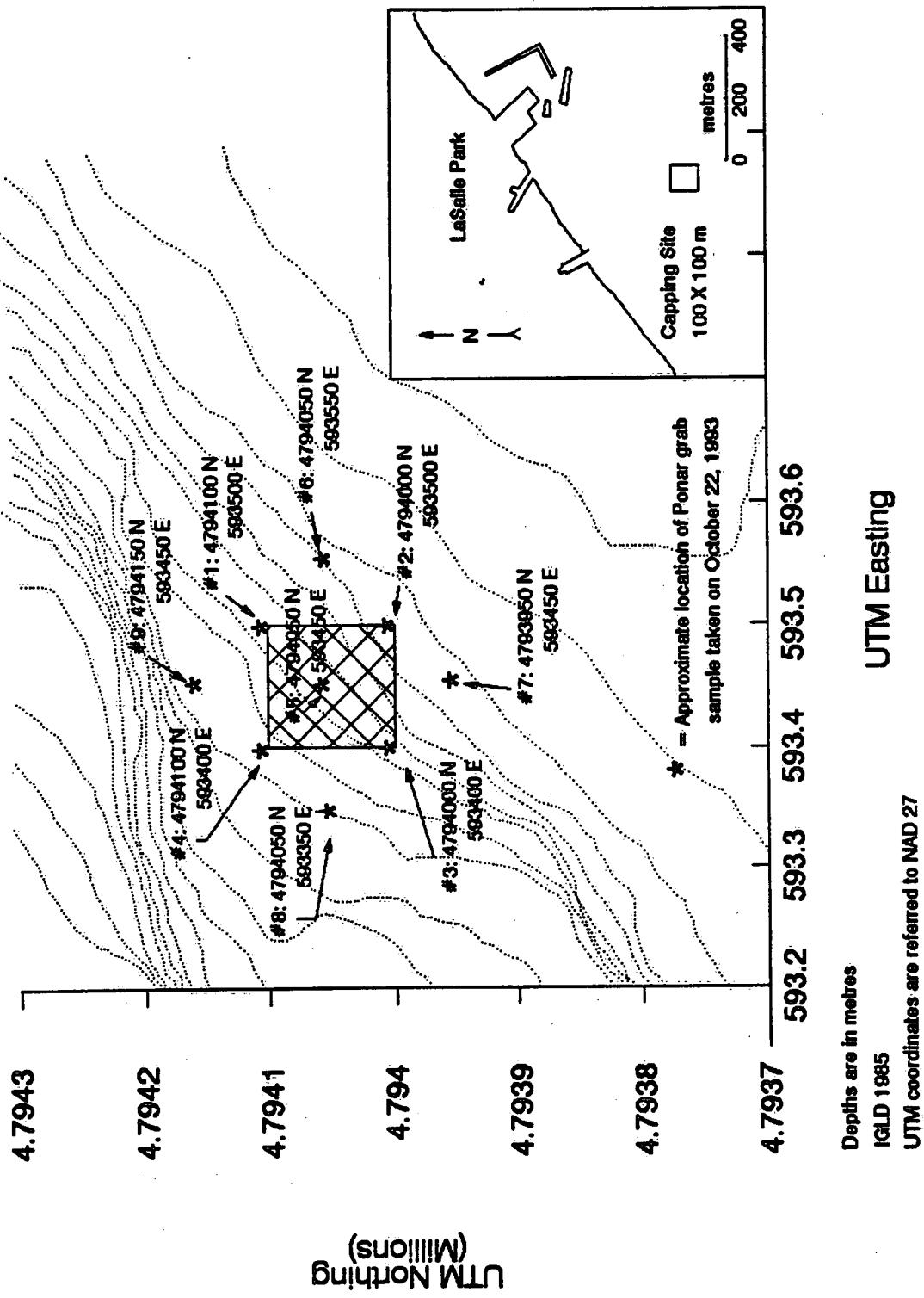
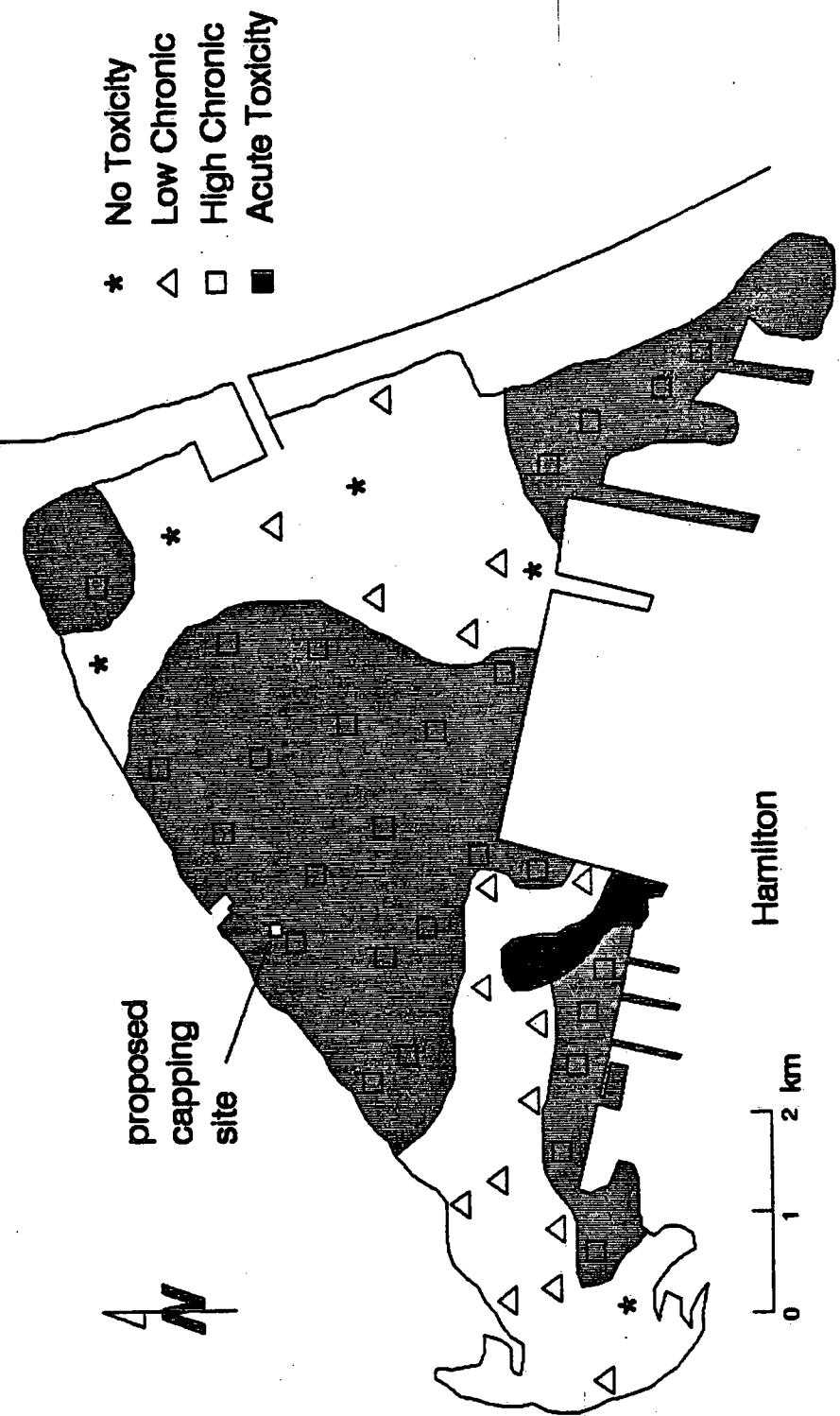


Figure 9

HAMILTON HARBOUR - L. ONTARIO

Sediment toxicity relative to reference sites
using oligochaete (*T. tubifex*) reproduction



SOURCE:
T.B. REYNOLDSON, NWRI

Figure 10

Survival & growth of Chironomus riparius in Hamilton Harbour capping experiment

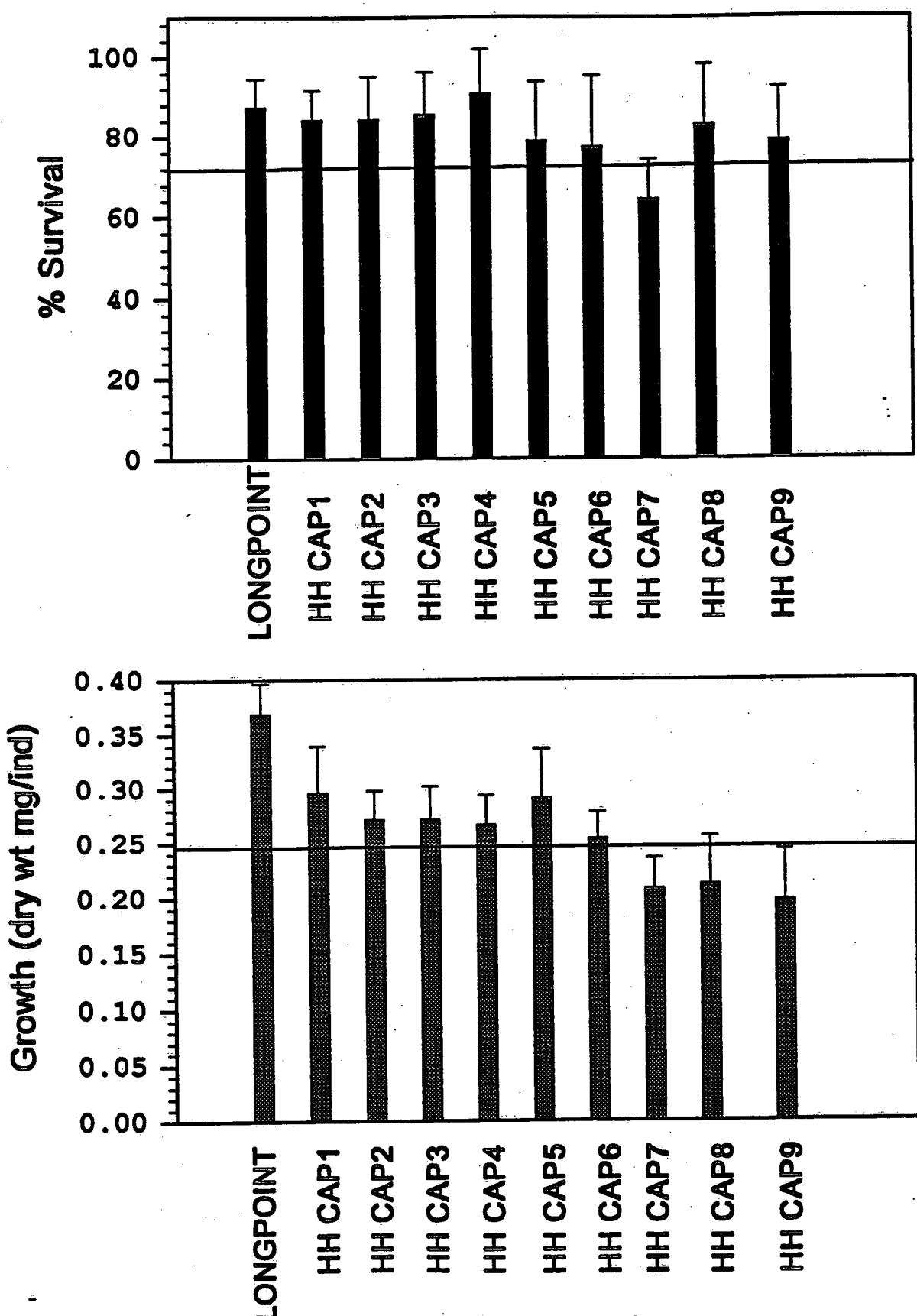


Figure 11

**Survival & growth of *Hyalella azteca*
in Hamilton Harbour capping experiment**

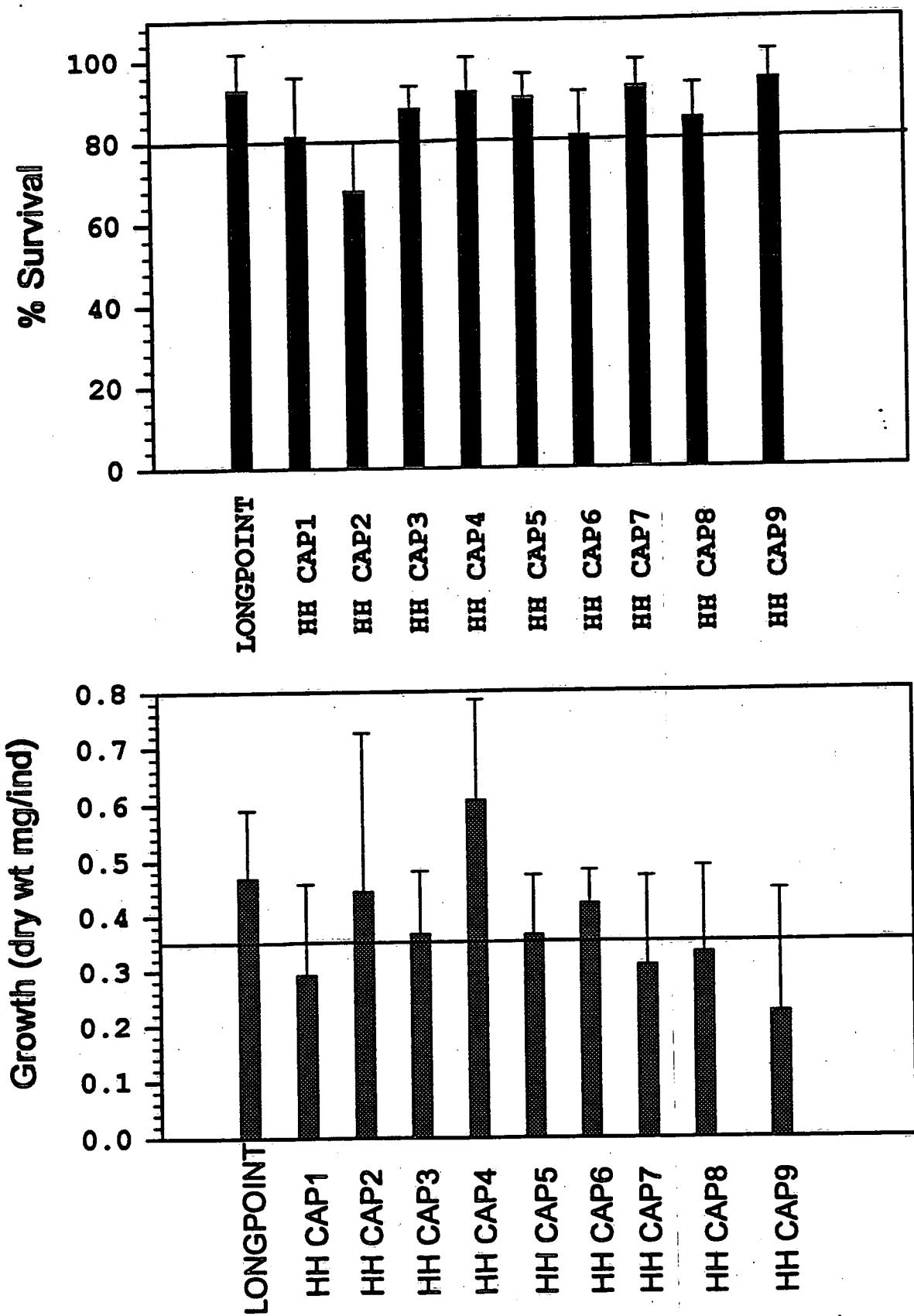


Figure 12

Survival & growth of *Hexagenia* spp.
in Hamilton Harbour capping experiment

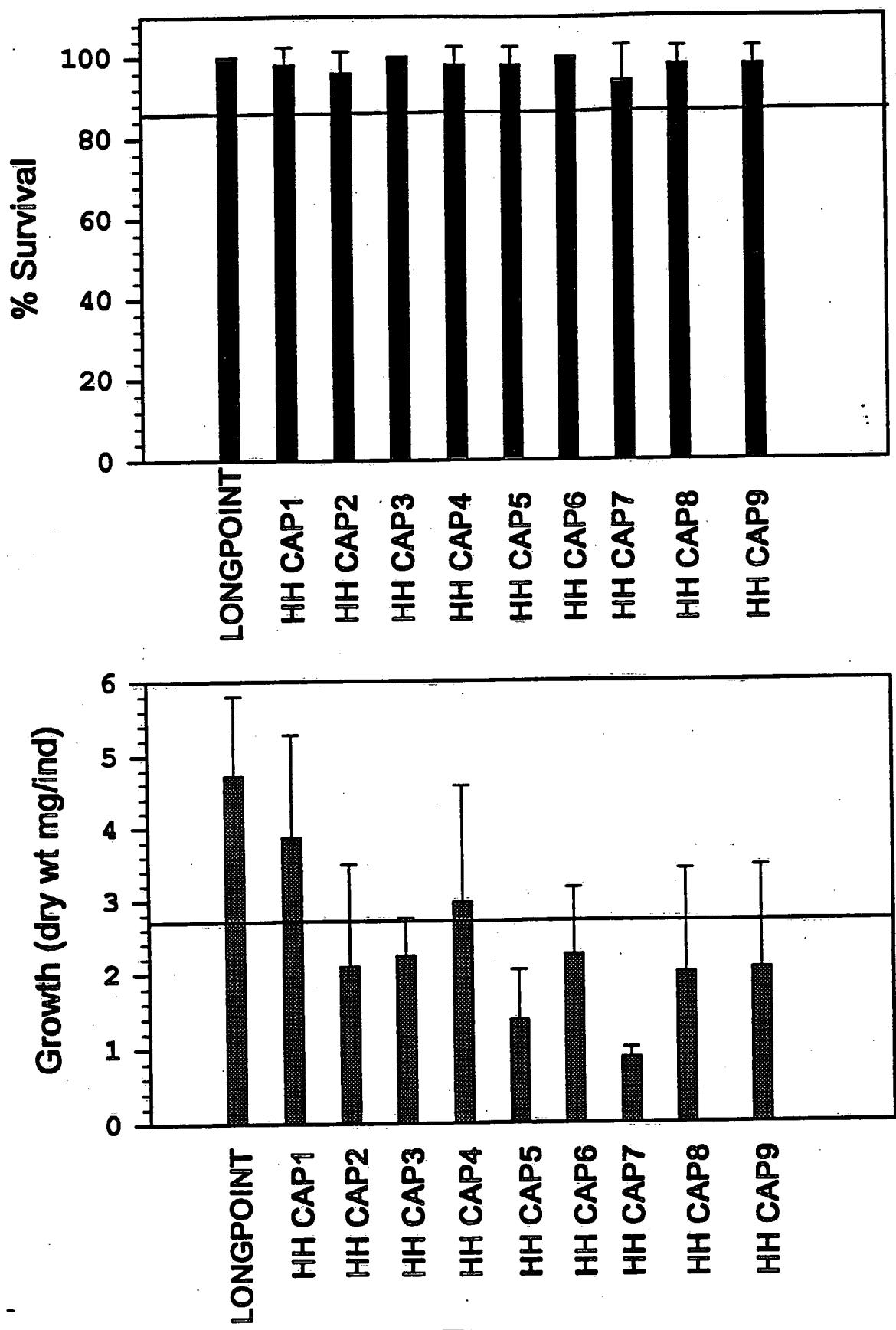


Figure 13

**Reproduction of *Tubifex tubifex*
in Hamilton Harbour capping experiment**

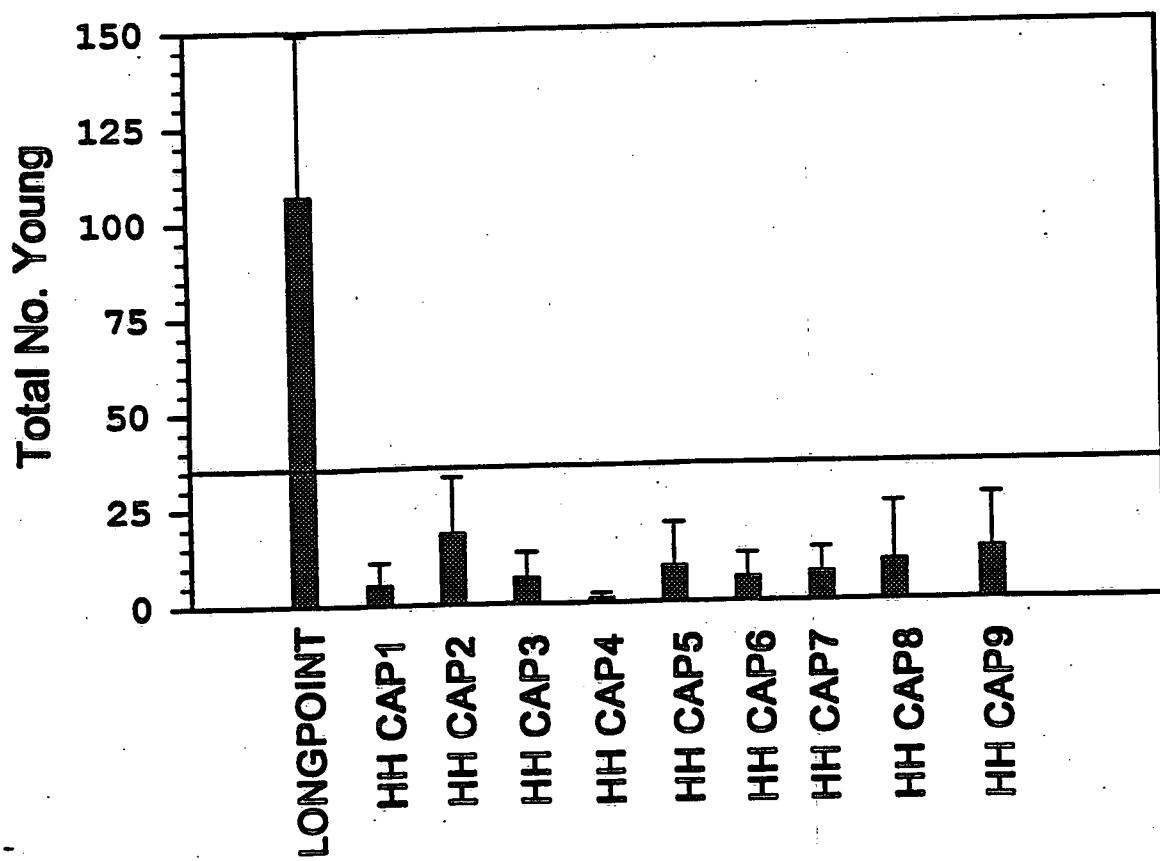
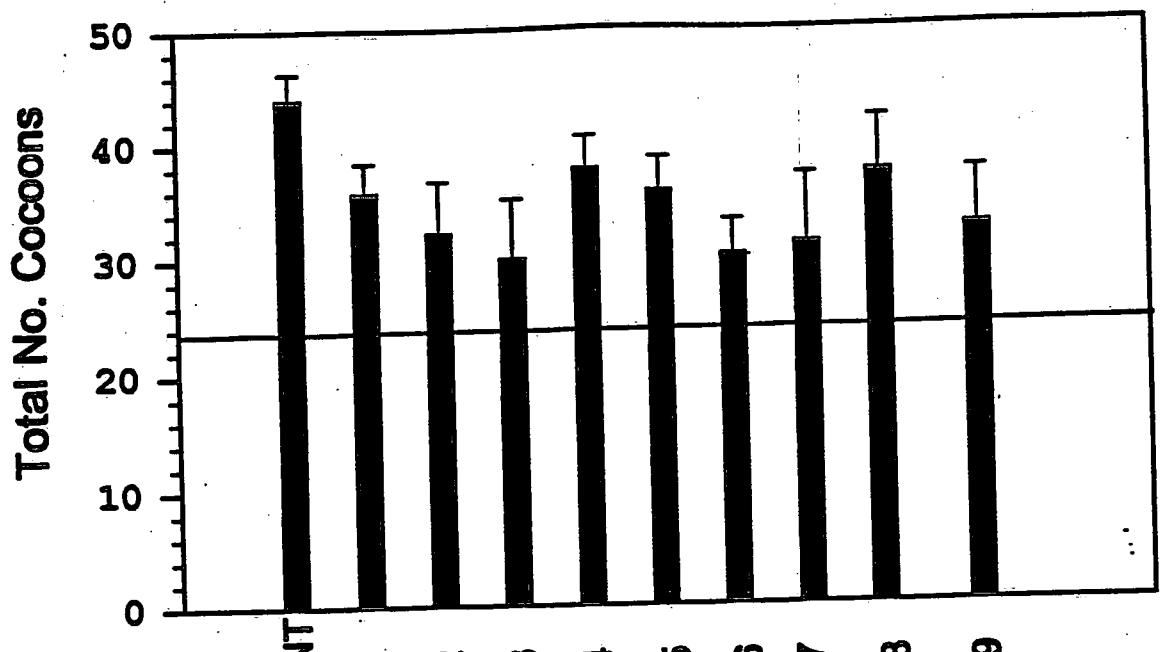
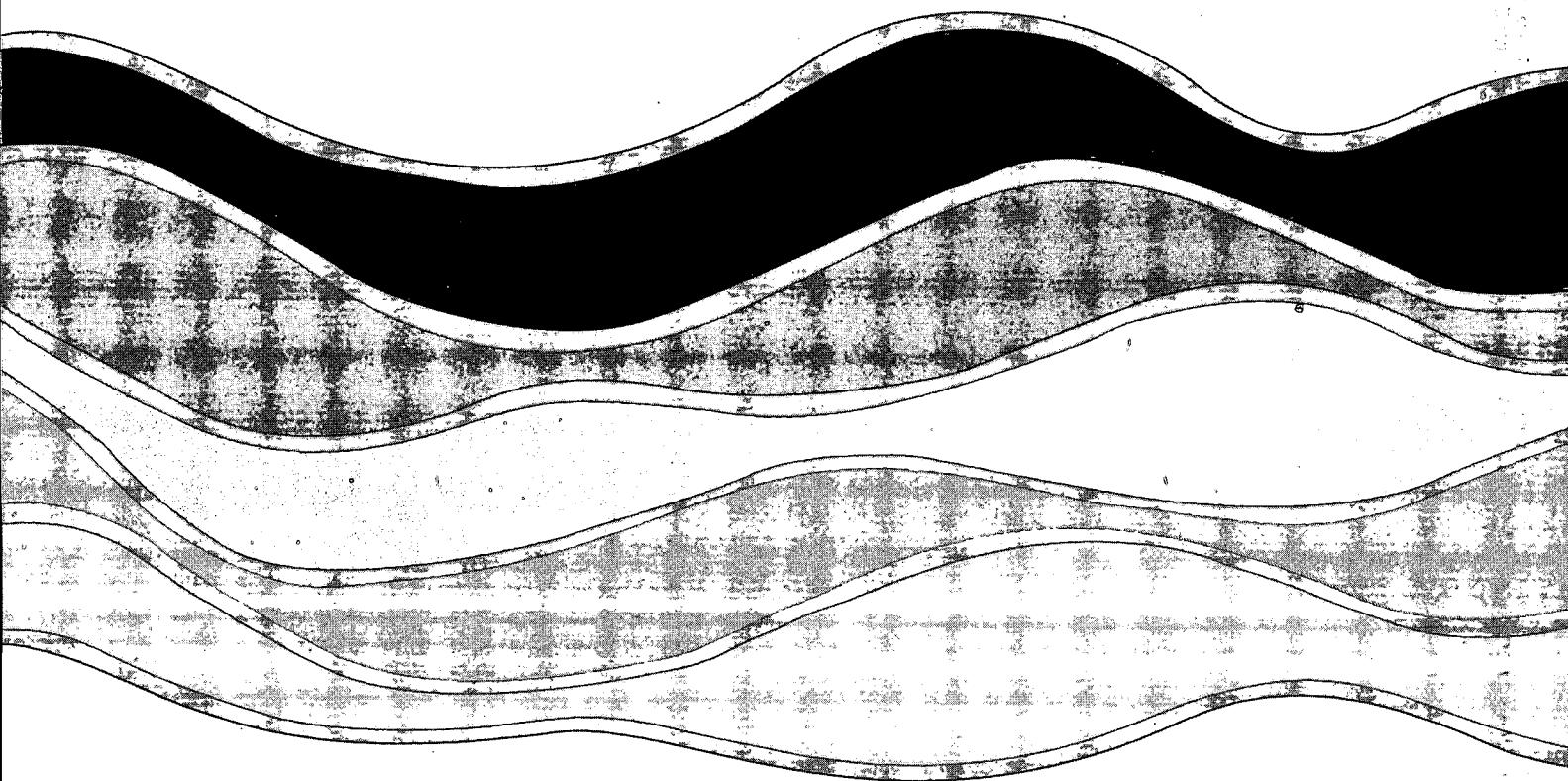


Figure 14

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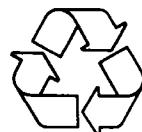
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