

**SEDIMENT AND POLLUTION  
ACCUMULATION IN THE  
HUMBER RIVER MARSH, TORONTO**

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## **Sediment and Pollutant Accumulation in the Humber River Marsh, Toronto**

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For: The Ontario Ministry of the Environment

OCTOBER 1988

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## Abstract

Historical sedimentation rates, the concentration and spatial distribution of six trace metals (Cd, Cr, Cu, Mn, Ni and Pb), PCBs DDT, DDD and DDE, and the mass of Pb, PCB's, DDT, DDD and DDE were determined for the Humber Marsh, Toronto. Eight sediment cores were collected in the fall of 1984 and spring of 1985 (two from the channel, two from the levees and four from the backwater ponds). Sedimentation rates measured by stratigraphy, pollen, or radio isotopes ranged from 0.2 - 0.3 cm/yr on the levees and from 0.9 - 1.9 cm/yr in the backwater ponds. Seven cores, ranging in length from 40 to 91 cm, were subsampled and tested for trace metals, PCB's and pesticide. Cadmium concentrations ranged from below detection limit to 7 µg/g, nickel from 17 - 85 µg/g, copper from 10 - 79 µg/g, chromium from 30 - 108 µg/g, lead from 12 - 190 µg/g and manganese from 420 - 970 µg/g. Chlorinated pesticide and PCB concentrations ranged from below detection limit (1 ng/g) to 21, 65, and 94 ng/g for DDE, DDT and DDD, respectively, and from below detection limit (10 ng/g) to 163 ng/g for PCB's. Concentrations of contaminants were generally higher in backwater pond sediments than in floodplain or channel sediments. The exception was DDT which was present at highest concentrations in the channel sediments. The results indicate that both metal and organic pollutants have been accumulating in the sediments of the Humber Marsh for at least 30 years. Contaminated sediments presently stored in the Marsh are a potential source of pollution for Humber Bay if they become remobilized. The presence of pollutants in surface sediments is a reflection of poor water quality in the Humber River which flows into Lake Ontario near several public beaches. The Humber Marsh is also a popular recreational area and valuable wildlife habitat; the presence of pollutants in the sediments is presumed to be incompatible with these uses.



## Sommaire

Notre tâche consistait à déterminer la vitesse de sédimentation, la concentration et la répartition spatiale de six métaux à l'état de traces (Cd, Cr, Cu, Mn, Ni et Pb), des BPC, du DDT, du DDD et du DDE, ainsi que la masse du Pb, des BPC, du DDT, du DDD et du DDE, dans le marais Humber, à Toronto. À cette fin, nous avons prélevé huit carottes de sédiments à l'automne de 1984 et au printemps de 1985 (deux du chenal, deux des levées et quatre des étangs de retenue). La vitesse de sédimentation, mesurée au moyen de la stratigraphie, du pollen ou des radio-isotopes, allait de 0,2 à 0,3 cm/an sur les levées et de 0,9 à 1,9 cm/an dans les étangs de retenue. Sept carottes, dont la longueur variait entre 40 et 91 cm, ont été sous-échantillonnées pour tester la présence de métaux à l'état de traces, de BPC et de pesticides. La concentration de cadmium allait d'une concentration inférieure au seuil de détection jusqu'à 7 µg/g; celle de nickel, de 17 à 85 µg/g; celle de cuivre, de 10 à 79 µg/g; celle de chrome, de 30 à 108 µg/g; celle de plomb, de 12 à 190 µg/g; et celle de manganèse, de 420 à 970 µg/g. La concentration de pesticides chlorés, pour sa part, oscillait entre une concentration inférieure au seuil de détection (1 ng/g) et 21, 65 et 94 ng/g pour le DDE, le DDT et le DDD respectivement. Dans le cas des BPC, elle était inférieure au seuil de détection (10 ng/g) pour atteindre 163 ng/g au plus. La concentration de polluants était généralement plus élevée dans les sédiments des étangs de retenue qu'elle ne l'était dans ceux de la zone inondable ou du chenal, sauf pour le DDT, plus abondant dans les sédiments du chenal. D'après les résultats, les polluants et métalliques et organiques s'accumulent dans le marais depuis au moins trente ans. Les sédiments contaminés qui sont actuellement déposés dans celui-ci risquent de polluer la baie Humber s'ils sont remis en mouvement. La présence de polluants dans les sédiments de surface sont signes que la qualité de l'eau laisse à désirer dans la rivière Humber, qui se verse dans le lac Ontario près de plusieurs plages publiques. Le marais Humber est un centre de loisirs très prisé et aussi un important habitat pour la faune; la présence de polluants dans les sédiments est incompatible avec ces usages.

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## **1. Introduction**

Since 1981 the Humber River has been the focus of several studies dealing with water quality as part of the Toronto Area Watershed Management Strategy Study (TAWMS). One of the tasks of the TAWMS study is to evaluate sediment and contaminant movement in the Humber River. The present study of the Humber Marshes contributes to TAWMS by providing data on the concentration of pollutants in the channel sediments, the spatial and temporal distribution of pollutants on the floodplain and floodplain sedimentation rates. Information provided here will assist those interested in evaluating contaminated sediments in the Humber Marsh and will serve as a basis for future studies on the Humber and similar urban rivers in Southern Ontario.

This study was initiated in September 1984 and fieldwork was carried out between October of the same year and February of 1985. The objectives of the study were three-fold:

- 1) to determine historical sedimentation rates in the Humber Marsh
- 2) to establish the concentration and spatial distribution of pollutants in the sediments
- 3) to calculate the total mass of pollutants stored in the Marsh.

## 2. Description of Study Area

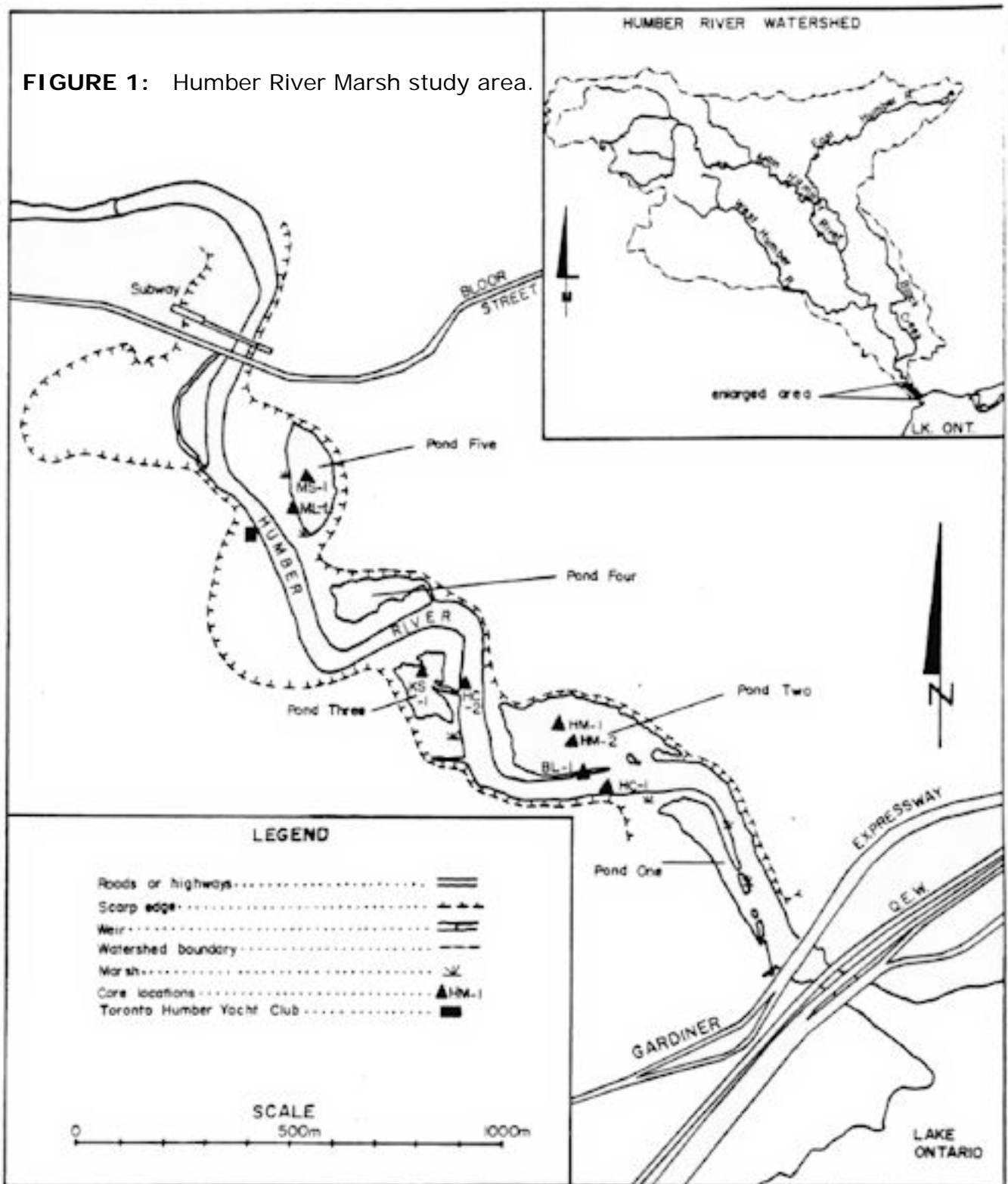
The Humber River drains an area of 897 square kilometers, rising in the morainic hills east of Orangeville and flowing in a southeasterly direction towards Lake Ontario. The upper part of the watershed is mainly rural in character whereas the lower portion (south of Steeles Avenue) is urbanized. Industrial land use is mainly concentrated along the reach bordered by Steeles Avenue in the north and Black Creek to the south. Potential sources of metal and organic pollution in the Humber watershed include industrial discharge, combined sewer outflow, agricultural runoff, and storm runoff. A more detailed description of the watershed is provided elsewhere.<sup>1</sup>

The study area consists of the lowermost reach of the Humber River and adjacent floodplain, from Bloor Street downstream to Lake Ontario, referred to in this report as the Humber River Marsh (Fig.1). During moderate summer flows, channel width and depth average 55.0 m and 1.48 m, respectively.<sup>2</sup>

The average slope of the bed in the study reach is 0.05 %, substantially less than the average slope of the reach immediately upstream (0.40 %).<sup>2</sup> The morphology of the study reach is that of a drowned river valley in which the longitudinal river profile has continuously adjusted to rising base level by depositing sediment. The wedge of sediment which now underlies the Humber Marsh varies in depth from 1.2 m near Bloor Street.<sup>2</sup> to over 20 m at Lake Ontario<sup>3</sup>. Pollen, radiocarbon and stratigraphic evidence from below the Marsh indicate that this valley-fill has been accumulating over the past millennia (ca.4000 years) in response to rising base levels in the Lake Ontario basin.<sup>4</sup> On a more recent time scale, examination of archival maps (the earliest dated 1834) confirms that the plan form of the river in the study reach has changed little in the past 150 years. Thus, the Humber Marsh appears to have existed in its present form for some time.

In the past century aggradation in the Humber Marsh has accelerated in response to the higher sediment yields associated with urbanization and land use change.

**FIGURE 1:** Humber River Marsh study area.



The magnitude of this process can be assessed directly from sediment stratigraphy and pollen and isotope accumulation rates, and indirectly from personal communications with local residents and members of the Toronto Humber Yacht Club (THYC) and from air photographs (the earliest taken in 1937). Most sources reveal that sediment is actively accumulating on the floodplain in response to annual overbank flow events.

### **3. Sedimentary Environments**

Three major sedimentary environments can be identified in the Humber Marsh study area, they are: the channel, the backwater ponds and the levee-floodplain (Fig. 2).

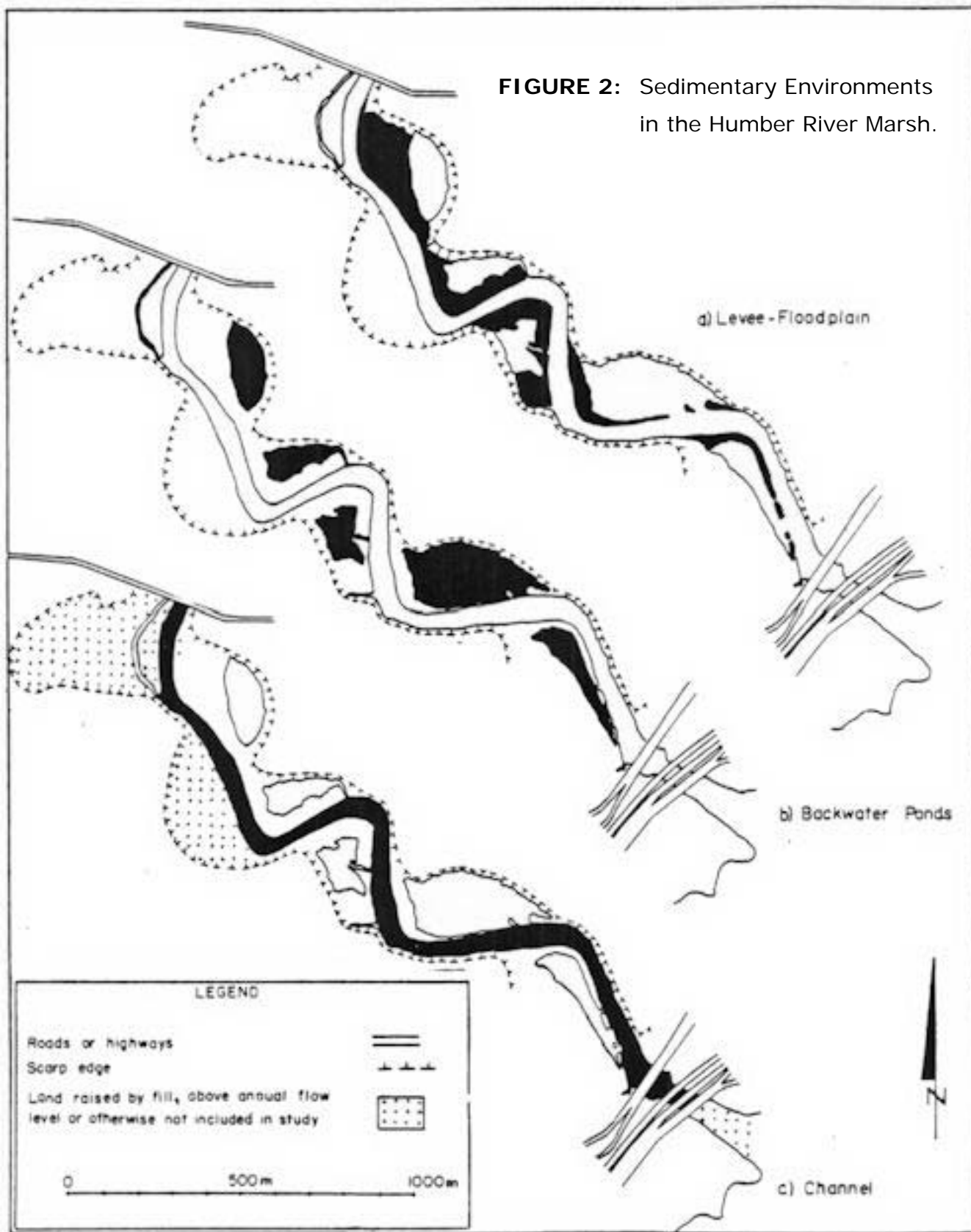
#### **3.1 Channel**

In the study reach the bed slope of the Humber river is lower and the channel is wider and deeper than farther upstream. Flow divergence results in lower velocities and a reduced capacity to transport sediment.

The results of the 1984 TAWMS study entitled "Physical Characteristics of the Humber River" indicate that loosely consolidated clay and silt deposits, ranging in depth from 0.10 - 0.20 m near Bloor St. and from 1.5 - 2.0 m near the Queen Elizabeth Way, overlie sand and consolidated clay and silt in the Humber channel. These observations indicate that sediment is stored in the channel, at least temporarily, in the study reach. In the Long term, due to continued isostatic readjustment, the level of Lake Ontario is rising at a rate of approximately 30 cm per century (0.3 cm/yr) <sup>5</sup>.

Thus a similar long term deposition rate can be expected in the Humber channel. In the short term however, seasonal fluctuations in lake level (on the order of 50 cm) probably exert a major control over sediment deposition and erosion in the channel. It can also be expected that sediment and associated pollutants are flushed lakeward during high flows and during spring breakup when ice scours the bottom of the channel. However, since construction of the Clairville dam on the west branch of the Humber River in 1964 and construction of the lower Humber weirs in 1966, peak flows and ice block formation have been reduced and the residence time of sediments in the channel has probably increased.

**FIGURE 2:** Sedimentary Environments in the Humber River Marsh.





### 3.2 Backwater Ponds

Figures 1 and 2 show five depressions bordering the Humber River within the study area (for convenience they have been numbered sequentially starting at Lake Ontario). In this report these depressions are referred to as 'backwater ponds'. Ponds Three and Four dried out during the summer of 1984 while the others contained water too deep to freeze to the bottom during the following winter. The ponds receive water and sediment directly from the channel during times of high flow, and from local runoff. In general, the sediment delivered to these ponds is fine-grained; because the backwater ponds commonly contain standing water these fine sediments are able to accumulate. As a result, the backwater ponds are the most likely sites on the floodplain for the accumulation of pollen and pollutants associated with fine-grained sediments. Although erosion may occur during unusually large flows events, it is probable that the backwater ponds have experienced the most continuous deposition of any area within the Marsh.

### 3.3 Levee-Floodplain

In addition to the channel and backwater areas, levees and floodplain-like surfaces border the channel and are gradually being built up through overbank flooding and the deposition of sediment. The levees immediately adjacent to the channel, are subject to the most frequent inundation and the deposition of the coarsest sediment. Their growth has helped to cut off the backwater ponds from the main channel. The floodplain slopes away from the levees towards the backwater ponds. For much of the year the levee-floodplain is a subaerial surface covered with vegetation. As a result, these areas are less likely to accumulate pollen and pollutants than are the nearby backwater ponds.

## 4. Methods

### 4.1 Sample Collection and Preservation

Representative coring sites for the determination of contaminant accumulation were selected from the three sedimentary environments in the Humber River Marsh. Two cores (HC-1 and HC-2) were taken from the channel area, two (BL-1 and ML-1) from the Levee-floodplain, and four (KS-1, MS-1, HM-1 and HM-2) from the backwater ponds. The approximate coring locations are shown in Fig. 1. No cores were taken from the floodplain-like areas on the west side of the river adjacent to and directly upstream from the Toronto Humber Yacht Club (THYC). The area upstream is well above mean annual flood level and is not actively accumulating sediment. The area adjacent to the THYC has been raised by the dumping of substantial amounts of fill. Neither of these areas is considered to be representative of the Marsh environment. The channel island between Bloor Street and the THYC was also excluded from the study.

Seven sediment cores were collected during October and November of 1984 using a 4.7 cm diameter, modified Livingstone-type sampler. These cores were either subsampled immediately upon return to the laboratory or were stored in a cool place overnight (~ 4°C) and subsampled the following day. After extruding a core it was described lithologically, then eight or nine 2 cm wide intervals were removed at mechanical, and lithologically appropriate, intervals. Each 2 cm high disk was then divided into three parts. One half of each disk was placed in a sterile, amber glass jar, sealed with an aluminium foil lined cap and stored (< 5 days) at 4°C before shipment to a laboratory for pesticide and PCB analysis.

The remaining portion of the disk was split in half again and each quarter stored in a pre-weighed, sterile glass jar at 4°C. Within three days these samples were oven dried at 100°C to determine moisture content. One of the quarters was used for metal analysis while the remaining quarter was stored in plastic for approximately three months before being submitted for radiochemical analysis.

An additional core was taken from Pond Two during February of 1985 using the Livingstone-type sampler. This core was extruded in the field and later described and subsampled for pollen and radiochemical analysis in the laboratory. Table 1 provides a summary of coring site information and analysis.

#### 4.2 Analytical Procedure

Diagnostic Research Laboratories analysed the samples for Cr, Cu, Mn, Ni, and Pb by direct current plasma emission spectroscopy and for Cd by atomic absorption spectroscopy. All samples were digested in hydrochloric, nitric and perchloric acids before metal analysis was performed. National Bureau of Standards River Sediment No. 1645 was used as a control.

Mann Testing Laboratories analysed the samples for the presence of PCB's, 4,4-DDT, 4,4-DDD and 4,4-DDE using dual capillary gas chromatography equipped with two electron capture detectors. Positive identification of DDT, DDD and DDE was based on chromatograms and partial mass spectra. Quantification of PCB mixtures was determined by summing the peak heights of the mass spectra of 10 individual PCB congeners and comparing these to the sum of the corresponding peaks in an appropriate, recently analysed Arochlor standard \*.

Flett Research Laboratory (Winnipeg, Manitoba) performed the radio-chemical analysis. Lead-210 is a naturally occurring radioactive isotope of the Uranium-233 decay series. Decay of the isotope  $^{226}\text{Ra}$  yields the inert gas  $^{226}\text{Rn}$  which eventually disintegrates into  $^{210}\text{Pb}$ . In the analysis of aquatic sediments, the  $^{210}\text{Pb}$  produced by the decay of naturally occurring  $^{226}\text{Rn}$  is termed the 'supported  $^{210}\text{Pb}$ '. Excess or 'unsupported  $^{210}\text{Pb}$ ' is added

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\* The PCB's detected in the samples resembled the Arochlor 1254 standard.

**Table 1:** Summary of Coring Site Information and Analyses Performed.

Core	Location	Sampling Date	Sedimentary Environment	Water Depth (cm)	Core Length (cm)	Pb-210	Metals and Organics	Pollen
MS-1	Pond Five	841025	backwater pond	40	91	yes	yes	no
KS-L	Pond Three	841025	backwater pond	--*	78	yes	yes	no
HM-1	Pond Two	841115	backwater pond	55	72	no	yes	no
HM-2	Pond Two	850209	backwater pond	53	> 200	yes	no	yes
ML-1	edge of Pond Five	841025	floodplain	N/A	73	yes	yes	no
BL-1	west of Pond Two	841101	levee	N/A	84	yes	yes	no
HC-1	west of Pond Two	341115	channel	45	40	no	yes	no
HC-2	east of Pond Three	841115	channel edge	N/A	63	no	yes	no

\* Marsh Three was seasonally dry when core was taken.

N/A = not applicable

to the sediment column primarily via the atmosphere as a bi-product of anthropogenic activities including the burning of coal and the use of leaded gasoline. Once incorporated into the sediment  $^{210}\text{Pb}$  decays in accordance with its half life of 22.26 years. Sedimentation rates can be determined from the decay of the unsupported component. The amount of unsupported  $^{210}\text{Pb}$  is determined from the difference between the total  $^{210}\text{Pb}$  activity and the supported  $^{210}\text{Pb}$ , the latter of which is determined by assay of the daughter Po-210 which is assumed to be in secular equilibrium with the parent. Here, sedimentation rates were determined from the decay of the daughter Po-210. In the analysis Po-210 was also added as a standard to determine process efficiency.

Analysis for pollen and total carbon was carried out in the Botany Laboratory of the Royal Ontario Museum by the author under the supervision of Dr J.H. McAndrews (curator). Sediment moisture content was determined by oven drying at  $100^{\circ}\text{C}$ . Organic carbon and  $\text{CaCO}_3$  content were determined from weight loss at  $550^{\circ}\text{C}$  and  $1000^{\circ}\text{C}$ , respectively. Between 1 and 2 ml of sediment from each level was spiked with a known number of *Lycopodium* spores and then processed by the standard treatment with HCl, KOH, HF and acetolysis. The resulting concentrate was stained with safranin and mounted in silicone oil. If sand was present the sample was sieved through 15 and  $150\ \mu\text{m}$  screens before mounting in silicone oil. Pollen concentration was estimated from the ratio of fossil pollen to added *Lycopodium*. Pollen and spores were identified by comparison with a modern pollen reference collection and with the aid of an illustrated key <sup>6</sup>.

Lithologic description was based on hand texturing and visual assessment. Mechanical grain size analysis would have been desirable but, due to limitations in the study, could not be carried out.

## 5. Results and Discussion

### 5.1 Stratigraphy and Sediment Accumulation Rates

#### 5.1.1 Core Stratigraphy

The stratigraphies of eight cores lifted from the Humber Marsh are shown in Fig. 3. The lithology of each core was determined by hand texturing and visual assessment before samples were removed for pollutant or pollen analysis. The lengths of cores obtained for pollutant analysis ranged from 41 cm (HC-1) to 91 cm (MS-1). An additional core obtained for pollen analysis was 11 m long, but only the upper 2.3 m are shown here. On the basis of lithology the cores can be divided into two groups. Sediments from cores HC-1 and HC-2, lifted from the channel area, are predominantly sand and silt with some pebbles, organic matter and shells (gastropods). Frequent Variations in grainsize are associated with fluctuating discharge. In the remaining cores obtained from still water or subaerial environments, silt and clay predominate although peaty sediments do occur (ie. at the bottom of BL-1). Grainsize variations are gradual and infrequent.

In all cores not obtained from the channel area an anomalous sand layer occurs less than 60 cm below the surface .This sand is associated with high energy flow conditions and was probably deposited during the last major flood on record - Hurricane Hazel in October 1954. If this assumption is made and the year 1954 is assigned to the sand unit then the overlying deposits represent deposition since that time. The top of the sand unit, a reasonably well defined boundary, was chosen as the upper limit of deposition in order to remove some of the bias introduced by sediment deposited during Hurricane Hazel. It is not possible to estimate how much material was eroded during the flood. Thus the sedimentation rates calculated for the cores (see Table 2) represent maximum net sedimentation since Hurricane Hazel (rates are not corrected for compaction which may have occurred during sampling).

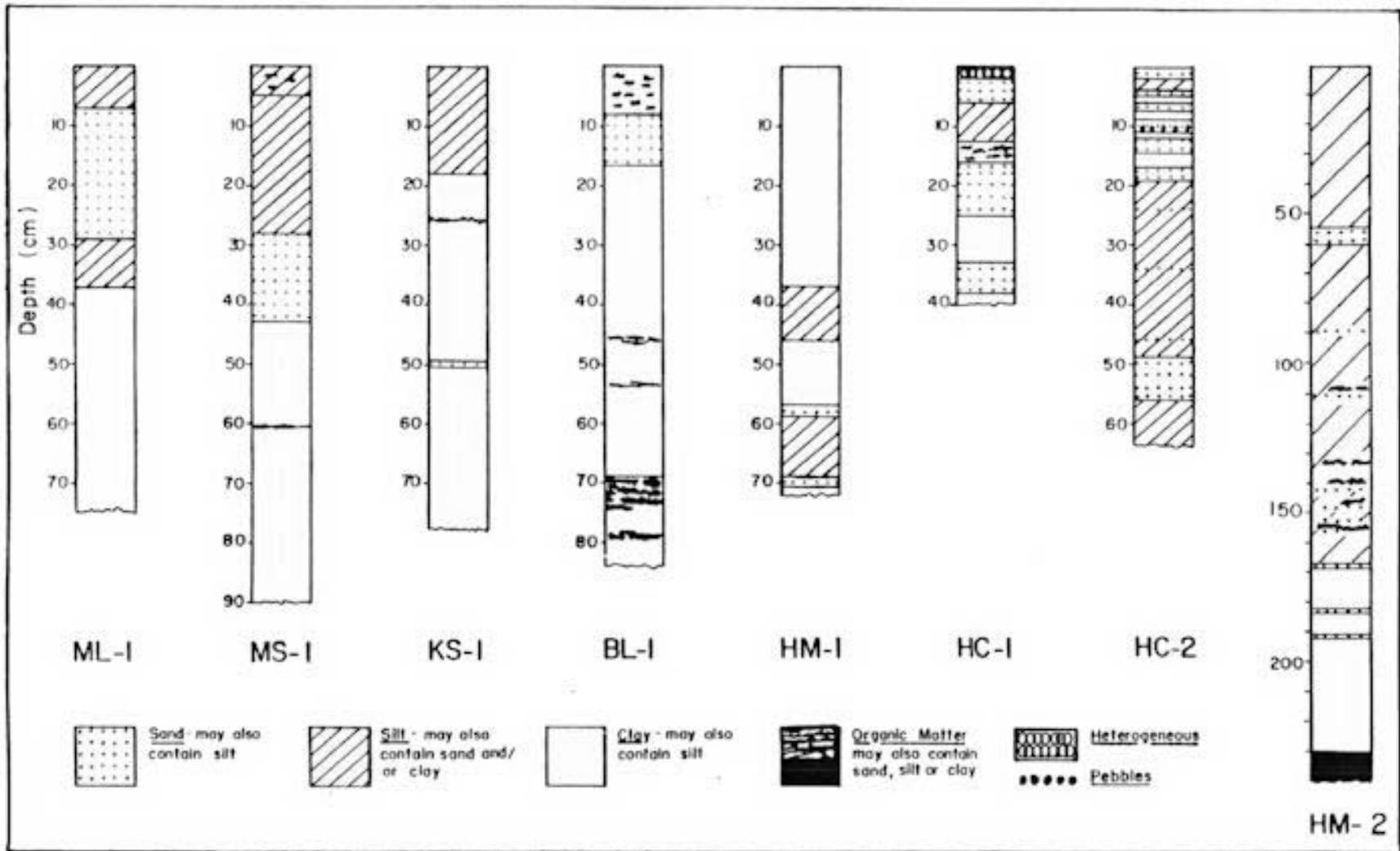


Figure 3: Stratigraphy of sediment cores from Humber Marsh (note change of scale on far right).

**Table 2:** Thirty Year Sedimentation Rates for Humber Marsh Sediment Cores.

Location	Core	Thickness of sand layer (cm)	Depth to sand layer (cm)	30-year sedimentation rates (cm/yr)
Pond Two	HM-1	2	57	1.9
	HM-2	4	56	1.9
Pond Three	KS-1	1	50	1.7
Pond Five	MS-1	15	28	0.9
Levee-Floodplain	ML-1	22	7	0.2
	BL-1	9	8	0.3

Backwater pond sedimentation rates were greater than those on the levee-floodplain (see Table 2); backwater pond sedimentation rates were also higher closer to Lake Ontario (Pond Two) than farther upstream (Pond Five). Sedimentation rates at the two levee sites were similar.

The two cores lifted from Pond Two (HM-1 and HM-2) were stratigraphically similar, both were predominantly clayey-silt and both had a sand layer between 50-60 cm. This similarity suggests that the sediment facies observed in the two cores are locally continuous and that the cores obtained in this study are more or less representative of the Marsh.

In summary, over the past 30 years, sedimentation rates in the backwater ponds ranged between 1 - 2 cm/yr while sedimentation rates on the adjacent levees and floodplain were on the order of 0.2 - 0.3 cm/yr.

#### 5.1.2 Pollen Analysis

The distribution of *Ambrosia* (ragweed) pollen in aquatic sediments from Eastern North America provides a marker for estimating modern sediment accumulation rates. Ragweed is a weedy herb which commonly invades disturbed ground. A marked



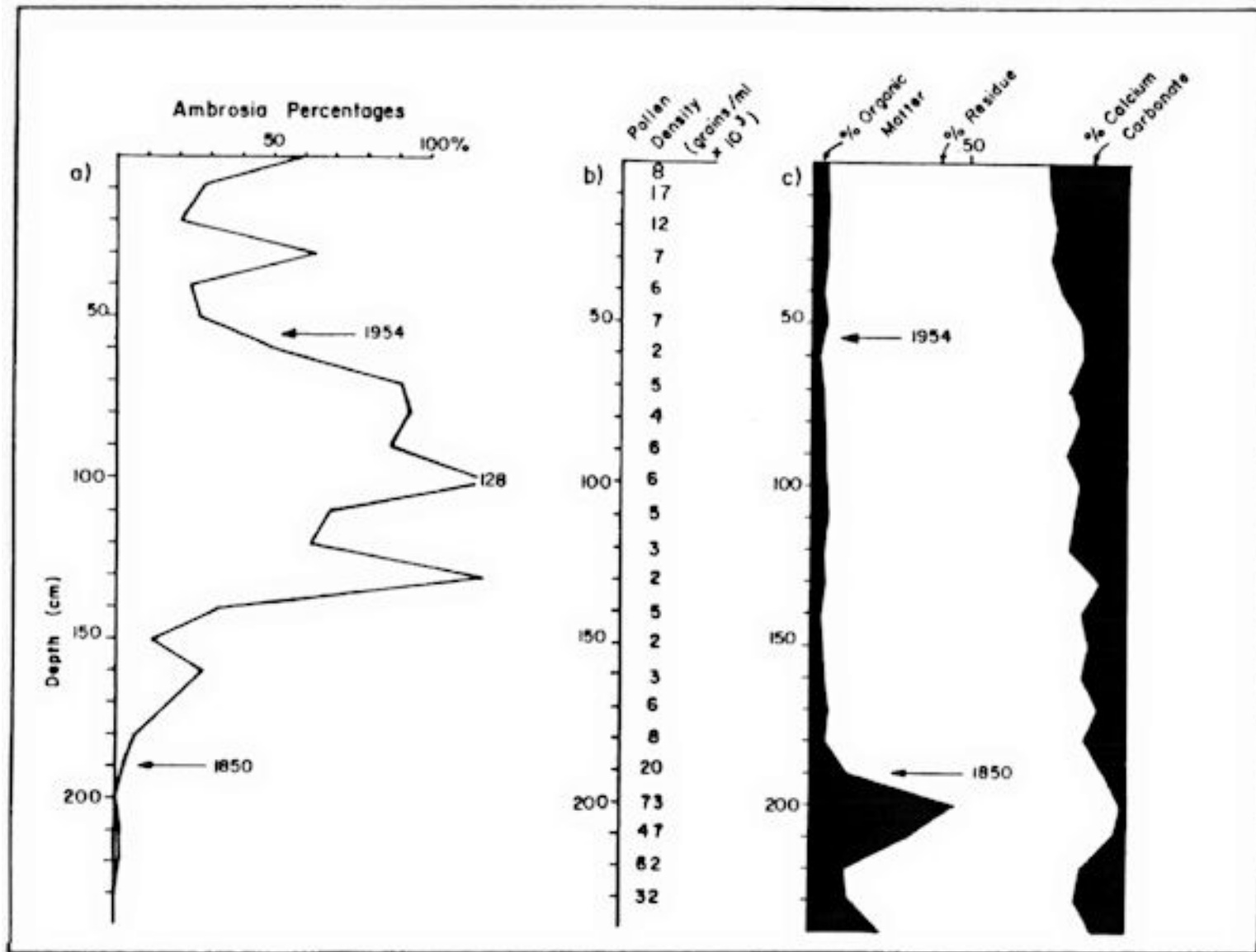
increase in the occurrence of *Ambrosia* pollen in recent sediments is generally associated with historical deforestation and human settlement. In southern Ontario the ragweed rise has been dated at 1850<sup>7</sup> AD and its occurrence allows for an estimation of average sediment accumulation rates over the past 135 years.

Figure 4a shows the occurrence of ragweed pollen as a percentage of total tree pollen in the upper 2.3 m of sediment from core HM-2. Pollen density and thermal analysis are also shown. On the basis of the sudden increase in *Ambrosia* percentages, historical sedimentation can be inferred to have begun at approximately 190 cm below the surface. One hundred and ninety centimeters of deposition in 135 years yields a net sedimentation rate of 1.4 cm/yr. The latter value is less than the 30-year sedimentation rate for the same core (see Table 2).

If sedimentation occurred at the higher rate of 1.9 cm/yr during the last 30 years then, in order to obtain a net sedimentation rate of 1.4 cm/yr over the entire 190 cm, the average sedimentation rate between 1850 and 1954 (60-190 cm) would have to have been less than 1.4 cm/yr.

Additional evidence supporting the claim that sediment above 190 cm was deposited since 1850 is provided by the pollen density calculations and thermal analysis (Figs. 4b and 4c). Pollen density decreases dramatically between 180 and 200 cm. This trend is largely a function of increased sediment yields in the watershed rather than any substantial decrease in the delivery of pollen to the sediments. Above 190 cm, percent residue is greater than below 190 cm also indicating increased delivery of elastic material to the Marsh.

Pollen analysis on a core recently obtained from Pond Five indicates that farther upstream the *Ambrosia* rise occurs between 80-90 cm below the surface. The resulting 135-year sedimentation rate of 0.6 cm/yr is less than the 30-year sedimentation rate calculated for the same Pond (see MS-1, Table 2). The decrease in depth to the *Ambrosia* rise between Ponds Two and Five, and the data in Table 2, further support the conclusion that the rate of sediment deposition in the Humber Marsh increases with decreasing distance from Lake Ontario.



**Fig.4 :** Ambrosia pollen percentages (a) calculated on the basis of total tree pollen, pollen density (b), and thermal analysis results (c) from core HM-2.

On a much longer time scale, a radiocarbon date of  $3800 \pm 80$  years BP from 1030 - 1040 cm below the surface of Pond Two yields a long-term average sedimentation rate of 0.2 cm/yr for sediment below 190 cm. Comparison of long-term and historical sedimentation rates in Pond Two suggests that there has been a seven-fold increase in the average rate of sedimentation in the past 135 years.

This increase can largely be attributed to historical land use practices in the Humber watershed since 1850. Initially, land clearance and agricultural practices caused increased sediment yields, later urban development was the main contributor. The rapid development of large areas of the Humber River drainage basin (i.e. Etobicoke) in the 1970's could explain why the 30-year sedimentation rates are higher than the average sedimentation rate for the entire period since 1850.

#### 5.1.3 Lead-210 dating

Lead-210 isotope analysis is one method of dating sediments deposited in the last 100 - 200 years. Although the technique has primarily been applied to lake sediments, at least one other study has used radio isotopes to determine recent sedimentation rates in a fluvial environment.<sup>3</sup> At this time the processes by which Pb-210 is deposited in fluvial sediments are not fully understood. Clearly the rate of sediment accumulation in a fluvial system is likely to be more variable than in a lacustrine one. Nevertheless, results from Pond Two indicate that in some fluvial environments there is justification for using the Pb-210 dating technique.

Samples from five cores (HM-2, MS-1, ML-1, KS-1, and BL-1) were submitted for isotope analysis for the purpose of determining sediment accumulation rates. For most of the cores the technique did not yield satisfactory results because the sampling intervals were too widely spaced and polonium-210 levels were not significantly above background values. Those cores in which background Po-210 levels were encountered close to the surface had lower sedimentation rates than core HM-2, from Pond Two, for which Po-210 analysis yielded good results.

## Core HM-2

Background levels of the isotope Po-210 were not encountered in this core (i.e. historical sedimentation is greater than 148 cm). However, if a background level of 1 DPM/g dry weight is assumed then the data suggests that the sediment accumulation rate in core HM-2 has varied between 1.0 and 1.7 cm/yr (see Fig 5). The profile in Fig. 5 has been divided into three discrete segments over which constant sedimentation rates were assumed. In the upper portion of the profile the line of best fit yields a sedimentation rate of 1.0 cm/yr for a period of approximately 32 years. Between 35 and 60 cm there is a zone of relatively constant Po-210 activity indicating the possibility of sediment mixing or extremely rapid sedimentation.

The stratigraphic position of this section suggests that it is related to the Hurricane Hazel flood of 1954. The thickness of this section suggests that additional sediment was deposited on top of the 4 cm sand layer during receding flow and confirms that the 30-year sedimentation rates are maximum possible rates. The two linear segments below the discontinuity yield sedimentation rates of 1.7 cm/yr between 60 and 100 cm (approximately 1954 to 1930 AD) and 1.1 cm/yr between 100 and 148 cm (approximately 1930 to 1886 AD). The reason for the break in slope at 100 cm is not clear, a sharp peak in *Ambrosia* percentage also occurs at this level. The average sedimentation rate for the entire analysed portion of the core is 1.4 cm/yr.

For the remaining cores it is essentially impossible to estimate sediment accumulation rates from Po-210 because there are too few data points above background. It is possible, however, to estimate sediment accumulation in these cores from the stable lead data obtained from the trace metal analysis. Previous studies<sup>9</sup> indicate that the concentration of anthropogenic lead in sediments started increasing significantly between 1850 and 1370 AD in Eastern North America in response to the burning of coal (since the 1920's the use of leaded gasoline has also contributed to atmospheric lead fallout).

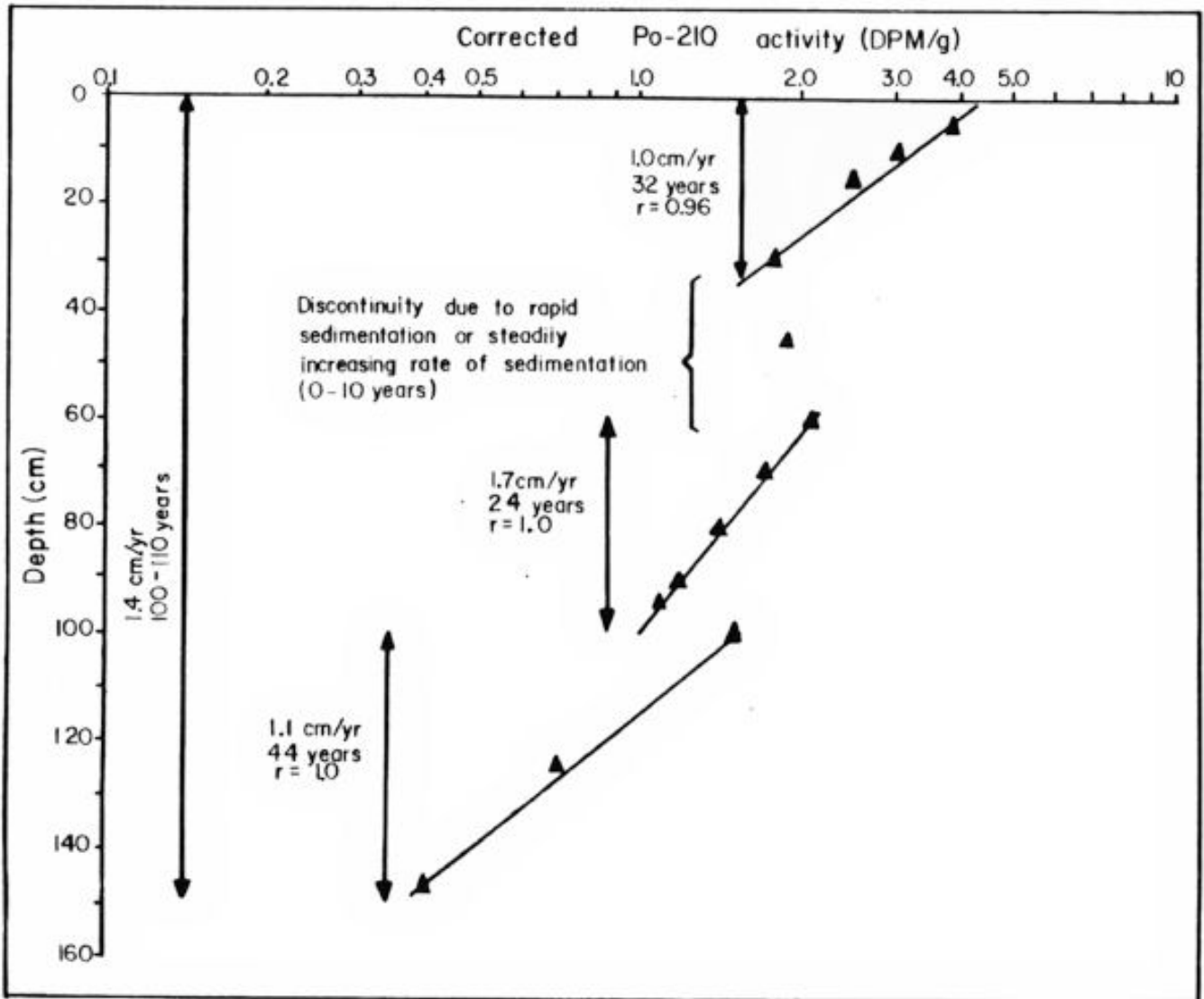


Fig. 5: Unsupported Po-210 activity (in disintegrations per minute per gram) for core HM-2.

This marked increase in lead concentration appears to be a useable marker for the determination of mean sediment accumulation rates over the past 124 years. A visual scan of stable lead values in the cores (see Appendix B-2) suggests that background levels of stable lead in the Humber Marsh are close to 18 µg/g. This value agrees with regional background values for lead in the Great Lakes basin. Thus, the stable lead concentration of 50 µg/g reached in the deepest section of core HM-1 is above background and the sediments are younger than 1860.

#### Core MS-1

The few Po-210 points above background in core MS-1 suggest a sedimentation rate of 0.5 cm/yr. However, examination of the stable lead profile suggests that background levels have been reached in the deepest section (89-91 cm). Ninety centimeters of deposition in 124 years yields an average sedimentation rate of 0.7 cm/yr which falls between the 30-year sedimentation rate of 0.9 cm/yr and the longer term 0.6 cm/yr rate based on pollen analysis.

#### Core KS-1

In core KS-1, stable lead concentration appears to have reached background at, or below, 68-70 cm resulting in an average sedimentation rate of 69 cm over 124 years, or 0.6 cm/yr. The 30-year sedimentation rate based on the presence of the sand layer is nearly three times as high.

#### Core ML-1

The stable lead profile suggests that background background levels have been reached between 53 and 70 cm in core ML-1. If the midpoint of 62 cm corresponds to the 1860 marker for stable lead then the average sedimentation rate would be 62 cm in 124 years, or 0.5 cm/yr. This value is greater than the 30-year sedimentation rate. The difference between these values may be related to the thickness of the sand layer found in this core. If the 22 cm of sand are not included in the stable lead calculation

(this is justified because the sand is assumed to have been deposited instantaneously) then the resulting average sedimentation rate is  $(62 - 22) \text{ cm} / 124 \text{ yrs} = 0.3 \text{ cm/yr}$ .

Core BL-1.

Stable lead concentrations appear to have been reached at shallow depth in core BL-1, possibly as low as 8-10 cm. However, if the sand layer between 8 and 17 cm was deposited in 1954 then a depth of 9 cm could not possibly correspond to 1860. Because of the proximity of site BL-1 to the channel it is probable that during the Hurricane Hazel flood an unknown depth of sediment was eroded before the sand was deposited. As a result, sediment below the sand layer is much older than 1954 and possibly older than 1860. This fact and the coarser grain size of the sand layer explain the low stable lead concentrations below 10 cm and the poor isotope analysis results.

## 5.2 Pollutant Analysis

Fifty-seven sediment samples were analysed for the trace metals Cd, Cr, Cu, Mn, Ni and Pb. Fifty-six samples were analysed for the presence of PCB's, DDT, DDD, and DDE (see Appendix A). Replicate analyses were not performed (except for metals in one sample). Hence the reliability of the concentration data (i.e. confidence limits) could not be assessed.

The Ontario MOE has established guidelines to determine whether contamination of aquatic sediments has taken place<sup>10</sup>. These guidelines were designed in order for the MOE to assess the suitability of dredgate spoils for open water disposal. The guidelines have been applied here to give an indication of sediment quality in the Humber Marsh. A list of sediment parameters and their abbreviations, detection limits, and MOE guidelines for dredgate are listed in Appendix A. Results of the pollutant analyses can be found in Appendices 3-2 and 3-3.

Several factors, other than grainsize, may help explain the higher concentration of pollutants in core HM-1. Firstly, the proximity of Pond Two to the main channel may be a significant factor. During high flow events water, suspended sediment and associated pollutants are able to pass more easily from the channel into Pond Two than into any other pond. As a result, Pond Two may receive a larger portion of polluted sediments than ponds farther upstream.

Secondly, a 1983 TAWMS study identified two dry weather outfalls that empty directly into Pond Two <sup>11</sup>. In addition to regular storm flow from rainfall events, these outfalls convey chronic flow from unknown sources and thus may represent a localized source of pollutants. The backup of water into Pond Two during storm events or during times of high water Levels in Lake Ontario may further influence sediment and pollutant accumulation in this pond.

#### 5.2.1 Trace Metal Accumulation

Sediments are a major storage compartment in fluvial systems for specific trace metals and other toxic substances. In this study, six trace metals (which by definition are normally present in sediment at low concentrations) were tested for. Duplicates of one sample were submitted from core HM-1 (46-43 cm). Comparison of the results suggests that concentration differences among samples on the order of those that occur between the duplicate samples cannot be considered significant. Results refer to total metal concentrations; no attempt was made to identify particular metal species.

Table 3 is a summary of trace metal concentrations in the sediments sampled. Mean concentrations of all elements were highest in core HM-1. Samples from core HM-1 also contained the highest concentrations of all elements except Mn. The lowest mean concentrations for all the elements were found in core HC-1.



**Table 3:** Summary of Trace Metal Concentrations in Sediment Cores from the Humber Marsh (all units are µg/g based on sediment dry weight).

Element	Cd (1.0)*		Cr (25)		Cu (25)		Mn		Ni (25)		Pb (50)	
Core	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg
ML-1	<0.5-1.5	<1.1	41-64	58	29-43	38	560-690	597	26-40	34	18-105	63
MS-1	<0.5-1.5	<0.9	39-72	58	23-42	35	650-780	726	21-43	34	18-110	56
BL-1	<0.5-2.5	<0.7	31-80	59	17-56	37	440-970	656	19-47	35	16-150	47
KS-1	<0.5-1	<0.6	53-79	68	36-59	46	660 900	780	34-42	39	22-160	78
HM-1	<0.5-7	<2.4	60-108	86	43-79	64	750-940	815	42-85	54	50-190	118
HC-1	<0.5	<0.5	30-48	42	10-31	22	420-640	534	17-30	25	12-41	18
HC-2	<0.5-1.5	<0.6	41-69	50	20-33	27	510-830	650	21-29	26	14-71	38

\* 1976 MOE Objectives

MOE guidelines for metals in dredgate material suitable for open water disposal provide a guideline for assessing Humber Marsh sediment quality.

Cadmium (1.0 µg/g)

Twenty-one percent of the samples (12) had cadmium values greater than the MOE guideline. Five exceedences occurred in the seven samples from core HM-1.

Chromium (25 µg/g)

All samples tested exceeded the guideline for chromium.

Copper (25 µg/g)

Seventy-nine percent of the samples (45) exceeded the guideline for copper. Most of the samples which did not exceed the guideline were from cores taken from the channel area (HC-1 and HC-2).

Manganese (no MOE objective available)

According to U.S. Environmental Protection Agency (EPA) criteria, sediments containing > 500 µg/g Manganese are heavily polluted. Fifty-three of the samples (93 %) analysed for Mn were above this limit. According to Thomas and Mudroch<sup>12</sup> the background level of manganese in the bluffs surrounding Lake Ontario is approximately 929 µg/g. Only two of the 51 samples analysed had manganese levels greater than this local background level.

Nickel (25 µg/g)

Eighty-six percent of the samples (49) had nickel values greater than the guideline. Of the eight samples which were below the guideline six were from the channel cores.

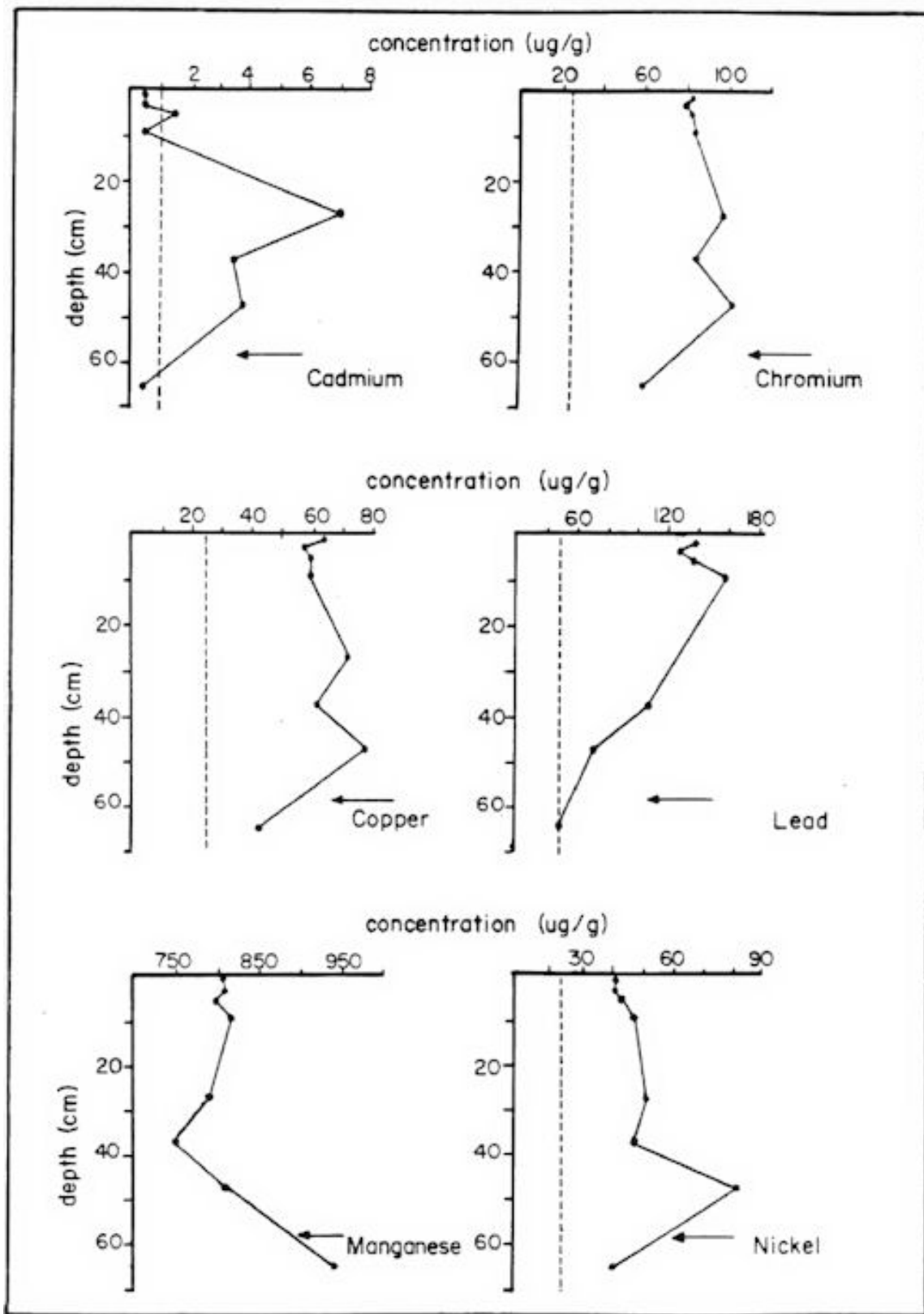
Lead (50 µg/g)

Forty-six percent of the samples (26) exceeded the guideline for lead. All samples taken from core HM-1 had lead concentrations which were greater than or equal to the MOE guideline.

Most elements show no systematic change in concentration with depth (see Fig. 6). The concentrations vary but do so erratically, possibly reflecting grain-size differences between samples, or variations in organic matter and/or metal (Fe, Mn) oxide coatings. Lead is the exception since all of the cores exhibit decreasing lead concentration with depth. The results from the one duplicate sample (core HM-1, 46-48 cm) suggest that concentration differences on the order of 0.5 µg/g for cadmium, 1 µg/g for copper, 2 µg/g for lead, 4 µg/g for nickel, 10 µg/g for chromium and 20 µg/g for manganese should not be considered significant.

Analysis of sediment cores can provide information on anthropogenically related trace metal accumulation. However, before determining if enrichment has occurred, background levels of the metals in question must be established for the environment under study. In cores with low lead concentrations at depth (i.e. 13 µg/g) it is probable that concentrations of other metals are also close to background. Cadmium, chromium, copper, manganese and nickel concentrations do not appear to vary significantly between the surface and the deepest sections analysed suggesting that little, if any, anthropogenic enrichment of these metals has occurred. This result was unexpected considering the urbanized nature of the Humber watershed. Increased sediment yields and grain size as a result of urban development in the Humber watershed may have diluted the effects of increased sediment pollutant concentration.

Background levels of lead were not reached in core HM-1 (Pond Two), as was to be expected based on the high sedimentation rate calculated for this site. However, comparison of metal concentrations in this core with those in neighboring cores indicates cadmium enrichment between 26 and 48 cm, as well as some chromium, copper and nickel enrichment.



**Fig. 6:** Trace metal concentrations in a sediment core (HM-I) from the Humber Marsh (note scale changes, dotted lines are MOE guidelines, ← = 1954).

### 5.2.2 PCB Accumulation

Polychlorinated biphenyls (PCB's) are a group of toxic chlorinated organic chemicals which are highly resistant to degradation. The chemical stability of PCB's allows them to persist and accumulate in the environment. PCB's tend to adsorb onto particulate matter and, in an aquatic environment they preferentially accumulate with fine-grained sediments. PCB's were used extensively in Canada for at least forty years before their use was restricted in 1977 under the Environmental Contaminants Act.

Sediments from the Humber Marsh were analysed for PCB content (see Table 4 for a summary of data). The MOE guideline for PCB's in dredgate soil is 50 ng/g. PCB concentrations in Humber Marsh samples ranged from below detection limit (10 ng/g) to 164 ng/g. The MOE guideline for dredgate was exceeded in 36% of the samples (20) analysed. No PCB's were detected in 20% of the samples. The highest concentrations of PCB's were found in core HM-1 from Pond Two (average 98.5 ng/g); seven out of eight samples from this core exceeded the Ministry guideline. The lowest concentrations occurred in core HC-1 (average 13.5 ng/g) from the channel. Differences in PCB concentration among the cores can be partly attributed to grain size.

The highest PCB concentrations generally occurred less than 10 cm below the surface in cores taken from the ponds and levees (see Fig. 7). Three cores (MS-1, KS-1, and HM-1) exhibited peaks in PCB concentration in sediment that was probably deposited around 1980. However, because of the shallow depths being considered and the uncertainties encountered in determining recent sedimentation rates, peaks in PCB concentration cannot be positively dated. The apparent decline in PCB concentration near the surface may be a reflection of decreased PCB input into the environment due to restrictions imposed on their use since 1977; however more data are needed to validate this trend. In two cores (ML-1 and BL-1) the highest PCB concentrations occurred in the deepest sections analysed. It is not known why such high PCB concentrations were found at this depth, but sedimentation rates, based on stratigraphy and stable lead concentrations, suggest that these sections were probably deposited before 1860.

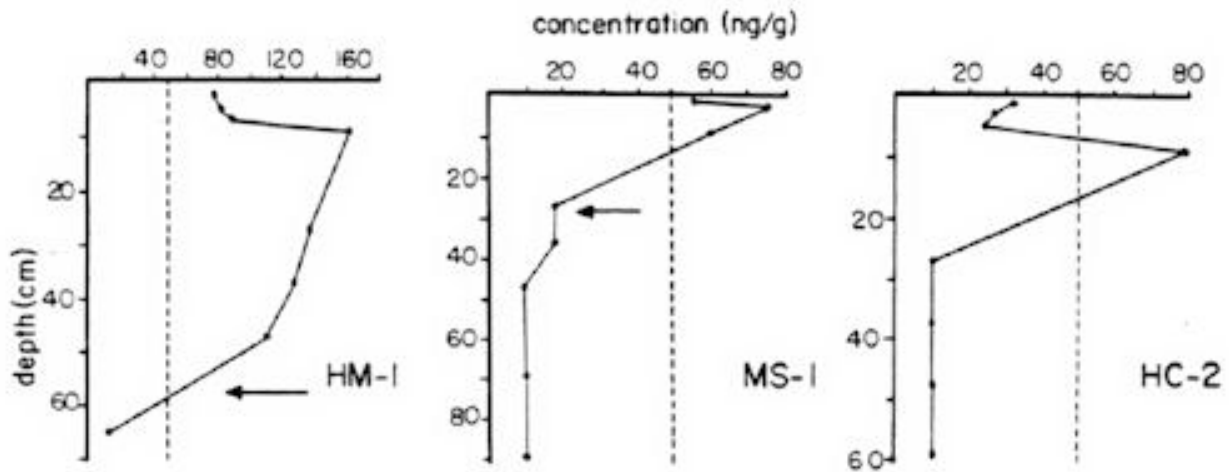
**Table 4:** Summary of PCB Concentrations in Sediment Cores from the Humber Marsh (all units are in ng/g).

Location	Core	Min.	Max.	Avg. <sup>a</sup>	Surf. Conc.
Pond Two	HM-1	12.4	163.4	98.5	68.9
Pond Three	KS-1	<10	139.8	47.2	58.6
Pond Five	MS-1	<10	76.6	32.6	56.6
Levee	ML-1	<10	60.0	39.5	52.7
	BL-1	<10	133.8	39.6	57.1
Channel	HC-1	<10	29.0	13.5	29.0
	HC-2	<10	78.8	25.2	32.3
Summary		<10	163.8	42.3	

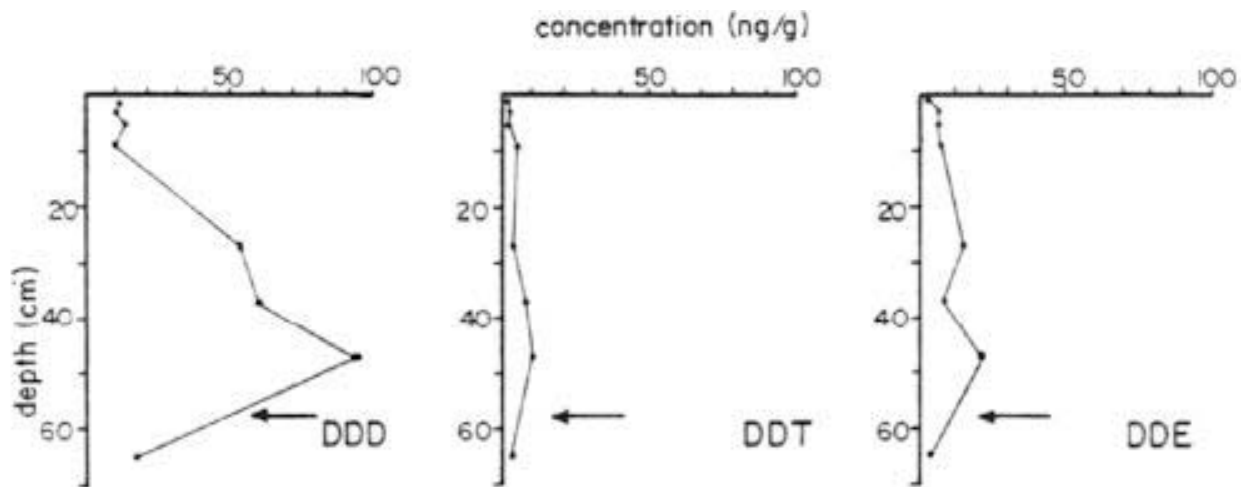
<sup>a</sup> Computed with <10 ng/g = 10 ng/g

PCB concentrations in sediment cores taken from the channel area were comparable to, or less than, concentrations of the same compound in cores from the ponds and levees. Any differences probably reflect grainsize variations between the channel and adjacent environments. Since PCB's have a greater affinity for organic rich suspended solids than for sand or silt most of the PCB's in the Humber River water are probably being transported in suspension downstream to Lake Ontario.

Data on PCB concentrations in nearby fluvial environments are available for comparison. Two surface bed-sediment samples taken from Black Creek and the Humber River in 1981 had PCB concentrations of 50 and 360 ng/g, respectively<sup>13</sup>. Both values are comparable to surface concentrations found in this study. The highest PCB concentrations found in this study were several orders of magnitude less than PCB concentrations found in bottom sediments from the Niagara River.<sup>14</sup>



**Fig. 7:** PCB concentrations in three sediment cores from the Humber Marsh (note scale differences, dotted lines are MOE guidelines, <— = 1954)



**Fig. 8:** DDD, DDT and DDE concentrations in a sediment core (HM-1) from the Humber Marsh (<— = 1954).

### 5.2.3 Pesticide Accumulation

DDT and its metabolites (breakdown products) DDD and DDE, like PCB's and other chlorinated hydrocarbons, are insoluble in water, resistant to degradation and tend to accumulate and persist in aquatic environments.

DDT was first used in Ontario in 1943<sup>15</sup> and was used widely until 1954. In 1954 the first government legislation was passed to control the use of both DDT and DDD in Ontario. Further legislation was passed in 1956, 1957, 1961, 1963 and 1964. By 1967 the Ontario Water Resources Commission had stopped issuing permits for the use of DDT in water and the Department of Lands and Forests had discontinued the use of DDT entirely in all its spraying programs. DDT is now rarely used in Ontario; however, it has not yet been entirely banned.

Results of the analysis for DDT, DDD and DDE are listed in Appendix B-4 and summarized in Table 5. There are no MOE guidelines for pesticide in aquatic sediments. Maximum pesticide concentrations generally occur just above or below the sand Layer attributed to Hurricane Hazel (ca. 1954) and at, or below, the level of maximum PCB concentrations (see Fig. 8). Declining pesticide concentrations near the surface may be a reflection of legislation passed in 1967 which virtually banned the use of DDT. The continued presence of DDT in surface samples is surprising since it is unlikely that there have been any significant inputs of DDT into the Humber watershed since 1967 (unexpectedly high concentrations of DOT were also found in Niagara River sediments<sup>14</sup>). The persistence of DDT is well documented however and its presence in surface sediments from the Humber Marsh may be related to the inwash of previously contaminated soil particles.



**Table 5:** Summary of Pesticide Concentrations in Sediment Cores from the Humber Marsh (all units are in ng/g).

Core	Parameter	Min.	Max.	Avg. <sup>a</sup>	Surf. Conc.
Pond HM-1	DDT	<1	7.5	3.0	1.5
	DDD	9.7	93.9	34.3	12.8
	DDE	<1	21.3	8.3	<1
MS-1	DDT	<1	38.0	6.0	1.6
	DDD	<1	35.1	15.6	13.8
	DDE	<1	6.7	3.4	4.0
KS-1	DDT	<1	11.3	3.7	9.9
	DDD	<1	38.2	17.2	19.1
	DDE	<1	12.0	5.5	5.5
Levee ML-1	DDT	<1	10.7	3.4	3.5
	DDD	<1	52.9	22.5	17.9
	DDE	<1	16.0	5.7	6.7
BL-1	DDT	<1	< 1	< 1	< 1
	DDD	<1	44.8	13.2	25.4
	DDE	<1	13.3	5.3	12.0
Channel HC-1	DDT	<1	5.0	1.7	4.5
	DDD	<1	6.7	1.9	7.2
	DDE	<1	10.7	2.2	18.7
HC-2	DDT	<1	65.0	10.1	5.0
	DDD	<1	70.4	12.4	6.7
	DDE	<1	18.7	5.1	10.7
Summary	DDT	<1	65.0	4.1	-
	DDD	<1	93.9	16.7	-
	DDE	<1	21.3	5.1	-

<sup>a</sup> Computed with <1 ng/g = 1 ng/g

DDT concentrations are generally lower than DDD or DDE concentrations as was to be expected. In the environment, DDT is gradually broken down into its more persistent isomers, DDD and DDE. Relatively low concentrations of DDT compared to its metabolites suggests that little DDT is of recent origin. DDD, the anaerobic breakdown product of DDT, is the most frequently occurring isomer in the Marsh environment. No DDT was detected in core BL-1; however its decomposition products DDD and DDE were present. The highest concentrations of DDD and DDE were also found in core HM-1 from Pond Two.

Surprisingly, the highest concentration of DDT (65 ng/g) was found in the channel sediments (core HC-2) between 8-10 cm. In this sample DDD concentrations were also higher than DDE concentrations. Since DDE is the more stable isomer it would be expected to occur in higher concentrations if no new DDT had been added to the system. These findings may indicate recent use of products containing DDT in the Humber River watershed. However, surface samples from both channel cores showed higher DDE than DDT or DDD concentrations as would be expected if no new DDT had been added.

A recent study dealing with toxic contaminants in the Niagara River reports DDT, DDD, and DDE concentrations in Niagara River bottom sediments ranging from below detection limit (<1 ng/g) to 73, 54, and 280 ng/g, respectively<sup>14</sup>. DDT and DDD concentrations found in the Humber Marsh are comparable to concentrations found in the Niagara River sediments, but DDE concentrations found in Humber Marsh are an order of magnitude lower than those found in Niagara River.

### 5.3 Estimate of Pollutant Masses in Humber Marsh Sediment Compartments

A crude estimate of the total mass of PCBs, chlorinated pesticide (DDT, DDD, DDE), and anthropogenic lead stored in Humber Marsh sediment-pore water compartments can be made from the core data. Estimates were not made for the other trace metals for which data was available because it did not appear that surface concentrations were significantly greater than local background levels. Although metal concentrations (particularly Cd) were elevated in core HM-1, mass estimates for anthropogenically derived trace metals were not determined for this site.

The following equation was used to estimate the mass of PCBs, pesticide and anthropogenic Pb stored in the Marsh sediments:

$$\text{Pollutant Mass} = \sum_{\text{core(s)}} (\sum C_i P_i H_i) A_s$$

where C is the pollutant concentration in kg/kg\* in a given interval,  
P is the bulk density of the sediment in kg/m<sup>3</sup> in a given interval,  
H is the length of an interval in m represented by given concentration and density measurements, and  
A<sub>s</sub> is the sedimentation area in m<sup>2</sup> represented by the core(s).

The pollutant mass calculation was weighted by the length of the interval represented by each concentration measurement, and by the area represented by each core. In all the calculations values recorded as less than the detection limit were set equal to the detection limit; as a result, the mass estimates are maximum possible masses based on the data presented in this study.

The major weaknesses with the mass estimate outlined above are the insufficient number of replicates required to calculate confidence limits, the lack of continuous data throughout the length of each core, the low density of cores in each sedimentary environment, and the possibility of contamination that may have occurred in a few of

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\* for lead, C is the concentration above background (i.e. 13 µg/g).

the deepest samples (i.e. ML-1 and BL-1). As a result, the pollutant masses listed in Table 6 should only be considered as approximations.

Approximate masses of PCBs, pesticide and anthropogenic Pb stored in the sedimentary environments shown in Figure 2 are listed in Table 6 below. However, the results should be considered as order of magnitude estimates. The largest mass of Pb, PCB's, DDE and DDD is associated with the backwater ponds. The largest mass of DDT is associated with the channel and backwater pond sediments.

**Table 6:** Masses of PCBs, Pesticide and Anthropogenic Lead in Humber Marsh Sediment Compartments.

Sedimentary Environment	Total Area (m <sup>2</sup> )	Pollutant Masses (kg)				
		PCB's	DDE	DDD	DDT	Pb
Backwater Ponds	120,000	8.3	1.0	4.6	0.4	8800
Levee-Floodplain	130,000	4.9	0.8	1.7	0.2	2400
Channel	120,000	1.5	0.2	0.5	0.4	500
<b>Totals</b>	<b>370,000</b>	<b>14.7</b>	<b>2.0</b>	<b>6.8</b>	<b>1.0</b>	<b>11700</b>

Data used to estimate the masses of selected pollutants stored in the Humber Marsh sediments are listed in Appendix B-5.

## 6. Summary and Discussion

Pollen, radiochemical and stratigraphic analyses of sediment cores from the Humber River Marsh indicate that rates of sediment accumulation were greater in the backwater ponds than on the levees and that sedimentation rates decreased with increasing distance from Lake Ontario. Historical sedimentation rates in the backwater ponds were several times greater than long term sedimentation rates calculated for Pond Two. However, since urban development in the Humber River watershed has now subsided, future sedimentation rates will probably be lower than those calculated for the past 30 - 124 years.

Contaminated sediments have been accumulating in the backwater ponds and on the levees for at least the past 30 years. This trend will probably continue as long as water quality remains unchanged and these areas continue to receive sediment. In the channel, contaminated sediments may accumulate temporarily (i.e. seasonally) before being transported downstream to Lake Ontario where they probably accumulate in the sediments of Humber Bay.

The channel area is characterized by lower pollutant concentrations than the backwater ponds. Pollutant concentration is directly related to sediment texture and to the fact that, in a marsh environment, fine sediments tend to be associated with organic matter which readily adsorbs both metal and organic contaminants. Two additional factors may help explain the higher pollutant concentrations and higher sedimentation rates found in Pond Two. First, chronic flow from two dry weather outfalls bordering the site may be a localized source of pollutants. Second, the proximity of the site to the channel and to Lake Ontario enables water, suspended sediment and associated pollutants to enter the pond during high flow events and at times of high lake level.

In general, the metal concentrations found in the Marsh were low (probably close to background levels); cadmium and lead were the exceptions. Cadmium concentrations were elevated in Pond Two. Lead concentrations were elevated in the surface sediments of all cores. Ontario Ministry of the Environment guidelines for metals in dredgate material suitable for open water disposal were frequently exceeded.

PCB's and pesticide were found in many of the samples analysed. The Ontario Ministry of the Environment guideline for PCB's in dredgate material was exceeded in about one third of the samples. In most cores, PCB and pesticide concentrations declined near the surface. DDT was found in near surface channel sediments possibly indicating recent use of this compound in the watershed.

Several general points relevant to urban river environmental quality are illustrated by this study. First, coarser channel sediments may remain relatively clean while nearby zones where fine-grained sediments accumulate may become polluted. As a result, samples taken from the channel areas may not be representative of local sediment (or water) quality. Second, since sediment deposited during and after urbanization is often coarser than previously deposited material, variations in sediment pollutant concentration with depth may not reflect changing water quality over time unless grainsize effects are removed. Third, the use of regionally established background levels for metals as an indication of local sediment quality may not always be appropriate because natural metal concentrations may vary considerably among different environments.

In this study for example, concentrations of Cr, Cu, Mn, and Ni exceeded MOE guidelines for dredgate even though surface concentrations of these metals did not appear to differ significantly from those at depth (i.e. background level). Fourth, because local sedimentation rates may vary considerably, it is important to investigate sedimentation rates before designing a sampling program to insure that background levels of compounds of interest are reached and that appropriate sampling intervals are chosen. Sampling can then proceed in the most focused manner and analytical expenses can be reduced.

Results from this study are relevant to future studies on the Humber River and to those interested in monitoring sediment and pollutant accumulation in urban rivers. The Humber Marsh is a popular recreational area and valuable wildlife habitat; the presence of pollutants in the sediments may be incompatible with these uses.

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## Appendices

**Appendix A:** List of Study Compounds and their Abbreviations, Detection Limits and MOE Objectives.

Compound	Abbreviation	Detection Limit (µg/g)	MOE Objective (µg/g)
Cadmium	Cd	0.5	1.0
Chromium	Cr	1	25
Copper	Cu	1	25
Manganese	Mn	2	NA
Nickel	Ni	2	25
Lead	Pb	2	50

		(ng/g)	(ng/g)
Polychlorinated biphenyls	PCB's	10	50
1,1,1 -trichloro-2,2-bis(4-chloro-phenyl)-ethane	4,4-DDT	1	NA
1,1 -dichloro-2,2-bis(4-chlorophenyl)- ethylene	4,4-DDE	1	NA
1,1 -dichloro-2,2-bis(4-chlorophenyl)- ethane	4,4-DDD	1	NA
Polonium	Po		
Radium	Ra		
Radon	Rn		

**Appendix B-1:** Results of Po-210 analysis for core HM-2.

Depth (cm)	Supported Po-210 Specific Activity DPM/g	Error in Po-210 Specific Activity (1 sigma) DPM/g
0-2	3.8	0.4
5-7	4.9	0.4
10-12	4.1	0.4
15-17	3.5	0.4
30-32	2.8	0.4
45-47	2.9	0.4
60-62	3.1	0.4
70-72	2.7	0.4
80-82	2.4	0.4
90-92	2.2	0.4
94-96	2.1	0.4
100-102	2.5	0.4
125-126	1.7	0.2
147-148	1.4	0.2

DPM/g = disintegrations per minute per gram

**Appendix B-2:** Complete Results of Metal Analysis (unspecified units are µg/g).

Core	Depth (cm)	Cd	Cr	Cu	Mn	Ni	Pb
		R=83% MDL=0.5	R=96% MDL= 1	R=105% MDL= 1	R=102% MDL= 2	R=112% MDL= 2	R=102% MDL= 2
ML-1	0-2	1.0	64	42	620	36	104
	3-5	1.0	59	42	590	35	105
	7-9	1.5	64	43	560	37	100
	12-14	1.5	59	40	600	33	77
	18-20	0.5	41	29	560	26	38
	34-36	1.5	54	39	690	34	46
	52-54	<0.5	64	36	560	40	29
	69-71	1.0	56	30	600	34	13
MS-1	0-2	1.0	64	42	780	38	95
	2-4	1.5	59	38	750	35	86
	8-10	1.5	63	41	740	37	110
	26-28	1.0	39	23	650	21	35
	35-37	<0.5	50	31	680	29	42
	46-43	1.0	72	39	750	43	43
	68-70	<0.5	64	33	700	40	22
	89-91	<0.5	50	29	760	32	18
KS-1	0-2	<0.5	75	59	740	34	120
	2-4	1.0	79	49	690	35	110
	8-10	<0.5	73	50	790	40	160
	26-28	<0.5	53	39	890	38	56
	36-38	<0.5	65	48	840	42	70
	46-48	<0.5	64	47	790	40	49
	58-60	<0.5	69	39	600	41	38
	68-70	<0.5	66	36	900	40	22
BL-1	0-2	<0.5	66	46	610	33	110
	2-4	2.5	72	56	580	47	150
	8-10	<0.5	31	17	480	19	24
	26-28	<0.5	52	28	660	31	20
	36-38	<0.5	80	38	800	39	21
	46-48	<0.5	60	34	970	33	18
	58-60	<0.5	56	34	710	35	16
	68-70	<0.5	56	43	440	38	18
HM-1	0-2	<0.5	83	64	810	43	140
	2-4	<0.5	80	58	810	43	130
	4-6	1.5	83	60	800	45	140
	3-10	<0.5	84	60	820	49	160
	26-28	7.0	98	72	790	53	190
	36-33	3.5	85	62	750	49	110
	46-48	4.0	98	78	800	81	74
	46-43	3.5	108	79	820	85	72
	64-66	<0.5	60	43	940	42	50

**Appendix B-2** cont.

Core	Depth (cm)	Cd	Cr	Cu	Mn	Ni	Pb
		R=83% MDL=0.5	R=96% MDL= 1	R=105% MDL= 1	R=102% MDL= 2	R=112% MDL= 2	R=102% MDL= 2
HC-1	0-2	<0.5	40	21	640	21	41
	2-4	<0.5	30	10	550	17	20
	6-8	<0.5	38	24	480	23	14
	8-10	<0.5	44	23	550	23	16
	12-14	<0.5	40	31	420	25	14
	26-28	<0.5	47	22	560	29	14
	28-30	<0.5	46	25	530	31	15
	33-40	<0.5	48	22	540	30	12
HC-2	0-2	<0.5	48	26	630	21	62
	2-4	<0.5	54	32	750	26	54
	4-6	<0.5	48	30	700	26	71
	8-1	1.5	52	33	830	29	62
	26-28	<0.5	46	27	510	23	14
	36-38	<0.5	69	25	530	28	14
	46-48	<0.5	41	20	650	24	14
	58-60	<0.5	42	20	600	25	14

R = percent recovery

MDL = method detection limit

**Appendix B-3:** Complete Results of Analysis for PCB's and Pesticides (unspecified units are ng/g).

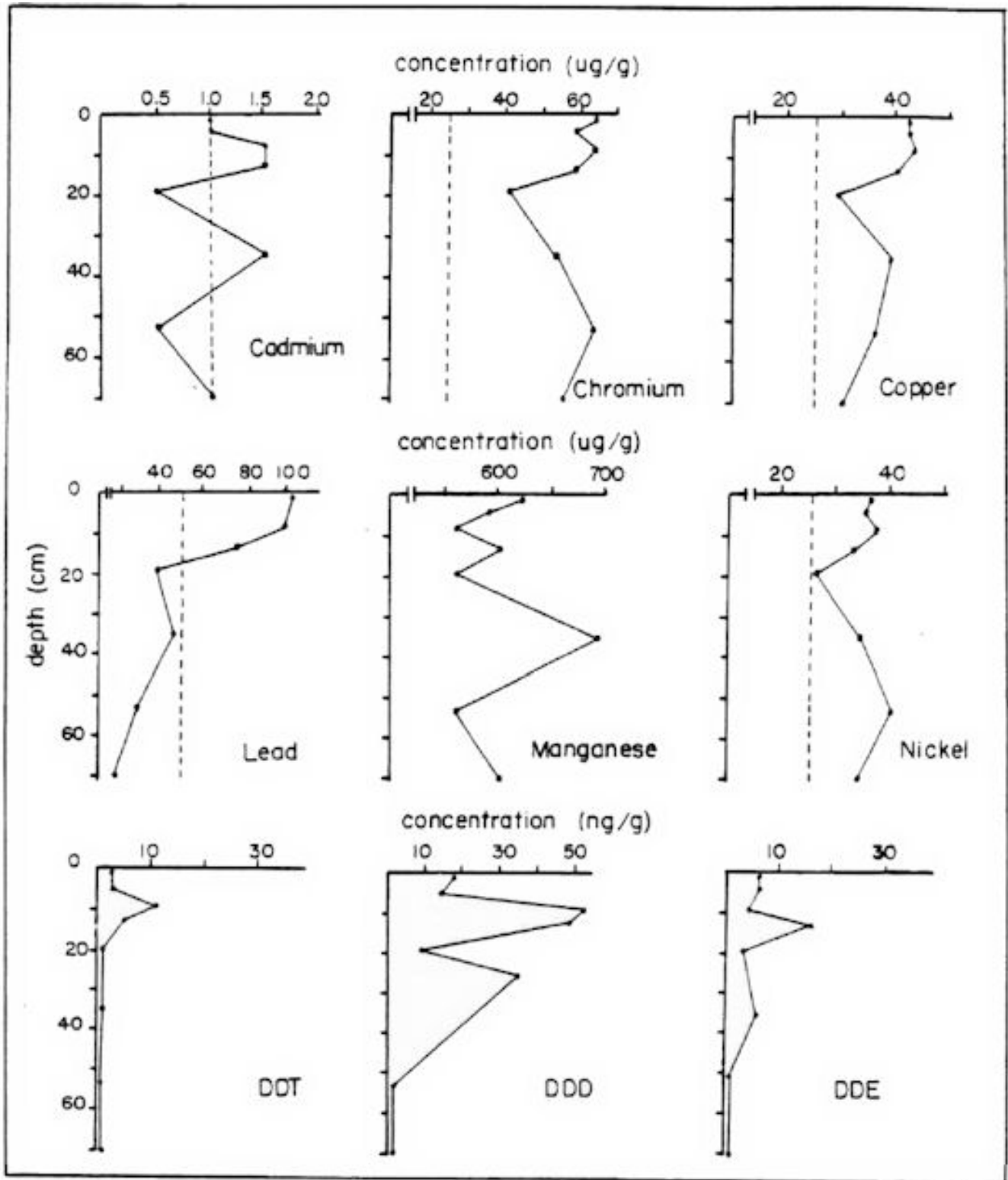
Core	Sediment Interval (cm)	Total PCB R=82% MDL=10	4,4-DDE R=85% MDL= 1	4,4-DDD R=90% MDL= 1	4,4-DDT R=92% MDL= 1
ML-1	0-2	52.7	6.7	17.9	3.5
	3-5	46.1	6.7	14.6	3.4
	7-9	60.7	4.0	52.9	10.7
	12-14	30.2	16.0	48.2	5.1
	13-20	16.5	3.3	9.6	1.1
	34-36	13.4	6.0	35.1	1.2
	52-54	< 10	< 1	<1	< 1
	69-71	86.5	1.5	<1	<1
MS-1	0-2	56.6	4.0	13.8	1.6
	2-4	76.6	6.7	13.2	38.0
	8-10	61.0	2.0	12.2	3.3
	26-28	18.4	4.7	28.0	< 1
	35-37	18.0	4.7	35.1	< 1
	46-48	< 10	2.7	19.2	< 1
	68-70	< 10	< 1	< 1	< 1
	89-91	10.2	1.3	2.3	<1
KS-1	0-2	58.6	5.5	19.1	9.9
	2-4	69.5	5.8	17.9	11.3
	8-10	139.0	6.0	14.4	< 1
	26-28	24.3	4.7	33.2	3.6
	36-38	31.7	12.0	13.8	< 1
	46-48	34.6	7.8	25.0	<1
	58-60	< 10	< 1	3.0	< 1
	68-70	< 10	< 1	< 1	< 1
BL-1	0-2	57.1	12.0	25.4	< 1
	2-4	76.2	13.3	44.8	< 1
	8-10	< 10	2.5	24.4	< 1
	26-28	< 10	8.7	6.0	< 1
	36-38	< 10	< 1	< 1	< 1
	46-48	< 10	< 1	< 1	< 1
	58-60	< 10	< 1	<1	< 1
	68-70	133.8	3.1	1.7	<1
HM-1	0-2	68.9	< 1	12.8	1.5
	2-4	79.6	6.0	11.9	2.2
	4-6	83.8	6.0	13.8	1.7
	8-10	163.4	6.7	9.7	4.5
	26-23	139.4	14.7	54.0	3.4
	36-38	128.5	8.0	60.4	7.5
	46-48	112.0	21.3	93.9	< 1
	64-66	12.4	3.3	17.8	2.4

**Appendix B-3** cont.

Core	Sediment Interval (cm)	Total PCB R=82% MDL=10	4,4-DDE R=85% MDL= 1	4,4-DDD R=90% MDL= 1	4,4-DDT R=92% MDL= 1
HC-1	0-2	29.0	10.7	6.7	5.0
	2-4	10.0	< 1	2.7	2.7
	6-8	<10	< 1	< 1	< 1
	8-10	< 10	< 1	< 1	< 1
	12-14	19.0	< 1	< 1	< 1
	26-28	<10	< 1	< 1	< 1
	23-30	< 10	< 1	< 1	< 1
	33-40	< 10	< 1	< 1	< 1
HC-2	0-2	32.3	18.7	7.2	4.5
	2-4	25.6	3.3	7.7	4.9
	4-6	24.0	4.7	9.7	2.8
	8-10	78.8	8.0	70.4	65.0
	26-28	< 10	2.7	< 1	< 1
	36-38	< 10	< 1	< 1	< 1
	46-48	<10	< 1	< 1	< 1
	58-60	< 10	< 1	< 1	< 1

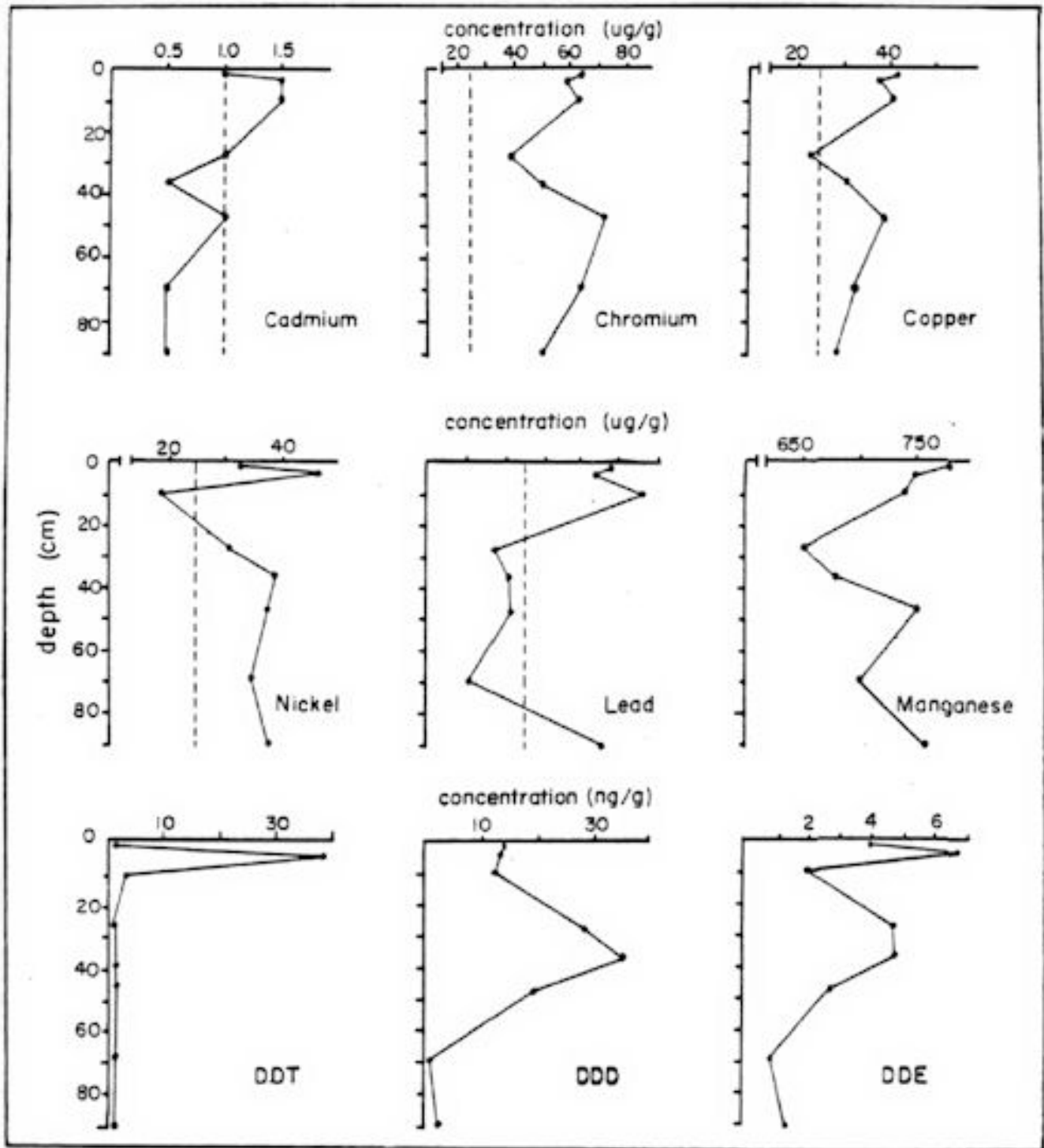
R = percent recovery

MDL = method detection limit

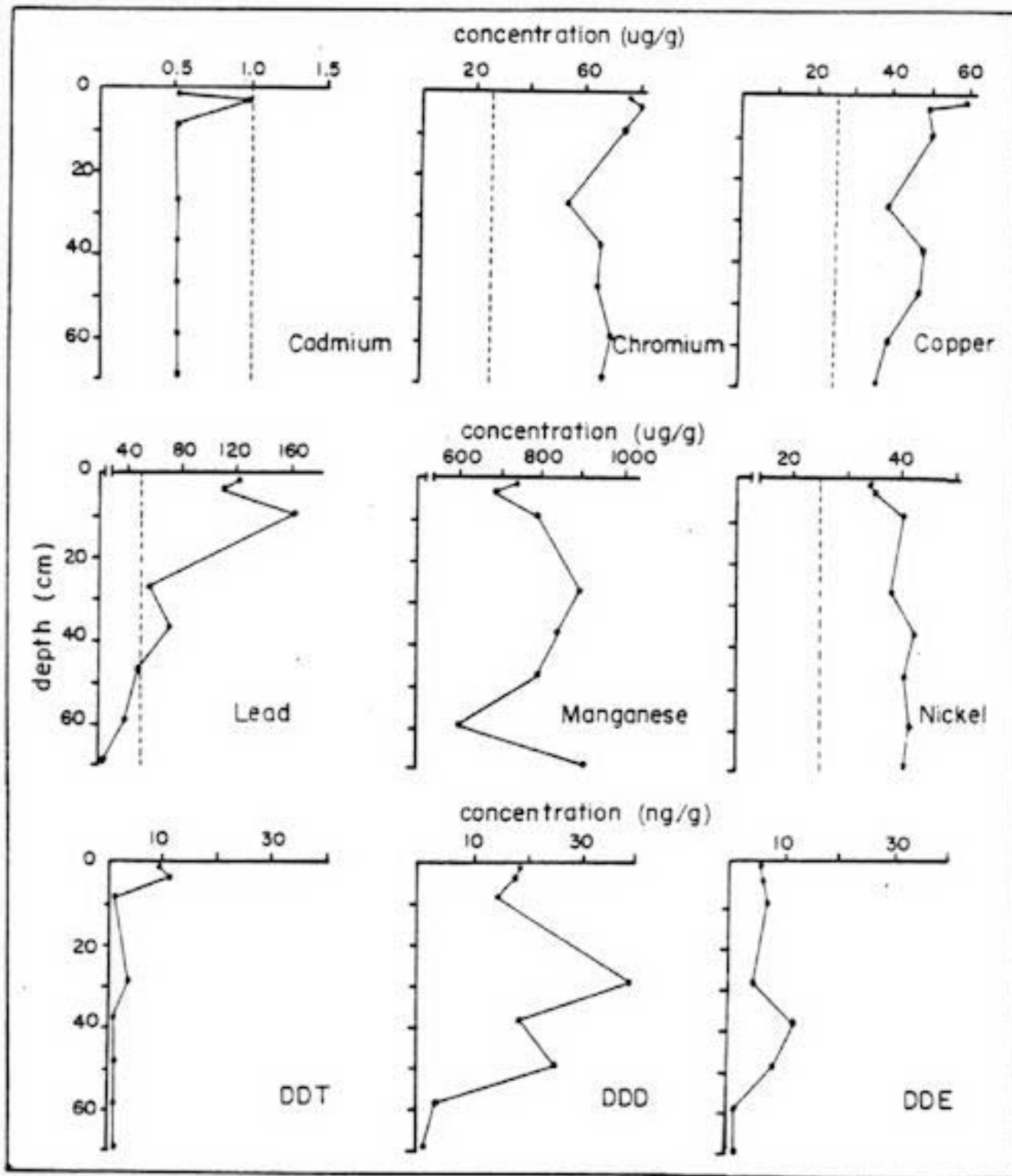


**Appendix B4a:** Contaminant concentration versus depth in core ML-1 (note scale changes, dotted lines are MOE guidelines )

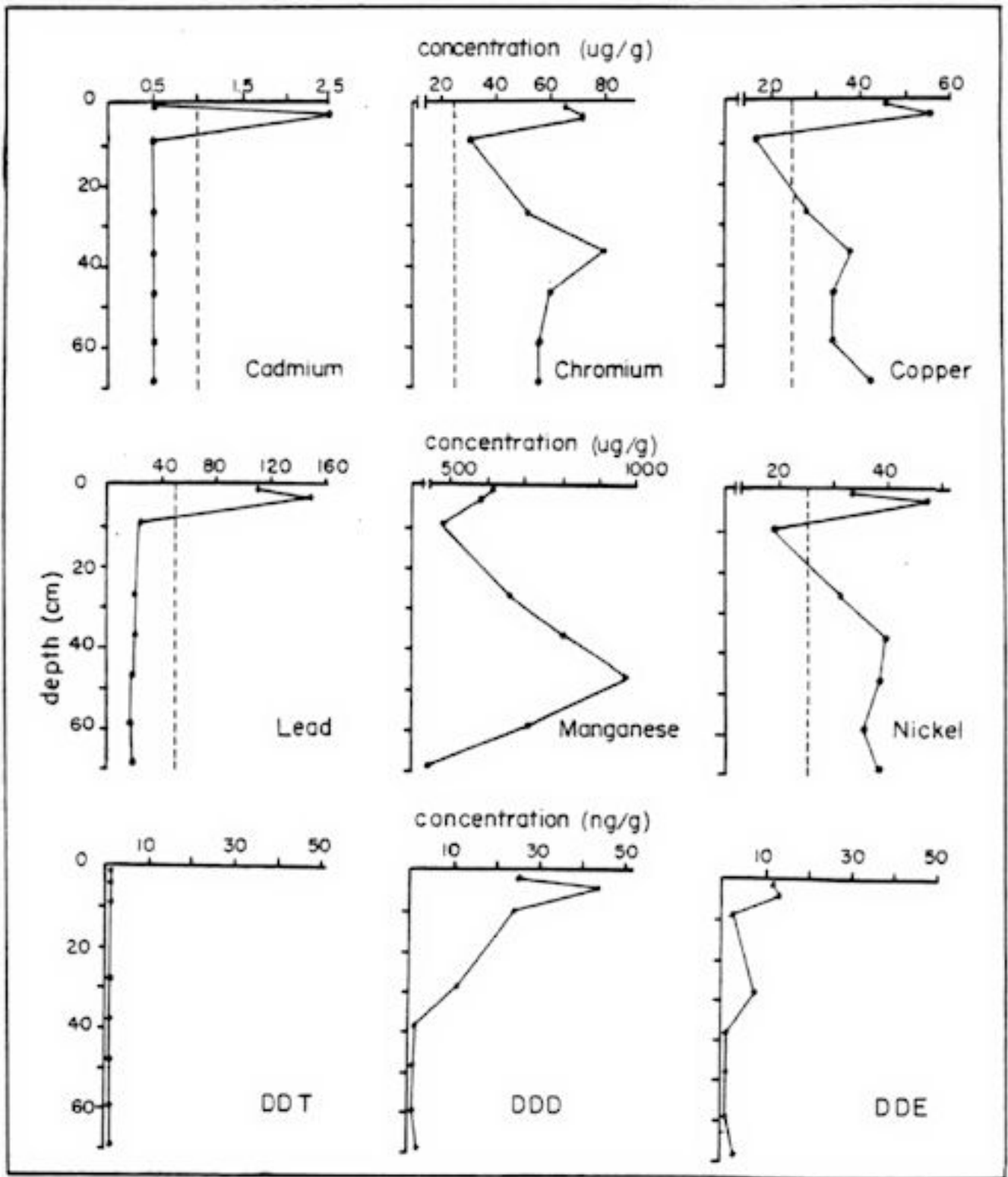




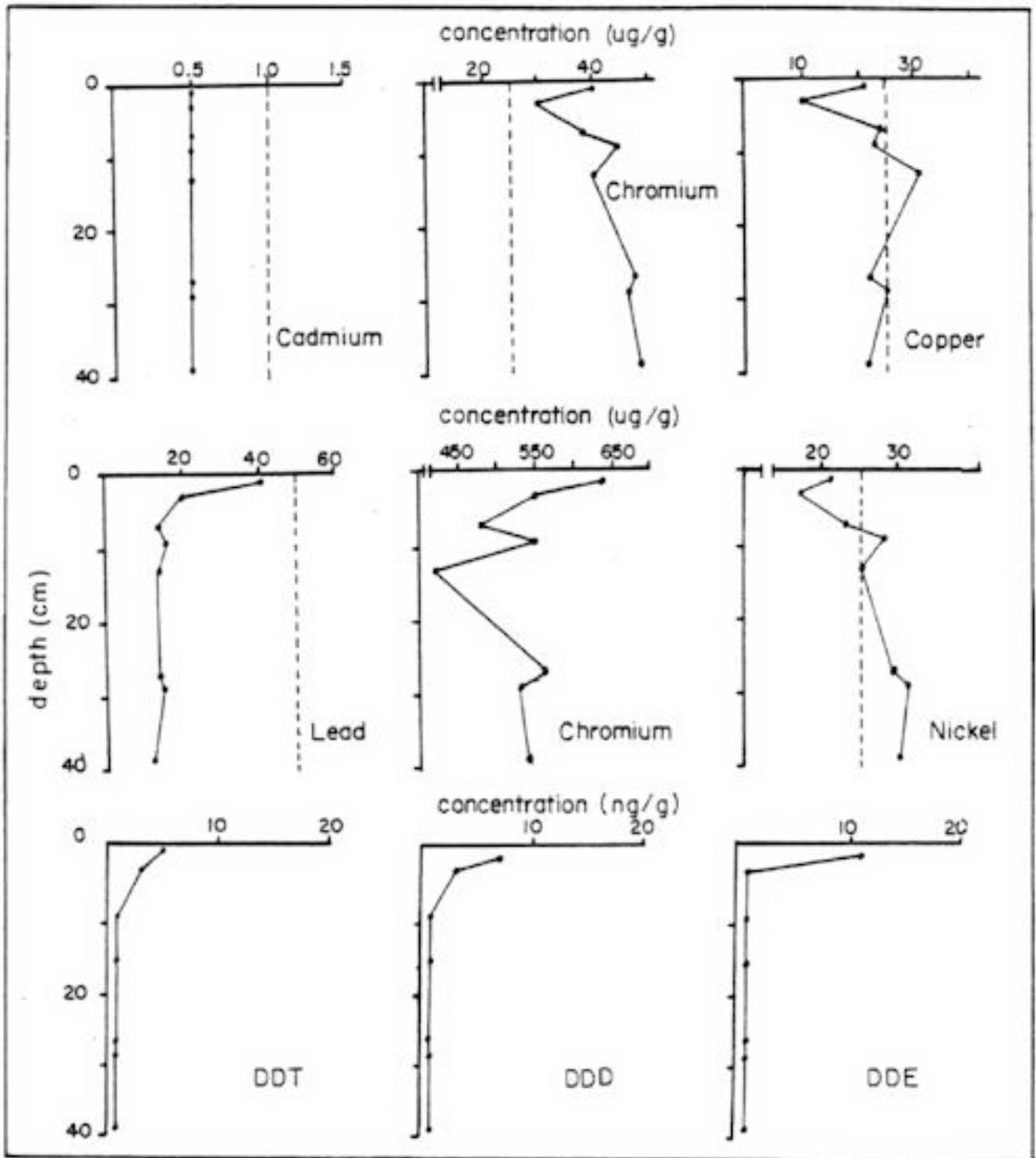
**Appendix B4b:** Contaminant concentration versus depth in core MS-I, (note scale differences, dotted lines are MOE guidelines).



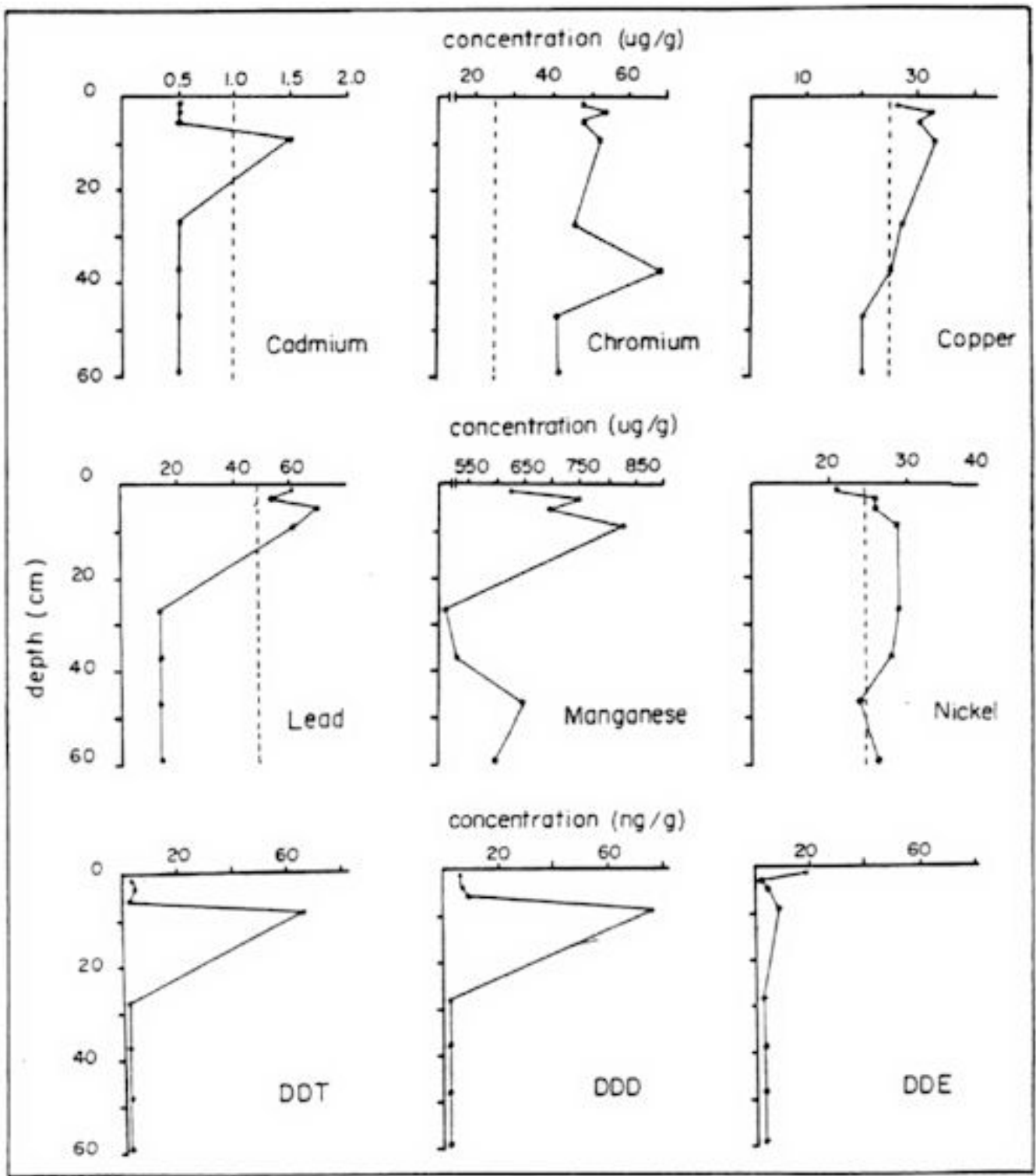
**Appendix B4c:** Contaminant concentration versus depth in core KS-1 (note scale changes, dotted lines are MOE guidelines).



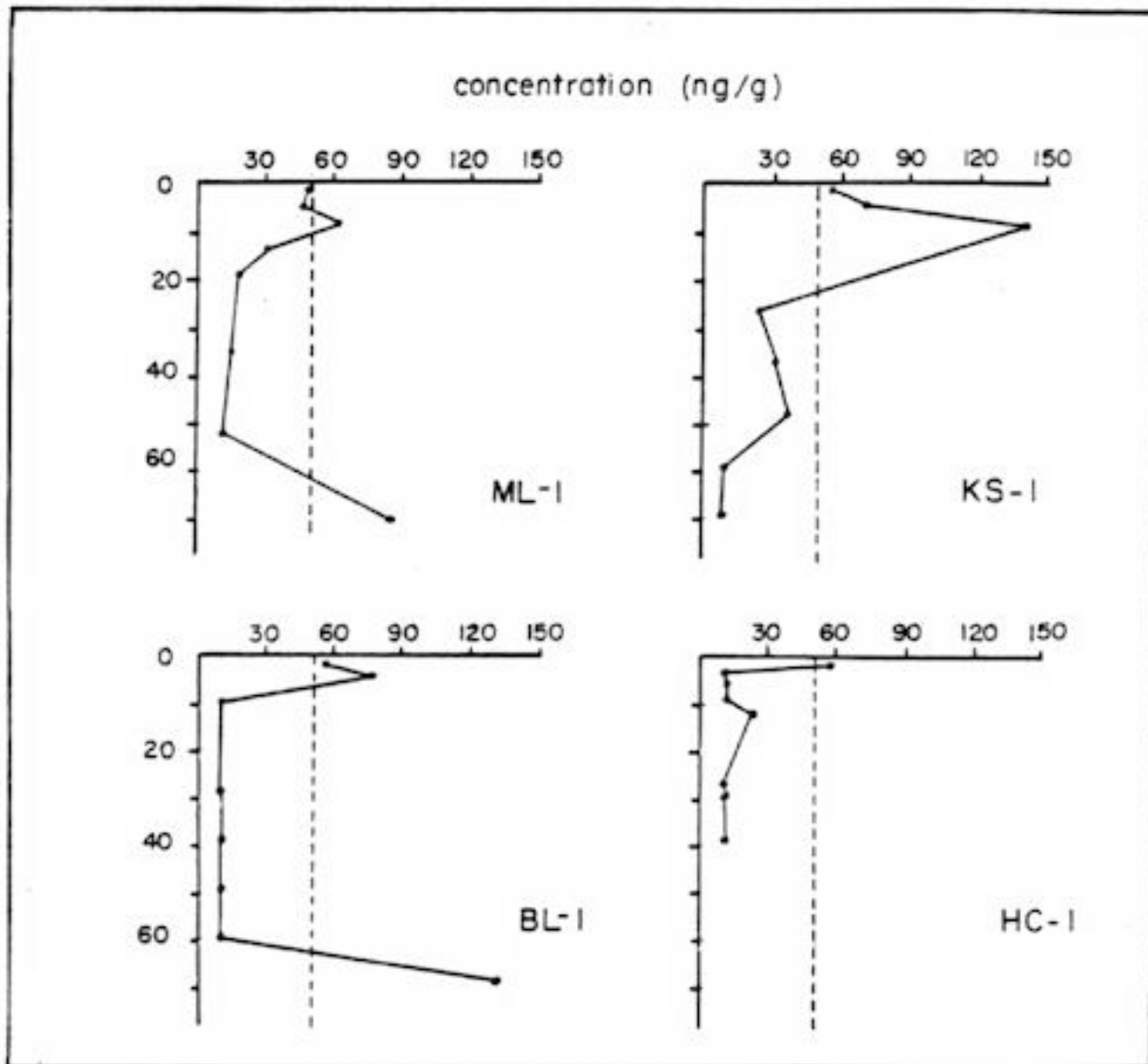
**Appendix B4d :** Contaminant concentration versus depth in core BL-1 (note scale changes, dotted lines are MOE guidelines).



**Appendix B4e:** Contaminant concentration versus depth in core HC-1 (note scale changes, dotted lines are MOE guidelines).



**Appendix B4f:** Contaminant concentration versus depth in core HC-2 (note scale changes , dotted lines are MOE guidelines).



**Appendix B4g :** PCB concentration versus depth in four cores from the Humber Marsh (dotted lines are MOE guidelines ).

**Appendix B-5:** Data Used to Estimate Pollutant Mass Balance.

Location	Core	PCB's	DDE	DDD	DDT	Pb	A <sub>s</sub>
		----- kg/m <sup>2</sup> •10 <sup>-6</sup> -----				kg/m <sup>2</sup> •10 <sup>-3</sup>	m <sup>2</sup> •10 <sup>3</sup>
Pond Two	HM-1	97.7	10.6	47.8	3.7	99.9	69
Pond Three	KS-1	40.8	8.2	30.3	3.7	51.5	21
Pond Five	MS-1	23.7	4.0	20.7	3.1	26.1	30
Levee- floodplain	ML-1	44.5	8.2	20.2	2.4	29.7	65
	BL-1	31.2	4.3	6.7	1.1	6.6	65
Channel	HC-1	7.5	0.8	0.8	0.8	0.4	60
	HC-2	17.2	2.6	7.4	6.6	7.7	60

**Appendix B-5:** Bulk Densities Used to Estimate Masses of Pollutants in Humber Marsh Sediment Compartments.

Core	Depth (cm)	Density g/cm <sup>3</sup>	Core	Depth (cm)	Density g/cm <sup>3</sup>
ML-1	0-2	1.46	HM-1	0-2	1.20
	3-5	1.36		2-4	1.58
	7-9	1.47		4-6	1.61
	12-14	1.88		8-10	1.73
	18-20	1.80		26-28	1.41
	34-36	1.74		36-38	1.74
	52-54	1.66		46-48	1.58
	69-71	1.78		64-66	2.10
MS-1	0-2	1.32	HC-1	0-2	1.56
	2-4	1.44		2-4	1.62
	8-10	1.46		6-3	1.71
	26-28	1.74		8-10	1.70
	35-37	1.86		12-14	1.45
	46-48	1.56		26-28	1.66
	68-70	1.63		28-30	1.72
	89-91	1.53		38-40	1.78
KS-1	0-2	1.54	HC-2	0-2	1.74
	2-4	1.62		2-4	1.86
	8-10	1.63		8-10	1.84
	26-28	1.84		8-10	2.06
	36-38	1.83		26-28	1.56
	46-48	1.72		36-38	1.62
	58-60	1.46		46-48	1.77
	68-70	1.59		58-60	1.62
BL-1	0-2	1.39			
	2-4	1.38			
	8-10	1.77			
	26-28	1.61			
	36-38	1.50			
	46-48	1.55			
	53-60	1.52			
	68-70	1.32			