BIOLOGICAL AND TOXICOLOGICAL INVESTIGATIONS OF CHICAGO AREA NAVIGATION PROJECTS

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Illinois Natural History Survey Contract Report

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CHAPTER 1: PURPOSE AND INTRODUCTION

PURPOSE

The purpose of this study was to obtain site-specific biological data necessary to evaluate the environmental impacts of dredging and disposal of contaminated bottom sediments from navigation projects in Chicago, Illinois. The study was designed with the following informational needs as goals:

1. Define the existing conditions of the biological communities inhabiting the study areas.

2. Define the existing levels of polychlorinated biphenyls (PCBs) in surface sediments and dominant biota within the study areas.

3. Determine the relative toxicity of existing surface sediments in the study areas using bioluminesent bacterial assays, microbial respiration, and protozoan community assays.

4. Provide site-specific biological data needed for the development of future contaminant-fate models.

5. Investigate the feasibility of monitoring indigenous organisms for PCB uptake in lieu of caging planted test organisms in future biomonitoring of dredging and disposal operations.

This study was funded by the US Army Corps of Engineers, Chicago District.

INTRODUCTION

Corps Mission

The US Army Corps of Engineers is authorized to maintain a number of projects serving commercial navigation in the Chicago area. The waterways of Chicago are principally man-made channels and harbors used by deep draft (>18 ft) and shallow draft (<10 ft) vessels. Periodic maintenance dredging of these waterways is required to remove bottom sediments and restore navigable depths. The Chicago waterways, like other urban rivers, accumulate bottom sediments contaminated with a variety of pollutants.

Bottom Sediments

Bottom sediments are the product of a number of hydrodrologic and hydraulic processes, including sheet and bank erosion and sedimentation. Bottom sediments are also a primary sink, or repository of pollution. Settleable pollutants, entering the waterways from street runoff, point discharges, and sewer overflows may accumulate below outfalls. Other pollutants, particularly those of low water solubility, may become adsorbed onto bottom sediments directly or onto suspended matter which settle downstream.

Bottom sediments may also represent a source of pollution to the overlying water column. Sediments having much organic matter can exert a significant oxygen demand on the overlying water column. Nitrogen, phosphorous, and other chemicals can also be released from bottom sediments in-place or through resuspension.

The impacts of contaminated in-place bottom sediments on water quality and aquatic biota had been largely overlooked by regulatory agencies until recently. The International Joint Commission on the

Great Lakes (IJC) has highlighted in-place pollutants as a subject of concern. The US Environmental Protection Agency (EPA) has been directed under the 1987 Clean Water Act (Section 118) to conduct demonstrations of technologies for remedial action to address in-place polluted sediments.

A study, conducted by the Corps' Waterways Experiment Station (WES) examined the impacts of contaminated sediments in the Grand Calumet River and Indiana Harbor Canal on water quality (Brannon et al., 1986). The relative importance of mechanisms controlling contaminant movement from bottom sediments in these waterways are as follows: transport of contaminants associated with particulates > transport of contaminants desorbed from suspended particulates > transport of contaminants desorbed from deposited sediment > bioaccumulation of contaminants from deposited sediments.

Dredging and Disposal

The presence of pollution in bottom sediments and concerns over the fate of this contamination have resulted in many changes to the Corps' dredging and disposal policies in the last 20 years. Dredged sediments containing levels of contaminants classified as polluted according to USEPA criteria (1977) are no longer suitable for unconfined, open-water disposal. Major research efforts have been conducted by the Corps and other agencies regarding the impacts of dredging and disposal. This study is a continuation of these efforts.

The Corps has built over 30 confined disposal facilities (CDFs) around the Great Lakes for the disposal of polluted sediments dredged from navigation projects. Confined disposal facilities have been constructed both on land and in water. The in-lake facilities are generally diked structures of graded stone. All CDFs have been designed to contain the sediment particulates, and the Corps and USEPA have concurred that these structures have performed this function quite effectively.

Recently, concerns have been expressed about possible leaching of low levels of dissolved contaminants from permeable in-lake CDFs and their effect on organisms attracted to reef-like habitat of the CDF dikes. Routine water quality monitoring has been unable to discern any long term leaching and other more sensitive monitoring techniques were proposed by the USEPA and US Fish and Wildlife Service (USFWS). An interagency CDF work group was formed by the Corps, USEPA and USFWS to determine the levels of contaminant release and its environmental significance. The Corps developed a mass balance model to predict the contaminant release from CDFs. In addition, biomonitoring is being considered for some existing facilities.

PCB Contamination in Water, Sediments, and Biota

On the Great Lakes, PCB contamination has received widespread attention largely because of the ubiquitous presence of this chemical group in game fish. Advisories on fish consumption have been in effect since the early 70's. Hydrophobic substances, such as PCBs, are by definition poorly soluble in water, yet may be found in readily detectable concentrations in fish tissues and many bottom sediments.

Great Lakes waters generally contain PCB concentrations well below routine detection limits (< 0.1 ppb). PCB body burdens in fish vary over a wide range. Generally, species having a high fat content exhibit greater PCB burdens. Concentrations of PCBs in bottom sediments also show a wide variation. High sediment PCB contamination is usually associated with large industrial areas or specific point sources. PCB contaminated sediments often contain a great amount of organic matter, though all highly organic sediments do not necessarily contain high concentrations of PCBs.

Equilibrium Partitioning

The affinity of non-polar contaminants for soils having a high organic content and for fish with a high fat content has been known for some time. The sorptive ability of a soil or sediment for PCBs has been correlated to its organic content. The concept, referred to as partitioning, is akin to a solubility index. PCBs are, in effect, dissolved in the organic matter associated with the sediment particles. Physically, this is an adsorbtive binding rather than a solute:solvent relationship. In fish tissues, the lipid also serves as a kind of non-polar solvent to which PCBs are preferentially partitioned.

The equilibrium partitioning approach provides a means to predict the sorptive ability of a sediment or biological tissue for any hydrophobic chemical. This method can be used to predict the relative concentrations of PCBs in sediment, water, or biological tissues at equilibrium. The relationship may be represented as follows:

$$\frac{C_s}{K_{ow}\ TOC\ F_c} = C_w = \frac{C_b}{K_{ow}\ LIP\ F_l}$$

where:
C_s = concentration of PCB in sediment (ppm)
C_w = concentration of PCB in water (ppm)
C_b = concentration of PCB in biological material (ppm)
K_{ow} = octanol:water partitioning coefficient (l/kg)
TOC = total organic carbon of sediment (%)
LIP = lipid content of biological material (%)
F_c = sediment carbon preference factor (rel. to octanol)
F_l = biological lipid preference factor (rel. to octanol)

The octanol:water partitioning coefficient for PCBs by Arochlor or for a specific congener can be determined by laboratory experiments. Sediment and biological preference factors account for the differences in the partitioning between octanol:water and sediment carbon:water and biological lipid:water. Sediment carbon and biological lipid may be more or less efficient than octanol as an "organic solvent".

Toxicity of Polluted Sediments

Sediments are complex mixtures of inorganic and organic compounds, both man-made and natural. Interactions between these many components cannot be detected by chemical analysis. Furthermore, using only chemical analyses may cause components of toxicological significance to be overlooked (Ross, 1987). Toxicity testing can predict whether components in a sediment are interacting in a manner hazardous to the aquatic ecosystem.

Single-species toxicity was performed on sediment extracts obtained by elutriation, a water leach using one part sediment to four parts leaching water. Elutriation, developed as an accurate method to predict which components of the sediment will be released into the water column, has been used in a wide range of conditions in marine, estuarine and freshwater systems (Engler, 1980).

Elutriates from sediment samples at project sites were used in the Microtox™ assay. This test was developed on the principle that the luminescent properties of the bacterium *Photobacterium phosphoreum* will be inhibited upon exposure to a toxic substance. The luminescence of cultures

exposed to a series of dilutions of elutriate was measured with the Microtox™ analyzer, a specially designed fluorometer. After correcting the decrease in luminescence of stressed cultures with the measured natural light decay in the blank samples, a dose-response curve is plotted by comparing elutriate concentrations with percent luminescence loss at each concentration.

One goal of hazard evaluation is to assess or predict the effect of released substances on organisms in an ecosystem. As appreciation of the complexity of ecosystems has grown, so has concern about possible bias in hazard assessments based solely on single-species tests under laboratory conditions. The microbial community that colonizes artificial substrates includes a variety of organisms ranging from bacteria to small metazoans such as insect larvae. This community is a composite of the communities inhabiting natural substrates. On group inhabiting these substrates is the Protozoa, which includes representatives of virtually every feeding type: primary producers, grazers, filter-feeders, and predators. Thus, the reactions of this group of organisms might be similar to the reactions of the broader community of organisms (algae, aquatic plants, mollusks, fish, etc.). In this study natural protozoan communities were exposed in a variety of experiments to sediments and elutriates from selected stations in the project area.

STUDY AREAS

Among the navigation projects in the Chicago Area that the Corps of Engineers is authorized to maintain are the Chicago River, the Chicago Harbor, and the Calumet River and Harbor (plate 1). The Corps has constructed a confined disposal facility at Calumet Harbor to contain polluted sediments dredged from these navigation projects. Biological investigations were conducted to provide information necessary for evaluating the environmental effects of maintenance dredging and confined disposal operations.

A limited number of study areas were selected for these biological investigations. These sites were; the Chicago River in the vicinity of Goose Island, the Chicago Area CDF, and two areas of Calumet Harbor.

Chicago River (Site D)

The Chicago River drains approximately 200 square miles of Cook and Lake Counties in Illinois, and discharges to the Illinois River via the Chicago Sanitary and Ship Canal. The flow regime is highly modified. Flows include large portions of municipal wastewater and diverted Lake Michigan water. The federal navigation channel extends from the Chicago Harbor to the North Avenue Turning Basin on the North Branch (plate 2). The channel is approximately 200-300 feet wide, with an authorized depth of 21 feet. The Chicago River, above Clark Street has not been dredged since 1966, and siltation of the channel has reduced depths to nearly half the authorized limits.

The bottom sediments of the Chicago River were sampled by the Corps in 1980, 1983, and 1986. A summary (USACE, 1980) of surficial sediment chemical analysis is shown on table 1. The river sediments are primarily fine-grained silts and clays. Pollutants present in the sediments include many heavy metals, nutrients, organic matter, and PCBs. The levels of pesticides and aromatic hydrocarbon contaminants in the sediments are generally not of concern. Sediment contamination is principally the result of municipal and industrial point discharges and overflows from the combined sewer system.

About 20 percent of sediment samples collected from the Chicago River above Clark Street in 1980 and 1983 contained PCBs at levels exceeding 50 ppm. The higher concentrations were generally found in the deeper layers, near project depth. Because of the high levels of PCBs, the sediments from this portion of the Chicago River were excluded from disposal to the CDF at the time of its construction. Recent sediment analysis has created some question as to the precise PCB levels in Chicago River sediments (USACE, in prog).

The Chicago River, in the vicinity of Goose Island was chosen as a study site because it represents

the only remaining portion of navigation channel not dredged in the last five years. As such it provides an opportunity for contrasting biological studies before and after maintenance dredging. This particular portion of the river was believed to contain the highest levels of PCBs in surface sediments.

Chicago Area Confined Disposal Facility (Site A)

The Corps of Engineers is authorized to construct, operate and maintain confined disposal facilities (CDFs) to contain polluted dredged materials. A facility for the disposal of dredged materials from the Chicago navigation projects was constructed by the Corps in 1983-4. The construction of the Chicago Area CDF was the result of an 11 year study to find a suitable disposal option for these dredged materials. In all, some 25 sites and/or combinations of disposal sites and dredging plans were analyzed and evaluated in the Final Environmental Impact Statement, Chicago Area Confined Disposal Facility and Maintenance Dredging in Cook County, Illinois (USACE, 1982).

The CDF is located in Calumet Harbor (plates 3 and 4). It is triangular in shape and covers 43 acres, extending out from existing shoreline. Its design capacity is 1.45 million cubic yards. The CDF is formed of a stone-filled dike, with a core of prepared limestone, and a crest elevation of +12 feet LWD.

The dike was built with a synthetic membrane liner along the entire interior face. During and after construction of the dike observations suggested that the liner was not intact. A blanket of silty-sand was constructed along the interior face of the CDF dike to provide a barrier of low permeability. The silty-sand was excavated from the lake bottom inside the CDF pond and placed mechanically against the dike (figure 1). The 'sand-blanket' has retarded the interchange (figure 2) between the lake and the CDF pond. The CDF dike is permeable, but effectively retains all sediments disposed.

The CDF is divided into two sections or basins. Dredgings are disposed to the larger section, which functions as a primary settling basin. During disposal operations water is pumped out of the smaller basin to filter cells. This pumpage serves to maintain a negative hydraulic gradient between the CDF and the harbor and limits flow through the dike. The filter cells remove residual suspended solids before the effluent is discharged to the Calumet River.

The sediments within the CDF are a combination of sediments existing preconstruction, sediments relocated during construction, and sediments disposed from maintenance dredging operations. During construction of the CDF (1983), approximately 38,000 cubic yards of material was removed hydraulically from the foundation area where the NE corner of the CDF dike wall now stands. This material was disposed to the south cell of the CDF (plate 5) to accomodate construction of the advancing dike wall. This material resembled fly ash and was polluted with oil and grease, heavy metals and nitrogen. PCB was non-detectable at 1 ppm in this 'special excavation' material.

During construction, silty sand was excavated from borrow areas within the CDF (plate 5) to form the sand blanket. The CDF has received sediments from three maintenance dredging operations since its construction:

Dredging location	Volume (cu. yds.)	Year
Calumet River	100,000	1984
Calumet River	100,000	1985
Chicago River/Harbor	70,000	1986

Maintenance dredging was conducted by clam-shell dredge and materials were transported to the CDF by barge. Dredgings were disposed to the CDF mechanically using methods shown on figure 3. This material was deposited in the north end of the CDF (plate 5). A volume weighted average of the

sediment chemical analysis from these maintenance dredgings is listed on table 2. Based on soundings within the CDF and sediment concentration data, rough calculations estimate the average surface concentrations of PCB to be 1.3 ppm PCB (dry weight).

The Corps has developed a management strategy for the CDF to optimize environmental performance and available space. Moderately polluted dredgings will be placed along the interior face of the dike wall in order to fortify the sand-blanket. Capacity in the center of the CDF will be reserved for more contaminated dredgings.

Water quality monitoring of the CDF during disposal operations includes sampling of five open water stations in the Harbor and River, one station in the CDF pond, and composite sampling of the filter cell effluent during disposal operations. Wells in the CDF dike and land adjacent to the facility are monitored year-round on a monthly and quarterly basis.

Results from water quality monitoring have shown the CDF to be operating as designed and meeting all discharge standards. Effluent from the filter cells during disposal operations has generally contained less than 10 mg/l suspended solids, indicating that > 99.99% of the sediment solids are being retained by the CDF. No significant change of ambient water quality conditions has been observed outside the dike walls or in monitoring wells. Water quality conditions within the pond during disposal operations are nearly identical to that of the harbor outside the CDF walls. Only small increases in suspended solids and nitrogen are evident in the CDF pond during disposal. Special monitoring of the CDF pond immediately around disposal operations indicate that there is little turbulence and resuspension from the mechanical disposal methods used beyond 50 feet of the disposal point.

The Chicago Area CDF was chosen as a study site because it is the only operational dredged disposal facility in the Chicago area, and a substantial data base already exists. The biological investigations at the Chicago CDF will provide much needed data for the further development of the mass balance model, information on the utilization of the CDF dike by aquatic communities, and guidance for the selection of a biomonitoring approach.

Calumet Harbor (Sites B and C)

Calumet Harbor is located at the southern boundary of Chicago. Portions of the Harbor are in Indiana. The Harbor is bounded on the north by a 6700 foot stone-filled timber crib breakwater, and on the northeast by a 5000 foot stone-filled sheetpile detached breakwater. The Harbor is approximately 3300 acres in area. The navigation channel is 3000 feet wide, with authorized depths of 28 and 29 feet (LWD). Calumet Harbor was last dredged in 1970, and existing depths are 2 to 3 feet less than the authorized limits.

The Harbor is bordered on the northwest by the US Steel South Works, and on the west by the Chicago Area CDF and the Iroquois Landing Port Facility operated by the Chicago Regional Port Authority. Iroquois Landing is a landfill which was once the site of Youngstown Sheet and Tube Steel Co. Borings analyzed indicate that this landfill is composed of slag, fly ash, steel mill and construction wastes.

The Calumet River flows inland toward the Illinois River and this flow is controlled at the O'Brien Lock and Dam. Flows are reversed to the Lake only rarely during extreme rainfall events. Bottom sediments of Calumet Harbor have been sampled by the USEPA (1975) and Corps (1980, 1981). USEPA sediment data (plate 6) shows that the levels of contamination decreased as one moves lakeward from the River "mouth". Harbor sediments were generally far more sandy than the river sediments. A summary of surficial sediment chemical analysis (USACE, 1980) is listed on table 1.

Two areas of Calumet Harbor were chosen as study sites in order to assess the impacts of the operating Chicago Area CDF on Calumet Harbor. Portions of the Harbor along the outside of the

CDF dike (site B) were studied because it is the area most likely to show such impacts. Portions of the Harbor along the attached crib breakwater (site C) were studied as a reference site. It was felt that the habitat provided by this breakwater was most similar to the CDF dike surface, yet far enough away to not be directly impacted by CDF operations.

SCOPE OF STUDY

During August, 1986, the Illinois Natural History Survey (INHS) was contracted by the Chicago District to perform biological and sediment-toxicity survey at the above study areas. Sediments, benthos, crayfish, periphyton, plankton and fish were collected from the four study sites:

Site A. Inside the Chicago Area Confined Disposal Facility (CDF) located south of the Calumet River on the west shoreline of Calumet Harbor (Lake Michigan) in Chicago, Illinois.

Site B. Immediately outside (within 200 feet) of 4,000 feet of the CDF rubble-mound dike walls.

Site C. Along the south side of the breakwater located approximately 3500 feet north of the CDF within Calumet Harbor as a designated reference area assumed outside the impact area of the CDF.

Site D. The Chicago River (North Branch) near Goose Island and the North Avenue Turning Basin in Chicago, Illinois.

Samples of sediment, fish and other biological materials were delivered frozen to Daily Analytical Laboratories of Peoria, Illinois for analysis of total PCBs, total organic carbon (TOC), lipid and water content under contract with the Chicago District. The INHS conducted Microtox™ bacterial toxicity, microbial respiration assays and protozoan colonization tests on collected sediments. The INHS also performed in-situ protozoan colonization tests inside and near the CDF. The INHS provided intensive taxonomic classification of the benthic comminuty and rough estimates of standing crop (biomass) for benthos, periphyton and plankton. The INHS also conducted a survey of fish populations using gill nets, traps and boat electrofishing.

The results of chemical analysis of sediment and biological materials are discussed in Chapter 2. The results of protozoan colonization and respiration bioassays are discussed in Chapter 3. The results of Microtox™ bacterial luminescence assays are discussed in Chapter 4. Appendix A gives the results of benthic collections as well as a discussion of annelid worm distribution. The fish and crayfish survey results are listed in Appendix B. A contract report of chemical assays performed by Daily Analytical Laboratories is included as Appendix C. The results of fish tissue analysis by the Illinois Environmental Protection Agency, by the request if the Illinois Department of Conservation, on 12 selected harbor fish samples is included as Appendix D.

Plate 7 shows the locations of sampling stations in this study.

Table 1. Results of Bulk Sediment Chemical Analyses of the Chicago River (near Goose Island) and Calumet Harbor (1980).

Parameter	Location: *Chicago River Average	Location: **Calumet Harbor Average
Ammonia Nitrogen	24	5.3
TKN	2750	860
Phenol	0.25	0.1
Total P	1100	206
O&G	8300	902
Cyanide (CN)	0.49	1.3
COD	335,000	86,000
TVS	26%	9.5%
Arsenic (As)	2.2	6.2
Cadmium (Cd)	61	3.2
Chromium (Cr)	503	46
Copper (Cu)	468	44
Lead (Pb)	895	144
Mercury (Hg)	2.0	0.4
Zinc (Zn)	1825	268
Manganese (Mn)	305	948
PCB's as Arcoclors	5.9	0.6

* 1 grab sample; 3 core samples (top 12-24 inches), 1980.
** 5 grab samples; includes Calumet River near mile 0.0, 1980.

Table 2. USACE bulk analysis of dredged material disposed to the Chicago CDF during 1984, 1985 and 1986

PARAMETER	MEANS (MG/KG dry weight) 1984	1985	1986	RANGE	Volume Weighted Mean
TS (%)	52.0	54.6	54.0	37-74	53.5
TVS (%)	11.1	7.2	9.3	2.4-19.0	9.2
TOC (%)	NA	NA	5.8	0.9-(.6	5.8
COD (%)	13.5	5.5	3.9	2.1-29.0	8.0
TKN	1624	722	910	81-4900	1105
Oil/Grease	7445	1888	3360	650-15000	4328
Ammonia-N	137.4	72.9	80.0	2.4-240.0	98.6
Phosphorous	514	308	360	180-1000	398
Arsenic	5.2	19.1	2.2	<0.3-74.0	9.6
Barium	46	28	66	8.4-190	45
Cadmium	2.89	1.30	2.70	0.82-5.10	2.25
Chromium	35	19	24	3-62	26
Cyanide	1.18	0.20	0.23	<0.01-5.10	0.57
Iron (%)	4.03	1.89	0.81	<0.54-5.40	2.40
Lead	297	88	140	18-520	179
Manganese	1069	452	140	130-2100	600
Mercury	0.16	8.10	0.57	<0.01-88	3.21
Nickel	27	24	14	8.6-50	23
Zinc	1108	270	170	61-2300	554
Copper	58	30	42	4.4-100	43
PCB	4.42	0.70	5.40	0.29-19.00	3.30
No. Samples	11	11	7		
Volume Disposed (cu. yd)	100,000	100,000	70,000		

1% = 10000 mg/kg dry weight.
NA = No analysis performed.

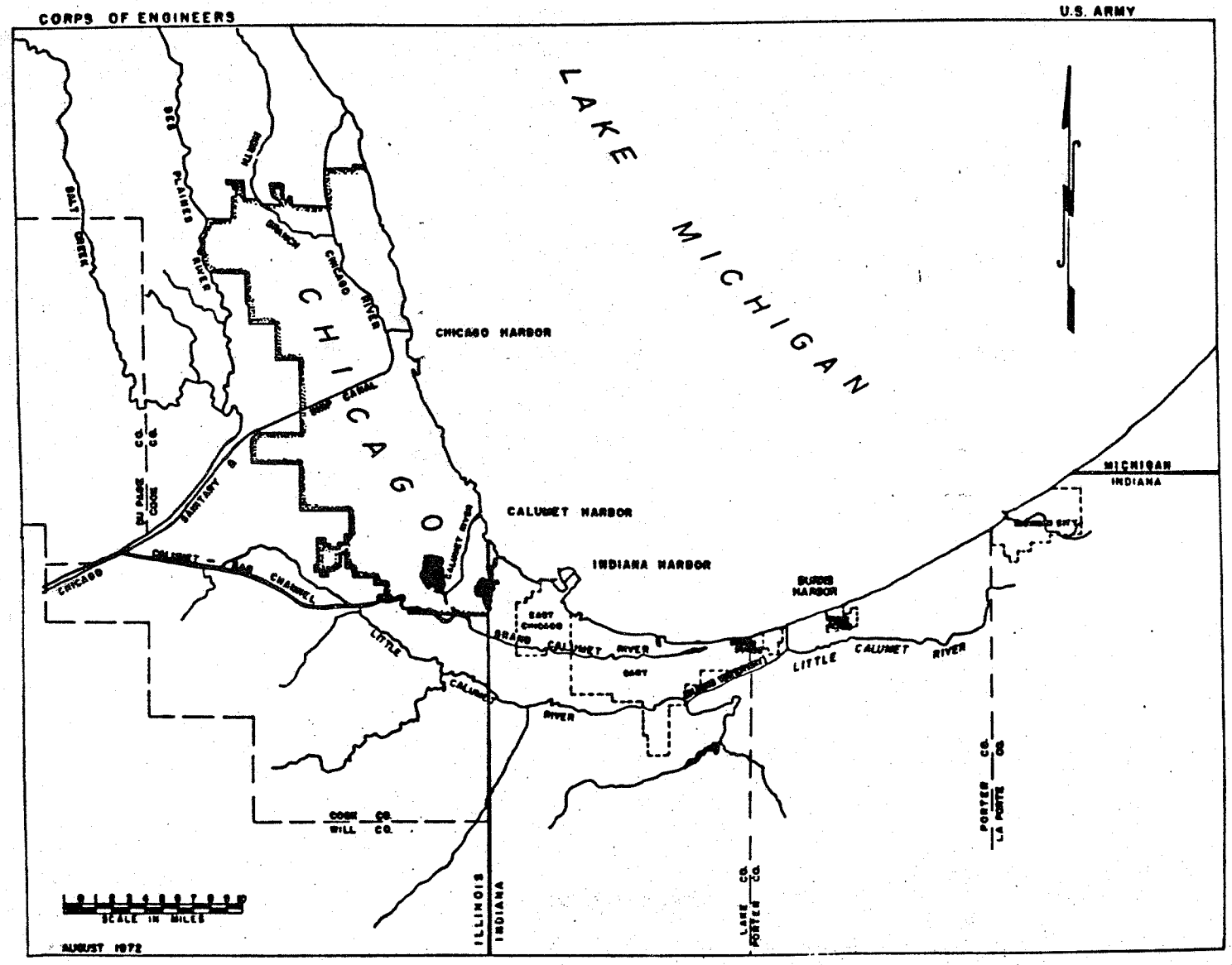


Plate 1. Chicago Area Navigation Projects

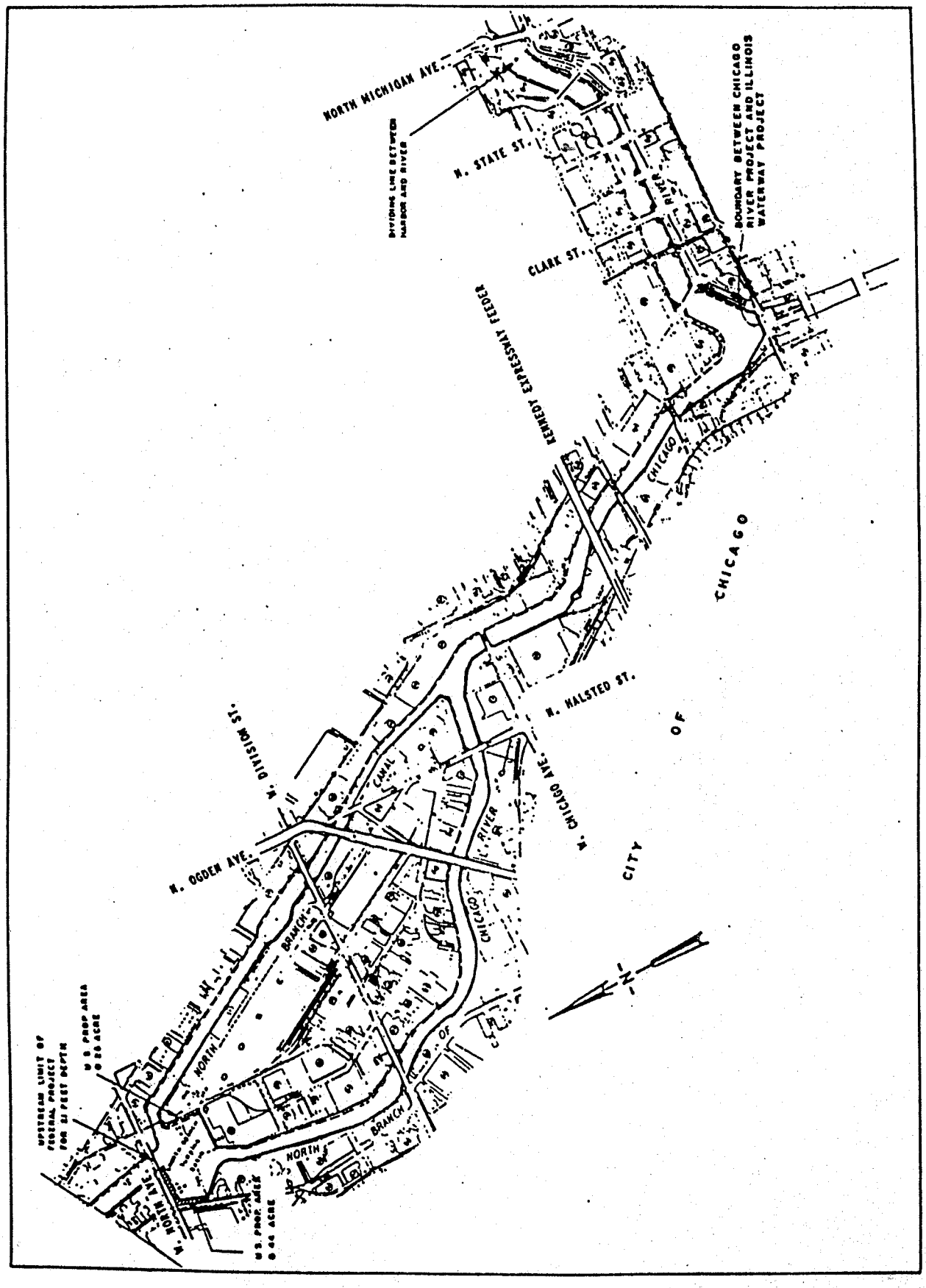


Plate 2. Area of Chicago River (North Branch) with PCB-Contaminated Sediments in need of Dredging

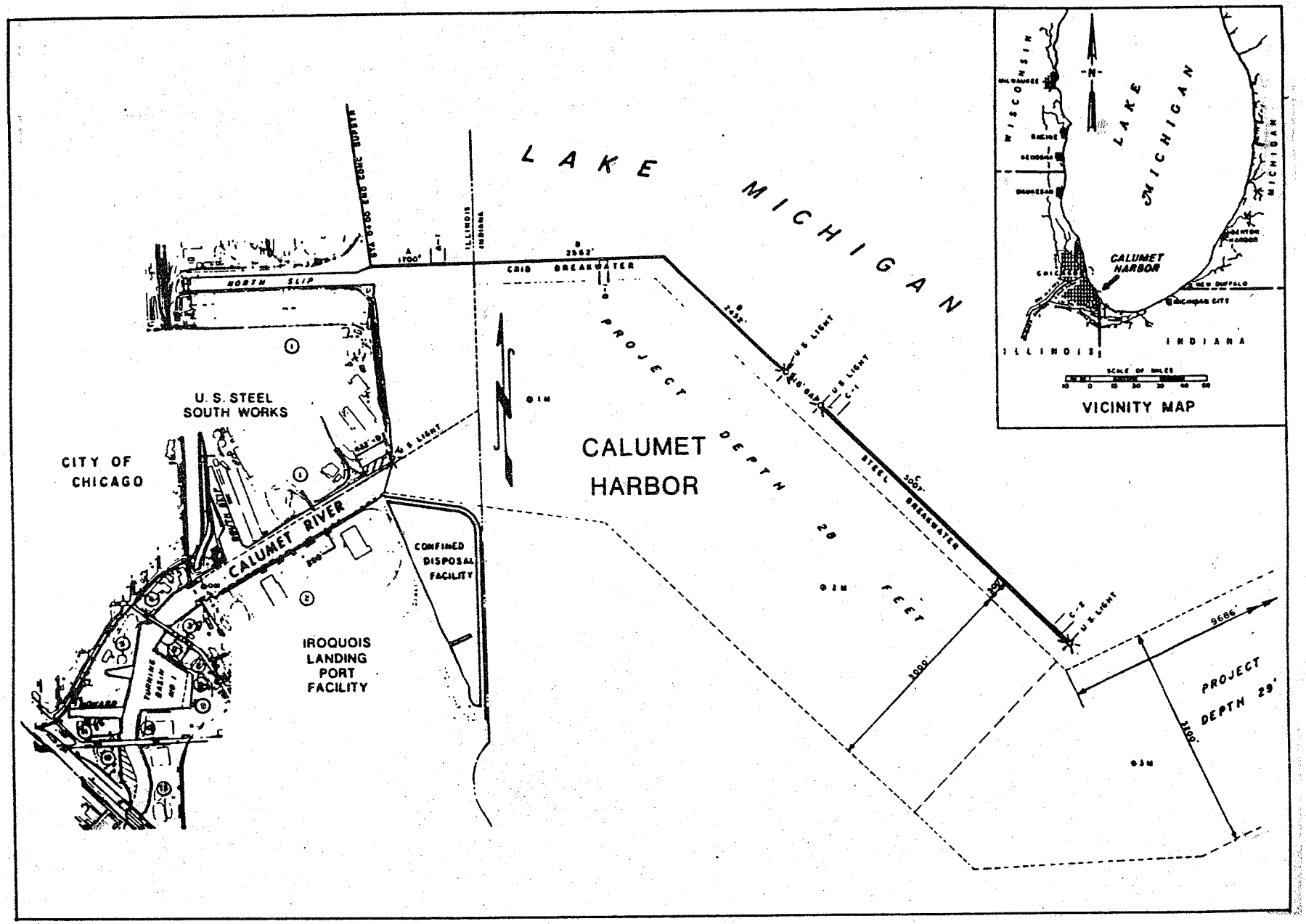


Plate 3. Calumet Harbor Navigation Channel and Location of Confined Disposal Facility (CDF)

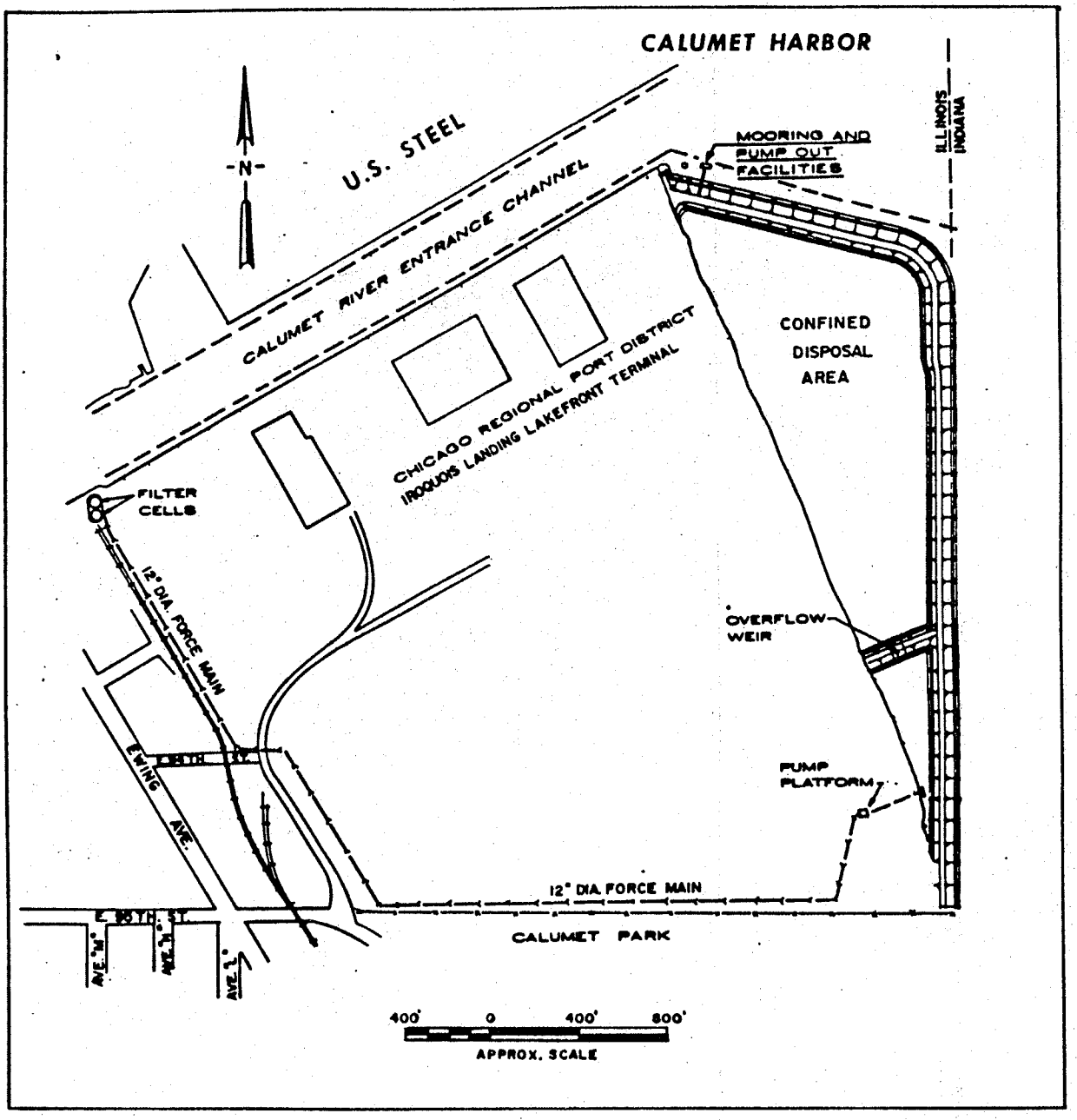


Plate 4. Chicago Area Confined Disposal Facility
Calumet Harbor, Illinois

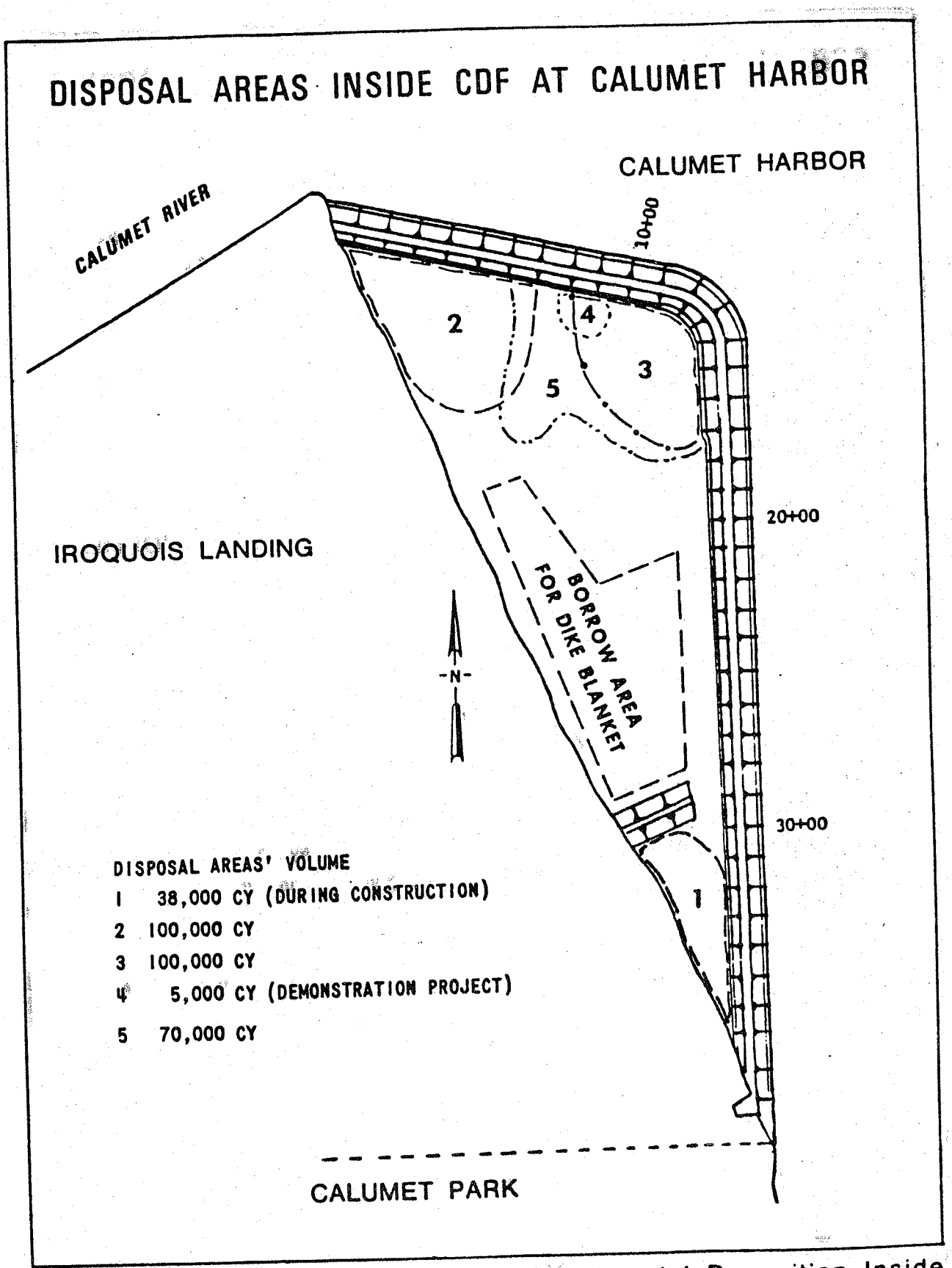


Plate 5 . Areal Distribution of Dredge Material Deposition Inside the Confined Disposal Facility (CDF) at Calumet Harbor to Date (1986)

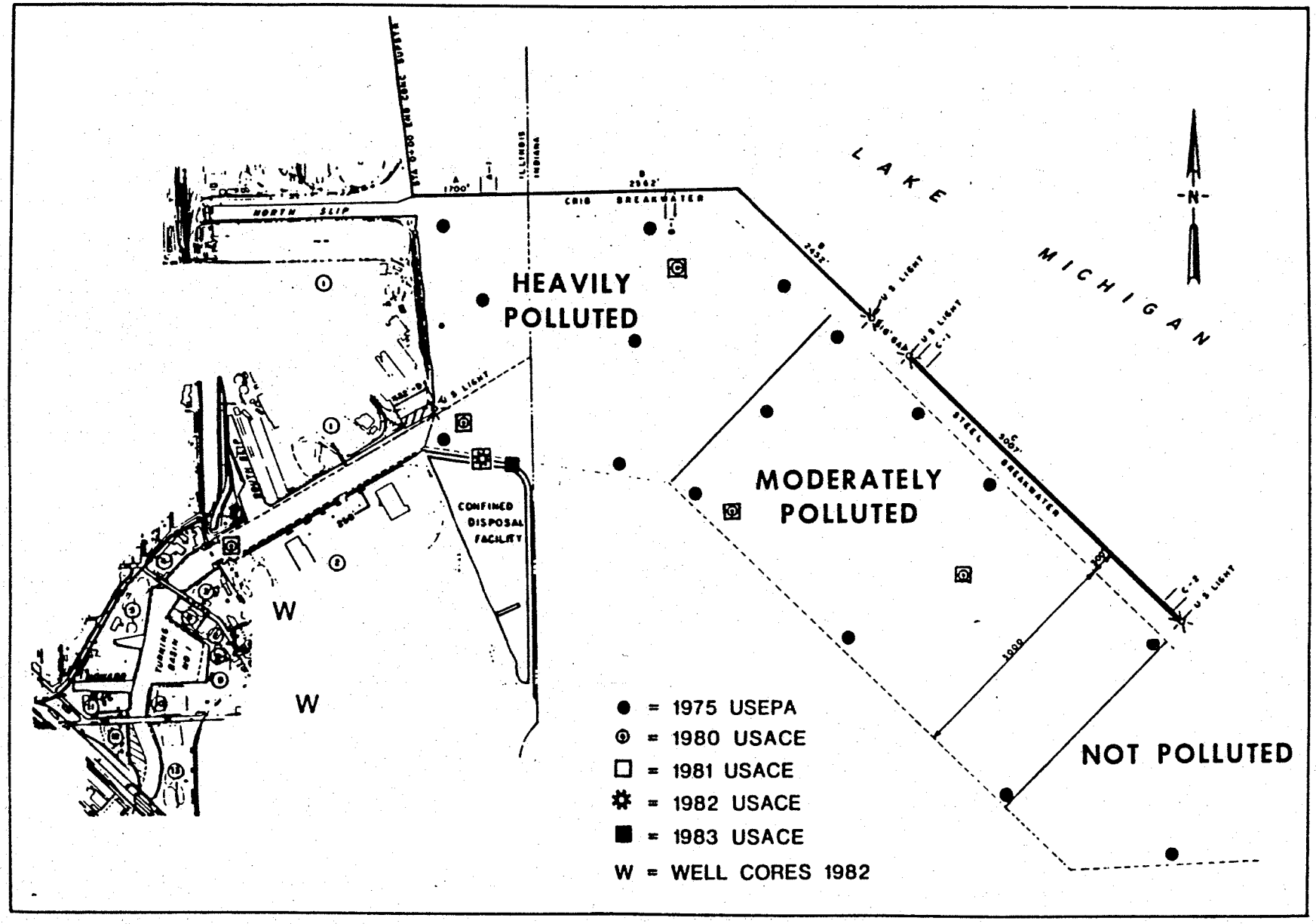


Plate 6 . Locations of Previous Sediment Samples Taken from Calumet Harbor

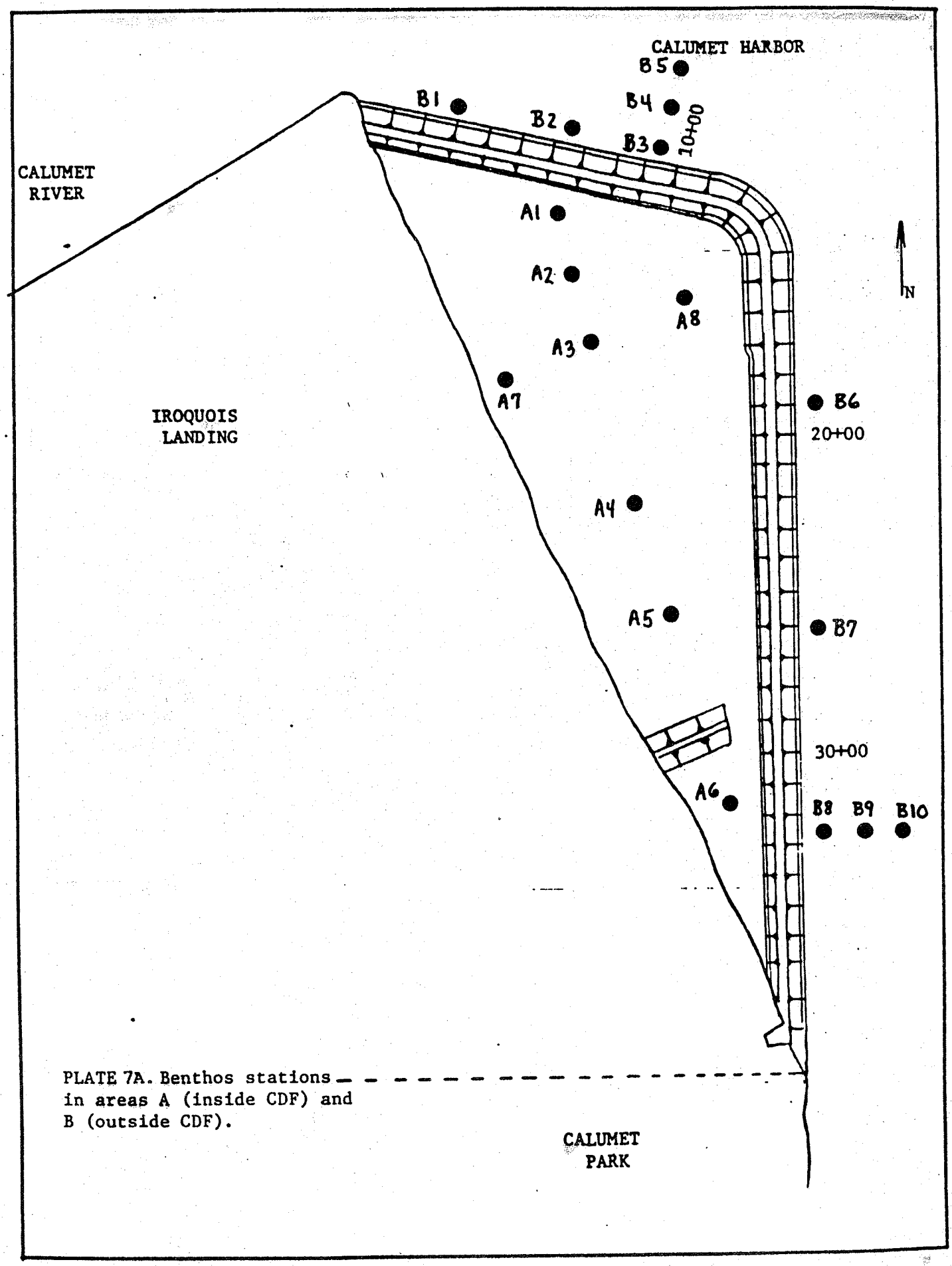


PLATE 7A. Benthos stations in areas A (inside CDF) and B (outside CDF).

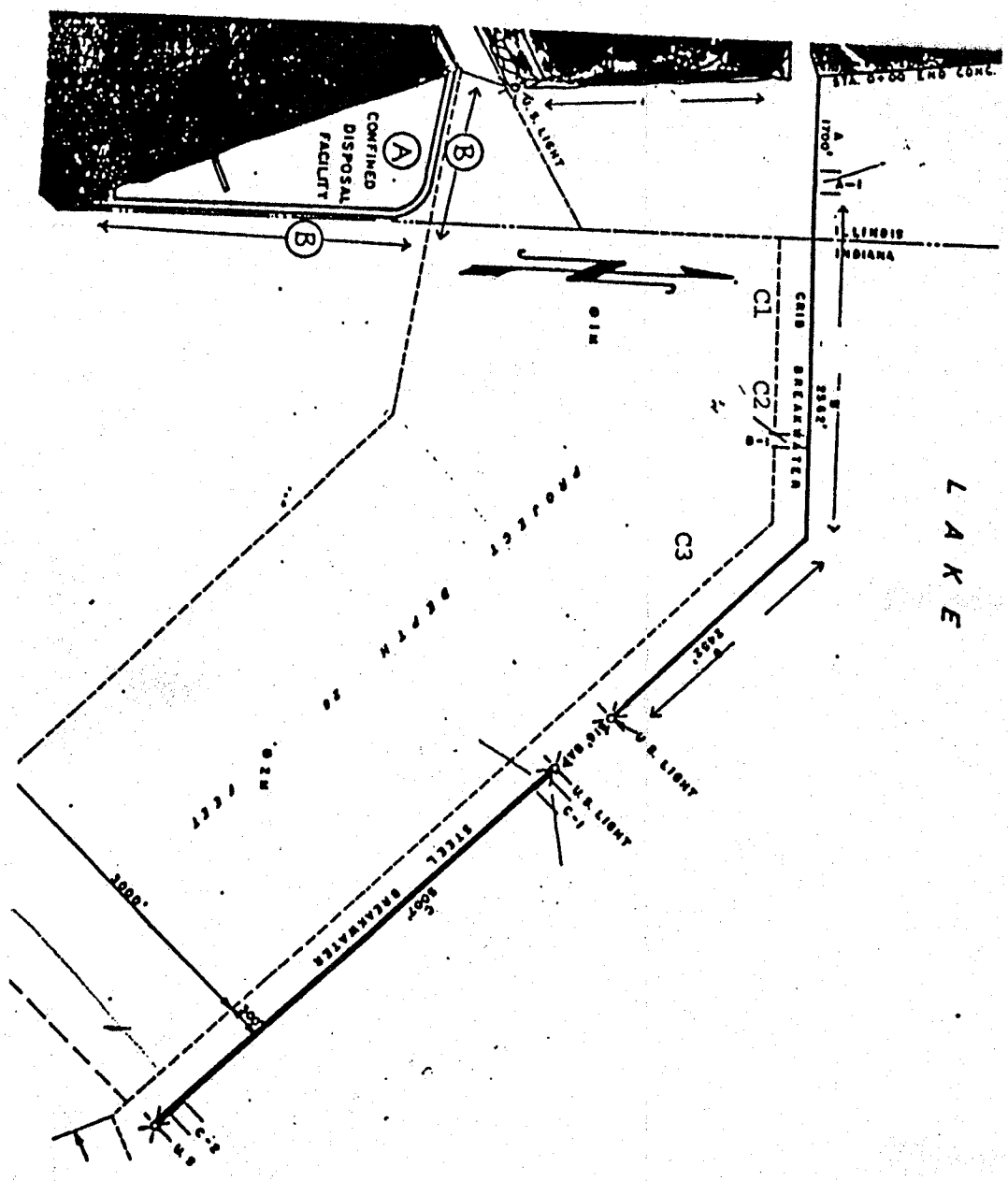


Plate 7B. Control sediment sampling stations C1, C2 and C3 at the Breakwater area outside Calumet Harbor

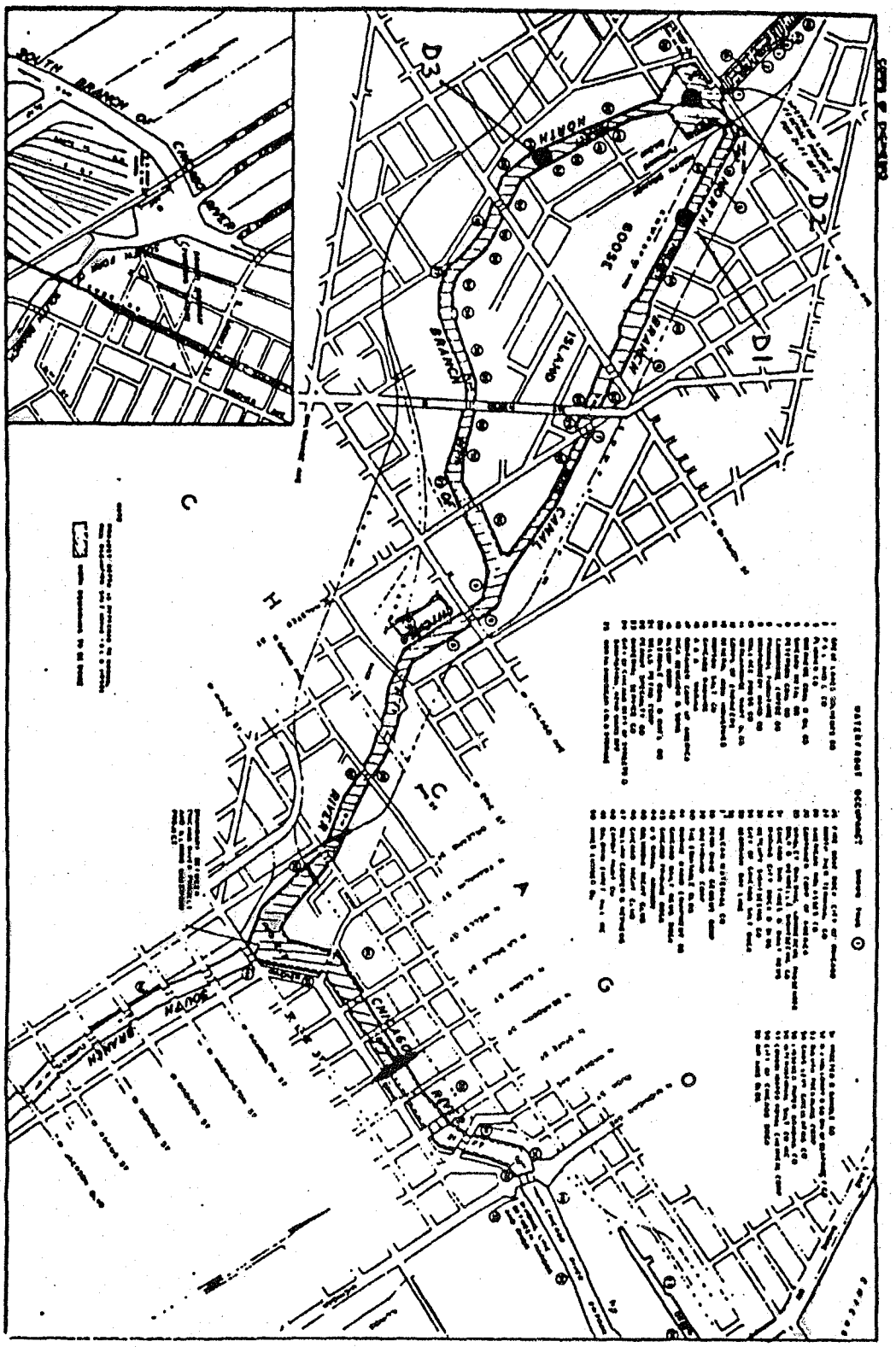


Plate 7C. Sediment sampling stations D1, D2 and D3, in the North Branch of the Chicago River (NBCR)

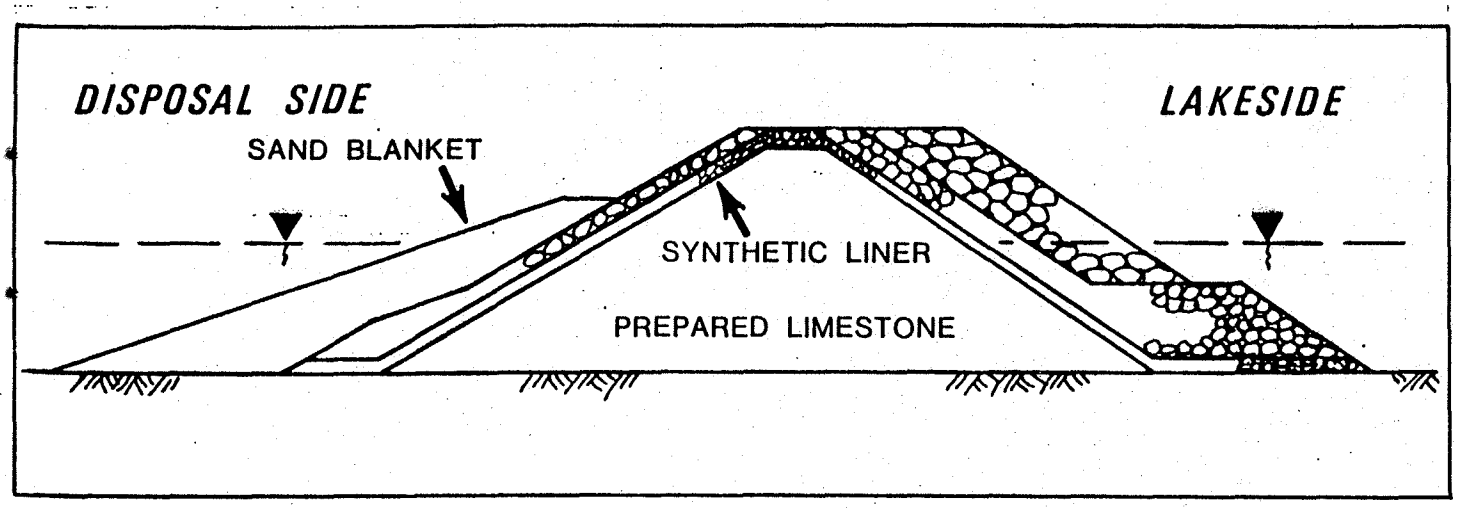


Figure 1. Typical Cross-Section of Stone Filled Dike, Chicago Area Confined Disposal Facility

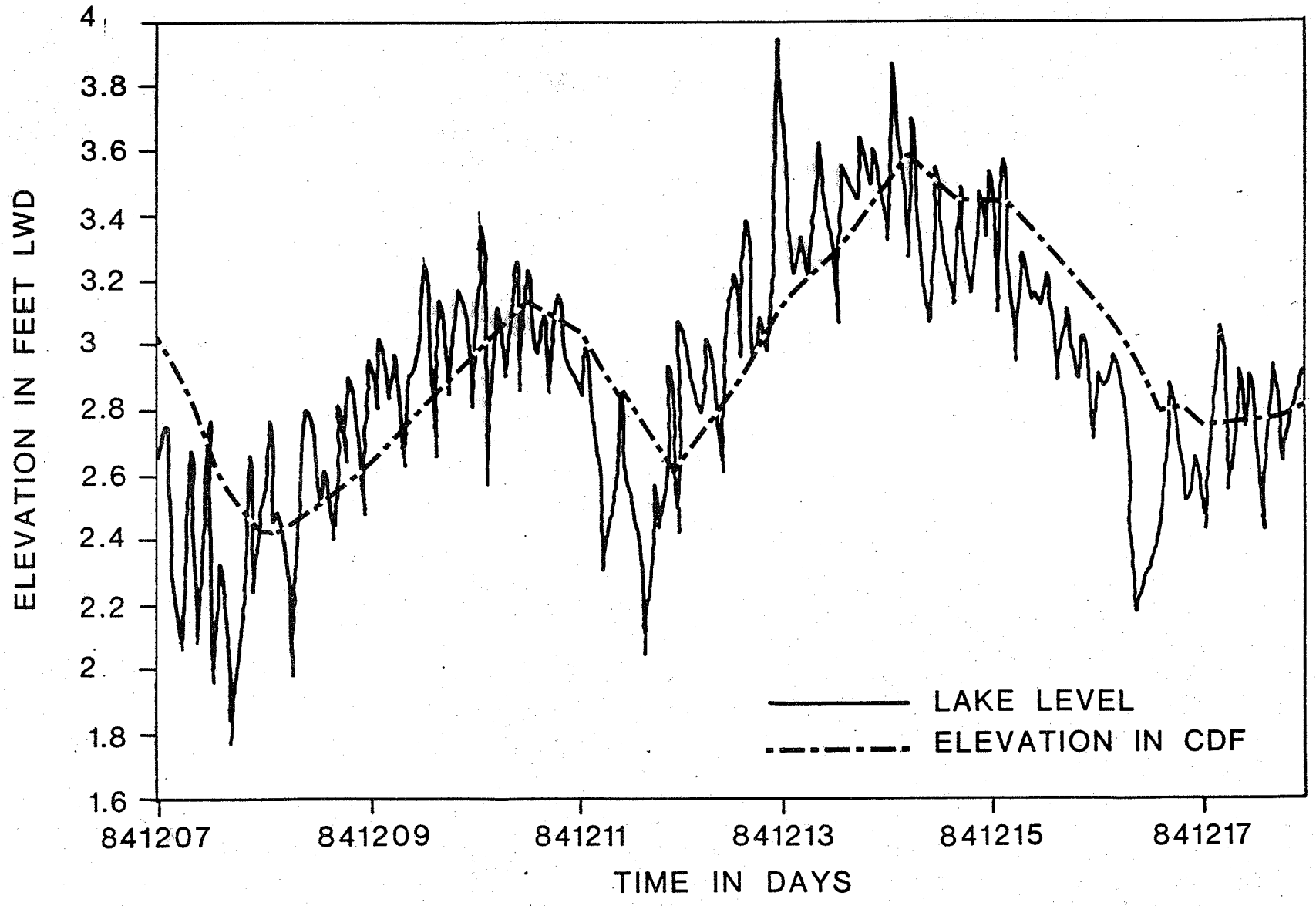


Figure 2. Chart of CDF Water Level vs. Lake Michigan Water Level Following Sand-Blanket Construction

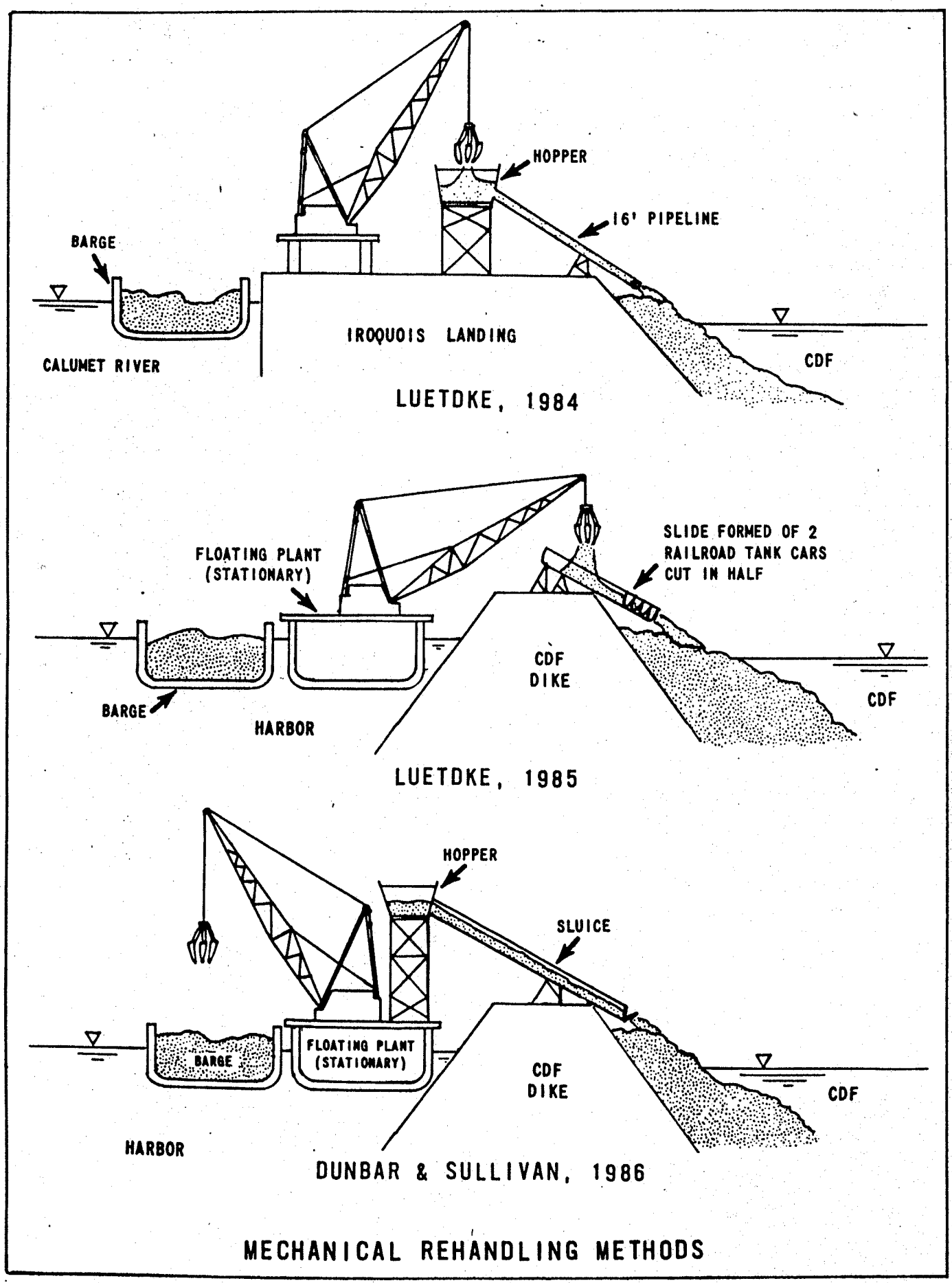

HOPPER
16' PIPELINE
BARGE
IROQUOIS LANDING
CALUMET RIVER
CDF
LUETDKE, 1984
FLOATING PLANT
(STATIONARY)
SLIDE FORMED OF 2
RAILROAD TANK CARS
CUT IN HALF
CDF
DIKE
CDF
BARGE
HARBOR
LUETDKE, 1985
HOPPER
SLUICE
BARGE
FLOATING PLANT
(STATIONARY)
CDF
DIKE
CDF
HARBOR
DUNBAR & SULLIVAN, 1986
MECHANICAL REHANDLING METHODS

Figure 3

PREPARATION AND ANALYSIS OF SAMPLES

Fifty biological tissue and seven sediment composite samples were analyzed for PCB, water, lipid and/or total organic carbon (TOC) content during this study. These samples consisted of logically (species, size and area) composited (pooled) organisms and sediment collected from inside the Chicago Area CDF pond, outside the CDF, near a breakwater (reference area north of the CDF) in Calumet Harbor and from the Chicago River in the vicinity of Goose Island. All samples were collected in August, 1986. Sample collection procedures are described in later sections.

Sediment samples were collected as discrete grab samples and composited in the laboratory to economically define the distribution of PCBs at the study sites. Biological composites were selected in two phases. Initially, fish were pooled in the field by species and size. An attempt was made to assemble sets of composites that could be compared among all four study locations. The paucity of fish at the Chicago River study area (site D), and difference in community structure between the harbor (sites B and C) and the inside CDF pond (site A) made this task difficult. Approximately half of the biological composites were analyzed before making final selection of the remaining series of biological composites to be prepared for PCB analyses.

Four fish composite samples were split and sent to the Illinois Environmental Protection Agency (IEPA) for contaminant analyses. Eight additional composite fish samples from the outside CDF and breakwater locations in Calumet Harbor will be analyzed by the IEPA for contaminant analyses.

A listing of samples delivered to Daily Analytical Laboratories and composites prepared are shown in Tables 1, 2, and 3 of Appendix C. Also included in this appendix are summaries of sample preparation, chemical analysis, and quality assurance procedures. A complete listing of chemical analysis results is contained in this appendix.

ANALYTICAL RESULTS

Tables 3, 4, 5, and 6 summarize the levels of PCB (average of two quantitation methods), lipid, water and TOC for all sediment and biological samples from study sites A, B, C, and D, respectively. Fish labelled 'IEPA' have been transferred to the State of Illinois lab for contaminant analyses.

Sediment Analysis Results

Three sediment samples from the Chicago River (site D) were composited. This composite contained levels of PCB of 1.4 ppm-dry weight and average TOC of 4.5 %. The total PCB level of this composite sample was much less than expected. Previous sediment sampling (USACE, 1980; USACE, 1983) had indicated surface concentrations in the order of 5 ppm. Ongoing laboratory analysis of Chicago River sediments (USACE, in progress) also has found far lower levels of total PCBs than indicated in the 1980 and 1983 sampling programs. The levels of sediment TOC from this study are consistent with results of analysis in progress.

Eight sediment samples taken from inside the CDF pond were composited to yield a surface sediment PCB concentration of 1.1 ppm-dry weight and a TOC content of 4.9 %. This is in agreement with the expected surficial PCB concentration of 1.3 ppm-dry weight calculated from existing information on sediments within the CDF from preconstruction and dredging records.

Sediment composite samples from the base of the outside of the CDF (50 feet away) and the base of the breakwater contained 0.14 and 0.04 ppm PCBs, respectively. Two discrete sediment samples

taken 200 feet away from the north and east CDF dike walls (outside) contained higher PCB levels (3.7 and 0.98 ppm, respectively). These values show a wider range than expected based on existing sediment PCB data for Calumet Harbor (USACE, 1980). The lateral distribution of PCBs is consistent with the overall sediment pollution distribution of the Harbor as seen in earlier sampling (USEPA, 1975). The highest concentrations are found near the Calumet River. Total organic carbon levels ranged from 0.65 to 4.9% in the Calumet Harbor sediments.

Biological Material Analysis Results

Sixteen fish (composited into five samples) and a composite of benthic macroinvertebrates from the Chicago River (site D) were analyzed (Table 5). The lipid contents of fish analyzed was consistent with the levels expected for these species and sizes of individuals. PCB burdens of the sampled fish ranged from 0.65 to 2.0 ppm wet weight. There is very little historic data on PCB burdens in fish from the Chicago River. A level of 0.68 ppm PCB wet weight was found in a carp collected from this river (IEPA, 1984, via STORET).

The benthic biota in Chicago River samples (almost entirely oligochaetes) contained lower concentrations of PCBs (0.18 ppm wet weight) than the fish. The dry weight concentrations in benthic biota was more significant (8.5 ppm PCB). With the benthic biomass determinations as high as 7 kg/square meter, as much as 7 lbs. of PCB may be contained in the standing crop of the worm population in a 10 acre area of the Chicago River near Goose Island.

One hundred and ninety-one fish (composited into twelve samples), eight crayfish (composited into two samples) and a composite of plankton from inside the CDF pond (site A) were analyzed (Table 3). Lipid contents of these organisms were typical of these species and size ranges except for one high (14%) lipid value for the alewife composite sample. PCB burdens ranged from 0.76 to 6.4 ppm wet weight for fish and crayfish. The plankton composite analysis was non-detectable for PCB wet weight (< 0.02 ppm).

One hundred and fifty-nine fish (composited into 24 samples) and 40 crayfish (composited into 4 samples) from Calumet Harbor (sites B and C) were analyzed (Tables 4 and 5). In addition one composite of three samples of periphyton scraped from the breakwater (site C) wall was analyzed (Table 5). Lipid contents of all organisms were typical of these species and size ranges. PCB burdens ranged from 0.17 to 3.7 ppm wet weight in the fish composites and from 0.05 to 0.32 ppm wet weight in the crayfish composites. PCBs were non-detectable in the periphyton composite (< 0.04 ppm wet weight).

Little is known about ambient PCB burdens in crayfish and periphyton in Lake Michigan. The fish collected from Calumet Harbor had PCB concentrations in their tissues typical of those reported for similar species in other portions of the lake. Species of fish with higher lipid content had higher PCB body burdens. There is very little historical PCB burden information specifically from Calumet Harbor. One 4.4 lb sample of brown trout (IEPA, 1981, via STORET) had 0.66 ppm wet weight PCB in fillet tissue. The two brown trout composites of 0.5 lb fish analyzed in this study had burdens of 1.8 and 2.4 ppm wet weight on a whole fish basis.

Some fish samples from all four study areas (A, B, C and D) had PCB burdens greater than the 2 ppm FDA action limit. This limit has been established as guidance for human consumption advisories of fishery products. All fish from sites A, B, C and D were analyzed whole, while skin-on fillets are customarily used for FDA action limit determinations by regulatory agencies.

Statistical Analyses of Results

Regression analysis of the PCB determinations was performed to test correlations between total PCBs and percent lipid content of biological samples in the study areas. Analysis of covariance (ANCOVA)

was also conducted to determine if significant differences exist between the PCB body burdens of biological samples at the different study sites.

Regression and ANCOVA statistics were performed by Joan Clarke of Waterways Experiment Station (personal communication, 1987) examining the relationship between % lipid and PCB concentration (mg/kg - wet weight) for the organisms collected in this study. The results of regression analyses are summarized in Table 7. Figures 4 and 5 show scattergrams of PCB (wet weight) vs. % lipid for the four CDF study locations (A, B, C and D). In addition, results from fish and crayfish composites selected for similarity of species and size are summarized on Tables 9, 10, and 11.

Regressions of PCB vs lipid using all biological samples are significant ($p = 0.05$) at three of the four study areas (A, B, and C). The regression at site D (Chicago River) was not significant, probably due to small sample size (n=6). No further statistical analysis was performed on this site.

Results of ANCOVA using location as the classification variable, PCB (wet weight) as the criterion variable and % lipid as the covariate are listed on Table 8. ANCOVA statistically adjusts the PCB variable for variation due to lipid content and allows comparison of PCB body burdens among data sets. These statistical techniques assume that % lipid is measured without error.

The results of ANCOVA suggest that the PCB accumulation trend in lipid of collected biota is similar at all areas studied in Calumet Harbor. The PCB accumulation trends in lipid at both walls (north and east) of study site B (outside CDF) were not different statistically and these trends did not differ statistically from the trend at study site C (breakwater). The PCB accumulation trend in lipid at study site A (inside the CDF pond) is different from the trend in the harbor biota (study sites B and C pooled).

Regression analysis and ANCOVA were also performed for fish samples (8 salmonid species; 784 individual skin-on fillets) from nine locations in the Wisconsin waters of Lake Michigan collected in 1985 (Masnado, 1986). Table 7 lists regression statistics for both this study and the Wisconsin fish data set. These calculations were performed using all biological sample data listed in Tables 3, 4, 5 and 6; and data published by Masnado (1986). The few non-detecable PCB analyses were set at detection limit in order to perform these calculations. Figure 6 shows scattergrams for PCB (wet weight) vs. % lipid for the open lake Wisconsin fish data alone and for the same data pooled with nearshore fish data. ANCOVA statistics comparing the results from sites evaluated in this study with the Wisconsin fish data set are listed on Table 8.

DISCUSSION

The results of this study confirm the ubiquitous nature of PCBs in the Chicago waterways. Nearly all sediment and biological samples collected contained detectable quantities of PCBs. Existing levels in surface sediments were generally at or below anticipated concentrations. Levels in biological samples were also consistent with the limited background data available. The study objective of defining existing levels of PCB contamination at four sites has generally been accomplished. The variability found in biological samples was expected. The variability found in Calumet Harbor sediments limited subsequent interpretation.

The high variability of PCB and lipid levels in biological samples collected for this study exemplify the necessity of large data sets for an investigation of contaminant distribution in any biological system, however small. Despite the limited number of samples, this study showed significant correlation between PCB and lipid content for three of four study sites. A statistical difference of PCB contamination in biological samples could only be established for one of these three sites (site A, inside the CDF). The levels of PCB contamination at two sites in Calumet Harbor, one immediately outside the CDF (site B), the other a reference station located at a remote breakwater (site C), were not shown to be significantly different.

Although this study does not provide conlusive proof that the Chicago Area CDF has not contaminated the adjacent harbor with PCBs, it certainly suggests that it has not.

Another objective of this study was to examine the applicability of biomonitoring to the Chicago Area CDF. At the center of this objective is the sensitivity of biomonitoring to detect any low level contaminant releases from this facility to the surrounding harbor waters. The ability to detect and quantify such losses by monitoring contaminant burdens in indigenous organisms around the CDF is confounded by two uncontrolled variables; the mobility of these organisms, and the variability of background contaminant exposure at locations in the harbor.

The first of these variables, the mobility of organisms used for biomonitoring, could be controlled by use of caged biota or by the use of organisms which have a fixed or very limited range. The disadvantage of this approach is that it overstates the impacts on organisms whose natural mobility does not limit them to the area immediately adjacent to the CDF.

The second of these variables, the levels of background contaminant exposure, is not subject to control. Levels of sediment PCBs varied by an order of magnitude in samples collected around the CDF dike. If the background conditions at the outside of the CDF can show this level of variation, it may be unreasonable to expect biomonitoring to detect anything short of a gross leakage.

The results of this study have provided baseline information of the biological communities at four sites in Chicago navigation projects, including PCB distributions in biological tissues and bottom sediments. An evaluation of these results was also made to assess available means for predicting PCB distributions. This evaluation was not the original intent of this study, but was undertaken as the results became available.

Historically, PCB distributions have been predicted by use of bioconcentration factors (BCFs) developed from laboratory experiments with specific organisms exposed to known levels of dissolved contaminants. Field application of these factors relied on the availability of dependable water quality data for the contaminant in question. In the case of PCBs, this data has been either lacking or insufficient owing to the low solubility of this contaminant and the limitations of standard analytical methods.

Equilibrium partitioning accounts for the differences among bioconcentration factors for various organisms by linking the relative PCB body burdens of organisms to their lipid content. The significant correlation of PCB burden and lipid content in biota collected from three sites in this study is consistent with equilibrium partitioning concepts.

Partitioning theory suggests that the distribution of PCBs among environmental compartments (biological lipid : water : sediment carbon) in a closed system will approach equilibrium if given sufficient time. The PCB:lipid correlations at three sites in this study were significant for different biological species and different trophic levels, even though only one of these sites (site A) could be considered a physically "closed" system. It is noteworthy that the correlation between PCB and lipid was best (R squared highest) at site A when compared to the other sites in this study and the Wisconsin data set.

There is disagreement in the literature as to the relative importance of the routes of contaminant uptake by aquatic biota. Direct uptake of PCB from water (Richardson and Waide, 1979; Gooch and Hamdy, 1983) and consumption of contaminated food (Rubenstein, Gilliam and Gregory, 1984) have been identified as major routes of contaminant uptake in biological organisms. Regardless of the mechanisms of uptake, the distribution of contaminants at equilibrium should be dependent on the availability and "solvent" characteristics of environmental compartments within the system.

Partitioning provides a means for predicting PCB body burdens of organisms at equilibrium with sediment PCBs:

$$\frac{C_s}{K_{ow}\ TOC\ F_c} = \frac{C_b}{K_{ow}\ LIP\ F_l}$$

Given data on the level of sediment PCB contamination and TOC content, expected lipid content of target organism, and preference factors, the PCB body burden can be predicted as:

$$C_b = \frac{C_s\ LIP\ F_l}{TOC\ F_c}$$

If the preference factors cannot be derived independently by laboratory experiment, a combined factor (Fl/Fc) can be determined directly by field or laboratory methods:

$$Fl/Fc = (C_b\ TOC)/(C_s\ LIP)$$

This factor relates the preference of PCBs for sediment carbon vs biological lipid. It may not be reasonable to expect a single value to adequately represent this factor. The sorptive ability of biological lipids may vary with species and at age classes within species. The sorptive ability of sediment carbon may also vary, depending on the types of carbon compounds which are associated with the sediment matrix.

McFarland and Clarke (1986) estimated this combined preference factor (pf) as 1.72 based on laboratory experiments. Results of biological and sediment analysis conducted for this study were used to examine this factor. The preference factor (Fl/Fc) at sites A, B, and C were determined using the mean levels of lipid normalized PCBs in all organisms and TOC normalized PCBs in sediment composites at these sites:

Site	F_l/F_c
A	3.2
B	0.88
C	13

The preference factor determined at site A (3.2) is considered the most reliable estimate because this site, within the CDF, is a "closed" system. The organisms collected from site A are confined, and have contact only with those sediments contained by the CDF dikes. In addition, the levels of PCBs and TOC in sediments collected at this site are consistent with previous sediment data. Sites B and C, on the otherhand, are not "closed". The mobility of organisms at these sites is not restricted, and these organisms may contact sediments outside the range of the sampling areas of this study. Further, the levels of sediment PCBs and TOC at sites B and C were highly variable. PCB levels found at site C were far lower than average levels of Calumet Harbor from previous sediment sampling (USACE, 1980).

SUMMARY

Sediment and biological samples were collected from four sites to determine existing levels of PCB contamination. Levels of PCBs in Chicago River surface sediments were below expected concentrations. Levels found in sediments within the Chicago Area confined disposal facility (CDF) were consistent with previous sediment data. Sediment PCB concentrations in Calumet Harbor samples showed high variability (0.04 to 3.7 ppm) and may require further examination. Levels of total organic carbon in sediments from the Chicago River and Chicago Area CDF were consistent with expectations. Sediment organic carbon concentrations in Calumet Harbor showed a wide range (0.65 - 4.9%).

Biological samples were composited based on species, size classes, and collection site. In all, fifty biological samples were analyzed. The lipid contents of fish analyzed were consistent with the levels expected for these species and sizes of individuals. PCB burdens of the sampled fish ranged from 0.11 to 6.6 ppm wet weight. Levels of PCB contamination in fish tissues were consistent with available data, though previous data is severely limited. PCB contamination as well as lipid content in other biological samples were generally lower than that in fish.

Data presented by this study on biota collected from Calumet Harbor, inside the Chicago Area CDF, and the Chicago River indicate that despite wide variability, trends in the relationship between PCB body burden and lipid content are evident. A significant correlation was found between PCB burden and lipid content in biota at three of four study sites. This correlation existed for organisms representing different species and trophic levels. Data from fish collected from the Wisconsin waters of Lake Michigan (Masnado, 1986) support this relationship. Through ANCOVA and regression techniques, these trends can be compared among species and locations.

The biota collected from within the Chicago Area CDF contained elevated PCB accumulation relative to Calumet Harbor. No statistically significant difference was found in PCB burdens of biota collected from Calumet Harbor sites. These results suggest that the operations of the Chicago Area CDF have not affected the PCB burdens of Calumet Harbor biota utilizing the outside CDF dike. Higher PCB levels in organisms from inside the CDF appear to be related to higher sediment concentrations of PCB (1.1 ppm-dry weight inside the CDF vs. 0.6 ppm-dry weight in harbor samples).

The study objectives of defining existing levels of PCB contamination and assessing the applicability of biomonitoring to CDF evaluations have generally been met. Additional work may be required to better describe the distribution of PCBs in Calumet Harbor sediments. Additional data on benthic and planktonic biota may be needed. The ability of biomonitoring to detect low level contaminant loss at the CDF is limited. Biomonitoring for contaminant uptake by caging organisms in specific locations would eliminate organism mobility, but the variability of background contaminant exposure outside the CDF may severely restrict the sensitivity of biomonitoring methods.

The results of this study were also used to examine preference factors used with equilibrium partitioning methods to predict PCB distributions in environmental compartments. Partitiong theory states that biota will approach equilibrium with the contaminants available in environmental compartments, and that the PCB burdens of biota can be predicted with information on the PCB and total organic carbon in exposed in- place sediments. The results of sediment and biota PCB levels at site A (within the CDF) were considered the best test of preference factors because this site is as nearly a closed system as may be found in the field. The preference factor (Fl/Fc) determined at site A (3.2) was greater than the 1.72 value developed by McFarland and Clarke (1986) from laboratory experiments.

TABLE 3 . SEDIMENT AND BIOLOGICAL PCB ANALYSES AT CAL HARBOR AND THE CHICAGO RIVER DURING THE BASELINE STUDY : AUGUST, 1986

INSIDE CDF POND

sample type	%TOC (dry)	%Water	PCB (mg/kg) dry	PCB (mg/kg) wet	PCB (mg/kg) dry/toc	@TBP
SEDIMENT	4.90	43.00	1.10	0.65	22.45	38.61

	%Lipid (wet)	%TOC (wet)	%Water	* ave. dry	* ave. wet	* ave. wet/lipid	(g) ave. weight	*** N
CRAYFISH	1.40	13.40	72.00	2.75	0.76	59.29	18.00	5.00
CRAYFISH	0.88	19.00	67.00	2.55	0.84	103.41	23.00	3.00
ALEWIFE	14.00	>32	60.00	16.00	6.40	47.14	56.00	4.00
YELLOW PERCH	3.40	>18	77.00	7.50	1.75	50.00	45.00	3.00
YELLOW PERCH	3.30	16.00	75.00	6.90	1.75	51.52	45.00	10.00
YELLOW PERCH	4.10	16.00	77.00	16.50	3.85	114.63	47.00	32.00
BLUNTNOSE-yoy	1.30	12.00	79.00	2.70	0.57	50.77	1.00	91.00
BLUNTNOSE	7.90	15.00	71.00	9.35	2.75	37.97	5.00	23.00
BLACK BULLHEAD	1.10	10.00	80.00	4.30	0.85	90.91	102.00	2.00
CHANNEL CATFISH	11.00	>26	68.00	11.50	3.65	35.45	1450.00	1.00
GREEN SUNFISH	2.00	19.00	73.00	7.45	2.00	100.00	50.00	1.00
GREEN SUNFISH	1.80	7.60	77.00	6.50	1.50	77.78	5.00	18.00
PUMPKINSEED	2.20	13.00	76.00	7.90	1.90	104.55	50.00	2.00
ORANGESPOT SF	1.10	13.00	77.00	4.00	0.92	80.00	10.00	5.00
PLANKTON	0.02	0.08	99.80	<10	<0.02	<83		
average **	3.96	16.43	73.50	7.73	1.97	72.45		
std. dev. **	3.93	7.18	8.32	4.26	1.59	25.63		

* Average of two quantitation methods.
** Detection limits assumed in calculations.
*** N = number of individuals in composite sample.
@ TBP = (Cs/toc)1.72 from McFarland and Clarke, 1986.

TABLE 4 . SEDIMENT AND BIOLOGICAL PCB ANALYSES AT CAL HARBOR AND THE CHICAGO RIVER DURING THE BASELINE STUDY : AUGUST, 1986

OUTSIDE CDF

sample type	%TOC (dry)	%Water	PCB (mg/kg) * ave. dry	PCB (mg/kg) * ave. wet	dry/toc	@TBP
SEDIMENT-N	4.60	33.00	0.13	0.05	2.83	4.86
SEDIMENT-E	1.20	40.00	0.15	0.05	12.50	21.50
SEDIMENT-N(200)	4.90	41.00	1.98	1.18	40.40	69.49
SEDIMENT-E(200)	0.65	44.00	0.53	0.30	81.54	140.25
average	2.84	39.50	0.70	0.39	34.32	59.02
std.dev.	1.93	4.03	0.76	0.46	30.56	52.56

	%Lipid (wet)	%TOC (wet)	%Water	* ave. dry	* ave. wet	* ave. wet/lipid	(g) ave. weight	*** N
CRAYFISH-E	0.62	6.20	73.00	0.61	0.17	26.61	16.00	10.00
CRAYFISH-N	0.54	16.50	71.00	1.11	0.32	58.33	23.00	10.00
ALEWIFE-N+E	4.20	17.00	76.00	4.30	1.05	24.88	36.00	20.00
ALEWIFE-N	3.20	12.00	78.00	8.85	1.95	60.94	34.00	10.00
ALEWIFE-N	3.50	18.00	76.00	5.60	1.35	38.57	34.00	10.00
YELLOW PERCH-E	3.40	12.00	76.00	2.30	0.56	16.32	45.00	10.00
YELLOW PERCH-N	3.50	17.00	76.00	1.95	0.46	13.00	45.00	10.00
YELLOW PERCH-E	4.00	17.00	74.00	3.95	1.05	26.25	106.00	10.00
YELLOW PERCH-E	5.20	>21	73.00	7.60	2.05	39.42	400.00	3.00
YELLOW PERCH-N	5.60	>22	73.00	7.10	1.90	33.93	362.00	1.00
RAINBOW TROUT-E	5.10	14.00	75.00	0.75	0.19	3.73	45.00	3.00
BROWN TROUT-N	12.00	23.00	67.00	5.55	1.80	15.00	498.00	2.00
GIZZARD SHAD-E	11.00	>25	69.00	12.00	3.70	33.64	815.00	1.00
IEPA GIZZARD SHAD-E							242.00	9.00
IEPA FRESHWATER DRUM-E							974.00	3.00
IEPA LONGNOSE SUCKER-E							204.00	2.00
IEPA YELLOW PERCH-N							72.00	10.00
average	4.76	16.98	74.46	5.41	1.27	30.05		
std. dev.	3.23	4.94	3.00	3.35	0.97	16.16		

* Average of two quantitation methods.
** Detection limits assumed in calculations.
*** N = number of individuals in composite sample.
@ TBP = (Cs/toc)1.72 from McFarland and Clarke, 1986.

TABLE 5. SEDIMENT AND BIOLOGICAL PCB ANALYSES AT CAL HARBOR AND THE CHICAGO RIVER DURING THE BASELINE STUDY : AUGUST, 1986

BREAKWATER AREA

			----- PCB (mg/kg) -----			
sample type	%TOC (dry)	%Water	dry	wet	dry/toc	@TBP
SEDIMENT	1.70	30.00	0.04	0.03	2.35	4.04

	%Lipid (wet)	%TOC (wet)	%Water	* ave. dry	* ave. wet	* ave. wet/lipid	(g) ave. weight	*** N
CRAYFISH	0.26	9.90	77.00	0.23	0.05	19.23	20.00	10.00
CRAYFISH	0.61	>22	73.00	0.64	0.18	28.69	18.00	10.00
ALEWIFE	3.60	14.00	76.00	1.85	0.44	12.08	35.00	20.00
ALEWIFE	1.70	11.00	79.00	7.40	1.55	91.18	41.00	10.00
YELLOW PERCH	4.40	16.00	74.00	2.85	0.74	16.70	48.00	10.00
YELLOW PERCH	3.50	13.00	76.00	1.29	0.35	10.00	50.00	9.00
YELLOW PERCH	2.80	16.00	76.00	3.95	0.95	33.93	5.00	11.00
YELLOW PERCH	4.80	18.00	74.00	5.20	1.35	28.13	340.00	1.00
YELLOW PERCH	2.70	17.00	75.00	4.60	1.15	42.59	100.00	10.00
RAINBOW TROUT	6.20	14.00	74.00	0.65	0.17	2.74	45.00	2.00
BROWN TROUT	11.00	18.00	68.00	7.35	2.35	21.36	555.00	2.00
BLACK BULLHEAD	2.20	14.00	74.00	1.70	0.45	20.45	272.00	1.00
CHANNEL CATFISH	14.00	26.00	64.00	9.80	3.50	25.00	1359.00	1.00
GIZZARD SHAD	17.00	25.00	64.00	9.30	3.45	20.29	928.00	2.00
CARP	6.60	18.00	68.00	4.25	1.35	20.45	3352.00	1.00
PERIPHYTON	0.05	0.52	96.00	<1	<0.04	<84		
IEPA WHITE SUCKER							974.00	1.00
IEPA RAINBOW TROUT							136.00	1.00
IEPA BROWN TROUT							508.88	3.00
IEPA YELLOW PERCH							839.18	5.00
average	5.09	15.78	74.25	3.88	1.13	29.80		
std. dev.	4.77	5.87	7.08	3.07	1.08	23.68		

* Average of two quantitation methods.
** Detection limits assumed in calculations.
*** N = number of individuals in composite sample.
@ TBP = (Cs/toc)1.72 from McFarland and Clarke, 1986.

TABLE 6. SEDIMENT AND BIOLOGICAL PCB ANALYSES AT CAL HARBOR AND THE CHICAGO RIVER DURING THE BASELINE STUDY : AUGUST, 1986

CHICAGO RIVER (NBCR)

				----- PCB (mg/kg) -----				
sample type		%TOC (dry)	%Water	dry	wet	dry/toc	@TBP	
SEDIMENT		4.50	68.00	1.40	0.45	31.11	53.51	
	%Lipid (wet)	%TOC (wet)	%Water	* ave. dry	* ave. wet	* ave. wet/lipid	(g) ave. weight	*** N
BLACK BULLHEAD	2.90	15.00	78.00	8.00	1.80	62.07	54.00	5.00
GREEN SUNFISH	3.50	>24	70.00	4.40	1.35	38.57	45.00	1.00
ORANGESPOT SF	2.70	16.00	72.00	2.30	0.65	24.07	9.00	5.00
CARP	4.30	>21	74.00	2.50	0.66	15.35	91.00	1.00
GOLDFISH	12.00	26.00	66.00	5.95	2.00	16.67	164.00	4.00
WORMS/LEECHES	0.13	0.16	98.00	8.50	0.18	138.46		
average	4.26	17.03	76.33	5.28	1.11	49.20		
std. dev.	3.69	8.51	10.35	2.44	0.66	42.98		

* Average of two quantitation methods.
** Detection limits assumed in calculations.
*** N = number of individuals in composite sample.
@ TBP = (Cs/toc)1.72 from McFarland and Clarke, 1986.

Table 7. Regression Statistics for PCB (wet weight) vs. % Lipid at CDF Study and Wisconsin (Masnado, 1986) Salmonid Study Locations.

CDF Study

Regression	Significance	N	r^2	p	Intercept	Slope
All	**	50	0.55	0.00000	0.395	0.227
Breakwater	**	16	0.80	0.00000	0.103	0.202
Chicago R. (NBCR)	NS	6	0.50	0.11689	0.571	0.126
Inside CDF (pond)	**	15	0.83	0.00010	0.610	0.367
Outside CDF	**	13	0.51	0.00576	0.249	0.215
- East Wall	**	6	0.78	0.01940	-0.445	0.354
- North Wall	NS	6	0.33	0.23440	0.788	0.108

Wisconsin Study

Regression	Significance	N	r^2	p	Intercept	Slope
All	**	784	0.41	0.00000	0.216	0.211
Lake Michigan	**	454	0.46	0.00000	0.204	0.235
Greenbay	**	121	0.46	0.00000	0.481	0.187
Sheboygan	**	89	0.19	0.00002	0.971	0.164
Menominee	**	39	0.33	0.00014	0.771	0.211
Sturgeon Bay	**	20	0.64	0.00002	0.880	0.250
Oconto River	**	43	0.40	0.00001	0.404	0.239
Root River	NS	13	0.18	0.14272	0.866	0.043
Twin West	NS	5	0.06	0.69305	0.089	0.085
Root + Twin	NS	18	0.14	0.12743	0.851	0.040
Pink salmon	NS	5	0.30	0.34336	0.267	0.028
Brook trout	**	88	0.19	0.00003	0.635	0.183
Rainbor trout	**	56	0.12	0.00747	0.411	0.111
Coho salmon	**	67	0.43	0.00000	0.146	0.157
Lake trout	**	147	0.47	0.00000	1.550	0.370
Brown trout	**	168	0.07	0.00066	1.491	0.063
Chinook salmon	**	193	0.33	0.00000	0.507	0.181
Splake	**	60	0.59	0.00000	0.340	0.198

Table 8. Analysis of Covariance (ANCOVA) Results for Comparison of PCB vs % Lipid Regression Lines for the CDF Study Locations and thee Wisconsin Pooled Fish Data.

Location Comparison	N	Parallelism	P	Coincidence	p
Outside CDF - East Wall vs Outside CDF - North Wall	12	YES	0.0753	YES	0.9253
Outside CDF (E&N) vs Breakwater	29	YES	0.8334	YES	0.3643
Outside CDF + Breakwater vs Inside CDF	44	NO	0.0029	YES	0.1558
CDF study (all locations) vs Wisconsin Salmonid Study (all locations)	834	YES	0.7394	YES	0.2262

TABLE 9. COMPARISON SET OF PCB ANALYSES. LIPID AND WATER CONTENT
FROM OUTSIDE-north VS OUTSIDE-east
AT CALUMET HARBOR DURING THE BASELINE STUDY : AUGUST, 1986

OUTSIDE-north

	%Lipid (wet)	%WATER	%TOC (wet)	PCB (mg/kg) * ave. dry	PCB (mg/kg) * ave. wet	PCB (mg/kg) * ave. wet/lipid	(g) ave. Weight	***N
CRAYFISH	0.54	71.00	16.50	1.11	0.32	58.33	23.00	10.00
YELLOW PERCH	3.50	76.00	17.00	1.95	0.46	13.00	45.00	10.00
YELLOW PERCH	5.60	73.00	>22	7.10	1.90	33.93	382.00	1.00
average **	3.21	73.33	18.50	3.39	0.89	35.09	143.33	7.00
std. dev. **	2.08	2.05	2.48	2.65	0.71	18.52	154.88	4.24

OUTSIDE-east

	%Lipid (wet)	%WATER	%TOC (wet)	PCB (mg/kg) * ave. dry	PCB (mg/kg) * ave. wet	PCB (mg/kg) * ave. wet/lipid	(g) ave. Weight	***N
CRAYFISH	0.62	73.00	6.20	0.61	0.17	26.61	16.00	10.00
YELLOW PERCH	3.40	76.00	12.00	2.30	0.56	15.59	45.00	10.00
YELLOW PERCH	5.20	73.00	21.00	7.60	2.05	39.42	400.00	3.00
average **	3.07	74.00	13.07	3.50	0.93	27.21	153.67	7.67
std. dev. **	1.88	1.41	6.09	2.98	0.81	9.74	174.59	3.30

* Average of two quantitation methods.
** Detection limits assumed in calculation.
*** N = number of organisms in composite sample.

TABLE 10. COMPARISON SET OF PCB ANALYSES. LIPID AND WATER CONTENT FROM OUTSIDE THE CDF AND NEAR THE BREAKWATER IN CALUMET HARBOR DURING THE BASELINE STUDY : AUGUST. 1986

OUTSIDE CDF

	% Lipid (wet)	%TOC (wet)	%WATER	----- PCB (mg/kg) ----- * ave. dry	* ave. wet	* ave. wet/lipid	(g) ave. weight	***N
CRAYFISH-E	0.62	6.20	73.00	0.61	0.17	26.61	16.00	10.00
CRAYFISH-N	0.54	16.50	71.00	1.11	0.32	58.33	23.00	10.00
ALEWIFE-N ****	3.50	18.00	76.00	5.60	1.35	38.57	34.00	10.00
ALEWIFE-N+E	4.20	17.00	78.00	4.30	1.05	24.88	36.00	20.00
RAINBOW TROUT-E	5.10	14.00	75.00	0.75	0.19	3.73	45.00	3.00
YELLOW PERCH-N	3.50	17.00	76.00	1.95	0.46	13.00	45.00	10.00
YELLOW PERCH-E	3.40	12.00	76.00	2.30	0.56	16.32	45.00	10.00
YELLOW PERCH-E	4.00	17.00	74.00	3.95	1.05	26.25	106.00	10.00
YELLOW PERCH-N	5.60	>22	73.00	7.10	1.90	33.93	362.00	1.00
BROWN TROUT-N	12.00	23.00	67.00	5.55	1.80	15.00	498.00	2.00
GIZZARD SHAD-E	11.00	>25	69.00	12.00	3.70	33.64	815.00	1.00
average **	4.86	17.06	73.27	4.11	1.14	26.39	184.09	7.91
st. dev. **	3.48	5.02	2.98	3.25	1.00	14.16	250.64	5.45

BREAKWATER AREA

	% Lipid (wet)	%TOC (wet)	%WATER	----- PCB (mg/kg) ----- * ave. dry	* ave. wet	* ave wet/lipid	(g) ave. weight	***N
CRAYFISH	0.61	>22	73.00	0.64	0.18	28.69	18.00	10.00
CRAYFISH	0.26	9.90	77.00	0.23	0.05	19.23	20.00	10.00
ALEWIFE	3.60	14.00	76.00	1.85	0.44	12.08	35.00	20.00
ALEWIFE	1.70	11.00	79.00	7.40	1.55	91.18	41.00	10.00
RAINBOW TROUT	6.20	14.00	74.00	0.65	0.17	2.74	45.00	2.00
YELLOW PERCH	4.40	16.00	74.00	2.85	0.74	16.70	48.00	10.00
YELLOW PERCH	3.50	13.00	76.00	1.29	0.35	10.00	50.00	9.00
YELLOW PERCH	2.70	17.00	75.00	4.60	1.15	42.59	100.00	10.00
YELLOW PERCH	4.80	18.00	74.00	5.20	1.35	28.13	340.00	1.00
BROWN TROUT	11.00	18.00	68.00	7.35	2.35	21.36	555.00	2.00
GIZZARD SHAD	17.00	25.00	64.00	8.30	3.45	20.29	928.00	2.00
average **	5.07	16.17	73.64	3.76	1.07	26.84	198.18	7.82
st. dev. **	4.71	4.32	4.03	3.05	1.01	22.78	281.75	5.41

* Average of two quantitation methods.

** Detection limits assumed in calculation.

*** N = number of fish in composite sample.

**** Sample e-2-4 was eliminated from comparison because of unusually high water content (89 %) which was later re-analyzed at 78%.

TABLE 11. COMPARISON SET OF PCB ANALYSES. LIPID AND WATER CONTENT FROM OUTSIDE + BREAKWATER VS INSIDE THE CDF POND AT CALUMET HARBOR DURING THE BASELINE STUDY : AUGUST. 1986

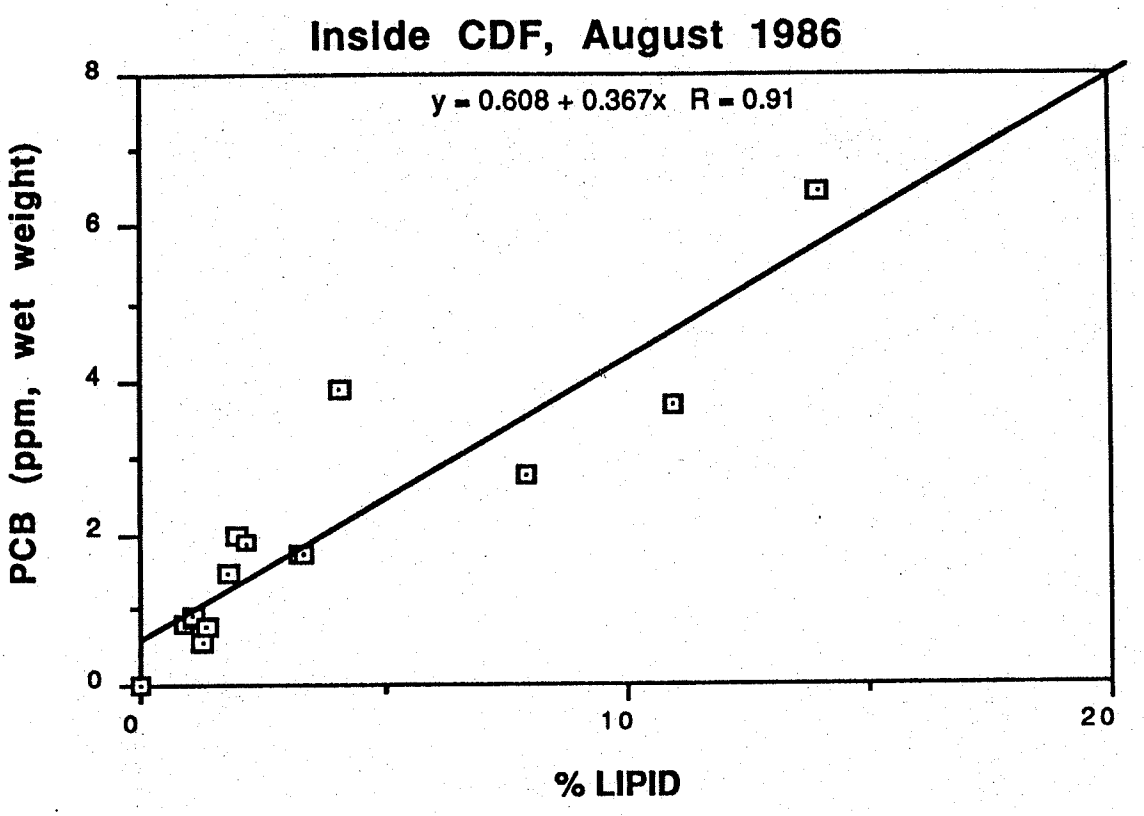
INSIDE CDF POND	%Lipid (wet)	%WATER	%TOC (wet)	PCB (mg/kg) * ave. dry	PCB (mg/kg) * ave. wet	PCB (mg/kg) * ave. wet/lipid	(g) ave. Weight	***N
CRAYFISH	1.40	72.00	13.40	2.75	0.76	54.29	18.00	5.00
CRAYFISH	0.88	67.00	19.00	2.55	0.84	95.45	23.00	3.00
YELLOW PERCH	3.30	75.00	18.00	6.90	1.75	53.03	45.00	10.00
YELLOW PERCH	3.40	77.00	>18	7.50	1.75	51.47	45.00	3.00
BLACK BULLHEAD	1.10	80.00	10.00	4.30	0.85	77.27	102.00	2.00
CHANNEL CATFISH	11.00	68.00	>26	11.50	3.65	33.18	1450.00	1.00
average **	3.51	73.17	17.07	5.92	1.60	60.78	280.50	4.00
std. dev. **	3.50	4.67	4.98	3.13	1.01	20.10	523.72	2.94

OUTSIDE CDF + BREAKWATER	%Lipid (wet)	%WATER	%TOC	PCB (mg/kg) * ave. dry	PCB (mg/kg) * ave. wet	PCB (mg/kg) * ave. wet/lipid	(g) ave. Weight	***N
CRAYFISH	0.61	73.00	>22	0.64	0.18	28.69	18.00	10.00
CRAYFISH-N	0.54	71.00	16.50	1.11	0.32	58.33	23.00	10.00
YELLOW PERCH-E	3.40	76.00	12.00	2.30	0.56	16.32	45.00	10.00
YELLOW PERCH-N	3.50	76.00	17.00	1.95	0.46	13.00	45.00	10.00
BLACK BULLHEAD	2.20	74.00	14.00	1.70	0.45	20.45	272.00	1.00
CHANNEL CATFISH	14.00	64.00	26.00	9.80	3.50	25.00	1359.00	1.00
average **	4.04	72.33	17.92	2.92	0.91	26.97	293.67	7.00
std. dev. **	4.61	4.11	4.75	3.13	1.17	14.95	484.48	4.24

* Average of two quantitation methods.

** Detection limits assumed in calculation.

*** N = number of organisms in composite sample.



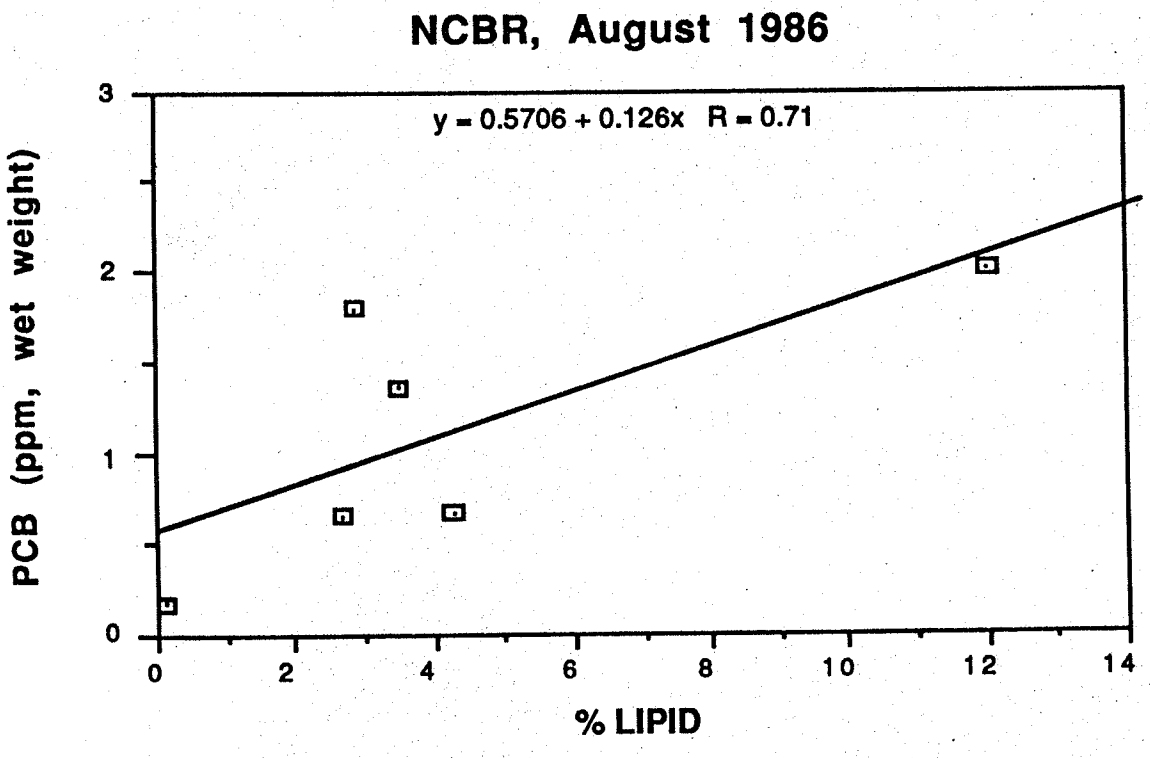


Figure 4. Scattergrams of regression lines generated for inside the Chicago Area CDF and for the Chicago River (NBCR) during the 1986 baseline study.

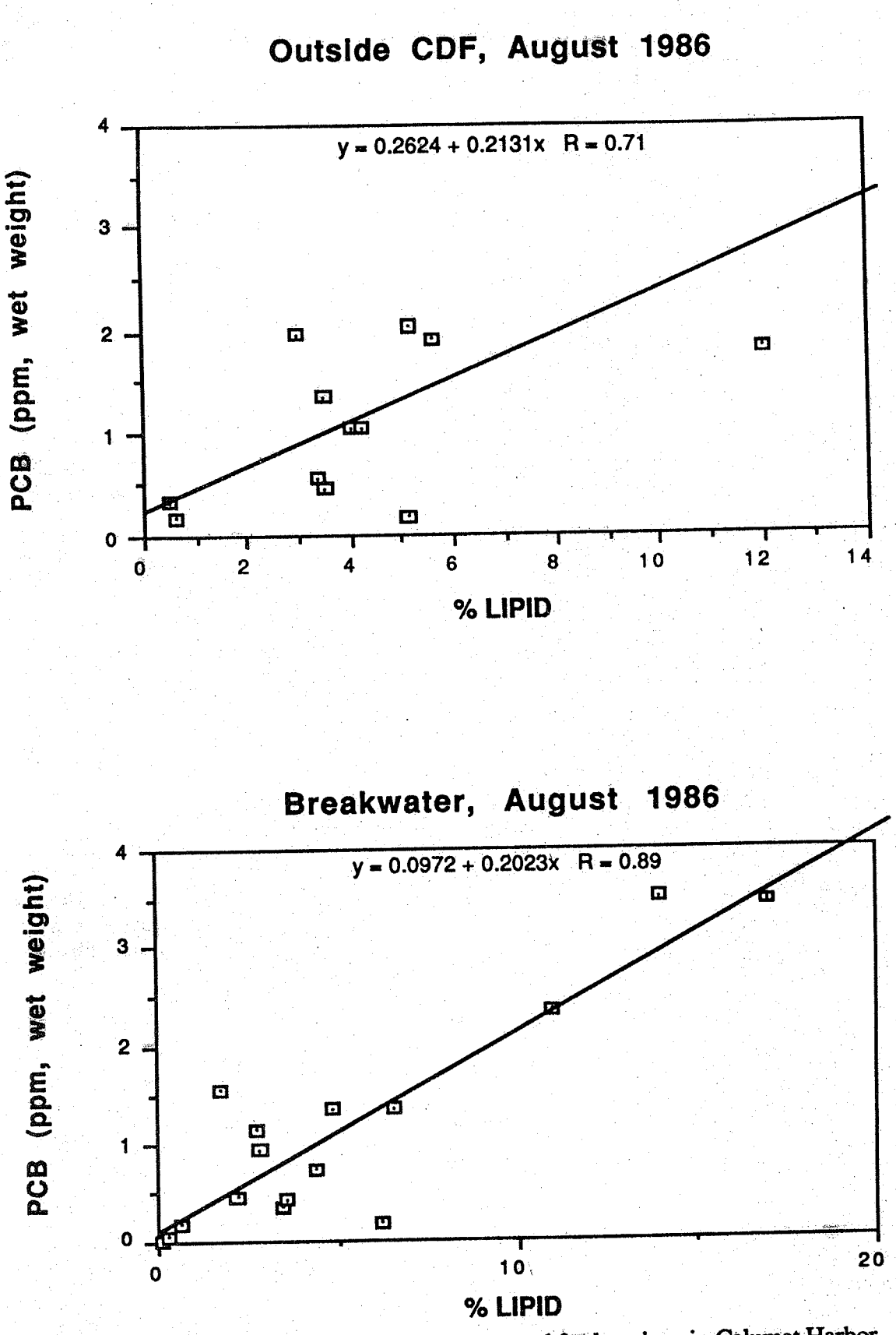


Figure 5. Scattergrams of regression lines generated for locations in Calumet Harbor near the Chicago Area CDF (outside) and away from the CDF (breakwater) during the 1986 baseline study.

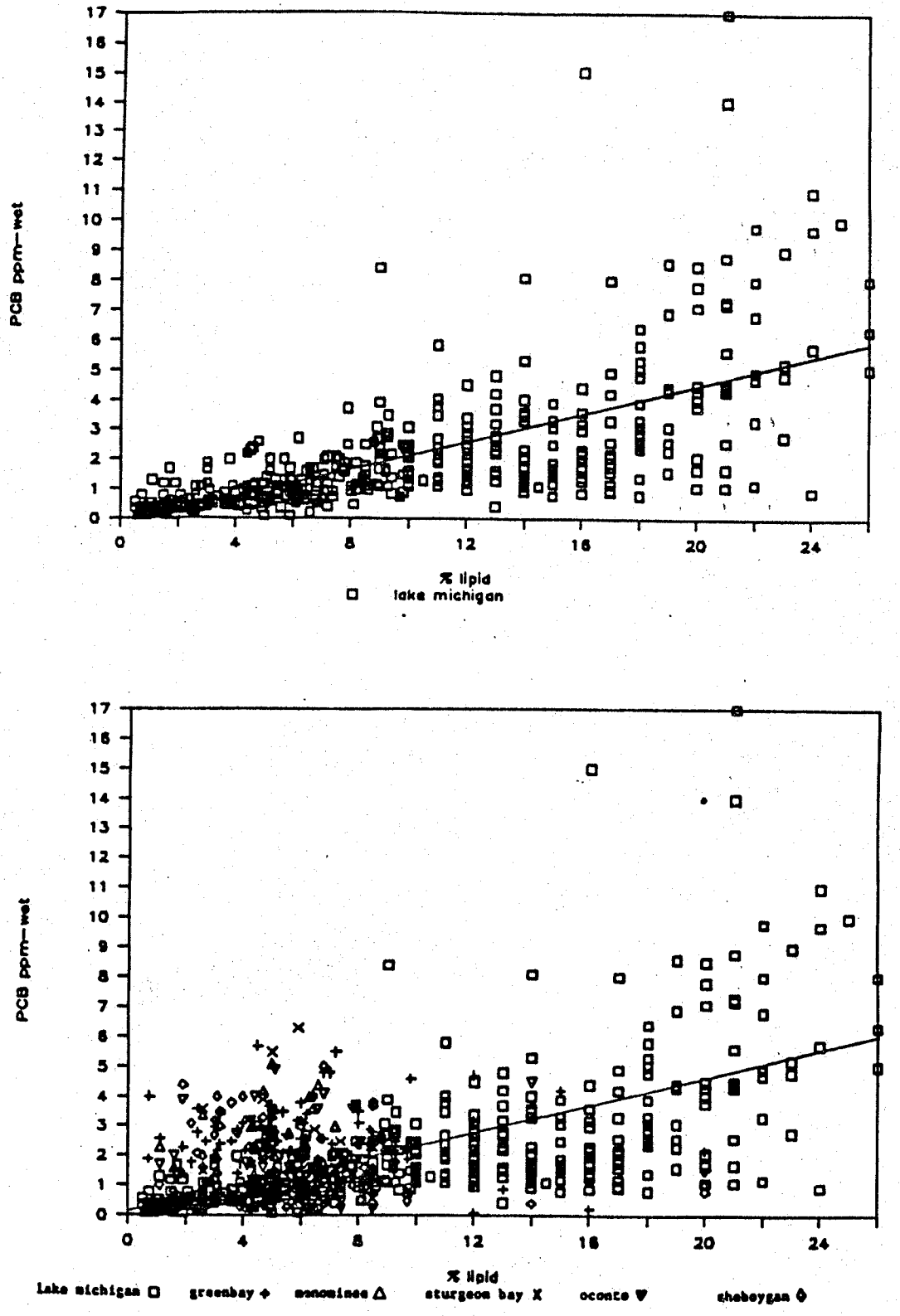


Figure 6. Scattergrams of regression lines generated for salmonids in Wisconsin waters of Lake Michigan in 1985 (Masnado, 1986).

CHAPTER 3: BIOASSAYS USING PROTOZOAN COMMUNITIES ON ARTIFICIAL SUBSTRATES

Introduction

Toxicity tests with single species have provided the majority of data used to evaluate the environmental hazard of chemicals (National Research Council 1981). As appreciation of the complexity of ecosystems has increased, so has concern about possible bias in hazard assessments based solely on the response of single species in isolation (Giesey 1980, Cairns 1984, Odum 1984).

The microbial community that colonizes artificial substrates includes a variety of taxa ranging from bacteria through protistans to small metazoans. This community is a composite of the communities inhabiting natural substrates (Henebry and Cairns 1984). Protozoan communities established on artificial substrates in natural systems are ideal units for toxicity studies (Cairns et al. 1985). Stable replicate communities (20-60 species) develop on the substrates within 3-21 days and are easily transfered intact from the field to the laboratory. Tests using these communities can be carried out rapidly (1 day for acute, 14-28 days for chronic) with minimal space and without elaborate apparatus (Cairns et al. 1980, McCormick et al. 1985). The use of these communities is scientifically valid since protozoa encompass several trophic levels (Pratt and Cairns 1985) and represent important components of aquatic food chains in both freshwater and marine ecosystems (Barsdate et al, 1974, Goldman 1983). In addition, most protozoan species exhibit a nearly cosmopolitan distribution, allowing the results of toxicity tests with protozoan communities to be applied to almost any system. Colonization experiments examining ecosystem level effects of nutrient loading in the Flint River (Georgia) demonstrated that protozoan communities more accurately reflected differences in water quality than other taxonomic groups examined, including algae, macroinvertebrates and fish (Pratt et al. 1985).

Structural and functional properties of protozoan communities have been used to evaluate the toxicity of heavy metals (Ruthven and Cairns 1973, Cairns et al. 1980, Niederlehner et al. 1985) and organic compounds (McCormick et al. 1985). Functional groups within the Protozoa (producers, bactivores, non-selective feeders, raptors, saprovores) may be differentially sensitive to different classes of toxicants.

Objectives

The objective of this portion of the study was to evaluate the responses of complex communities to contaminated sediments associated with the Chicago Area confined disposal facility (CDF). These responses were evaluated in a series of laboratory and *in situ* tests. The following hypotheses were tested: 1) Indigenous protozoan communities near the contaminated sediments previously disposed to the CDF would differ structurally from communities on the outside wall of the CDF and at sites in Lake Michigan assumed free of toxic contamination; and 2) experimental exposure to elutriates of contaminated sediments would cause changes in the structure and function of protozoan communities.

Materials and Methods

In situ colonization:

In order to evaluate the effect of possible seepage of contaminants from the CDF on indigenous communities in the ecosystem we compared the structure of protozoan communities colonizing polyurethane foam (PF) artificial substrates at stations inside and outside the CDF wall, and in a control area assumed to be free of toxic contamination. Substrates were placed near benthic Stations A5, A6 and A8 inside the CDF; at benthic stations B2, B3 and B6 directly outside the CDF wall; at benthic stations C1, C2 and C3 in the control area; and at benthic stations D1, D2 and D3 in the North Branch of the Chicago River.

We evaluated the structure of protozoan communites at each station by anchoring five identical PF artificial substrates (7.5 x 6.5 x 5 cm) in the lower portion (20 cm above the sediment surface) of the water column. All five substrates were collected after sufficient time (30 days at lake and CDF sites, 7-10 days at river sites) was allowed for the establishment of mature communities. Each substrate was sampled by squeezing it over a clean collecting vessel to remove as much of the contents as possible. The contents were allowed to settle, and the number of colonizing species and their abundances were determined by repeated subsampling and microscopic observation. Taxa were identified to genus and species when possible using standard taxonomic references (e.g., Kudo 1966). These methods and their repeatability are described in detail in Cairns et al. (1976) and Cairns et al. (1979). Protozoan species were classified into trophic levels based on feeding types (Pratt and Cairns 1985) similar to the classification scheme used for aquatic macroinvertebrates (Cummins 1973).

Laboratory bioassays:

Dredged material from the Chicago River and Harbor was collected from Station A1 on 3 September 1986 using a Ponar dredge. The material was mixed for homogenity, put into clean glass jars and stored at 4°C until chemical analysis and elutriation. Subsamples were elutriated by adding them to parts distilled filtered (1.2-µm nominal porosity) pond water in an acid-washed glass container. Air was bubbled through the system for two hours. After a settling period, the elutriate was filtered through a glass fiber filter (1.2-µm nominal porosity) and then diluted appropriately for the bioassays.

Protozoan communities were allowed to colonize PF substrates at a an assumed "clean" site; an 0.08-ha artificial pond (Illinois Natural History Survey [INHS] Pond 12) which had no history of toxic contamination (Gorden et al. 1981). After sufficient time was allowed for mature communities to develop, 6 to 12 PF substrates were collected and acclimated to a 16 h light (~1500 lux), 8 h dark regime and to ambient laboratory temperatures (24-26°C) for 48 to 96 h in 20-L filtered (1-um pore size) dilution water from INHS Pond 12. For each test, three substrates were exposed to a concentration of elutriate (25-100%) and three substrates (controls) to filtered Pond 12 water in separate 1000-mL acid washed beakers. The test and control systems were exposed to the light and temperature regime to which they had been acclimated. After 24-h substrates were removed from beakers and evaluated as in the colonization experiments.

Changes in photosynthetic and respiration rates were evaluated by transfering 20 replicate mature communities from INHS Pond 12 directly into 300-mL glass stoppered bottles (BOD bottles). To measure photosynthesis, three bottles containing communities in elutriate of contaminated sediment and three bottles containing communities in filtered pond water (controls) were exposed to light continuously. Dissolved oxygen (D.O.) in the bottles was measured with a YSI model 51B dissolved oxygen meter (equipped with a probe and an powered stirrer which was specifically designed for use with BOD bottles) at the start of the experiment and at 4, 8, 24, and 48-h. Photosynthesis rates were evaluated as the gain in D.O. in the bottles. To measure respiration three bottles containing mature communities in elutriate and three containing filtered pond water were kept in complete darkness and D.O. was measured at the intervals and by the method previously described. Respiration rates were evaluated as the loss in D.O.

The effect of elutriates on the colonization rate of barren substrates was evaluated usings microcosms in which small artificial *islands* were colonized by protozoa from known source pools (*epicenters*) (Cairns et al. 1980, Cairns and Pratt 1985). Our epicenters were protozoan communities which had been allowed to develop on PF substrates in INHS Pond 12. Static test systems consisted of 30-L plastic tubs filled with dechlorinated tap water containing 6 initially barren PF substrate islands one-fourth the size of the epicenters (Fig. 7). Filtered pond 12 water was used in preparing elutriates. Concentrations of elutriates (filtered pond water only in controls) were added to the test systems followed by placement of the islands. Epicenters were added last. Epicenters and islands were tied

with monofilament line to anchor loops on the tank bottom.

Six test tanks (three with elutriate of contaminated sediments, and three controls) were placed randomly under fluorescent lighting to provide a base level of photosynthesis (unmeasured) and to prevent nonrandom colonization by phototactic species. Light intensity was ~1500 lux, and was maintained on a 16L:8D schedule; temperature was 24-26°C. Dissolved oxygen was measured regularly in each tank and was never below 80% saturation.

One island from each tank was removed for sampling after 1, 3, 7, and 15 days. Epicenters were removed and examined for protozoa at the conclusion of the experiment. Contents of the substrates were sampled and examined as previously described.

Data analysis:

A Mann-Whitney U-test (Sokal and Rolf 1969) was used to test for differences in structural and functional parameters between test and control communities in the laboratory bioassays. A diversity index (H, Shannon and Weaver 1963) was calculated for protozoan communities on artificial substrates at each station. Differences in H were tested with a Kruskal-Wallis nonparametric analysis of variance (AOV) and a nonparametric multiple comparisons test by STP (Sokal and Rolf 1969). The Kruskal-Wallis AOV was also used to test for other structural differences (e.g., number of species) in communities located at different stations. Differences were considered significant at $P \leq 0.05$).

Results and Discussion

In situ communities:

The PF artificial substrate samplers were either lost or impossible to recover at Stations A6, B3, B6, C1, C2, and C3. Therefore, Stations C1 and C2 are not the same as the benthic stations with the same labels. Station C1 was 2-m off the breakwater north of the CDF, near benthic Station C2. Station C2 was 2-m off a breakwater in an assumed clean area of Waukegan Harbor. While not directly associated with the CDF project, Station C2 was on Lake Michigan and was sampled in August, 1986. A Kruskal-Wallis nonparametric AOV revealed highly significant differences in diversity (H) between stations (U_S=18.08, $P<0.001$). Mature protozoan communities on artificial substrates at Station A5 had a significantly higher value of H and communities on substrates at Station A8 (A5 and A8 were inside the CDF) had a significantly lower H- value than communities on substrates at other stations (Table 12). Communities on substrates outside the CDF (B2), had the same H- value as communities at Station C1 and D3; communities in control area C2, and in the at D1 and D2 in the Chicago River all had higher H- values (Table 12).

Differences in numbers of species (U_S=15.40, $P<0.009$), total abundance of protozoa (U_S=15.78, $P<0.007$) and phototrophic abundance (U_S=16.31, $P<0.006$) between stations were all highly significant. Mature PF substrate communities at Stations A5 and A8, Station B2 and Station D3 all had significantly lower numbers of protozoan species than substrates in the control areas (Fig. 8A). Substrates at Station A5 had significantly higher and substrates at Station A8 had significantly lower total abundances of protozoa than substrates at other stations (Fig. 8B). Substrate communities at station A5 had more than twice the abundance of phototrophs as communities at any other station (Fig. 8C); communities at the three Chicago River stations (D1, D2, D3) had less than half the phototrophic abundance found at other station.

Since pollution is generally thought to decrease biological diversity, it may be surprising that protozoan communities on PF substrates at a station inside the CDF (A5) had the highest H diversity, the highest total abundance of protozoa and the highest phototroph abundance. These findings

suggest that whatever their burden of toxic materials the dredged material contained substances which served as nutrients for protozoa.

Protozoan communities respond to all but the very highest levels of organic and inorganic nutrient pollution (i.e., almost any levels below those found in untreated sewage effluent) with increases in species diversity (Cairns 1966, Henebry and Cairns 1980). Pollution in the form of increased nutrient availability increases populations of rarer species of protozoa, which, in turn, increases measures of community diversity. and may alter the percentage of protozoa in each trophic category. Station A5 was located near the midpoint of the CDF about 200-m from the site of the most recently deposited dredged material (Station A1). It appears that protozoan communities at Station A5 may have benefitted from increased levels of nutrients inside the CDF without being exposed to significant amounts of toxic material from from the site of sediment deposition. Soluble organic matter in the dredge spoil probably stimulated production of bacteria which serve as food for bactivorous protozoa, and inorganic nutrients leached from the sediments may have stimulated production of autotrophic protozoa.

Substrate communities at Station A8 were apparently exposed to levels of toxic substances which counteracted any stimulatory effects of nutrients contained in the dredged sediments. As a comparison, protozoan communities which colonized artificial substrates in an area of Waukegan Harbor which had high levels (300-14,000 ppm) of PCB contamination in the sediments had significantly lower numbers and abundances of phototrophic protozoans than communities on substrates in an area of the harbor assumed to be free of PCB contamination (Ross et al., in preparation).

It appears that pollution (probably nutrient pollution from municipal sewage effluent) in the Chicago River stimulated populations of heterotrophic, bactivorous protozoa. Mature protozoan communities in uncontaminated systems are composed primarily of bactivorous-detritivorous species (70-90%) and phototrophic species (15-20%) (Pratt and Cairns 1985). The numbers of species and the total abundance of protozoa in substrate communities were higher in the Chicago River than at most other stations, but the phototroph abundance was very low (0-5%). Some of the abundant bactivorous-detritivorous species in substrate communities at the Chicago River stations (e.g., *Vorticella microstoma*) are considered indicators of organic pollution (Bick 1972, Henebry and Ridgeway 1979). In contrast to the situation in the Chicago River the percentage of the total protozoan abundance composed of phototrophic species ranged from 40-78% in communities at the assumed clean stations in Lake Michigan and at stations inside and outside the CDF. Higher turbidities (not measured) may have also had a role in reducing the importance of phototrophic species in protozoan communities at stations in the Chicago River.

Communities colonizing PF substrates at Station A5 and exposed to light for 24 hours had significantly higher oxygen liberation (photosynthesis) than communities from other stations (Fig. 9). Communities colonizing PF substrates at stations inside the CDF, just outside the CDF and at control sites all liberated oxygen when exposed to light (Fig. 9); but, PF substrate communities from stations in the North Branch of the Chicago River only consumed oxygen.

These results supported the changes in structural patterns seen in the PF substrate communities. The highest amount of oxygen liberation occurred in communities from Station A5, where nearly 80% of the protozoa in the communities were phototrophs. Communities from stations in the Chicago River had few phototrophs, and they consumed oxygen even under continuous exposure to light.

Laboratory bioassays:

Because the PF artificial substrates held about 150-mL of water and detritus it was impossible to run respiration bioassays in 300-mL B.O.D. bottles at greater than a 50% elutriate concentration. After 24 hours exposure of mature communities from INHS Pond 12 to a 50% concentration of Station A1 elutriate significantly less oxygen was liberated in test than in control communities (Fig. 10).

These results indicate that dissolved materials from sediments in the North Branch of the Chicago River and Harbor are somewhat toxic to phototrophic protozoa, but may stimulate the acitivities of heterotrophs. In another study (Ross et al., in preparation), the oxygen liberation by PF substrate protozoan communities was significanctly reduced by exposure to elutriates of PCB-contaminated sediments; exposure to elutriate from the PCB-contaminated sediments had little effect on oxygen consumption.

There was no significant decrease in numbers of species in PF substrate epicenter communities in either test or control systems during the 15-day island/epicenter experiments (Table 13). The total abundance on test communities was significantly reduced over that in controls. Numbers, abundance, and percentage of phototrophic species in epicenter communities increased significantly during the bioassays (Table 13).

The epicenters in the colonization test systems served not only as sources of species in the colonization experiments but as mature communities which were directly exposed to elutriate from the site of deposition of Chicago River and Harbor dredge spoil. Numbers of protozoan species on the epicenters exposed to CDF sediment elutraite were not significantly reduced over numbers in control systems, even after 15 days. In comparison, numbers of species in mature communities from INHS Pond 12 were significantly reduced within 24 hours when exposed to 100% elutriate from a PCB contaminated site (14,000 ppm PCB) in Waukegan Harbor (Ross et al., in preparation). The reduction in total abundance of protozoa in both test and control laboratory systems has been observed previously (Ross et al, in preparation) and is thought to be caused by a combination of reduced nutrient availability and the lack of colonization pressure from new immigrants (MacArthur and Wilson 1967).

Numbers of protozoan species (Fig. 11a) and their total abundance (11b) and phototrophic abundance (Fig. 11c) on island PF substrates were significantly lower in test (100% Chicago River dredge spoil elutriate) than control (no elutriate) systems at the conclusion of the colonization experiments. The significant reductions in numbers of species and in phototrophic abundance on islands in test systems indicates that 100% Chicago River dredge spoil elutriate does have an inhibitory effect on on the colonization of barren islands by protozoa. In a similar study (Ross et al., in preparation) a 25% concentration of elutriate from an area of Waukegan Harbor contaminated with PCB (300-14,000 ppm in sediments) significantly retarded colonization. The colonization of barren island substrates is a more sensitive endpoint than the reduction in number of species in mature communities (Cairns et al. 1980, Cairns and Pratt 1985).

Ecotoxicological significance:

The results of the various types of community tests were consistent, and several trends were clear. First, contaminants in the dredged material depsited at Station A1 did have detectable effects on the structure and function of protozoan communities. Because *in situ* colonization tests were conducted with indigenous species, we do not need to exptrapolate laboratory data to predict the impact of dredge spoil contaminants on protozoan communities. Since Shannon-Weaver diversity, numbers of species and total abundance of protozoa in PF substrate communities were reduced at a station (A8) near the site of deposition of dredged sediments, we can state with a fair degree of confidence that exposure to contaminants in dredged material caused the changes seen in the protozoan communities. It appears that the impact of the contaminants in the dredge spoil did not extend outside the CDF.

The information provided by this series of protozoan tests is more complex than that provided by single the species bioassays. The results are probably more realistic in terms of predicting the impact of sediment contamination on actual communities, or the ecosystem. However, caution must be exercised in conducting these experiments and in interpreting the resulting data. For example, the high diversity (H) at a station inside the CDF seems contradictory to the concept that pollution decreases the diversity of organisms in communities. However, when the study of the Chicago Area CDF was

initiated it was suggested that contaminants in the dredge spoil included a combination of PCB and heavy metals (toxicants) and nitrogen (a nutrient). It appears that exposure to contaminants in sediment at a station (A8) near the site of deposition of dredged sediment reduced Shannon-Weaver diversity and caused a shift in the community toward heterotrophy. At the same time autotrophs seemed to have been stimulated at station (A5), located about 200-m from the site of dredge spoil deposition. Polychlorinated biphenyls and heavy metals tend to adhere to particulate matter, whereas ammonia is very water soluble (Sawyer and McCarty 1978). Since particulate matter would settle out quickly in a small, protected body of water such as the CDF, it is likely that the distribution of toxic contaminants in the CDF would be more limited in area than the ammonia. As a result, the toxic effect of contaminants should occur over a more limited area than stimulatory effect of the ammonia.

The sensitivity of protozoans to toxic chemicals seems to span the range defined by more standard test organisms (Ruthven and Cairns 1973, Dive 1981); as a group they are neither particularly sensitive or resistant.

After examining a large number of damaged and healthy aquatic ecosystems, Niederlehner et al. (1986) found convincing evidence that levels of soluble cadmium in the range between the concentration causing reduction in numbers of protozoan species in mature communities (459 ug Cd/L) and the concentration causing impairment of colonization (0.20 ug Cd/L) were within a rational range -- the minimum defined by median cadmium concentrations in healthy aquatic systems (0.05 ug Cd/L) and the maximum defined by median cadmium concentrations in damaged systems (9.2 ug Cd/L). Niederlehner et al. (1986) state that in the absence of field validation, it is impossible to confirm the predictive utility of either population or community level estimates of a permissible acute level of a toxicant.

The combination of field and laboratory tests used in this study of the Chicago Area CDF show that protozoan communities on artificial substrates may provide a field validation method which is rapid, accurate and cost-effective. Since protozoan communities include representatives of almost every trophic level (feeding type), these results presented here should be useful in predicting the responses of other organisms to contamination in the dredged material.

Conclusions

The laboratory studies showed that contaminants in recently dredged sediments from the North Branch of the Chicago River and Harbor that were deposited into the CDF resulted in predictable structural and functional changes in the protozoan communities. The *in situ* tests suggested that contaminanted sediments in the CDF were only moderately toxic to protozoans colonizing artificial substrates suspended in the water column above recently deposited material. The toxic effect was limited in area, such that toxicity diminished with increased distance from the deposition site. There was no detectable impact on protozoan communities at a station on the outside wall of the CDF. It is recommended that additional stations be monitored to confirm these preliminary findings.

SUMMARY

A series of laboratory bioassays and *in situ* studies with indigenous protozoan communities were used to evaluate the ectotoxicological hazard of contaminants in the Chicago Area Confined Disposal Facility (CDF). The laboratory studies showed that contaminants in recently dredged sediments (from the North Branch of the Chicago River and Harbor) deposited into the CDF resulted in structural and functional changes in the protozoan communities. The *in situ* tests suggested that contaminated sediments in the CDF were only moderately toxic to protozoans colonizing artificial substrates suspended in the water column about 20-cm above recently deposited sediments. The toxic effect was limited in area, in other words the toxicity diminished with increased distance from the site of deposition of dredged material. There was no detectable impact on protozoan communities at a station on the outside wall of the CDF. It is recommended that additional stations be monitored to confirm these preliminary findings.

Table 12a. Diversity (H) and evenness (e) of protozoan communities colonizing artificial substrates at stations within the four study areas; ± one standard deviation.

Station	N	H	e
Inside CDF			
A5	3	7.09±0.55	5.15±0.29
A8	3	2.10±0.23	1.80±0.21
Outside CDF			
B2	3	2.63±0.17	1.96±0.07
Control Stations			
C1	3	2.88±0.06	1.91±0.03
C2	3	3.48±0.31	2.39±0.26
Chicago River			
D1	3	3.47±0.21	2.37±0.15
D2	2	3.93±0.32	2.69±0.22
D3	3	3.03±0.07	2.25±0.07

Table 12b. Nonparametric multiple comparisons (STP) applied to H at stations within the four study areas. Values connected by lines are not significantly different (P<0.05).

A8	B2	C1	D3	D1	C2	D2	A8
2.10	2.63	2.88	3.03	3.47	3.48	3.93	7.09

Table 13. Structure of protozoan communities used as epicenters in laboratory colonization experiments. Each value represents the mean of three replicates; Standard deviations are in parentheses. Significant differences ($\partial \leq 0.05$) from start of experiments (a) and of test communities from controls (b) are indicated.

Parameter	At start of experiments	After 15 days in control systems (filtered pond water)	After 15 days in test systems (100% elutriate)
# Species	23.3±3.7	19.7±2.5	18.7±2.3
Total Abundance	429.3±17.3	94.3±13.5[a]	60.3±8.7[a,b]
# Phototrophic Species	2.1±1.1	4.3±2.5	4.3±2.2
Phototroph Abundance	3.3±1.5	27.7±6.3[a]	24.5±4.2[a]
% Phototrophs	8.7	21.1	22.2
% Abundance Phototrophs	0.7	28.7	40.0

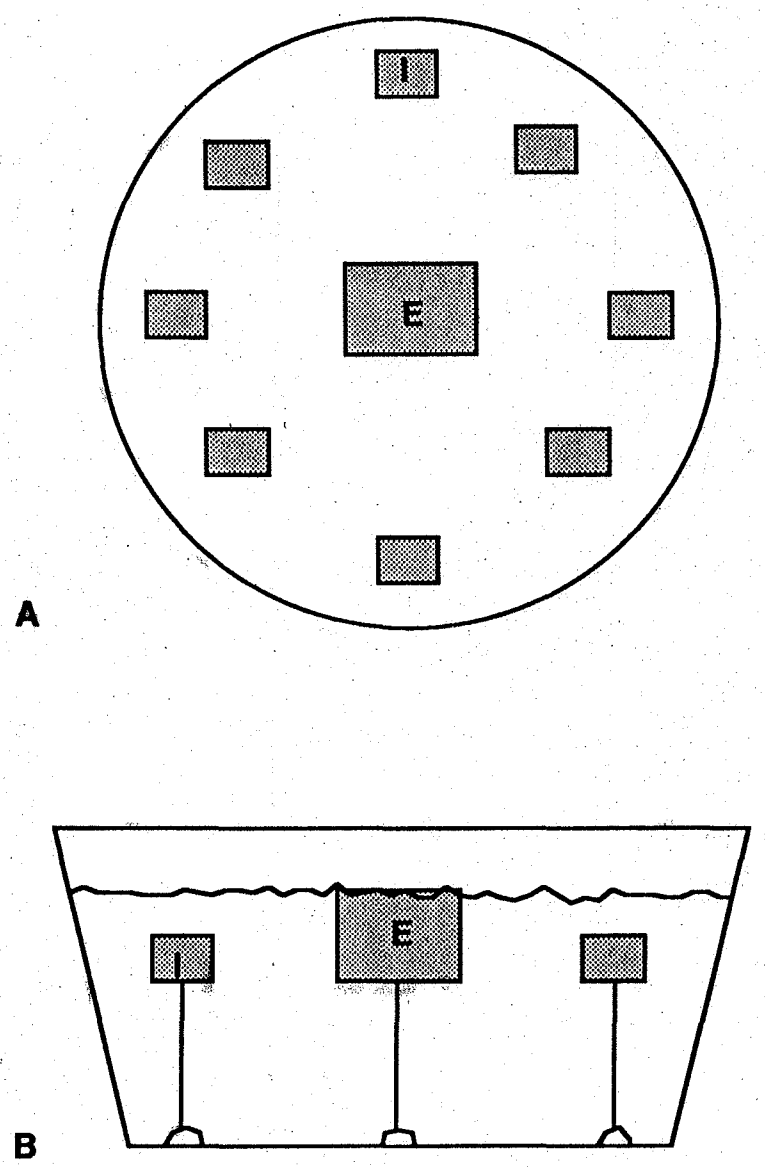


Figure 7. Top (A) and lateral (B) views of 30-L test systems used in island (I)/epicenter (E) colonization experiments. Not drawn to scale.

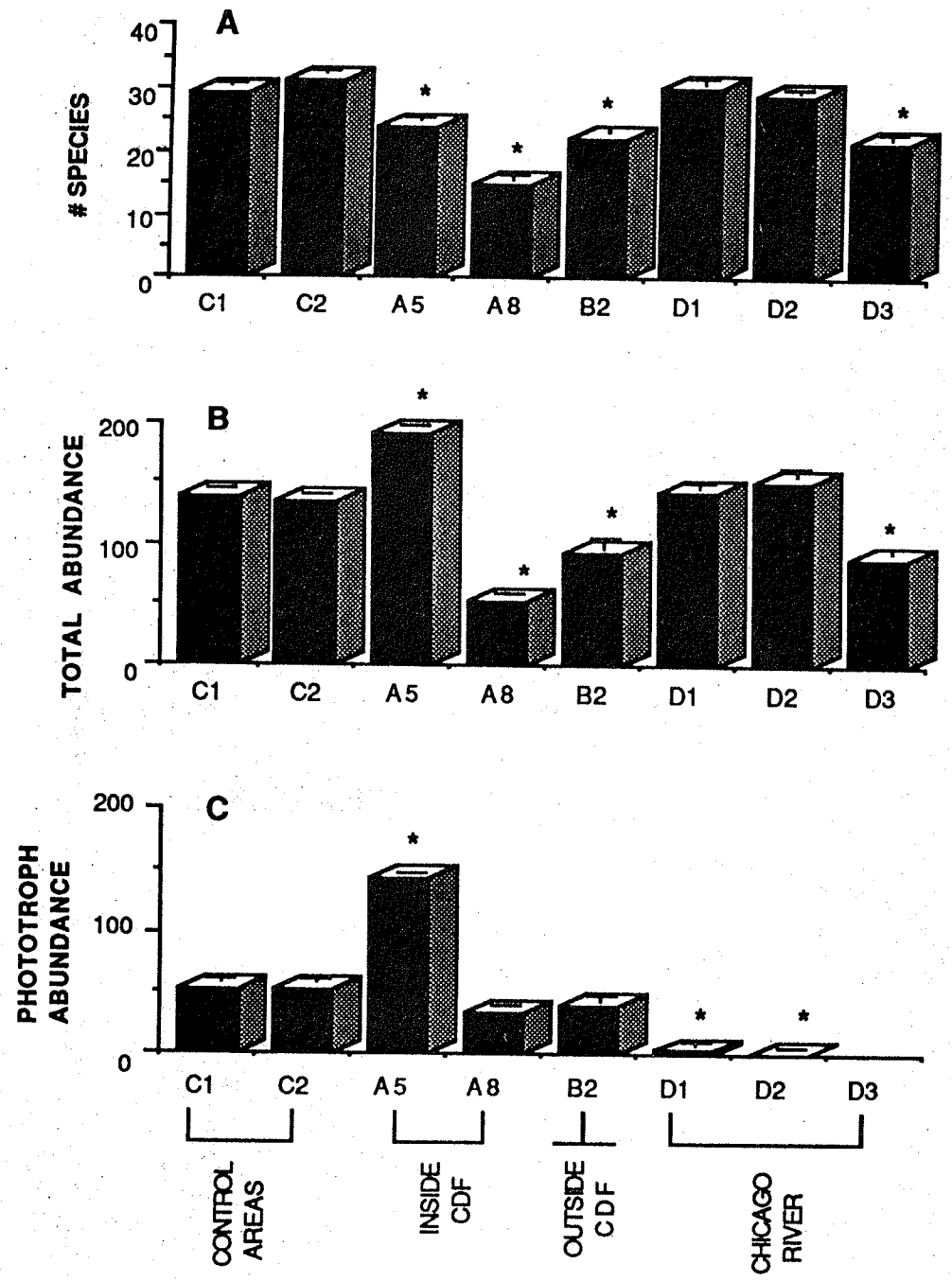


Figure 8. Number of species (A), total abundance (B) and phototroph abundance (C) in mature protozoan communities on artificial substrates at stations within the four study areas. Each value is the mean of three replicates. Asterisks (*) indicate significant differences from controls.

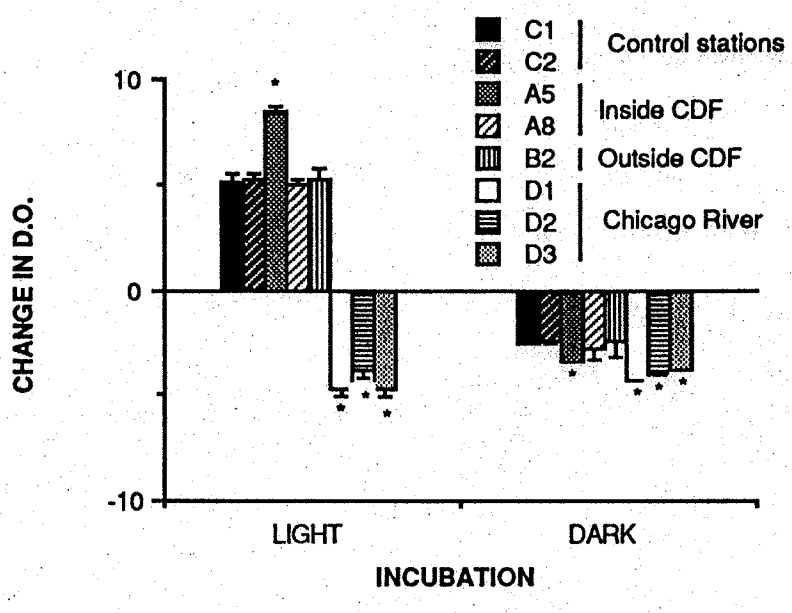


Figure 9. Dissolved oxygen changes in mature substrate communities from stations associated with the Chicago Area Confined Disposal Facility after 24 hours in laboratory microcosms; three replications. Asterisks (*) indicate significant differences from controls.

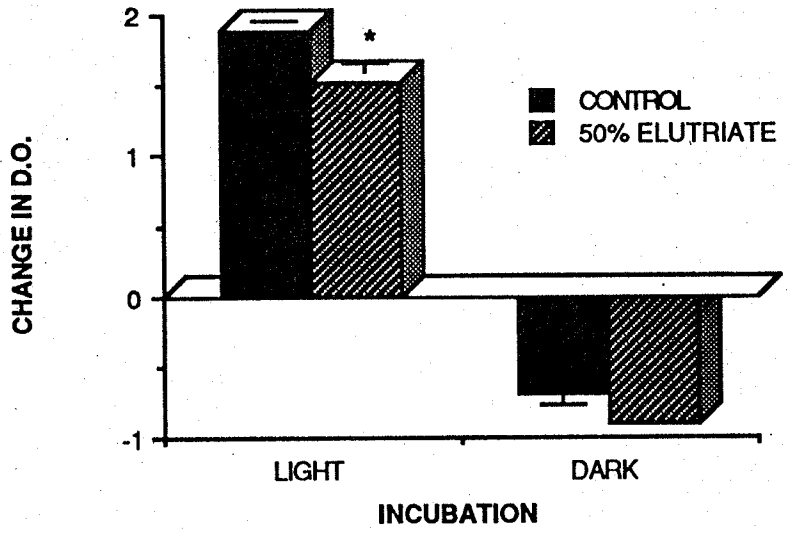


Figure 10. Dissolved oxygen changes in mature artificial substrate communities from INHS Pond 12 after 24 hours exposure to elutriate of sediment from Station A1 inside the Chicago Area Confined Disposal Facility; three replicates. Asterisk (*) indicates significant difference from control.

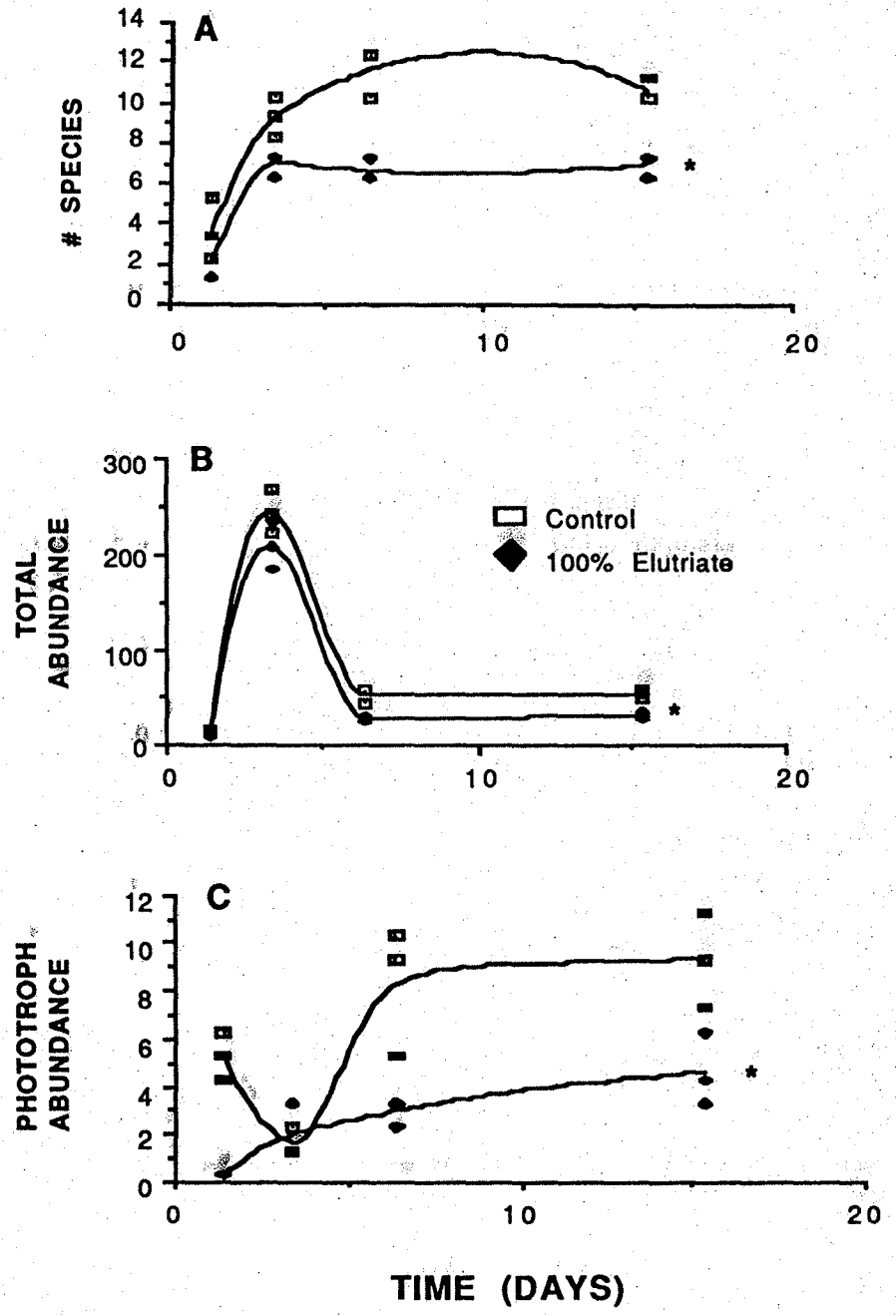


Figure 11. Experimental colonization of barren islands by protozoa from mature epicenters during exposure to elutriate of dredged material from the Chicago River and Calumet Harbor (collected at station A1). Shown are changes in numbers of species (A), total abundance (B) and phototroph abundance (C) in protozoan communities. Asterisks (*) indicate significant differences from controls on final day of colonization.

CHAPTER 4: BACTERIAL BIOLUMINESCENCE BIOASSAYS

Introduction

The objective of this segment of the study was to provide baseline toxicity data on existing surface sediments at the various study locations (Chicago Area CDF, Calumet Harbor, Breakwater Reference Area, and North Branch Chicago River). Elutriation, a water leach using one part sediment to four parts leaching water, was developed as an accurate method to predict which components of the sediment will be released into the water column. It has been used in a wide range of conditions in marine, estuarine and freshwater systems (Engler, 1980). Elutriates from sediment samples at study sites in Chicago Area Confined Disposal Facility Project sites were used in a single-species bacterial bioluminescence assay, the Microtox™ test.

Materials and Methods

Samples were collected by Ponar dredge and transported and stored at 4°C until analysis. The Microtox™ assay was developed on the principle that the luminescent properties of the bacterium *Photobacterium phosphoreum* will be inhibited upon exposure to a toxic substance. The luminescence of cultures exposed to a series of dilutions of elutriate was measured with the Microtox™ analyzer, a specially designed fluorometer. After correcting for the measured natural light decay in blank samples, the decrease in the luminescence of stressed cultures was calculated. A dose-response curve was plotted by comparing elutriate concentrations with percent luminescence loss at each concentration. This test was performed on elutriates of sediment samples from 22 stations.

Table 14 lists these stations as well as a calculated toxicity value for each. This value, the EC_{50}, represents the estimated elutriate concentration at which 50% of the luminscence in the test culture is lost, relative to an unstressed culture (the control). The lower the EC_{50} value, the more toxic is the sediment elutriate, as it takes less elutriate to produce a 50% inhibition.

A calculated EC_{50} value above 100% indicates that there was some measureable (statistically significant) inhibition of luminescence, but that this inhibition never reached 50%, even at the 100% test concentration of elutriate. Thus an extrapolation of the dose-response curve reaches 50% inhibition at an elutriate concentration value greater than 100%.

It is also possible to have an EC_{50} value slightly less than zero. These negative values indicate that even the lowest elutriate concentration tested produced almost total inhibition, so that the concentration producing 50% inhibition would have to be even lower than that. In this case, extrapolation of the dose-response curve to 50% inhibition will yield a very low estimated EC_{50}, which can sometimes be slightly below zero.

The notation "no toxicity" indicates that no statistically significant inhibition of luminescence was observed, even at the 100% test concentration.

Results

At the stations inside the CDF, the most toxic sediments were from stations A-1 (at the site of deposition of dredged material from 1986 operations) and A-7 (very close to the existing shoreline at Iroquois Landing). Both of these sediments would be classed as highly toxic in the Microtox™ test, as EC_{50} values were below 10%. Another sediment sample from station A-6, the deposition

site of the "special excavation" (fly-ash-like material relocated during dike construction), would be classified as moderately toxic, with an EC_{50} below 50%.

At stations outside the CDF walls, sediments from one station off the east wall (B-9) and from one station off the north wall (B-5) registered as highly toxic, while five other stations were classified as moderately toxic (Table 14).

At stations in the Calumet Harbor Breakwater Area, the control area for the study, the two stations near the northeast-facing segment of the wall showed very low toxicity, while the station on the north-facing segment, nearer the shoreline (C-1) showed high toxicity. Without further knowledge of the area, it is difficult to explain the toxicity at this station.

The three sediment samples from the North Branch of the Chicago River (Stations D-1, D-2 and D-3) were all evaluated as highly toxic in the Microtox™ test.

Discussion

The method employed allows for standardized and reproducible measurements of the potential toxicity in surface sediments. There is at present no ability to predict whether any of this measured toxicity is being expressed in aquatic biota at the site, either normally or during dredging/disposal operations. Elutriate tests may exaggerate disturbance of sediment, and the use of deionized water as the dilution medium may not be representative of natural reduction to toxicity expression caused by the natural buffering capacity of harbor waters. The method does, however, allow for an excellent description of the potential sediment toxicity for the purpose of monitoring changes occuring in the harbor.

The Chicago River sediments were consistently highly toxic, based on the three samples collected from an area known to be the most contaminated reach involved in the current navigation project. This toxicity would be most likely to be expressed under condotions of extreme sediment disturbance, such as violent storms or hydraulic dredging/disposal activities. No assessment of the degree of toxicity expression from disturbance of these sediments under natural conditions is possible from the present data.

Some patches of bottom yield sediments with high toxic potential, while others do not. The Calumet harbor substrate is highly variable in this respect. Surprisingly, the substrate inside the CDF pond is also highly variable with respect to measured toxicity, despite the fact that these sediments had been previously dredged and rehandled. This suggests that the toxic substances in these sediments may be tightly bound to sediment particles, or that they may quickly return to particle binding sites under field (lake water) buffering conditions.

Table 14. Toxic response in the MICROTOX bioassay to elutriates from sediments at Chicago Area CDF Project sites.

STATION	MICROTOX EC50 % ELUTRIATE (15 min, 15°C)
A-1	5.08
A-3	no toxicity
A-4	166.91
A-5	662.74
A-6	37.64
A-7	-5.11
A-8	62.08
B-1	24.36
B-2	712.58
B-3	22.26
B-4	37.21
B-5	6.03
B-6	35.08
B-7	25.47
B-8	110.80
B-9	5.56
C-1	5.88
C-2	127.34
C-3	96.89
D-1	4.80
D-2	10.35
D-3	6.63

APPENDIX A: BENTHOLOGICAL STUDIES

Samples for benthic studies were collected in the Calumet Harbor areas (A, B, and C) on 30 and 31 July 1986, and from the North Branch of the Chicago River on 28 August 1986. These samples were collected and analyzed to provide baseline macroinvertebrate population data for future monitoring of changes to the harbor biota. Biomass information was collected and analyzed to assist in future contaminant fate modelling that may require these estimates. A petite ponar dredge was the sampling device. Sediments were screened and sorted, and animals preserved and mounted according to standard procedures.

Tables A-1 through A-10 give detailed taxonomy and biomass data for each of the four study sites. In addition, a separate, annotated report of the oligochaete taxonomy and distribution is given at the end of this appendix, beginning on page 68.

Biomass and species richness at stations within the CDF (A stations) were uniformly low. This is understandable, since newly deposited sediments require several years to develop a typical benthic fauna. At stations outside the CDF, the north wall of the CDF (stations B-1 to B-5) and the breakwater control area (C stations) show similar assemblages, while the east wall of the CDF (stations B-6 to B-10) had only half the biomass of the other two areas, presumably because it is more exposed to Lake Michigan wave action.

The most striking result of the benthic study was the high biomass and low diversity at the Chicago River stations. Only 4 taxa were found, and 99.8% of the biomass consisted of oligochaetes. The mean biomass value, 4.4 kg dry weight per square meter, is extremely high and is almost entirely accounted for by tubificids.

The population densities and diversity of benthic fauna sampled in this study are consistent with those reported in similar studies of moderately polluted areas of Lake Michigan by other investigators.

Table A-1. Biomass (mg/m^2, dry wt) and % composition of the dominant major invertebrate groups collected by petite ponar dredge from Area A (inside CDF) on 31 July 1986.

TAXA	Station A1		A2		A3		A4		A5		A6		A7		A8		Mean	
	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%	mg	%
Nematoda	0.17	<0.1	--	--	0.08	<0.1	--	--	1.25	0.1	0.33	<0.1	--	--	--	--	0.22	<0.1
Oligochaeta	720.8	93.4	437.1	85.5	437.1	86.5	--	--	1581.8	96.3	754.1	98.2	662.6	98.4	1131.5	77.9	715.6	90.5
Leptodoridae	--	--	--	--	--	--	--	--	0.2	<0.1	--	--	--	--	0.2	<0.1	0.05	<0.1
Chironomidae	50.83	6.5	74.2	14.5	68.33	13.5	--	--	59.2	3.6	13.1	1.7	10.8	1.6	320.8	22.1	74.7	9.4
TOTAL BIOMASS	771.75		511.27		505.51		0		1642.36		767.55		673.46		1452.54		790.55	

Table A-2. Density (No./m^2) and % composition of invertebrates collected by petite ponar dredge from Area A (inside CDF) on 31 July 1986.

TAXA	Station A1 /m2	%	A2 /m2	%	A3 /m2	%	A4 /m2	%	A5 /m2	%	A6 /m2	%	A7 /m2	%	A8 /m2	%	Mean /m2	%
Aschelminthes																		
Nematoda (uniden)	83	2.7	--	--	42	1.6	--	--	625	5.5	167	3.9	--	--	42	0.3	120	2.5
Annelida																		
Oligochaeta																		
Naididae																		
(unidentified)	542	17.5	125	9.7	42	1.6	--	--	1333	11.7	167	3.9	458	12.8	2750	22.5	677	14.1
Bratislava undentata	--	--	42	3.3	--	--	--	--	--	--	--	--	--	--	--	--	5	0.1
Dero digitata	125	4.0	83	6.4	375	14.5	--	--	4667	41.0	42	1.0	833	23.2	2708	22.2	1104	23.0
TOTAL NAIDIDAE	667	21.5	250	19.3	417	16.1	--	--	6000	52.7	209	4.8	1291	36.0	5458	44.7	1786	37.1
Tubificidae																		
Aulodrilus pigueti	--	--	--	--	--	--	--	--	--	--	--	--	--	--	42	0.3	5	0.1
Ilyodrilus templetoni	--	--	--	--	--	--	--	--	--	--	--	--	42	1.2	--	--	5	0.1
Limnodrilus cervix	--	--	83	6.4	--	--	--	--	750	6.6	292	6.7	83	2.3	--	--	151	3.1
L. cervix var.	--	--	--	--	42	1.6	--	--	--	--	--	--	--	--	125	1.0	21	0.4
L. hoffmeisteri	292	9.4	292	22.6	42	1.6	--	--	250	2.2	417	9.6	292	8.1	4	0.3	203	4.2
L. maumeensi	--	--	--	--	--	--	--	--	83	0.7	--	--	--	--	42	0.3	16	0.3
L. udekemianus	--	--	42	3.3	--	--	--	--	--	--	--	--	--	--	--	--	5	0.1
Potamothrix vejdovskyi	--	--	--	--	--	--	--	--	--	--	--	--	42	1.2	--	--	5	0.1
Quistadrilus multisetosus	250	8.1	125	9.7	--	--	--	--	--	--	83	1.9	--	--	167	1.4	78	1.6
TOTAL TUBIFICIDAE	667	21.5	584	45.2	167	6.5	--	--	1250	11.0	834	19.2	459	12.8	543	4.4	563	11.7
*UIW/OCC (mostly Tub)	1167	37.7	125	9.7	1708	66.1	--	--	3083	27.1	2833	65.4	1167	32.6	4583	37.5	1833	38.1
**UIWCC (mostly Tub)	208	6.7	83	6.4	--	--	--	--	167	1.5	42	1.0	83	2.3	167	1.4	94	2.0
TOTAL OLIGOCHAETA	2679	86.5	1042	80.7	2292	88.7	--	--	10500	92.3	3918	90.4	3000	83.7	10751	88.1	4273	88.9
Arthropoda																		
Crustacea																		
Cladocera																		
Leptodoridae																		
Leptodora kindti	--	--	--	--	--	--	--	--	42	0.4	--	--	--	--	--	--	5	0.1
Insecta																		
Diptera																		
Chironomidae																		
Tanypodinae																		
Coelotanypodinae																		
Coelotanypus	42	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	0.1
Procladiini																		
Procladius	167	5.4	208	16.1	208	8.0	--	--	208	1.8	125	2.9	583	16.3	417	3.4	240	5.0
Chironominae																		
Chironomini																		
Chironomus	42	1.4	--	--	42	1.6	--	--	--	--	--	--	--	--	1000	8.2	136	2.8
Cladopelma	--	--	42	3.3	--	--	--	--	--	--	--	--	--	--	--	--	5	0.1
Tanytarsini																		
Tanytarsus	83	2.7	--	--	--	--	--	--	--	--	125	2.9	--	--	--	--	26	0.5
TOTAL CHIRONOMIDAE	334	10.8	250	19.3	250	9.7	--	--	208	1.8	250	5.8	583	16.3	1417	11.6	412	8.6
TOTAL ORGANISMS	3096		1292		2584		--		11375		4335		3583		12210		4809	
Number of taxa	8		8		6		0		7		7		6		9		6.4	
Diversity Value	1.69		1.90		1.62		0		1.38		1.56		1.51		1.77		1.43	
Eveness	0.77		0.87		0.83		0		0.67		0.74		0.84		0.77		0.69	

-- denotes taxa not present

* denotes unidentifiable immatures without capilliform setae

** denotes unidentifiable immatures with capilliform setae

Table A-3. Biomass (mg/m2, dry wt) and % composition of the dominant major invertebrate groups collected by petite ponar dredge from the north wall of Area B (outside CDF) on 30 July 1986.

	Station											
TAXA	B1 mg/m2	%	B2 mg/m2	%	B3 mg/m2	%	B4 mg/m2	%	B5 mg/m2	%	Mean mg/m2	%
Nematoda	1.88	<0.1	–	–	–	–	–	–	0.02	<0.1	0.38	<0.1
Bryozoa	3.13	0.1	–	–	–	–	–	–	2.50	<0.1	1.13	<0.1
Hirudinea	–	–	–	–	–	–	–	–	300.00	1.9	60.00	0.9
Oligochaeta	4123.00	98.6	4730.60	99.4	1788.70	97.6	8463.01	98.3	13692.71	87.3	6559.60	93.5
Physidae	–	–	–	–	–	–	65.42	0.8	52.29	1.2	23.54	0.3
Sphaeriidae	18.21	0.4	–	–	–	–	71.46	0.8	1539.50	9.8	325.83	4.6
Empididae	9.75	0.2	–	–	–	–	–	–	--	--	1.95	<0.1
Chironomidae	25.00	0.6	28.33	0.6	43.33	2.4	10.83	0.1	94.16	2.3	40.33	0.6
TOTAL	4180.97		4758.93		1832.03		8610.72		15681.18		7012.77	

Table A-4. Density (No./m2) and % composition of invertebrates collected by petite ponar dredge from the north wall of Area B (outside CDF) on 30 July 1986.

TAXA	Station B1 No/m2	%	B2 No/m2	%	B3 No/m2	%	B4 No/m2	%	B5 No/m2	%	Mean No/m2	%
Aschelminthes												
Nematoda (uniden)	292	0.3	–	–	–	–	–	–	42	<0.1	67	0.1
Bryozoa (Ectoprocta)	1	<0.1	–	–	–	–	–	–	1	<0.1	<1	<0.1
Annelida												
Hirudinea												
Glossisiphoniidae												
Helobdella elongata	–	–	–	–	–	–	–	–	167	0.1	33	<0.1
H. stagnalis	–	–	–	–	–	–	–	–	667	0.3	133	0.1
Oligochaeta												
Naididae												
(unidentified)	417	0.5	–	–	332	3.4	–	–	--	--	150	0.2
Nais sp.	–	–	–	–	332	3.4	–	–	--	--	66	0.1
N. communis	417	0.5	–	–	–	–	–	–	--	--	83	0.1
N. pardalis	2083	2.3	–	–	–	–	–	–	--	--	417	0.4
N. variabilis	–	–	–	–	–	–	–	–	3332	1.6	666	0.7
Paranais frici	833	0.9	–	–	–	–	–	–	--	--	167	0.2
Slavina appendiculata	1250	1.4	–	–	–	–	–	–	--	--	250	0.3
Vejdovskiella intermedia	–	–	–	–	–	–	–	–	3332	1.6	666	0.7
TOTAL NAIDIDAE	5000	5.6	–	–	664	6.8	–	–	6664	3.2	2466	2.5
Tubificidae												
Aulodrilus americanus	–	–	–	–	–	–	–	–	1668	0.8	334	0.3
A. limnobius	417	0.5	–	–	–	–	–	–	--	--	83	0.1
A. pigueti	6250	7.0	–	–	–	–	–	–	1668	0.8	1584	1.6
A. pluriseta	3333	3.8	500	1.0	–	–	–	–	11167	5.6	3100	3.2
Ilyodrilus templetoni	417	0.5	–	–	–	–	–	–	--	--	83	0.1
Limnodrilus sp.	1250	1.4	1332	2.6	668	6.8	–	–	3332	1.6	1316	1.3
L. cervix	833	0.9	2168	4.3	1000	10.2	3332	2.6	--	--	1467	1.5
L. hoffmeisteri	417	0.5	500	1.0	1332	13.6	1668	1.3	5000	2.4	1783	1.8
L. maumeensis	–	–	500	1.0	–	–	–	–	1668	0.8	434	0.4
Potamothrix moldaviensis	–	–	500	1.0	–	–	–	–	--	--	100	0.1
Potamothrix vejdovskyi	–	–	500	1.0	–	–	–	–	1668	0.8	434	0.4
Quistadrilus multisetosus	20417	23.0	2500	5.0	1500	15.3	15000	11.5	8332	4.0	9550	9.8
TOTAL TUBIFICIDAE	33334	37.5	8500	16.9	4500	45.8	20000	15.3	35004	16.7	20268	20.7
*UIW/OCC (mostly Tub.)	48333	54.4	38667	77.0	3833	39.0	93333	71.6	153333	73.2	67500	69.0
**UIWCC (mostly Tub.)	1667	1.9	3000	6.0	500	5.1	16667	12.8	10000	4.8	6367	6.5
TOTAL OLIGOCHAETA	88334	99.4	50167	99.8	9497	96.6	130000	99.7	205001	97.8	96600	98.8
Mollusca												
Gastropoda (unidentif)	–	–	–	–	–	–	–	–	42	<0.1	8	<0.1
Physidae												
Physa sp.	–	–	–	–	–	–	42	<0.1	--	--	8	<0.1
Pelecypoda (unidentif)	–	–	–	–	–	–	–	–	292	0.1	58	0.1
Sphaeriidae (unidentif)	–	–	–	–	–	–	–	–	83	<0.1	17	<0.1
Pisidium sp.	–	–	–	–	–	–	292	0.2	2917	1.4	658	0.7

Table A-4 (cont.)

TAXA	Station B1 No/m2	%	B2 No/m2	%	B3 No/m2	%	B4 No/m2	%	B5 No/m2	%	Mean No/m2	%
Arthropoda												
Insecta												
Diptera												
Empididae (unidentif)	42	<0.1	–	–	–	–	–	–	--	--	8	<0.1
Chironomidae												
Tanypodinae												
Procladiini												
Procladius sp.	83	0.1	84	0.2	208	2.1	–	–	292	0.1	133	0.1
Orthocladiinae												
Psectrocladius sp	–	–	–	–	42	0.4	–	–	42	<0.1	17	<0.1
Chironominae												
Chironomini												
Chironomus sp	42	<0.1	–	–	42	0.4	42	<0.1	--	--	17	<0.1
Dicrotendipes sp	–	–	–	–	42	0.4	–	–	--	--	8	<0.1
TOTAL CHIRONOMIDAE	125	0.1	84	0.2	334	3.4	42	<0.1	334	0.2	184	0.2
TOTAL ORGANISMS	88877		50251		9831		130376		209546		97776	
Number of taxa	17		8		8		6		17		11.2	
Diversity Value	1.87		1.84		1.76		0.74		1.98		1.64	
Eveness	0.65		0.84		0.77		0.38		0.68		0.67	

-- denotes taxa not present
* denotes unidentifiable immatures without capilliform setae
** denotes unidentifiable immatures with capilliform setae

Table A-5. Biomass (mg/m2, dry wt) and % composition of the dominant major invertebrate groups collected by petite ponar dredge from the east wall of Area B (outside CDF) on 30 July 1986.

	Station											
	B6		B7		B8		B9		B10		Mean	
TAXA	mg/m2	%	mg/m2	%	mg/m2	%	mg/m2	%	mg/m2	%	mg/m2	%
Hydridae	–	–	–	–	–	–	0.21	<0.1	<0.01	<0.1	0.04	<0.1
Planariidae	–	–	15.21	0.3	–	–	–	–	--	--	3.04	0.1
Nematoda	1.62	0.1	10.71	0.2	<0.01	<0.1	<0.01	<0.1	0.63	<0.1	2.59	0.1
Bryozoa	–	–	–	–	–	–	4.38	0.2	--	--	0.88	<0.1
Hirudinea	498.96	19.6	404.38	7.7	850.00	14.6	118.75	4.5	392.71	13.7	452.96	11.8
Oligochaeta	1596.50	62.8	3044.20	57.9	4247.00	72.8	310.00	11.8	93.78	3.3	1858.30	48.6
Hydrobiidae	–	–	–	–	227.29	3.9	23.12	0.9	--	--	50.08	1.3
Planorbidae	–	–	–	–	–	–	4.58	0.1	134.13	4.7	27.74	0.7
Sphaeriidae	47.62	1.9	664.58	12.6	209.58	3.6	1928.84	73.2	1047.08	36.6	779.54	20.4
Gammaridae	247.92	9.8	283.21	5.4	159.75	2.7	184.29	7.0	1131.50	39.6	401.33	10.5
Asellidae	35.21	1.4	443.88	8.4	–	–	7.33	0.3	--	--	97.28	2.5
Acarina	–	–	–	–	–	–	–	–	11.04	0.4	2.21	0.1
Hydroptilidae	1.88	0.1	–	–	–	–	–	–	--	--	0.38	<0.1
Leptoceridae	–	–	–	–	–	–	0.83	<0.1	--	--	0.17	<0.1
Chironomidae	110.83	4.4	391.67	7.4	140.83	2.4	54.17	2.1	49.17	1.7	149.33	3.9
TOTAL BIOMASS	2540.54		5257.84		5834.45		2636.50		2860.04		3825.87	

Table A-6. Density (No./m2) and % composition of invertebrates collected by petite ponar dredge from the east wall of Area B (outside CDF) on 30 July 1986.

	Station											
	B6		B7		B8		B9		B10		Mean	
	No/m2	%	No/m2	%	No/m2	%	No/m2	%	No/m2	%	No/m2	%
Cnidaria												
Hydroida												
Hydridae	–	–	–	–	–	–	83	0.6	42	0.4	25	0.1
Platyhelminthes												
Turbellaria												
Planariidae (unidentif)	–	–	42	0.1	–	–	–	–	---	--	8	<0.1
Aschelminthes												
Nematoda (uniden)	167	0.6	1083	3.1	83	0.3	125	0.9	83	0.9	308	1.4
Bryozoa (Ectoprocta)	–	–	–	–	–	–	1	<0.1	---	--	<1	<0.1
Annelida												
Hirudinea												
Erpobdellidae (unidentif)	42	0.2	42	0.1	42	0.2	42	0.3	42	0.4	42	0.2
Glossisiphoniidae												
Helobdella elongata	–	–	83	0.2	–	–	–	–	---	--	17	0.1
Oligochaeta												
Naididae (unidentif)	167	0.6	–	–	–	–	–	–	42	0.4	42	0.2
Chaetognaster diaphanus	–	–	–	–	–	–	167	1.2	---	--	33	0.1
Nais sp.	333	1.2	–	–	333	1.2	167	1.2	--	--	167	0.7
N. communis	–	–	–	–	–	–	167	1.2	--	--	33	0.1
N. pardalis	1667	6.0	–	–	–	–	–	–	167	1.8	367	1.6
N. variabilis	–	–	–	–	667	2.4	167	1.2	167	1.8	200	0.9
Ophidonais serpentina	1000	3.6	–	–	667	2.4	–	–	--	--	333	1.5
Piguetiella michiganensis	–	–	–	–	–	--	1167	8.7	583	6.1	350	1.5
Pristina leidyi	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Slavina appendiculata	167	0.6	500	1.4	1333	4.8	333	2.5	--	--	467	2.1
Specaria josinae	–	–	–	–	–	–	667	5.0	42	0.4	142	0.6
Stylaria lacustris	–	–	–	–	–	–	167	1.2	583	6.1	150	0.7
TOTAL NAIDIDAE	3334	12.0	500	1.4	3000	10.9	3002	22.4	1626	17.1	2292	10.1
Tubificidae												
Aulodrilus americanus	1667	6.0	2833	8.1	6333	23.0	833	6.2	250	2.6	2383	10.5
A. pigueti	167	0.6	167	0.5	1333	4.8	500	3.7	--	--	433	1.9
Ilyodrilus templetoni	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Isochaetides freyi	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Limnodrilus sp.	167	0.6	–	–	–	–	–	–	--	--	33	0.1
L. cervix	167	0.6	–	–	–	–	–	–	--	--	33	0.1
L. hoffmeisteri	1167	4.2	1333	3.8	3666	13.3	–	–	--	--	1233	5.5
Potamothrix vejdovskyi	167	0.6	–	–	–	–	–	–	--	--	33	0.1
Quistadrilus multisetosus	167	0.6	–	–	333	1.2	–	–	--	--	100	0.4
TOTAL TUBIFICIDAE	3669	13.2	4333	12.5	11665	42.4	1333	9.9	334	3.5	4267	18.9
*UIW/OCC (mostly Tubif.)	16667	60.0	24333	69.9	8333	30.3	2500	18.6	83	0.9	10383	45.9
**UIWCC (mostly Tubif.)	1167	4.2	–	–	1333	4.8	833	6.2	125	1.3	692	3.1
TOTAL OLIGOCHAETA	24837	89.4	29166	83.8	24331	88.5	7668	57.1	2168	22.8	17634	78.0
Mollusca												
Gastropoda (unidentif)	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Hydrobiidae												
Amnicola sp.	–	–	–	–	42	0.2	208	1.5	--	--	50	0.2
Planorbidae												
Gyraulus sp.	–	–	–	–	–	–	42	0.3	125	1.3	33	0.1
Pelecypoda (unidentif)	–	–	–	–	–	–	–	–	750	7.9	150	0.7
Sphaeriidae (unidentif)	375	1.3	250	0.7	250	0.9	1792	13.4	167	1.8	567	2.5
Pisidium sp.	167	0.6	750	2.2	375	1.4	1125	8.4	667	7.0	617	2.7

Table A-6 (cont.)

	Station B6 No/m2	%	B7 No/m2	%	B8 No/m2	%	B9 No/m2	%	B10 No/m2	%	Mean No/m2	%
Arthropoda												
Crustacea												
Amphipoda												
Gammaridae (unidentif)	1000	3.6	1417	4.1	1333	4.8	1250	9.3	2625	27.6	1525	6.7
Gammarus pseudolimnaeus	375	1.3	417	1.2	–	–	125	0.9	1250	13.2	433	1.9
Isopoda												
Asellidae												
Asellus sp.	83	0.3	667	1.9	–	–	375	2.8	--	--	225	1.0
A. intermedius	–	–	208	0.6	–	–	–	–	--	--	42	0.2
Acarina	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Insecta												
Trichoptera												
Hydroptilidae												
Hydroptila sp.	42	0.2	–	–	–	–	–	–	--	--	8	<0.1
Leptoceridae												
Oecetis sp.	–	–	–	–	–	–	42	0.3	--	--	8	<0.1
Diptera												
Chironomidae												
Tanypodinae												
Procladiini												
Procladius sp.	333	1.2	292	0.8	292	1.1	–	–	42	0.4	192	0.8
Orthocladiinae												
Cricopterus sp.	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
C. vierriensis	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
Heterotrissocladius sp.	–	–	–	–	–	–	–	--	42	0.4	8	<0.1
Psectrocladius sp.	125	0.4	292	0.8	333	1.2	125	0.9	83	0.9	192	0.8
Orthocladius/Cricopt.	–	–	42	0.1	–	–	–	–	--	--	8	<0.1
Prodiamesinae												
Monodiamesa	83	0.3	42	0.1	167	0.6	250	1.9	875	9.2	283	1.3
Chironominae												
Chironomini												
Chironomus sp.	83	0.3	–	–	208	0.8	–	–	--	--	58	0.3
Cryptochironomus	83	0.3	–	–	–	–	83	0.6	--	--	33	0.1
Parachironomus	–	–	–	–	–	–	42	0.3	--	--	8	<0.1
Polypedilum	–	–	–	–	42	0.2	–	–	125	1.3	33	0.1
Tanytarsini												
Paratanytarsus	–	–	–	–	–	–	42	0.3	208	2.2	50	0.2
Tanytarsus	–	–	–	–	–	–	–	–	42	0.4	8	<0.1
TOTAL CHIRONOMIDAE	707	2.5	668	1.9	1042	3.8	542	4.0	1501	15.8	892	3.9
TOTAL ORGANISMS	27795		34793		27498		13420		9504		22600	
Number of taxa	20		15		17		24		24			20
Diversity Value	1.99		1.41		1.84		2.38		2.12			1.95
Eveness	0.65		0.52		0.64		0.75		0.66			0.64

-- denotes taxa not present

* denotes unidentifiable immatures without capilliform setae

** denotes unidentifiable immatures with capilliform setae

Table A-7. Biomass (mg/m2, dry wt) and % composition of the dominant major invertebrate groups collected by petite ponar dredge from Area C (control) on 30 July 1986.

TAXA	Station C1 mg/m2	%	C2 mg/m2	%	C3 mg/m2	%	Mean mg/m2	%
Hydridae	18.37	0.3	–	–	–	–	6.12	0.1
Planariidae	2.04	<0.1	–	–	–	--	0.68	<0.1
Nematoda	0.67	<0.1	–	–	0.12	<0.1	0.26	<0.1
Bryozoa	48.33	0.7	18.12	0.2	10.17	0.1	25.54	0.3
Oligochaeta	5025.88	71.8	11442.11	97.6	6486.76	94.8	7651.58	89.8
Hydrobiidae	108.37	1.5	–	–	–	–	36.12	0.4
Planorbidae	<0.01	<0.1	–	–	–	–	<0.01	<0.1
Sphaeriidae	624.79	8.9	244.00	2.1	67.92	1	312.23	3.7
Gammaridae	303.33	4.3	–	–	6.71	0.1	103.35	1.2
Asellidae	418.75	6	<0.01	<0.1	–	–	139.58	1.6
Chironomidae	451.67	6.4	115.83	0.1	267.50	3.9	245.00	2.9
TOTAL BIOMASS	7002.20		11720.06		6839.18		8520.46	

Table A-8. Density (No./m2) and % composition of invertebrates collected by petite ponar dredge from Area C (control) on 30 July 1986.

TAXA	Station C1 No/m2	%	C2 No/m2	%	C3 No/m2	%	Mean No/m2	%
Cnidaria								
Hydroida								
Hydridae	1792	2.4	--	--	--	--	597	0.7
Platyhelminthes								
Turbellaria								
Planariidae (unidentif)	42	0.1	--	--	--	--	14	<0.1
Aschelminthes								
Nematoda (uniden)	125	0.2	--	--	542	0.8	222	0.3
Bryozoa (Ectoprocta)	1	<0.1	1	<0.1	1	<0.1	1	<0.1
Annelida								
Oligochaeta								
Naididae (unidentif)	2083	2.9	--	--	1667	2.6	1250	1.5
Dero digitata	--	--	--	--	833	1.3	278	0.3
Nais sp.	--	--	500	0.5	417	0.6	306	0.4
N. pardalis	--	--	--	--	2917	4.5	972	1.2
Slavina appendiculata	--	--	1500	1.4	1250	1.9	917	1.1
Specaria josinae	--	--	500	0.5	--	--	167	0.2
Stylaria lacustris	417	0.6	--	--	--	--	139	0.2
Vejdovskiella intermedia	--	--	1000	0.9	--	--	333	0.4
TOTAL NAIDIDAE	2500	3.4	3500	3.3	7084	10.9	4361	5.3
Tubificidae								
Aulodrilus limnobius	417	0.6	3000	2.8	--	--	1139	1.4
A. pigueti	7500	10.4	3000	2.8	2500	3.8	4333	5.3
A. pluriseta	417	0.6	500	0.5	--	--	306	0.4
Ilyodrilus templetoni	833	1.1	1000	0.9	--	--	611	0.7
Limnodrilus sp.	--	--	2000	1.9	2083	3.2	1361	1.7
L. cervix	834	1.2	500	0.5	2500	3.8	1278	1.6
L. hoffmeisteri	3333	4.6	6000	5.6	1667	2.6	3667	4.5
L. maumeensis	--	--	1000	0.9	--	--	333	0.4
Potamothrix vejdovskyi	--	--	1000	0.9	--	--	333	0.4
Quistadrilus multisetosus	3750	5.2	7000	6.6	15417	23.6	8722	10.7
Tubifex tubifex	--	--	1000	0.9	--	--	333	0.4
TOTAL TUBIFICIDAE	17084	23.6	26000	24.3	24167	37.0	22417	27.5
*UIW/OCC (mostly Tubif.)	41250	56.9	61000	57.1	28333	43.4	43528	53.4
**UIWCC (mostly Tubif.)	4167	5.8	14500	13.6	4167	6.4	7611	9.3
TOTAL OLIGOCHAETA	65001	89.7	105000	98.3	63751	97.7	77917	95.6
Mollusca								
Gastropoda								
Hydrobiidae								
Amnicola sp.	42	<0.1	--	--	--	--	14	<0.1
Planorbidae								
Gyraulus sp.	42	<0.1	--	--	--	--	14	<0.1
Pelecypoda								
Sphaeriidae								
Pisidium sp.	1250	1.7	1542	1.4	250	0.4	1014	1.2
Arthropoda								
Crustacea								
Amphipoda								
Gammaridae (unidentif)	833	1.1	--	--	250	0.4	361	0.4
Gammarus pseudolimnaeus	542	0.7	--	--	--	--	181	0.2

Table A-8 (cont.)

TAXA	Station C1 No/m2	%	C2 No/m2	%	C3 No/m2	%	Mean No/m2	%
Arthropoda								
Crustacea								
Isopoda								
Asellidae								
Asellus sp.	1000	1.4	42	<0.1	--	--	347	0.4
A. intermedius	458	0.6	--	--	--	--	153	0.2
Insecta								
Diptera								
Chironomidae								
Tanypodinae								
Procladiini								
Procladius sp.	833	1.1	125	0.1	250	0.4	403	0.5
Prodiamesinae								
Monodiamesa	--	--	42	<0.1	--	--	14	<0.1
Chironominae								
Chironomini (unidentif)	42	<0.1	--	--	--	--	14	<0.1
Chironomus sp	458	0.6	42	<0.1	208	0.3	236	0.3
Cryptochironomus	--	--	42	<0.1	--	--	14	<0.1
TOTAL CHIRONOMIDAE	1333	1.8	251	0.2	458	0.7	681	0.8
TOTAL ORGANISMS	72461		106835		65252		81516	
Number of taxa	19		22		14		18.3	
Diversity Value	1.89		2.12		1.56		1.86	
Eveness	0.64		0.69		0.58		0.64	

-- denotes taxa not present
* denotes unidentifiable immatures without capilliform setae
** denotes unidentifiable immatures with capilliform setae

Table A-9. Biomass (mg/m2, dry wt) and % composition of the dominant major invertebrate groups collected by petite ponar dredge from the North Branch of the Chicago River (Area D) on 28 August 1986.

	Station							
	D1		D2		D3		Mean	
TAXA	mg/m2	%	mg/m2	%	mg/m2	%	mg/m2	%
Nematoda	--	--	21.3	<0.1	--	--	7.1	<0.1
Oligochaeta	226796.2	99.4	7147365.7	99.7	6027148.8	99.9	4467103.6	99.8
Sphaeriidae	1287.3	0.6	20466.7	0.3	4741.3	0.1	8831.8	0.2
Psychodidae	--	--	--	--	40.0	<0.1	13.3	<0.1
Chironomidae	133.3	<0.1	--	--	--	--	44.4	2.1
TOTAL BIOMASS	228216.8		7167853.7		6031930.2		4476000.2	

Table A-10. Density (No./m2) and % composition of invertebrates collected by petite ponar dredge from the North Branch of the ChicagoRiver (Area D) on 28 August 1986.

	Station							
	D1		D2		D3		Mean	
TAXA	No/m2	%	No/m2	%	No/m2	%	No/m2	%
Aschelminthes								
Nematoda (uniden)	--	--	26667	1.3	--	--	8889	0.8
Annelida								
Oligochaeta								
Naididae								
Dero digitata	--	--	26667	1.3	--	--	8889	0.8
TOTAL NAIDIDAE	--	--	26667	1.3	--	--	8889	0.8
Tubificidae								
Limnodrilus hoffmeisteri	--	--	106667	5.0	53333	4.0	53333	4.6
TOTAL TUBIFICIDAE	--	--	106667	5.0	53333	4.0	53333	4.6
*UIW/OCC (mostly Tubif.)	20000	90.9	1866668	88.0	1186667	90.2	1024445	88.9
**UIWCC (mostly Tubif.)	--	--	80000	3.8	66667	5.1	48889	4.2
TOTAL OLIGOCHAETA	20000	90.9	2080002	98.1	1306667	99.3	1135556	98.5
Mollusca								
Pelecypoda								
Sphaeriidae (unidentif)	1333	6.1	13333	0.6	8000	0.6	7555	0.7
Arthropoda								
Insecta								
Diptera								
Psychodidae	--	--	--	--	1333	0.1	444	<0.1
Chironomidae								
Tanypodinae								
Procladiini								
Procladius sp.	667	3.0	--	--	--	--	222	<0.1
TOTAL ORGANISMS	22000		2120002		1316000		1152666	
Number of taxa	3		4		3		3	
Diversity Value	0.36		0.17		0.04		0.19	
Eveness	0.33		0.12		0.04		0.16	

-- denotes taxa not present

* denotes unidentifiable immatures without capilliform setae

** denotes unidentifiable immatures with capilliform setae

ANNOTATED REPORT: AQUATIC ANNELIDA COLLECTED FROM FOUR COOK COUNTY, ILLINOIS, SITES IN CONJUNCTION WITH THE ARMY CORPS OF ENGINEERS CONFINED DISPOSAL FACILITY IN CALUMET HARBOR

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METHODS

After specimens were returned to the laboratory, they were sorted under a stereo dissecting microscope and temporarily stored in either 10% buffered formalin or 70% ethanol. Aquatic Oligochaeta then were processed through an alcohol series and permanently mounted on slides with Eukitt or Harleco Synthetic Resin. Hirudinea were sorted, identified, and stored in 70% ethanol.

Identifications of aquatic Oligochaeta were made using an Olympus model BH-2 compound microscope with Nomarski differential interference contrast. Only whole individuals and fragments identifiable as anterior ends were included in statistical analyses.

After identification, all specimens were deposited in the Illinois Natural History Survey Annelid Collection.

Taxonomic Interpretations:

Sperber (1948, 1950), Brinkhurst and Jamieson (1971), Hiltunen and Klemm (1980), Stimpson, Klemm, and Hiltunen (1982), Brinkhurst and Coates (1985), and Brinkhurst (1986) were used in the identification of aquatic oligochaete specimens. Hiltunen (1967), Mozley and Garcia (1972), Mozley and Howmiller (1977), Spencer (1980), Wetzel (1981), Wetzel (1982a), Whitley and Wetzel (1976), Brinkhurst and Wetzel (1984), and Wetzel (1988) provided additional taxonomic and ecological information useful in the collection and study of aquatic Oligochaeta. Nomenclatural information followed Reynolds and Cook (1976, 1981), Brinkhurst and Wetzel (1984), and Brinkhurst (1986).

Klemm, Huggins, and Wetzel (1979), Klemm (1982), Wetzel (1982b), and Wetzel (1989) were used in the identification and study of the Hirudinea (leeches).

External as well as internal characteristics were examined in the identification of all Annelida. Identification of most tubificids was completed to species level only when specimens were sexually mature. Immature oligochaetes (mostly tubificids) were classified as unidentifiable immature with capilliform chaetae (UIW/CC) or unidentifiable immature without capilliform chaetae (UIW/OCC).

RESULTS

Table A-11 lists those species of aquatic Annelida known to occur in inland waters of northeastern Illinois and inshore Lake Michigan.

Tables A-12, A-13, and A-14 list the results of the June and July 1986 collections for macroinvertebrates from the sampling localities within the Army Corps of Engineers Confined Disposal Facility (CDF) project area in Cook County, Illinois.

Table A-11: Aquatic Annelida (Oligochaeta and Hirudinea) known to occur in northeastern Illinois watersheds, including inland Lake Michigan, Cook and Lake counties, Illinois † Species noted with an asterisk were collected by INHS personnel from one or more sites associated with the Army Corps of Engineers Confined Disposal Facility study during June and July 1986.

ANNELIDA (true segmented worms)
ACLITELLATA
APHANONEURA
Aeolosomatidae
Aeolosoma sp.

CLITELLATA
OLIGOCHAETA (aquatic microdriles)
Haplotaxida
Haplotaxidae
Haplotaxis gordioides (Hartmann)

Enchytraeidae

Naididae
Chaetogaster diaphanus (Gruithuisen) *
Chaetogaster diastrophus (Gruithuisen
Chaetogaster limnaei von Baer
Bratislavia unidentata (Harman)*
Dero (Aulophorus) furcata (Müller)
Dero (Aulophorus) vaga (Leidy)
Dero (Dero) digitata (Müller) *
Nais behningi (Michaelsen)
Nais barbata Müller
Nais bretscheri (Michaelsen)
Nais communis Piguet *
Nais elinguis Müller
Nais pardalis Piguet *
Nais pseudobtusa Piguet
Nais simplex Piguet
Nais variabilis Piguet *
Ophidonais serpentina (Müller) *
Piguetiella michiganensis Hiltunen *
Pristina sp. *
Pristina breviseta Bourne
Pristinella jenkinae (Stephenson)
Pristina leidyi (Smith) *
Slavina appendiculata (d'Udekem) *
Specaria josinae (Vejdovsky) *
Stylaria lacustris (Linnaeus) *
Uncinais uncinata (Orsted)
Vejdovskiella intermedia (Bretscher) *

(Table A-11 concluded on next page)

Table A-11 (concluded).

Tubificidae
Aulodrilus americanus Brinkhurst & Cook *
Aulodrilus limnobius Bretscher *
Aulodrilus pigueti Kowalewski *
Aulodrilus pluriseta (Piguet) *
Branchiura sowerbyi Beddard
Ilyodrilus templetoni (Southern) *
Isochaetides freyi (Brinkhurst) *
Limnodrilus angustipenis Brinkhurst & Cook
Limnodrilus cervix Brinkhurst *
Limnodrilus cervix variant *
Limnodrilus claparedianus Ratzel
Limnodrilus hoffmeisteri Claparède *
Limnodrilus hoffmeisteri variant *
Limnodrilus hoffmeisteri form *spiralis* *
Limnodrilus maumeensis Brinkhurst & Cook *
Limnodrilus maumeensis variant *
Limnodrilus profundicola (Verrill)
Limnodrilus udekemianus Claparède *
Potamothrix bedoti (Piguet)
Potamothrix moldaviensis Vejdovsky & Mrazek *
Potamothrix vejdovskyi (Hrabe) *
Quistadrilus multisetosus (Smith) †† *
Rhyacodrilus coccineus (Vejdovsky)
Spirosperma nikolskyi (Lastockin & Sokolskaya)
Tubifex ignotus (Stolc)
Tubifex tubifex (Müller) *

Lumbriculida
Lumbriculidae
Lumbriculus variegatus (Müller)
Stylodrilus heringianus Claparède

HIRUDINEA (leeches)
Erpobdellidae
Erpobdella punctata (Leidy)

Glossiphoniidae
Helobdella elongata (Castle) *
Helobdella stagnalis (Linnaeus) *

† = Records from Stimpson et al. (1975), Whitley and Wetzel (1976), Spencer (1980), MSDGC (1975, 1977a, 1977b), and Wetzel (1988). Phylogeny follows Brinkhurst (1986).

†† = Two subspecies, *Quistadrilus multisetosus multisetosus* and *Q. multisetosus longidentus*, have been recognized by several authors and reported from Lake Michigan as well as from a wide range of cosmopolitan habitats. Please see text for additional systematic information.

Table A-12. Aquatic Annelida (Oligochaeta and Hirudinea) collected during 1986 from inside Army Corps of Engineers Confined Disposal Facility in Calumet Harbor (Station A), Cook County, Illinois.

SPECIES	STATION A1	A2	A3	A4	A5	A6	A7	A8
NEMATODA	-	-	-	-	-	-	-	-
ANNELIDA								
OLIGOCHAETA								
Haplotaxida								
Naididae	13	3	1	-	32	4	11	66
Chaetogaster diaphanus	-	-	-	-	-	-	-	-
Chaetogaster limnaei	-	-	-	-	-	-	-	-
Bratislavia unidentata	-	1	-	-	-	-	-	-
Dero sp.	-	-	-	-	-	-	-	-
Dero digitata	3	2	9	-	112	1	20	65
Nais sp.	-	-	-	-	-	-	-	-
Nais behningi	-	-	-	-	-	-	-	-
Nais bretscheri	-	-	-	-	-	-	-	-
Nais communis	-	-	-	-	-	-	-	-
Nais pardalis	-	-	-	-	-	-	-	-
Nais variabilis	+	-	-	-	-	-	-	-
Ophidonais serpentina	-	-	-	-	-	-	-	-
Paranais frici	-	-	-	-	-	-	-	-
Piguetiella michiganensis	-	-	-	-	-	-	-	-
Pristina sp.	-	-	-	-	-	-	-	-
Pristina leidyi	-	-	-	-	-	-	-	-
Slavina appendiculata	-	-	-	-	-	-	-	-
Specaria josinae	-	-	-	-	-	-	-	-
Stylaria lacustris	-	-	-	-	-	-	-	-
Vejdovskyella intermedia	-	-	-	-	-	-	-	-
Tubificidae								
Aulodrilus americanus	-	-	-	-	-	-	-	-
Aulodrilus limnobius	-	-	-	-	-	-	-	-
Aulodrilus pigueti	-	-	-	-	-	-	-	-
Aulodrilus pluriseta	-	-	-	-	-	-	-	-
Ilyodrilus templetoni	-	-	-	-	-	-	1	-
Isochaetides freyi	-	-	-	-	-	-	-	-

(Table A-12 concluded on next page)

Table A-12 (concluded).

SPECIES	STATION A1	A2	A3	A4	A5	A6	A7	A8
Tubificidae (concluded)								
Limnodrilus sp. §	3	1	2	-	4	1	-	3
Limnodrilus cervix	-	2	-	-	18	7	2	-
Limnodrilus cervix variant	-	-	1	-	-	-	-	3
Limnodrilus hoffmeisteri	7	7	1	-	6	10	7	-
L. hoffmeisteri variant	-	-	-	-	-	-	-	1
L. hoffmeisteri f. *spiralis*	-	-	-	-	-	-	-	-
Limnodrilus maumeensis	-	-	-	-	2	-	-	-
L. maumeensis variant	-	-	-	-	-	-	-	1
Limnodrilus udekemianus	-	1	-	-	-	-	-	-
Potamothrix vejdovskyi	-	-	-	-	-	-	1	-
Quistadrilus m. longidentus	-	-	-	-	-	-	-	-
Quistadrilus m. multisetosus	6	3	-	-	-	2	-	4
Tubifex tubifex	-	-	-	-	-	-	-	-
* UIW/OCC	28	3	41	-	74	68	28	110
** UW/CC	5	2	-	-	4	1	2	4
HIRUDINEA (Leeches)								
Erpobdellidae (unidentifiable)	-	-	-	-	-	-	-	-
Glossiphoniidae								
Helobdella elongata	-	-	-	-	-	-	-	-
Helobdella stagnalis	-	-	-	-	-	-	-	-

+ = Indicates that this taxon was collected only qualitatively from this sampling location.

† = Individual specimens identified as "Naididae" appeared, for the most part, to be anterior ends of *Dero digitata* or *Nais* sp.

§ = Developing penis sheaths were present in these individuals (most likely *Limnodrilus cervix* or *Limnodrilus maumeensis*).

* = Unidentifiable immature without capilliform chaetae (mostly Tubificidae).

** = Unidentifiable immature with capilliform chaetae (mostly Tubificidae).

Table A-13. Aquatic Annelida (Oligochaeta and Hirudinea) collected during 1986 from outside Army Corps of Engineers Confined Disposal Facility in Calumet Harbor (Station B), Cook County, Illinois.

SPECIES	STATION B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
NEMATODA	-	-	-	-	-	-	-	-	-	-
ANNELIDA										
OLIGOCHAETA										
Haplotaxida										
Naididae †	10	-	2	-	-	1	-	-	-	1
Chaetogaster diaphanus	-	-	-	-	-	-	-	-	1	-
Chaetogaster limnaei	-	-	-	-	-	-	-	-	-	-
Bratislavia unidentata	-	-	-	-	-	-	-	-	-	-
Dero sp.	-	-	-	-	-	-	-	-	-	-
Dero digitata	-	-	-	-	-	-	-	-	-	-
Nais sp.	-	-	2	-	-	2	-	2	1	-
Nais behningi	-	-	-	-	-	-	-	-	-	-
Nais bretscheri	-	-	-	-	-	-	-	-	-	-
Nais communis	10	-	-	-	-	-	-	-	1	-
Nais pardalis	50	-	-	-	-	10	-	-	-	4
Nais variabilis	-	-	-	-	20	-	-	4	1	4
Ophidonais serpentina	-	-	-	-	-	6	-	4	-	-
Paranais frici	20	-	-	-	-	-	-	-	-	-
Piguetiella michiganensis	-	-	-	-	-	-	-	-	7	14
Pristina sp.	-	-	-	-	-	-	-	-	-	-
Pristina leidyi	-	-	-	-	-	-	-	-	-	1
Slavina appendiculata	30	-	-	-	-	1	3	8	2	-
Specaria josinae	-	-	-	-	-	-	-	-	4	1
Stylaria lacustris	-	-	-	-	-	-	-	-	1	14
Vejdovskyella intermedia	-	-	-	-	20	-	-	-	-	-
Tubificidae										
Aulodrilus americanus	-	-	-	-	10	10	17	38	5	6
Aulodrilus limnobius	10	-	-	-	-	-	-	-	-	-
Aulodrilus pigueti	150	-	-	-	10	1	1	4	3	-
Aulodrilus pluriseta	80	3	-	-	70	-	-	-	-	-
Ilyodrilus templetoni	10	-	-	-	-	-	-	-	-	1
Isochaetides freyi	-	-	-	-	-	-	-	-	-	1

(Table A-13 concluded on next page)

Table A-13 (concluded).

SPECIES	STATION B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Tubificidae (concluded)										
Limnodrilus sp. §	30	8	4	-	20	1	-	-	-	-
Limnodrilus cervix	20	13	6	20	-	1	-	-	-	-
Limnodrilus cervix variant	10	3	1	10	-	-	-	-	-	-
Limnodrilus hoffmeisteri	-	3	8	10	20	6	8	14	-	-
Limnodrilus hoffmeisteri variant	-	-	-	-	-	-	-	-	-	-
L. hoffmeisteri form *spiralis*	10	-	-	-	10	1	-	4	-	-
Limnodrilus maumeensis	-	3	-	-	10	-	-	-	-	-
Limnodrilus maumeensis variant	-	-	-	-	-	-	-	-	-	-
Limnodrilus udekemianus	-	-	-	-	-	-	-	-	-	-
Potamothrix moldaviensis	-	3	-	-	-	-	-	-	-	-
Potamothrix vejdovskyi	-	3	-	-	10	1	-	-	-	-
Quistadrilus m. longidentus	-	-	-	10	10	-	-	2	-	-
Quistadrilus m. multisetosus	490	15	9	80	40	1	-	-	-	-
Tubifex tubifex	-	-	-	-	-	-	-	-	-	-
UIW/OCC *	1,160	232	23	560	920	100	146	50	15	2
UW/CC **	40	18	3	100	60	7	-	8	5	3
HIRUDINEA (Leeches)										
Erpobdellidae (unidentifiable)	-	-	-	-	-	1	1	1	1	1
Glossiphoniidae										
Helobdella elongata	-	-	-	-	4	-	2	-	-	-
Helobdella stagnalis	-	-	-	-	16	-	-	-	-	-

† = Individual specimens identified as "Naididae" appeared, for the most part, to be anterior ends of *Dero digitata* or *Nais* sp.

§ = Developing penis sheaths were present in these individuals (most likely *Limnodrilus cervix* or *Limnodrilus maumeensis*).

* = Unidentifiable immature without capilliform chaetae (mostly Tubificidae).

** = Unidentifiable immature with capilliform chaetae (mostly Tubificidae).

Table A-14. Aquatic Annelida (Oligochaeta and Hirudinea) collected during 1986 from outside Army Corps of Engineers Confined Disposal Facility in Calumet Harbor (Station C), and the North Branch of the Chicago River (Station D), Cook County, Illinois.

SPECIES	STATION C1	C2	C3	D1	D2	D3
NEMATODA	-	-	10	-	-	-
ANNELIDA						
OLIGOCHAETA						
Haplotaxida						
Naididae †	50	-	40	-	-	-
Chaetogaster diaphanus	-	-	-	-	-	-
Chaetogaster limnaei	-	-	-	-	-	-
Bratislavia unidentata	-	-	-	-	-	-
Dero sp.	-	-	-	-	-	-
Dero digitata	-	-	20	-	1	-
Nais sp.	-	3	10	-	-	-
Nais behningi	-	-	-	-	-	-
Nais bretscheri	-	-	-	-	-	-
Nais communis	-	-	-	-	-	-
Nais pardalis	-	-	70	-	-	-
Nais variabilis	-	-	-	-	-	-
Ophidonais serpentina	-	-	-	-	-	-
Paranais frici	-	-	-	-	-	-
Piguetiella michiganensis	-	-	-	-	-	-
Pristina sp.	-	-	-	-	-	-
Pristina leidyi	-	-	-	-	-	-
Slavina appendiculata	-	9	30	-	-	-
Specaria josinae	-	3	-	-	-	-
Stylaria lacustris	10	-	-	-	-	-
Vejdovskyella intermedia	-	6	-	-	-	-
Tubificidae						
Aulodrilus americanus	-	-	-	-	-	-
Aulodrilus limnobius	10	18	-	-	-	-
Aulodrilus pigueti	180	18	60	-	-	-
Aulodrilus pluriseta	10	3	-	-	-	-
Ilyodrilus templetoni	20	6	-	-	-	-
Isochaetides freyi	-	-	-	-	-	-

(Table A-14 concluded on next page)

Table A-14 (concluded).

SPECIES	STATION C1	C2	C3	D1	D2	D3
Tubificidae (concluded)						
Limnodrilus sp. §	-	12	50	-	-	-
Limnodrilus cervix	10	3	40	-	-	-
Limnodrilus cervix variant	10	-	20	-	-	-
Limnodrilus hoffmeisteri	80	33	30	-	3	4
Limnodrilus hoffmeisteri variant	-	-	10	-	-	-
L. hoffmeisteri form *spiralis*	-	3	-	-	1	-
Limnodrilus maumeensis	-	6	-	-	-	-
Limnodrilus maumeensis variant	-	-	-	-	-	-
Limnodrilus udekemianus	-	-	-	-	-	-
Potamothrix moldaviensis	-	-	-	-	-	-
Potamothrix vejdovskyi	-	6	-	-	-	-
Quistadrilus m. longidentus	-	3	-	-	-	-
Quistadrilus m. multisetosus	90	39	370	-	-	-
Tubifex tubifex	-	6	-	-	-	-
UIW/OCC *	990	366	680	3	70	89
UW/CC **	100	87	100	-	3	5
HIRUDINEA (Leeches)						
Erpobdellidae (unidentifiable)	-	-	-	-	-	-
Glossiphoniidae						
Helobdella elongata	-	-	-	-	-	-
Helobdella stagnalis	-	-	-	-	-	-

† = Individual specimens identified as "Naididae" appeared, for the most part, to be anterior ends of *Dero digitata* or *Nais* sp.

§ = Developing penis sheaths were present in these individuals (most likely *Limnodrilus cervix* or *Limnodrilus maumeensis*).

* = Unidentifiable immature without capilliform chaetae (mostly Tubificidae).

** = Unidentifiable immature with capilliform chaetae (mostly Tubificidae).

DISCUSSION

Annelid Systematics

Thirty-six taxa of aquatic annelids were collected during 1986 from the CDF project area in Cook County, Illinois. These included 17 taxa of Naididae and 19 taxa of Tubificidae (Tables A through D). In addition, three taxa of leeches representing two families, two genera, and two species also were collected.

Branchiobdellidae. The monotypic order Branchiobdellida (Holt 1965) consists of five families, 18 recognized genera and 124 nominal species, of which 15 and 95, respectively, occur in North America (Holt 1986). These worms are known as epizoites, or commensal "parasites" on freshwater Holarctic crustaceans, primarily the astacoidean crayfishes. Other minor hosts include a freshwater crab, freshwater shrimp, cave isopods, the gill chambers of the marine crab *Callinectes sapidus,* and the freshwater snail *Physa* .

Since these annelids are epizoites on crustaceans, their water quality requirements are reflected at least in those of the host species. Holt (1974) suggested that branchiobdellids are extremely intolerant to some inorganic pollutants such as coal-mine effluents and sulfates. Blackford (1966) demonstrated the tolerance of these worms to low oxygen concentrations, suggesting the possibility that they are facultative anaerobes.

A generic key is provided by Holt (1978). Specific identification usually requires dissection and/or sectioning. No branchiobdellids were collected during this project.

Enchytraeidae. The current taxonomic knowledge of this family in North America is insufficient for species identifications (Hiltunen 1967; Howmiller 1974a; Cook 1975; Maciorowski et al. 1977). Howmiller (1974b) reviewed the major Great Lakes research reports concerning oligochaetes. The most common taxon of the enchytraeids seemed to be the genus *Lumbricillus*._One other specimen collected from Lake Michigan appears to be of the *Henlea-Enchytraeus* group. Since the majority of the known enchytraeids are thought to be terrestrial, the possibility exists that some of these same species also may tolerate highly organically enriched water systems in the presence of marginal dissolved oxygen. Several systematists in North America currently are working with this family.

No enchytraeids were collected during this study.

Haplotaxidae. Two species in this family are known to occur in North America: *Haplotaxis gordioides* (Hartmann), and *H. brinkhursti* Cook. Only *H. gordioides* is thought likely to occur in the CDF study area. This species is known to be primarily an inhabitant of ground waters, springs, and wells. Subterranean sources of water entering the open waters of this study area may account for its presence. This species never has been collected in its sexually mature state.

No haplotaxids were collected during this study.

Lumbricidae. This family of oligochaetes is almost entirely terrestrial, although two species are known to occur in aquatic and semi-aquatic habitats: *Eiseniella tetraedra* (Savigny), occurring in mountain streams and stream reaches which are polluted or have soft substrates, and *Eisenia foetida* Savigny, often collected from highly organically enriched substrates, as well as among leaf packets in enriched streams and rivers.

Neither species was collected during this study, although both are thought likely to occur in Illinois waters.

Lumbriculidae. Eight genera and 25 nominal species of lumbriculids are known to occur in North America (Brinkhurst 1986). Of the four lumbriculids known to occur in the St. Lawrence Great Lakes, two - *Lumbriculus variegatus* (Müller) and *Stylodrilus heringianus* Claparède - are known to occur in Lake Michigan. No lumbriculids were collected during this study.

Naididae. Twenty-one genera and 70 nominal species of naidids are known to occur in North America (Brinkhurst 1986). Thirteen genera and seventeen species of naidids were collected from the CDF study area during 1986.

External morphological features, such as presence or absence of probosces, eyes and gills, as well as number, type, and arrangement of chaetae were the characters used for naidid identification. Loden and Harman (1980) discussed chaetotaxy, the problems encountered when chaetae are the primary characters used in identification, and ecophenotypic variation of species populations in relation to chaetal morphology. Specimens identified only to the familial level of Naididae consisted of individuals lacking clarity due to factors such as presence of a silt-sand tube, numerous incomplete chaetal bundles, or poorly oriented chaetae.

Tubificidae. Nineteen genera and sixty-five nominal species of this family are known to occur in North America (Brinkhurst 1986). Seven genera and fourteen species were collected during this study.

The somatic chaetae and morphology of the male genitalia were the primary structures used for species identifications. The species *Aulodrilus pigueti* Kowalewski and *Quistadrilus multisetosus* (Smith) were identifiable regardless of sexual maturity. Other species in the family Tubificidae collected during this study include: *Ilyodrilus templetoni* (Southern), *Limnodrilus cervix* Brinkhurst, *Limnodrilus hoffmeisteri* Claparède, *Limnodrilus maumeensis* Brinkhurst and Cook, and *Limnodrilus udekemianus* Claparède. These species are identifiable only in the sexually mature state. Immature tubificids were divided into two groups: unidentifiable immature without capilliform chaetae (UIW/OCC), and unidentifiable immature with capilliform chaetae (UIW/CC).

Limnodrilus represents the largest and perhaps most complex and controversial genus in this family. Those specimens collected during this study and identified as *Limnodrilus* sp. possessed at least part of a penis sheath. Most often, the observed character was either underdeveloped, or partially obscured by gut content.

Numerous specimens of *Limnodrilus* collected during this study possessed atypical penis sheaths. This phenomenon has been observed in most of the collections taken during the course of this project. Several other authors (Brinkhurst 1965, 1975, 1976; Hiltunen 1967, 1969a, 1969b, 1969c, 1973; Kennedy 1969; Howmiller and Beeton 1970; Brinkhurst and Jamieson 1971; Cook and Johnson 1974; Howmiller 1974b; Stimpson et al. 1975; Howmiller and Loden 1976; Loden 1977; Maciorowski et al. 1977; Barbour et al. 1979; Spencer 1980; and Wetzel (1981, 1988) have

noted this occurrence in their research. Although the morphological and systematic explanations for these variations are still unclear, the general observation has been that occurrence of morphological variations is positively correlated with increasing levels of organic and industrial pollution.

There has been considerable debate about the identity of a number of *Limnodrilus* species described by Eisen during the last century, particularly *Limnodrilus spiralis,* also referred to as *Limnodrilus hoffmeisteri* form *spiralis* (see papers listed above). Brinkhurst (1986) and others maintain that some character other than the normal anatomical characters needs to be utilized to sort out this problem, which may involve polyploidy and hybridization, but for which more conjecture than evidence currently exists. Stimpson et al. (1982) maintained that the *spiralis* form is a distinct taxon from the typical form because of apparent differences in ecological requirements (or tolerances); the *spiralis* form has been reported from a variety of habitats, but generally was found to be most abundant in grossly polluted habitats, often attaining large population densities in the

absence of typical *L. hoffmeisteri.* Some individuals most closely resembling the *spiralis* form were collected from several localities during this study, but always from the same localities as individuals identified as *L. hoffmeisteri* or *L. hoffmeisteri* variant. Many variants of *L. hoffmeisteri* also were observed in the 1986 collections; only a very few resembled the *spiralis* form.

Two subspecies, *Quistadrilus multisetosus multisetosus* and *Q. m. longidentus,* have been recognized by several authors and reported from Lake Michigan as well as a from a wide range of cosmopolitan habitats. Although other authors have reported these morphs to occur in differing habitats, *Q. m. longidentus* were found in all samples yielding *Q. m. multisetosus.*

CONCLUSIONS

None of the species of aquatic Annelida collected during this study is considered rare, unusual, or particularly indicative of grossly polluted conditions. While the reported densities of several of the species collected during this study (particularly the tubificids) suggest a moderate level of organic or industrial pollution, these densities do not differ significantly from those densities reported in other recent Lake Michigan benthic studies conducted in the vicinity of Cook and Lake counties. Further, the densities of aquatic annelids collected during this study reflect the existing populations of the habitat without any inferrence of influence from existing CDF leakage, if leakage occurs.

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APPENDIX B: FISH AND CRAYFISH COLLECTIONS

PURPOSE

Fish and crayfish were collected during this study to provide data for comparision with past and future monitoring of the harbor and to provide tissue material for an assessment of the present contaminant levels of organisms utilizing the harbor.

SITE DESCRIPTIONS

Fish and crayfish were collected from four sample areas:

A. Outside the CDF - immediately outside and along the 4,000-ft. dike walls in Calumet Harbor, Lake Michigan

B. Inside the CDF pond

C. Control - Along the inside of the Calumet Harbor seawall

D. Chicago River - At the proposed dredging location in the North Branch of the Chicago River containment facility

Note that the Scope of Work had identified the area inside the CDF as area A and that immediately outside the CDF as area B. Because the composite samples sent to Daily and Associates bear our letter designations, the designations of A as outside the CDF and B as inside the CDF are used for the crayfish and fish collections.

At each area (A-D) individual sample sites were numbered consecutively. Thus, site B-1 is the first sample site in the CDF pond (area B) and site C-2 is the second sample site in the control area (area C).

FIELD METHODS

Fish

Fish were collected using experimental gill nets and by electrofishing. Both methods were used at all four sample areas except in the Chicago River where gill nets were not used because of anticipated snagging caused by excessive debris in the water. A small number of fish were collected in the crayfish traps inside the containment facility, but, because this was not an established method for collecting fish samples, these fish were not included in catch summaries.

All fish collected were identified to species, measured to the nearest millimeter in length, and those greater than 0.05 lbs weighed to the nearest 0.05 lb. Individuals weighing less than 0.05 lb. were collectively weighed. Fish for contaminant analysis were combined by species and size, where possible, to provide composit samples. Species, weight, and mean length of each composite sample were recorded. Composites were wrapped in aluminum foil and stored on ice until transfered to a frozen storage facility. Voucher specimens of each species were preserved in 10 % formalin.

Gill netting

We used 125-ft long x 6-ft high experimental gill nets to collect fish from areas A, B, and C. These nets consist of five 25-ft panels of square mesh sizes 3/4-in., 1-in., 1-1/2-in., 2- in., and 2-1/2-in. They were set in pairs on the bottom, perpendicular to shoreline or structure and alternating mesh size nearest shoreline or structure. All nets were left over night. After a net was ruined by snagging on debris at site A-1, SCUBA divers were used to check for debris prior to net placement and to prevent snagging during retreival at site A-2 and in area C. Divers were not used inside the CDF (area B).

Electrofishing

A boat-mounted, 230-volt, 180-cycle, 3-phase alternating current, boom electrofisher was used for all electrofishing collections. Fish that were stunned were netted and placed in 35-gallon plastic garbage cans until they were processed. Electrofishing time was recorded for all sites and areas electrofished were marked on maps so electrofishing distances could be calculated.

Crayfish

To collect crayfish we used inverted cone minnow traps that were modified by enlarging the openings from 1-inch to 2-inches. Traps were baited with surplus fish and placed at each end of gillnets set in sample areas A and C. In areas B and D, traps were set several meters off shore. Crayfish samples from each area were composited for contaminant analysis.

PERSONNEL

Laboratory and field personnel responsible for fish and crayfish collections and data summaries for the Confined Disposal Facility Study, 28 July - 1 August 1986.

Richard E. Sparks, Ph.D	Professional Scientist
K. Douglas Blodgett, MS	Associate Research Biologist
David R. Douglas, MS	Assistant Research Biologist
Alan D. McLuckie, BS	Technical Supportive Scientist
Ruth Sparks, MS	Technical Supportive Scientist

Table B-1. Fish and crayfish composite samples delivered 4 August 1986 by Illinois Natural History Survey to Daily and Associates, Peoria, IL, for PCB analysis.

Sample						Weight (gm)		Length (mm)		
Site	Composite Number	Method	Name	Species	Number	Total	Mean	Mean	Min.	Max.
Outside CDF										
A-1	1&2	trap	crayfish	*Orconectes sp.*	10	227	23			
A-1	1	net	drum	*Aplodinotus grunniens*	3	2922	974	395	330	434
A-1	2	net	gizzard shad	*Dorosoma cepedianum*	1	815	815	418	418	418
A-1	3	net	gizzard shad	*Dorosoma cepedianum*	9	2174	242	271	250	293
A-1	4	net	yellow perch	*Perca flavescens*	3	1200	400	309	296	326
A-1	5	net	yellow perch	*Perca flavescens*	10	1065	106	210	202	217
A-1	6	net	yellow perch	*Perca flavescens*	10	430	43	157	151	168
A-1	7	net	yellow perch	*Perca flavescens*	10	453	45	159	148	173
A-1	8	net	steelhead	*Salmo gairdneri*	3	136	45	164	160	173
A-1	9	net	alewife	*Alosa pseudoharengus*	10	362	36	167	158	179
A-1	10	net	longnose sucker	*Catastomus catostomus*	2	408	204	257	252	262
A-2	1&2	trap	crayfish	*Orconectes sp.*	10	159	16			
A-2	1	net	yellow perch	*Perca flavescens*	10	453	45	159	150	180
A-2	2	net	alewife	*Alosa pseudoharengus*	10	362	36	168	159	178
A-2	4	net	alewife	*Alosa pseudoharengus*	10	340	34	169	160	183
A-2	5	net	yellow perch	*Perca flavescens*	10	725	72	187	158	216
A-2	6	net	brown trout	*Salmo trutta*	2	997	498	350	340	360
A-2	7	net	yellow perch	*Perca flavescens*	1	362	362	301	301	301
A-2	8	net	gizzard shad	*Dorosoma cepedianum*	1	294	294	293	293	293
Inside CDF										
B-1&2	1	trap	crayfish	*Orconectes sp.*	5	91	18			
B-1&2	2	trap	crayfish	*Orconectes sp.*	3	68	23			
B-1	1	trap	green sunfish	*Lepomis cyanellus*	8	45	6	60	30	81
B-2	1	trap	green sunfish	*Lepomis cyanellus*	10	45	5	56	30	102
B-3	1	E-F	bluntnose minnow	*Pimephales notatus*	23	< 100	< 5	56		
B-3	2	E-F	orangespotted sunfish	*Lepomis humilis*	5	< 50	< 10	75	72	80
B-3	3	E-F	bluntnose minnow	*Pimephales notatus*	91	< 50	< 1	28		
B-3	4	E-F	yellow perch	*Perca flavescens*	3	136	45	130	56	170
B-4	1	net	yellow perch	*Perca flavescens*	5	249	50	164	156	168
B-4	2	net	yellow perch	*Perca flavescens*	5	204	41	156	147	165
B-4	3	net	yellow perch	*Perca flavescens*	5	227	45	162	154	174
B-4	4	net	alewife	*Alosa pseudoharengus*	3	181	60	176	164	187
B-4	5	net	green sunfish	*Lepomis cyanellus*	1	< 50	< 50	108	108	108
B-4	6	net	pumpkinseed	*Lepomis gibbosus*	1	< 50	< 50	118	118	118
B-5	1	net	channel catfish	*Ictalurus punctatus*	1	1450	1450	500	500	500
B-5	2	net	black bullhead	*Ictalurus melas*	2	204	102	180	173	186
B-5	3	net	yellow perch	*Perca flavescens*	10	408	41	155	147	163
B-5	4	net	yellow perch	*Perca flavescens*	10	453	45	165	156	172
B-5	5	net	yellow perch	*Perca flavescens*	8	408	51	171	164	175
B-5	6	net	alewife	*Alosa pseudoharengus*	1	45	45	165	165	165
B-5	7	net	pumpkinseed	*Lepomis gibbosus*	1	45	45	118	118	118
Breakwater control area										
C-1	1&2	trap	crayfish	*Orconectes sp.*	10	204	20			
C-1	1	net	carp	*Cyprinus carpio*	1	3352	3352	585	585	585
C-1	2	net	brown trout	*Salmo trutta*	3	2582	861	397	376	409
C-1	3	net	white sucker	*Catostomus commersoni*	1	974	974	420	420	420
C-1	4	net	gizzard shad	*Dorosoma cepedianum*	1	906	906	405	405	405
C-1	5	net	yellow perch	*Perca flavescens*	10	476	48	163	145	175
C-1	6	net	yellow perch	*Perca flavescens*	10	997	100	207	192	236
C-1	7	net	yellow perch	*Perca flavescens*	1	340	340	297	297	297

Table B-1 (continued)

Sample						Weight (gm)		Length (mm)		
Site	Composite Number	Method	Name	Species	Number	Total	Mean	Mean	Min.	Max.
C-1	8	net	steelhead	*Salmo gairdneri*	2	91	45	163	155	170
C-1	9	net	alewife	*Alosa pseudoharengus*	10	362	36	167	157	175
C-1	10	net	alewife	*Alosa pseudoharengus*	10	408	41	181	176	187
C-2	1&2	trap	crayfish	*Orconectes sp.*	10	181	18			
C-2	1	net	channel catfish	*Ictalurus punctatus*	1	1359	1359	495	495	495
C-2	2	net	gizzard shad	*Dorosoma cepedianum*	1	951	951	420	420	420
C-2	3	net	brown trout	*Salmo trutta*	2	1110	555	348	340	356
C-2	4	net	steelhead	*Salmo gairdneri*	1	136	136	240	240	240
C-2	5	net	black bullhead	*Ictalurus melas*	1	272	272	240	240	240
C-2	6	net	yellow perch	*Perca flavescens*	9	453	50	163	155	174
C-2	7	net	yellow perch	*Perca flavescens*	5	340	68	185	176	199
C-2	8	net	alewife	*Alosa pseudoharengus*	10	340	34	164	156	168
C-2	9	net	yellow perch	*Perca flavescens*	11	59	5	86	80	91
North Branch Chicago River										
D-1	1	E-F	black bullhead	*Ictalurus melas*	5	272	54	158	142	172
D-1	2	E-F	goldfish	*Carassius auratus*	2	385	193	210	180	240
D-1	3	E-F	goldfish	*Carassius auratus*	2	272	136	180	177	183
D-1	4	E-F	carp	*Cyprinus carpio*	1	91	91	169	169	169
D-1	5	E-F	orangespotted sunfish	*Lepomis humilis*	5	45	9	78	70	84
D-1	6	E-F	green sunfish	*Lepomis cyanellus*	1	45	45	120	120	120

Total no. of composites = 68

Table B-2. Fish and crayfish composite samples arranged by food types.

Sample						Weight (gm)			Length (mm)			
Site	Composite No.	Meth.	Name	Species	No.	Tot.	Mean	Mean	Min	Max	Major Food
A-1	9	net	alewife	*Alosa pseudoharengus*	10	362	36	167	158	179	zooplankton
A-2	3	net	alewife	*Alosa pseudoharengus*	10	340	34	168	160	179"	"
A-2	4	net	alewife	*Alosa pseudoharengus*	10	340	34	169	160	183	"
A-2	2	net	alewife	*Alosa pseudoharengus*	10	362	36	168	159	178	"
B-4	4	net	alewife	*Alosa pseudoharengus*	3	181	60	176	164	187	"
B-5	6	net	alewife	*Alosa pseudoharengus*	1	45	45	165	165	165	"
C-1	9	net	alewife	*Alosa pseudoharengus*	10	362	36	167	157	175	"
C-1	10	net	alewife	*Alosa pseudoharengus*	10	408	41	181	176	187	"
C-2	8	net	alewife	*Alosa pseudoharengus*	10	340	34	164	156	168	"
A-1	2	net	gizzard shad	*Dorosoma cepedianum*	1	815	815	418	418	418	algae, plankton (mudfeeder)
A-1	3	net	gizzard shad	*Dorosoma cepedianum*	9	2174	242	271	250	293	"
A-2	8	net	gizzard shad	*Dorosoma cepedianum*	1	294	294	293	293	293	"
C-1	4	net	gizzard shad	*Dorosoma cepedianum*	1	906	906	405	405	405	"
C-2	2	net	gizzard shad	*Dorosoma cepedianum*	1	951	951	420	420	420	"
B-3	3	E-F	bluntnose minnow	*Pimephales notatus*	91	< 50	< 1	28			all types (mudfeeder)
B-3	1	E-F	bluntnose minnow	*Pimephales notatus*	23	< 100	< 5	56			"
B-5	2	net	black bullhead	*Ictalurus melas*	2	204	102	180	173	186	all types (bottom feeder)
C-2	5	net	black bullhead	*Ictalurus melas*	1	272	272	240	240	240	"
D-1	1	E-F	black bullhead	*Ictalurus melas*	5	272	54	158	142	172	"
C-1	1	net	carp	*Cyprinus carpio*	1	3352	3352	585	585	585	benthic invertebrates
D-1	4	E-F	carp	*Cyprinus carpio*	1	91	91	169	169	169	"
D-1	2	E-F	goldfish	*Carassius auratus*	2	385	193	210	180	240	benthic invertebrates
D-1	3	E-F	goldfish	*Carassius auratus*	2	272	136	180	177	183	"
A-1	1	net	drum	*Aplodinotus grunniens*	3	2922	974	395	330	434	benthic invertebrates
A-1	10	net	longnose sucker	*Catastomus catostomus*	2	408	204	257	252	262	benthic invertebrates
C-1	3	net	white sucker	*Catostomus commersoni*	1	974	974	420	420	420	benthic invertebrates
B-4	6	net	pumpkinseed	*Lepomis gibbosus*	1	< 50	< 50	118	118	118	insects
B-5	7	net	pumpkinseed	*Lepomis gibbosus*	1	45	45	118	118	11	"
B-3	2	E-F	orangespotted sunfish	*Lepomis humilis*	5	< 50	< 10	75	72	80	insects
D-1	5	E-F	orangespotted sunfish	*Lepomis humilis*	5	45	9	78	70	84	"
B-1	1	trap	green sunfish	*Lepomis cyanellus*	8	45	6	60	30	81	insects, fish
B-2	1	trap	green sunfish	*Lepomis cyanellus*	10	45	5	56	30	102	"
B-4	5	net	green sunfish	*Lepomis cyanellus*	1	< 50	< 50	108	108	108	"
D-1	6	E-F	green sunfish	*Lepomis cyanellus*	1	45	45	120	120	120	"
A-1	7	net	yellow perch	*Perca flavescens*	10	453	45	159	148	173	insects, fish, crayfish
A-1	6	net	yellow perch	*Perca flavescens*	10	430	43	157	151	168	"
A-1	5	net	yellow perch	*Perca flavescens*	10	1065	106	210	202	217	"
A-1	4	net	yellow perch	*Perca flavescens*	3	1200	400	309	296	326	"
A-2	5	net	yellow perch	*Perca flavescens*	10	725	72	187	158	216	"
A-2	1	net	yellow perch	*Perca flavescens*	10	453	45	159	150	180	"
A-2	7	net	yellow perch	*Perca flavescens*	1	362	362	301	301	301	"
B-3	4	E-F	yellow perch	*Perca flavescens*	3	136	45	130	56	170	"
B-4	2	net	yellow perch	*Perca flavescens*	5	204	41	156	147	165	"

Table B-2. (continued)

Sample Site	Composite No.	Meth.	Name	Species	Weight (gm) No.	Tot.	Mean	Length (mm) Mean	Min	Max	Major Food
B-4	3	net	yellow perch	*Perca flavescens*	5	227	45	162	154	174	insects, fish, crayfish
B-4	1	net	yellow perch	*Perca flavescens*	5	249	50	164	156	168	"
B-5	4	net	yellow perch	*Perca flavescens*	10	453	45	165	156	172	"
B-5	3	net	yellow perch	*Perca flavescens*	10	408	41	155	147	163	"
B-5	5	net	yellow perch	*Perca flavescens*	8	408	51	171	164	175	"
C-1	5	net	yellow perch	*Perca flavescens*	10	476	48	163	145	175	"
C-1	6	net	yellow perch	*Perca flavescens*	10	997	100	207	192	236	"
C-1	7	net	yellow perch	*Perca flavescens*	1	340	340	297	297	297	"
C-2	6	net	yellow perch	*Perca flavescens*	9	453	50	163	155	174	"
C-2	9	net	yellow perch	*Perca flavescens*	11	59	5	86	80	91	"
C-2	7	net	yellow perch	*Perca flavescens*	5	340	68	185	176	199	"
A-1	8	net	steelhead	*Salmo gairdneri*	3	136	45	164	160	173	insects, fish
C-1	8	net	steelhead	*Salmo gairdneri*	2	91	45	163	155	170	"
C-2	4	net	steelhead	*Salmo gairdneri*	1	136	136	240	240	240	"
A-2	6	net	brown trout	*Salmo trutta*	2	997	498	350	340	360	fish, insects, crayfish
C-1	2	net	brown trout	*Salmo trutta*	3	2582	861	397	376	409	"
C-2	3	net	brown trout	*Salmo trutta*	2	1110	555	348	340	356	"
B-5	1	net	channel catfish	*Ictalurus punctatus*	1	1450	1450	500	500	500	fish, insects
C-2	1	net	channel catfish	*Ictalurus punctatus*	1	1359	1359	495	495	495	"
A-1	1&2	trap	crayfish	*Orconectes sp.*	10	227	23				carnivorous scavenger
A-2	1&2	trap	crayfish	*Orconectes sp.*	10	159	16				"
B-1&2	1	trap	crayfish	*Orconectes sp.*	5	91	18				"
B-1&2	2	trap	crayfish	*Orconectes sp.*	3	68	23				"
C-1	1&2	trap	crayfish	*Orconectes sp.*	10	204	20				"
C-2	1&2	trap	crayfish	*Orconectes sp.*	10	181	18				"

Table B-3. Fish species[a] captured at 4 locations using gill nets (N) and electrofishing (E).

Scientific Name	Common Name	Outside CDF (A)	Inside CDF (B)	Breakwater Control (C)	Chicago[b] River (D)
Alosa pseudoharengus (Wilson)	alewife	N	N	N	
Dorosoma cepedianum (Lesueur)	gizzard shad	N		N	
Salmo gairdneri Richardson	rainbow trout	N		N	
Salmo trutta Linnaeus	brown trout	N		N	
Onchorynchus kisutch Walbaum	coho salmon			N	
Osmerus mordax (Mitchill)	american smelt			N	
Carassius auratus (Linnaeus)	goldfish				E
Cyprinus carpio Linnaeus	carp			N/E	E
Pimephales notatus (Rafinesque)	bluntnose minnow		E		
Catostomus catostomus (Forster)	longnose sucker	N			
Catostomus commersoni (Lacepede)	white sucker			N	
Ictalurus melas (Rafinesque)	black bullhead		N	N	E
Ictalurus punctatus (Rafinesque)	channel catfish		N	N	
Micropterus salmoides (Lacepede)	largemouth bass				E
Lepomis cyanellus Rafinesque	green sunfish		N/E		E
Lepomis gibbosus (Linnaeus)	pumpkinseed		N/E		
Lepomis humilis (Girard)	orangespotted sunfish		E		E
Perca flavescens (Mitchill)	yellow perch	N	N/E	N/E	
Aplodinotus grunniens Rafinesque	freshwater drum	N			
No. of Species:	Total species = 19	7	8	11	6

[a] Taxonomy follows that of Smith (1979)
[b] Not sampled using gill nets

Table B-4. Summary of fish collections from outside the CDF wall, Calumet Harbor, 28-29 July 1986. No fish were taken during electrofishing.

	Gill Nets					
	No.	Total Wt. (g)	No./ Net-Hr.	Wt./ Net-Hr. (g)	% of Total No.	% of Total Wt. (g)
Common Name						
alewife	100	3500	2.8	99.3	36.9%	16.1%
gizzard shad	17	4726	0.5	134.1	6.3%	21.8%
rainbow trout	4	180	0.1	5.1	1.5%	0.8%
brown trout	3	1155	0.1	32.8	1.1%	5.3%
longnose sucker	3	612	0.1	17.4	1.1%	2.8%
yellow perch	141	9306	4	264	52.0%	42.9%
freshwater drum	3	2217	0.1	62.9	1.1%	10.2%
Total	271	21696	7.7	615.5		
No. of Species	7					

Table B-5. Summary of fish collections from inside the CDF, Calumet Harbor, 31 July-1 August 1986.

Common Name	Gill Nets						Electrofishing								Both Methods			
	No.	Total Wt. (g)	No./ Net-Hr.	Wt./ Net-Hr. (g)	% Total No.	% Total Wt.	No.	Total Wt. (g)	No./ 30 min.	Wt./ 30 min. (g)	No./ 400m	Wt./ 400m (g)	% Total No.	% Total Wt.	No.	Total Wt. (g)	% Total No.	% Total Wt.
alewife	4	220	0.1	4.7	7.3%	5.5%									4	220	1.9%	5.0%
bluntnose minnow							114	114	68.4	68.4	125.3	125.3	75.5%	31.5%	114	114	55.3%	2.6%
black bullhead	3	273	0.1	5.8	5.5%	6.8%									3	273	1.5%	6.2%
channel catfish	1	1450	<0.1	31.1	1.8%	36.1%									1	1450	0.5%	33.1%
green sunfish	1	23	<0.1	0.5	1.8%	0.6%	25	50	15	30	27.5	54.9	16.6%	13.8%	26	73	12.6%	1.7%
pumpkin-seed	2	68	<0.1	1.5	3.6%	1.7%	1	23	0.6	13.8	1.1	25.3	0.7%	6.4%	3	91	1.5%	2.1%
orange-spotted sunfish							8	40	4.8	24	8.8	44	5.3%	11.0%	8	40	3.9%	0.9%
yellow perch	44	1980	0.9	42.4	80.0%	49.3%	3	135	1.8	81	3.3	148.4	2.0%	37.3%	47	2115	22.8%	48.3%
Total	55	4014	1.2	86			151	362	90.6	217.2	165.9	397.8			206	4376		
No. of Species	6						5								8			

Table B-6. Summary of fish collections from the breakwater control area, Calumet Harbor, 29-30 July 1986.

	Gill Nets						Electrofishing								Both Methods			
	No.	Total Wt. (g)	No./ Net-hr	Wt./ Net-hr (g)	% Total No.	% Total Wt.	No.	Total Wt. (g)	No./ 30 min	Wt./ 30 min (g)	No./ 400m	Wt./ 400m (g)	% Total No.	% Total Wt.	No.	Total Wt. (g)	% Total No.	% Total Wt.
Common Name																		
alewife	104	3744	3.1	111.1	44.3%	15.5%									104	3744	41.9%	13.7%
gizzard shad	2	1858	0.1	55.1	0.9%	7.7%									2	1858	.8%	6.8%
rainbow trout	4	272	0.1	8.1	1.7%	1.1%									4	272	1.6%	1.0%
brown trout	8	7568	0.2	224.6	3.4%	31.3%									8	7568	3.2%	27.7%
coho salmon	1	45	<0.1	1.3	0.4%	0.2%									1	45	0.4%	0.2%
american smelt	1	91	<0.1	2.7	0.4%	0.4%									1	91	0.4%	0.3%
carp	1	585	<0.1	17.4	0.4%	2.4%	1	2763	1.0	2763.0	0.9	2434.4	7.7%	88.1%	2	3348	0.8%	12.2%
white sucker	1	974	<0.1	28.9	0.4%	4.0%									1	974	0.4%	3.6%
black bullhead	1	272	<0.1	8.1	0.4%	1.1%									1	272	0.4%	1.0%
channel catfish	2	2310	0.1	68.5	0.9%	9.5%									2	2310	0.8%	8.4%
yellow perch	110	6490	3.3	192.6	46.8%	26.8%	12	372	12.0	372.0	10.6	327.8	92.3%	11.9%	122	6862	49.2%	25.1%
Total	235	24209	7.0	718.4			13	3135	13.0	3135.0	11.5	2762.1			248	27344		
No. of Species	11						2								11			

Table B-7. Summary of fish collections from the North Branch of the Chicago River, 1 August 1986.

	Electrofishing							
	No.	Total Wt. (g)	No/ 30 min	Wt./ 30 min (g)	No./ 400m	Wt./ 400m (g)	% of Total No.	% of Total Wt.
Common Name								
goldfish	4	656	2.0	328.0	1.4	223.3	22.2%	58.5%
carp	1	91	0.5	45.5	0.3	31.0	5.6%	8.1%
black bullhead	5	270	2.5	135.0	1.7	91.9	27.8%	24.1%
largemouth bass	2	14	1.0	7.0	0.7	4.8	11.1%	1.2%
green sunfish	1	45	0.5	22.5	0.3	15.3	5.6%	4.0%
orangespotted sunfish	5	45	2.5	22.5	1.7	15.3	27.8%	4.0%
Total	18	1121	9.0	560.5	6.1	381.6		
No. of Species	6							

Table B-8. Summary of crayfish *(Orconectes viralis)* collected from four sample locations, 28 July - 1 August 1986.

	Outside CDF (A)	Inside CDF (B)	Breakwater Control (C)	Chicago River (D)
No. Collected	42	12	50	0
Total Wt.(g)	630	228	800	-
Mean Wt.(g)	15	19	16	-
No. Traps	4	4	4	4
Trap-Hrs.	81.3	80.2	67.4	6.0
No./Trap-Hr.	0.5	0.2	0.7	-
Wt.(g)/Trap-Hr.	7.8	2.8	11.9	-

APPENDIX C:

CHEMICAL ANALYSES BY DAILY ANALYTICAL LABORATORIES:

CONTRACT REPORT

Daily Analytical Laboratories
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Laboratory Director

PCB's in Fish, Sediments and other Biological Materials

D/A Project #5161.02
#5671.12

I. Introduction

The Chicago District, U.S. Army Corps of Engineers has conducted an investigation of the biological communities inhabiting the inside and outside of the Chicago area confined disposal facility (CDF) and the Chicago River (NBCR) proposed dredging area. The purpose of the analytical portion of the program is to provide additional information on the levels of PCB's and their distribution through the aquatic food chains in the study areas.

II. Receipt of Samples

Two sets of samples were received from the Illinois State Natural History Survey, the contracted samplers. The first set, received August 4, 1986, consisted of fish and sediment samples (See Table 1). The second set, received approximately one month later, consisted of sediment samples and "other" biological samples (See Table 2). The sample site designations for fish, crayfish, sediments and "other" biological materials were as follows:

Site Description	Sediment and All Other Samples Designation	Fish Samples Designation
Inside CDF	A	B
Outside CDF	B	A
Control-inside breakwater	C	C
N. Branch of Chicago River	D	D

Table 1

Sample Designation	Type of Fish/(Sediment)
B-4-6	Pumpkinseed Sunfish
B-5-4	Yellow Perch
B-4-3	Yellow Perch
B-4-2	Yellow Perch
B-2	Green Sunfish
B-4-1	Yellow Perch
B-5-6	Alewife
A-1-9	Alewife
A-1-4	Yellow Perch
A-1-1	Drum
A-1-2	Gizzard Shad
A-1-7	Yellow Perch
A-1-8	Rainbow Trout
A-2-8	Gizzard Shad
A-2-2	Alewife
A-2-1	Yellow Perch
A-2-7	Yellow Perch
B-1&2-1	Crayfish
C-2-7	Yellow Perch
C-2-1	Channel Catfish
C-1-9	Alewife
C-2-4	Rainbow Trout
C-2-5	Black Bullhead
C-9	Small Yellow Perch
C-2-8	Alewife
C-1-6	Yellow Perch
C-1-3	White Sucker
B-1&2-2	Crayfish
A-1-1&2	Crayfish
C-1-1&2	Crayfish
C-2-1&2	Crayfish
A-2-1&2	Crayfish
B-5-7	Pumpkinseed Sunfish
B-4-5	Green Sunfish
B-3-1	Bluntnose Minnows
B-3-2	Orange Spotted Sunfish
B-1	Green Sunfish
B-3-4	Yellow Perch
B-5-1	Channel Catfish
B-5-5	Yellow Perch
B-5-2	Black Bullhead
B-5-3	Yellow Perch
B-4-4	Alewife
B-3-3	Minnows

Table 1 Cont'd.

A-2-6	Brown Trout
A-1-10	Longnose Sucker
A-1-5	Yellow Perch
A-1-6	Yellow Perch
A-1-3	Gizzard Shad
A-2-3	Alewife
A-2-4	Alewife
A-2-5	Yellow Perch
C-1-1	Carp
C-1-5	Yellow Perch
C-1-7	Yellow Perch
C-2-3	Brown Trout
C-2-2	Gizzard Shad
C-2-6	Yellow Perch
C-1-4	Gizzard Shad
C-1-10	Alewife
C-1-2	Brown Trout
C-1-8	Rainbow Trout
D-1-1	Black Bullhead
D-1-5	Orange Spotted Sunfish
D-1-3	Goldfish
D-1-4	Carp
D-1-2	Goldfish
D-1-6	Green Sunfish
A-2	Sediment
B-4	Sediment
B-3	Sediment
C-3	Sediment
B-6	Sediment
B-9	Sediment
C-1	Sediment
B-10	Sediment
B-7	Sediment
B-1	Sediment
B-5	Sediment
A-5	Sediment
C-2	Sediment
A-8	Sediment
A-4	Sediment
A-7	Sediment
A-1	Sediment
A-3	Sediment
A-6	Sediment
B-8	Sediment
B-2	Sediment

Table 2

Sample Type	Station	Location
Sediment	D1	Chicago River (NBCR)
Sediment	D2	Chicago River (NBCR)
Sediment	D3	Chicago River (NBCR)
Periphyton	C1	Control Area
Periphyton	C2	Control Area
Periphyton	C3	Control Area
Periphyton	B1	North Wall CDF
Periphyton	B2	North Wall CDF
Periphyton	B3	North Wall CDF
Periphyton	B6	East Wall CDF
Periphyton	B7	East Wall CDF
Periphyton	B8	East Wall CDF
Zooplankton	Area A	Inside Confinement
Invertebrates	D1	Chicago River (NBCR)
Invertebrates	D2	Chicago River (NBCR)
Invertebrates	D3	Chicago River (NBCR)

III. Sample Preparation

A. Composites of Samples

The samples were composited, prepared, and analyzed in three sets, Set X, Set Y, and Set Z. All instructions for compositing came from Mr. Jan Miller, Army Corps of Engineers and are summarized in Table 3. The periphyton samples were composited using a Waring Blender Model 7012S with a stainless steel container to blend the samples together. The same methodology was used for the invertebrate samples.

B. Chopping the Fish Samples

All frozen fish samples were chopped into 0.5 to 1.0 inch chunks using a meat cleaver and a hammer on a polypropylene chopping board. The chopping board and meat cleaver were scrubbed with water and paper towels a minimum of three times between samples (or until no more fish material could be scrubbed off of the chopping block).

This avoided cross contamination between the different fish samples. The fish chunks were stored in plastic food storage bags to await further preparation. (See D below)

Table 3

Set X

(Analyzed 10/13/86 to 11/6/86, Reported 11/13/86)

D/A #	Sample Designation	Type of Fish		Sample Wt. Extracted (gm)
6297-10	A-1-1&2	Crayfish		15.95
6297-11	A-2-1&2	Crayfish		15.53
6297-12	B-1&2-1	Crayfish		13.46
6297-13	B-1&2-2	Crayfish		14.09
6297-14	C-1-1&2	Crayfish		13.86
6297-15	C-2-1&2	Crayfish		14.62
6297-16	B-4-4	Alewife	Composited	16.20
	B-5-6	Alewife		
6297-17	A-1-9	Alewife	Composited	14.25
	A-2-2	Alewife		
6297-18	C-1-9	Alewife	Composited	15.74
	C-2-8	Alewife		
6297-19	D-1-2	Goldfish	Composited	14.66
	D-1-3	Goldfish		
6297-20	B-5-4	Yellow Perch		15.13
6297-21	B-3-4	Yellow Perch		14.21
6297-22	A-1-7	Yellow Perch		15.16
6297-23	A-2-1	Yellow Perch		15.14
6297-24	C-1-5	Yellow Perch		14.69
6297-25	C-2-6	Yellow Perch		14.50
6297-26	B-3-2	Orange Spotted Sunfish		12.88
6297-27	D-1-5	Orange Spotted Sunfish		14.12
6297-28	A-1-8	Rainbow Trout		14.80
6297-29	C-1-8	Rainbow Trout		14.81
6297-30	B-5-2	Black Bullhead		16.33
6297-31	C-2-5	Black Bullhead		15.94
6297-32	D-1-1	Black Bullhead		15.40
6297-33	D-1-4	Carp		15.14
6297-34	C-1-1	Carp		16.32
6297-35	A-2-6	Brown Trout		17.59
6297-36	C-2-3	Brown Trout		16.25
6297-37	B-5-1	Channel Catfish		17.21
6297-38	C-2-1	Channel Catfish		16.62
6294-83	A1	Sediment		
	A2	Sediment		
	A3	Sediment		
	A4 A	Sediment	Composited	20.00
	A5	Sediment		
	A6	Sediment		
	A7	Sediment		
	A8	Sediment		

Table 3 Cont'd

Set X Cont'd

6294-84	B1		Sediment		
	B2	Ba	Sediment	Composited	21.50
	B3		Sediment		
6294-85	B6		Sediment		
	B7	Bb	Sediment	Composited	20.54
	B8		Sediment		
6294-86	C1		Sediment		
	C2	C	Sediment	Composited	21.29
	C3		Sediment		
6294-87	D1		Sediment		
	D2	D	Sediment	Composited	20.68
	D3		Sediment		

Table 3 Cont'd

Set Y

(Analyzed 12/23/86 to 2/11/87, Reported 3/11/87)

D/A #	Sample Designation	Type of Fish		Sample Wt. Extracted (gm)
*6357-10	A-1-5	Yellow Perch		15.47
*6357-11	A-2-4	Alewife		15.18
6357-12	C-2-9	Yellow Perch		14.42
6357-13	A-2-7	Yellow Perch		14.84
6357-14	C-1-7	Yellow Perch		15.47
6357-15	B-3-3	Bluntnose Minnow		5.10
6357-16	B-3-1	Bluntnose Minnow		6.22
6357-17	D-1-6	Green Sunfish		14.48
6357-18	B-4-5	Green Sunfish		8.05
6357-19	D1	Invertebrates		
	D2	Invertebrates	Composited	30.33
	D3	Invertebrates		
6357-20	Area A	Zooplankton		32.86

* Samples to be split and sent to IEPA

Table 3 Cont'd

Set Z

(Analyzed 2/3/87 to 3/6/87, Reported 3/11/87)

D/A#	Sample Designation	Type of Fish		Sample Wt. Extracted (gm)
7033-01	A-1-2	Gizzard Shad		14.072
7033-02	A-2-3	Alewife		13.775
7033-03	A-1-4	Yellow Perch		12.736
7033-04	C-1-4	Gizzard Shad	Composited	13.276
	C-2-2	Gizzard Shad		
7033-05	B-2-1	Green Sunfish	Composited	11.800
	B-1-1	Green Sunfish		
7033-06	B-4-6	Pumpkinseed Sunfish	Comp	10.502
	B-5-7	Pumpkinseed Sunfish		
7033-07	B-4-2	Yellow Perch		
	B-4-3	Yellow Perch		
	B-4-1	Yellow Perch	Composited	13.549
	B-5-3	Yellow Perch		
	B-5-5	Yellow Perch		
*7037-01	C-1-6	Yellow Perch		12.082
*7037-02	C-1-10	Alewife		14.963
7048-28	B-5	Sediment		31.440
7048-29	B-10	Sediment		30.424
7048-30	C1	Periphyton	Composited	31.490
	C3	Periphyton		

* Samples to be split and sent to IEPA

C. The frozen fish chunks were ground to a fine powder using dry ice and a Waring Blender Model 7012S with a stainless steel container.(1) The dry ice kept the sample cold enough to fracture the chunks relatively easily and also to keep the water in the fine particles from melting. When necessary, multiple batches of grindings were composited in a plastic food storage bag after grinding. In order to minimize cross contamination among samples, the blender was cleaned with a water rinse, soap and water wash, another water rinse, an acetone rinse, and then air drying.

D. After being ground, the samples were split into two approximately equal portions and returned to the freezer in plastic food storage bags pending furher preparation for analysis. The plastic food storage bags were closed loosely at the top to allow the carbon dioxide from the dry ice to escape from the bag.(1) Those ground samples which were to be sent to the Illinois Environmental Protection Agency for analysis were put into hexane-rinsed jars with aluminum foil lined caps. There is no set procedure for storage of biological samples. Benville and Tindle(1) and Schmitt, Zajicek, and Ribick(2) both used polyethylene bags for homogenization of the samples. There have been reports, however, of both contamination of the sample from the storage container and significant loss of PCB by adsorption to the container walls, both glass and plastic.(3,4) It has been recommended that the whole sample as well as the container walls be extracted to minimize these effects.(4) This approach was not feasible for this project, since it would not be possible to extract the whole sample for the larger fish.

IV. Sample Extraction

A. All Fish

A weighed portion of a powdered fish sample was placed into a 250 ml flat bottom flask. A one hundred (100) milliliter aliquot of methylene chloride was added to the sample and the flask was stoppered tightly. The flask was placed on a Burrell Model 75 wrist-action shaker for 45 minutes. The extract was poured (with rinsing) through a 2cm x 15cm drying column of granular anhydrous sodium sulfate into a Kuderna-Danish concentrator. The extract was evaporated to less than 10ml in a Kuderna-Danish concentrator and was transferred to a 10ml volumetric flask and brought to volume with methylene chloride.

(1) Benville, P.E. and Tindle, R.C., J. Agr. Food Chem., Vol 18, #5, 1970.

(2) Schmitt, C.J., Zajicek, J.L. and Ribick, M.A.; Arch. Environ. Contam. Toxicol; 14, p. 226, 1985.

(3) Hutzinger, O., Safe, S.; and Zitko, V.; The Chemistry of PCB's, CRC Press, 1979, pp. 9, 197, 198.

(4) Erickson, Mitchell D., Analytical Chemistry of PCB's, Butterworth Publishers, 1986, pp. 68, 69, 114, 115.

B. Sediments

Two different methods of extraction were used for sediments; a wrist-action shaker method and a sonicator method. (5,6) The wrist-action shaker method was used for Set X while the sonicator method was used for Set Z. The sonicator method was preferred because of higher percentage recovery of spiked materials but had not been verified in our laboratory before extracting samples from Set X.

1. From Set X

A weighed portion of sediment sample was placed into a 500ml flat bottom flask. A 25ml portion of deionized water was added along with a 100ml portion of 50/50 methylene chloride/hexane mixture. The flask was stoppered tightly and was placed on a Burrell Model 75 wrist-action shaker for 40 minutes on a setting of 7.5. The liquid was decanted into a 250ml Erlenmeyer flask containing enough anhydrons granular sodium sulfate to cover the bottom of the flask. The flask was shaken gently and allowed to stand for 10 minutes. The extract was decanted into a graduated cylinder and the liquid volume was recorded to the nearest milliliter. The sodium sulfate remaining was loose and free-flowing. The extract was quantitatively transferred to a Kuderna-Danish concentrator and reduced to less than 10ml after addition of 50 ml of hexane. The extract was then transferred to a 10ml volumetric flask and diluted to volume with hexane.

2. From Set Z

A weighed portion of the sediment was placed into a 400ml beaker. Anhydrous powdered sulfate (2-4 x the sample weight) was added slowly to the sample with constant stirring until the sample was powdery. The sample was extracted three times with approximately 100ml of 50/50 acetone/methylene chloride using a Tekmar Model TM500 High Intensity Ultrasonic Processor for three minutes. The extract was decanted off into a vacuum filtration apparatus between extractions. After the final extraction, the whole sample was transferred to the vacuum filtration apparatus and allowed to partially dry. The extract was quantitatively transferred to a Kuderna-Danish concentrator and reduced to less than 10ml after addition of 50 ml of hexane. The extract was transferred to a 10ml volumetric flask and diluted to volume with hexane.

(5) Illinois Environmental Protection Agency Laboratory Methods Manual, Vol. 1, Organic Methods, P. 4-1 to 4-15.

(6) USEPA Contract Laboratory Program, "Statement of Work for Organics Analysis", October, 1986, pp. PEST D-13 thru PEST D-27.

C. Other Biological Materials

The other biological materials (invertebrates, phytoplankton, and periphyton) were prepared by the same sonication method as above for sediments. More anhydrons powdered sodium sulfate had to be added to the samples, however, since the percentage water was higher than for the sediments. Also, the addition of hexane to the concentration step was not necessary because these samples would be further prepared by gel permeation chromatography.

V. Sample Cleanup

A. Size Exclusion Chromatography

Size Exclusion Chromatography or Gel Permeation Chromatography (GPC) was used as a cleanup step for the fish samples and the other biological samples.(7) This particular technique separates the lipid material (molecular weight >600) from the polychlorinated biphenyls (PCB's) (molecular weight 200-400).

A 5.7ml aliquot of the concentrated extract was injected into an ABC Laboratories manual Gel Permeation Chromatograph equipped with a glass column (2.5 x 48cm) containing 60 grams of Biobeads SX-3. The chromatographic conditions were as follows:

Solvent: 50/50 cyclohexane / methylene chloride
Flow Rate: 5ml/min.

The lipids elute from the column first. The first fraction, collected from the GPC between 0 and 30 minutes, was transferred to a tared beaker, allowed to evaporate for 48 hours, and reweighed. The weight difference from this procedure was the amount of lipid in the sample.

The second fraction, collected from the GPC between 30 and 60 minutes, contained the PCB's and was transferred to a Kuderna-Danish concentrator, reduced to less than 10ml after addition of 50ml of hexane, transferred to a 10ml volumetric flask and diluted to volume with hexane.

(7) Stalling, D.L.; Tindle, R.C., and Johnson, J.L., J. AOAC, Vol 55, #1, 1972.

B. Sulfuric Acid/Florisil cleanup

All samples were subjected to sulfuric acid and Florisil slurry cleanup procedures. The sulfuric acid oxidizes both potential GC interferents as well as many macromolecules which may not have been separated during the GPC procedure. The oxidized materials will remain in the sulfuric acid layer. The Florisil slurry cleanup is an added step to remove any other possible interferents which the sulfuric acid did not remove or which could have formed during the sulfuric acid step and remained in the organic phase.

A portion of the final concentrated extract (1.5-2ml) was added to a vial containing approximately 2ml of concentrated sulfuric acid. The vial was capped and mixed on a vortex mixer for 10-15 seconds. The aqueous and organic layers were allowed to separate. A portion of the organic layer (most of it) was transferred to another vial containing approximately 1/4 gram of Florisil. The vial was swirled gently and stored in a refrigerator at 40 deg. F. The samples were then ready to be analyzed.

VI. Analytical Methodology

All cleaned extracts were analyzed for PCB's by gas chromatography using a Perkin Elmer 3920B gas chromatograph equipped with an electron capture detector (ECD) and a Hewlett Packard 3362 data system. The following chromatographic conditions were used:

Column: glass 6' x 2mm ID packed with 1.95% SP2401/1.5% SP2250 on 100/120mesh Supelcoport.

Injection Temp: 275 deg C
Detector Temp: 300 deg C
Oven Temp: 210 deg C (Isothermal)
Detector: ECD
Carrier Gas: P-5 Mix @ 90 ml/min.
(95% Argon/55 Methane)
Standing Current: 0.5
Injection Volume: 2ul

VII. Quantitation

A. Mixed Standard Calibration

All samples were analyzed by packed column gas chromatography using three calibration standards containing a mixture of the four Aroclors of concern, namely, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260. The areas under the peaks indicative of Aroclor were summed for each standard. A calibration curve was constructed by entering into a computer programmed for linear regression the standard concentration (in ug/ml) as the abscissa values and the summed areas as the ordinate values. The areas under the same peaks as the standards were also summed for the samples. The summed areas for the samples were entered into the computer generated linear regression analysis and a corresponding concentration was obtained. From the concentration value, the following equations were used to generate the amounts of PCB in fish, other biological materials, and sediments, respectively: (on a wet weight basis)

$$\text{Fish: Total PCB (mg/kg)} = \frac{\text{ug/ml} \times 10\text{ml} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample weight (gm)(wet)}}$$

Other Biological Material:

$$\text{Total PCB (mg/kg)} = \frac{\text{ug/ml} \times 10\text{ml} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample weight(gm)(wet)}}$$

$$\text{Sediments: Total PCB (mg/kg)} = \frac{\text{ug/ml} \times 10\text{ml}}{\text{sample weight(gm)(wet)}}$$

B. Sum of Individual Aroclor Components

All samples were also analyzed by packed column gas chromatography using three levels of calibration standards of each of the four individual Aroclors; Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260. Retention times and areas were recorded for each of the peaks indicative of each individual Aroclor at each concentration level. Response factors were calculated for each peak as per the following formula:

$$\text{Response Factor} = \frac{\text{Peak Area}}{(2\text{ul}(\text{Std Conc.(ng/ul)})}$$

The response factors for each retention time for each Aroclor were averaged. These averages as well as retention times were entered into a computer spreadsheet program. Areas of the peaks in a sample chromatogram which matched the retention times of the Aroclor standard peaks were also entered into the computer program. The program then matched those peaks specific only to Aroclor 1260, calculated an amount of Aroclor 1260 for each unique peak, in ug, and averaged those values. The average value along with the rest of the Aroclor 1260 response factors were used to back-calculate areas that would correspond to Aroclor 1260 but overlap with the other Aroclors. The back-calculated areas were subtracted from the original sample areas and the amount left over was a remainder from which Aroclor 1254 was calculated in the same manner. This process was repeated to the point where an amount of Aroclor 1242 was calculated. The amounts of each Aroclor were summed to give a total PCB in ug for that sample. This calculation procedure is from a manuscript to be submitted for publication.

From the total ug of PCB found above, the following equations are examples of those used to generate the amounts of each Aroclor and total PCB in fish, other biological material, and sediments, respectively:

Fish: Aroclor 1242 (mg/kg) = $\dfrac{\text{ug} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample wt.(gm)(wet)}}$

Total PCB (mg/kg) = $\dfrac{\text{ug} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample wt.(gm)(wet)}}$

Other Biological Material: Aroclor 1242 (mg/kg) = $\dfrac{\text{ug} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample wt.(gm)(wet)}}$

Total PCB (mg/kg) = $\dfrac{\text{ug} \times \frac{10\text{ml}}{5.7\text{ml}}}{\text{sample wt.(gm)(wet)}}$

Sediments: Aroclor 1242 (mg/kg) = $\dfrac{\text{ug}}{\text{sample wt.(gm)(wet)}}$

Total PCB (mg/kg) = $\dfrac{\text{ug}}{\text{sample wt.(gm)(wet)}}$

C. When the total PCB's from each of the quantitation techniques were compared, there was reasonably good agreement between the two methods with a few exceptions. One explanation for those exceptions was that the response factors used for the individually calibrated Aroclors were different from those used for the mixed standard calibration. If one peak area was used in calculations involving two different response factors, the results would be different. Another explanation was that the sample chromatograms exhibited different background or shoulder peaks from the different standards which, in turn resulted in different integration treatment of the shoulder peaks.

VIII. Quality Assurance Program

A. Background

To assure the quality of data generated for the samples, procedural blanks, procedural blank spikes, matrix spikes and matrix spike duplicates were run along with the samples. The rationale behind using matrix spike duplicates is twofold. First, a matrix spike will indicate the accuracy of the procedure for the matrix in question, through a percent recovery of the amount of compound used to fortify the sample. Second, the duplicate matrix spike will indicate the precision of the procedure especially in the case where no compounds are found in any of the samples.

B. Procedures

All quality assurance samples were spiked with the same total ug of Aroclor 1254, 4.92 ug, prior to extraction procedures. The samples were then extracted, concentrated, cleaned up, and analyzed as in the procedures above. Percents recovery were calculated using the following formula:

$$\% \text{ Recovery} = \frac{\text{Amt.(ug) observed in spiked sample} - \text{Amt.(ug) observed in original sample}}{4.92 \text{ ug}} \times 100$$

C. Results & Discussion

Percents recovery for procedural blanks, fish, and sediments for Sets X and Y were calculated based upon the calibration by mixed Aroclor standards, while the percents recovery for fish and procedural blanks for Set Z were calculated based upon Aroclor 1254 alone. There were some interferents in the fish spikes and procedural blank spikes of Set Z which caused the recoveries to appear artificially very high if calculated based upon mixed standard calibration.

The percents recovery from the procedural blank spikes averaged 100% +/- 2% which indicates no loss of Aroclor 1254 from the extraction procedure through analysis and good precision of the technique. The percents recovery from sediments from Set X using the wrist-action shaker extraction procedure averaged 25% +/- 1% showing good precision but poor procedural recovery. The percents recovery from sediments from Set Z, using the sonication extraction procedure averaged 100% +/- 20% showing a much more efficient extraction procedure but not as good precision (based upon only two samples).

The percents recovery from the different fish that were analyzed ranged from 40% to 170% with wide variability. This is not a very unusual phenomenon considering the variability of biological matrices.

VIII. PERCENT MOISTURE FOR FISH, BIOLOGICAL COMPOSITES, AND SEDIMENTS

Percent moisture was determined for fish, biological composites, and sediments by drying a weighed portion of sample in a 103 deg. C oven overnight, dessicating for 0.5 hours in the morning and reweighing.

PERSONNEL PERFORMING ANALYSES

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C.L. Holliman
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ATTN: Mr. Jan Miller

DATE RECEIVED: October 21, 1986

CLIENT P.O. #: DACW23-84-D-0012

D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6294-83	6294-84	6294-85	6294-86
SAMPLE DESCRIPTION		A Sediment	Ba Sediment	Bb Sediment	C Sediment
% Water	%w/w	43%	33%	40%	30%
% Lipid (wet wt.)	%w/w	N.R.	N.R.	N.R.	N.R.
% Lipid (dry wt.)	%w/w	N.R.	N.R.	N.R.	N.R.
Aroclor 1242 (wet)	mg/kg	0.47	0.06	0.06	0.02
Aroclor 1242 (dry)	mg/kg	0.82	0.09	0.10	0.03
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1254 (dry)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1260 (wet)	mg/kg	0.18	0.03	0.03	0.01
Aroclor 1260 (dry)	mg/kg	0.32	0.04	0.05	0.01
Total PCB (wet) *	mg/kg	0.65	0.09	0.09	0.03
Total PCB (dry) *	mg/kg	1.1	0.13	0.15	0.04
Total PCB (wet) **	mg/kg	#	#	#	#
Total PCB (dry) **	mg/kg	#	#	#	#
TOC (wet wt) @	%w/w	2.8%	3.1%	0.72%	1.2%
TOC (dry wt) @	%w/w	4.9%	4.6%	1.2%	1.7%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
N.R. - Not Required
@ - Analysis performed by Environmental Laboratories, Inc.
# - Not quantified from "Mixed Standards"

Analysis Certified By: _____

James F. Dallmeyer
Laboratory Director

Analysis and Testing shall be performed in accordance with U.S EPA's current manual of practice or with other procedures acceptable to U.S.EPA and IEPA.

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DATE RECEIVED: October 21, 1986

CLIENT P.O. #: DACW23-84-D-0012

D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.	6294-87 D
SAMPLE DESCRIPTION	Sediment

% Water	%w/w	68%
% Lipid (wet wt.)	%w/w	N.R.
% Lipid (dry wt.)	%w/w	N.R.
Aroclor 1242 (wet)	mg/kg	0.35
Aroclor 1242 (dry)	mg/kg	1.1
Aroclor 1248 (wet)	mg/kg	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.
Aroclor 1254 (wet)	mg/kg	N.I.
Aroclor 1254 (dry)	mg/kg	N.I.
Aroclor 1260 (wet)	mg/kg	0.10
Aroclor 1260 (dry)	mg/kg	0.31
Total PCB (wet) *	mg/kg	0.45
Total PCB (dry) *	mg/kg	1.4
Total PCB (wet) **	mg/kg	#
Total PCB (dry) **	mg/kg	#
TOC (wet wt) @	%w/w	1.4%
TOC (dry wt) @	%w/w	4.5%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
N.R. - Not Required
@ - Analysis performed by Environmental Laboratories, Inc.
# - Not quantified from "Mixed Standards".

Analysis Certified By: _____

James F. Dallmeyer
Laboratory Director

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DA Daily Analytical Laboratories
1621 W. Candletree Drive Peoria, Illinois 61614
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ATTN: Mr. Jan Miller

DATE RECEIVED: October 24, 1986
CLIENT P.O. #: DACW23-84-D-0012
D/A PROJECT #: 5671.12
DATE OF REPORT : April 7, 1987 (revised report)

D/A SAMPLE NO.		6297-10	6297-11	6297-12
SAMPLE DESCRIPTION		Crayfish A-1-1+2	Crayfish A-2-1+2	Crayfish B-1+2-1
% Water	%w/w	73%	71%	72%
% Lipid (wet wt.)	%w/w	0.62%	0.54%	1.4%
% Lipid (dry wt.)	%w/w	2.3%	1.9%	5.0%
Aroclor 1242 (wet)	mg/kg	N.I.	N.I.	0.35
Aroclor 1242 (dry)	mg/kg	N.I.	N.I.	1.3
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	0.14	0.21	0.35
Aroclor 1254 (dry)	mg/kg	0.51	0.74	1.3
Aroclor 1260 (wet)	mg/kg	0.04	0.15	0.12
Aroclor 1260 (dry)	mg/kg	0.15	0.53	0.44
Total PCB (wet) *	mg/kg	0.18	0.37	0.83
Total PCB (dry) *	mg/kg	0.66	1.3	3.0
Total PCB (wet) **	mg/kg	0.15	0.26	0.69
Total PCB (dry) **	mg/kg	0.55	0.91	2.5
TOC (wet wt) @	%w/w	6.2%	16.5	13.4
TOC (dry wt) @	%w/w	23%	57%	48%

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D/A SAMPLE NO.		6297-13	6297-14	6297-15	6297-16
SAMPLE DESCRIPTION		Crayfish B-1+2-2	Crayfish C-1-1+2	Crayfish C-2-1+2	Alewives B-4-4 B-5-6
% Water	%w/w	67%	77%	73%	60%
% Lipid (wet wt.)	%w/w	0.88%	0.26%	0.61%	14%
% Lipid (dry wt.)	%w/w	2.7%	1.1%	2.2%	35%
Aroclor 1242 (wet)	mg/kg	0.52	0.02	N.I.	1.6
Aroclor 1242 (dry)	mg/kg	1.6	0.10	N.I.	3.9
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	3.1
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	7.8
Aroclor 1254 (wet)	mg/kg	0.22	N.I.	0.16	1.1
Aroclor 1254 (dry)	mg/kg	0.67	N.I.	0.59	2.8
Aroclor 1260 (wet)	mg/kg	0.16	0.02	0.04	0.78
Aroclor 1260 (dry)	mg/kg	0.50	0.11	0.14	2.0
Total PCB (wet) *	mg/kg	0.91	0.05	0.20	6.6
Total PCB (dry) *	mg/kg	2.8	0.21	0.73	16
Total PCB (wet) **	mg/kg	0.77	0.05	0.15	6.2
Total PCB (dry) **	mg/kg	2.3	0.24	0.55	16
TOC (wet wt) @	%w/w	19%	9.9%	>22%	>32%
TOC (dry wt) @	%w/w	57%	43%	>80%	>80%

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D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6297-17	6297-18	6297-19	6297-20
		Alewives	Alewives	Goldfish	Yellow
SAMPLE DESCRIPTION		A-1-9	C-1-9	D-1-2	Perch
		A-2-2	C-2-8	D-1-3	B-5-4
% Water	%w/w	76%	76%	66%	77%
% Lipid (wet wt.)	%w/w	4.2%	3.6%	12%	3.4%
% Lipid (dry wt.)	%w/w	18%	15%	35%	15%
Aroclor 1242 (wet)	mg/kg	0.57	N.I.	0.58	0.03
Aroclor 1242 (dry)	mg/kg	2.4	N.I.	1.7	0.15
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	0.66	0.83
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	2.0	3.6
Aroclor 1254 (wet)	mg/kg	0.35	0.28	0.24	0.59
Aroclor 1254 (dry)	mg/kg	1.5	1.2	0.71	2.6
Aroclor 1260 (wet)	mg/kg	0.07	0.02	0.24	0.26
Aroclor 1260 (dry)	mg/kg	0.30	0.08	0.70	1.1
Total PCB (wet) *	mg/kg	0.99	0.30	1.7	1.7
Total PCB (dry) *	mg/kg	4.1	1.3	5.1	7.4
Total PCB (wet) **	mg/kg	1.1	0.57	2.3	1.8
Total PCB (dry) **	mg/kg	4.5	2.4	6.8	7.6
TOC (wet wt) @	%w/w	17%	14%	26%	>18%
TOC (dry wt) @	%w/w	72%	59%	77%	>80%

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D/A SAMPLE NO.		6297-21	6297-22	6297-23	6297-24
SAMPLE DESCRIPTION		Yellow Perch B-3-4	Yellow Perch A-1-7	Yellow Perch A-2-1	Yellow Perch C-1-5
% Water	%w/w	75%	76%	76%	74%
% Lipid (wet wt.)	%w/w	3.3%	3.4%	3.5%	4.4%
% Lipid (dry wt.)	%w/w	13%	14%	14%	17%
Aroclor 1242 (wet)	mg/kg	0.03	0.22	N.I.	0.24
Aroclor 1242 (dry)	mg/kg	0.14	0.90	N.I.	0.91
Aroclor 1248 (wet)	mg/kg	0.78	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	3.1	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	0.61	0.24	0.27	0.26
Aroclor 1254 (dry)	mg/kg	2.4	0.99	1.1	0.99
Aroclor 1260 (wet)	mg/kg	0.26	0.07	0.10	0.15
Aroclor 1260 (dry)	mg/kg	1.0	0.30	0.42	0.58
Total PCB (wet) *	mg/kg	1.7	0.53	0.37	0.64
Total PCB (dry) *	mg/kg	6.7	2.2	1.6	2.5
Total PCB (wet) **	mg/kg	1.8	0.58	0.54	0.83
Total PCB (dry) **	mg/kg	7.1	2.4	2.3	3.2
TOC (wet wt) @	%w/w	16%	12%	17%	16%
TOC (dry wt) @	%w/w	66%	48%	72%	61%

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D/A PROJECT #: 5671.12
DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6297-25	6297-26	6297-27	6297-28
SAMPLE DESCRIPTION		Yellow Perch C-2-6	Orange Spotted Sunfish B-3-2	Orange Spotted Sunfish D-1-5	Rainbow Trout A-1-8
% Water	%w/w	76%	77%	72%	75%
% Lipid (wet wt.)	%w/w	3.5%	1.1%	2.7%	5.1%
% Lipid (dry wt.)	%w/w	14%	4.8%	9.6%	20%
Aroclor 1242 (wet)	mg/kg	N.I.	0.29	N.I.	N.I.
Aroclor 1242 (dry)	mg/kg	N.I.	1.3	N.I.	N.I.
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	0.56	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	2.0	N.I.
Aroclor 1254 (wet)	mg/kg	0.21	0.47	N.I.	0.07
Aroclor 1254 (dry)	mg/kg	0.87	2.0	N.I.	0.29
Aroclor 1260 (wet)	mg/kg	0.07	0.12	0.07	0.05
Aroclor 1260 (dry)	mg/kg	0.30	0.53	0.24	0.21
Total PCB (wet) *	mg/kg	0.28	0.88	0.63	0.12
Total PCB (dry) *	mg/kg	0.87	3.8	2.2	0.50
Total PCB (wet) **	mg/kg	0.42	0.96	0.67	0.26
Total PCB (dry) **	mg/kg	1.7	4.2	2.4	1.0
TOC (wet wt) @	%w/w	13%	13%	16%	14%
TOC (dry wt) @	%w/w	53%	55%	57%	58%

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D/A SAMPLE NO.		6297-29	6297-30	6297-31	6297-32
SAMPLE DESCRIPTION		Rainbow Trout C-1-8	Black Bullhead B-5-2	Black Bullhead C-2-5	Black Bullhead D-1-1
% Water	%w/w	74%	80%	74%	78%
% Lipid (wet wt.)	%w/w	6.2%	1.1%	2.2%	2.9%
% Lipid (dry wt.)	%w/w	24%	5.5%	8.5%	13%
Aroclor 1242 (wet)	mg/kg	N.I.	0.65	0.23	0.90
Aroclor 1242 (dry)	mg/kg	N.I.	3.2	0.89	4.1
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	0.33
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	1.5
Aroclor 1254 (wet)	mg/kg	0.07	0.23	0.20	0.16
Aroclor 1254 (dry)	mg/kg	0.27	1.1	0.79	0.72
Aroclor 1260 (wet)	mg/kg	0.04	0.15	0.07	0.18
Aroclor 1260 (dry)	mg/kg	0.15	0.75	0.26	0.83
Total PCB (wet) *	mg/kg	0.11	1.0	0.50	1.6
Total PCB (dry) *	mg/kg	0.42	5.1	1.9	7.1
Total PCB (wet) **	mg/kg	0.23	0.70	0.40	2.0
Total PCB (dry) **	mg/kg	0.87	3.5	1.5	8.9
TOC (wet wt) @	%w/w	14%	10%	14%	15%
TOC (dry wt) @	%w/w	55%	51%	55%	68%

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DATE OF REPORT : April 7, 1987
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D/A SAMPLE NO.		6297-33	6297-34	6297-35	6297-36
SAMPLE DESCRIPTION		Carp D-1-4	Carp C-1-1	Brown Trout A-2-6	Brown Trout C-2-3
% Water	%w/w	74%	68%	67%	68%
% Lipid (wet wt.)	%w/w	4.3%	6.6%	12%	11%
% Lipid (dry wt.)	%w/w	16%	21%	36%	34%
Aroclor 1242 (wet)	mg/kg	0.34	0.85	1.1	1.8
Aroclor 1242 (dry)	mg/kg	1.3	2.7	3.3	5.7
Aroclor 1248 (wet)	mg/kg	0.15	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	0.57	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	0.08	0.33	0.84	0.63
Aroclor 1254 (dry)	mg/kg	0.32	1.0	2.5	2.0
Aroclor 1260 (wet)	mg/kg	0.05	0.31	0.10	0.29
Aroclor 1260 (dry)	mg/kg	0.20	0.98	0.32	0.90
Total PCB (wet) *	mg/kg	0.63	1.5	2.0	2.7
Total PCB (dry) *	mg/kg	2.4	4.7	6.2	8.6
Total PCB (wet) **	mg/kg	0.69	1.2	1.6	2.0
Total PCB (dry) **	mg/kg	2.6	3.8	4.9	6.1
TOC (wet wt) @	%w/w	>21%	18%	23%	18%
TOC (dry wt) @	%w/w	>80%	56%	69%	57%

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DATE RECEIVED: October 24, 1986
December 23, 1986
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D/A PROJECT #: 5671.12
DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6297-37	6297-38	6357-10	6357-11
SAMPLE DESCRIPTION		Channel Catfish B-5-1	Channel Catfish C-2-1	A-1-5 Yellow Perch	A-2-4 Alewife
% Water	%w/w	68%	64%	74%	78%
% Lipid (wet wt.)	%w/w	11%	14%	4.0%	3.2%
% Lipid (dry wt.)	%w/w	34%	39%	15%	14%
Aroclor 1242 (wet)	mg/kg	2.2	1.1	0.24	0.34
Aroclor 1242 (dry)	mg/kg	6.8	3.0	0.94	1.5
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	0.06	0.26
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	0.23	1.2
Aroclor 1254 (wet)	mg/kg	0.95	1.7	0.50	0.86
Aroclor 1254 (dry)	mg/kg	3.0	4.8	1.9	3.9
Aroclor 1260 (wet)	mg/kg	0.77	0.83	0.20	0.23
Aroclor 1260 (dry)	mg/kg	2.4	2.3	0.75	1.0
Total PCB (wet) *	mg/kg	3.9	3.6	1.0	1.7
Total PCB (dry) *	mg/kg	12	10	3.8	7.7
Total PCB (wet) **	mg/kg	3.4	3.4	1.1	2.2
Total PCB (dry) **	mg/kg	11	9.6	4.1	10
TOC (wet wt) @	%w/w	>26%	26%	17%	12%
TOC (dry wt) @	%w/w	>80%	73%	64%	55%

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D/A SAMPLE NO.		6357-12	6357-13	6357-14	6357-15
		C-2-9	A-2-7	C-1-7	B-3-3
SAMPLE DESCRIPTION		Yellow Perch	Yellow Perch	Yellow Perch	Bluntnose Minnow
% Water	%w/w	76%	73%	74%	79%
% Lipid (wet wt.)	%w/w	2.8%	5.6%	4.8%	1.3%
% Lipid (dry wt.)	%w/w	12%	21%	18%	6.4%
Aroclor 1242 (wet)	mg/kg	0.21	0.62	0.24	0.06
Aroclor 1242 (dry)	mg/kg	0.88	2.3	0.92	0.29
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	0.58	0.86	1.0	0.60
Aroclor 1254 (dry)	mg/kg	2.4	3.2	3.9	2.8
Aroclor 1260 (wet)	mg/kg	0.14	0.43	0.16	N.I.
Aroclor 1260 (dry)	mg/kg	0.58	1.6	0.61	N.I.
Total PCB (wet) *	mg/kg	0.93	1.9	1.4	0.66
Total PCB (dry) *	mg/kg	3.9	7.1	5.4	3.1
Total PCB (wet) **	mg/kg	0.97	1.9	1.3	0.48
Total PCB (dry) **	mg/kg	4.0	7.1	5.0	2.3
TOC (wet wt) @	%w/w	16%	>22%	18%	12%
TOC (dry wt) @	%w/w	69%	>80%	69%	58%

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ATTN: Mr. Jan Miller

DATE RECEIVED: December 23, 1986

CLIENT P.O. #: DACW23-84-D-0012

D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6357-16	6357-17	6357-18	6357-19
		B-3-1	D-1-6	B-4-5	D1-D2-D3
SAMPLE DESCRIPTION		Bluntnose Minnow	Green Sunfish	Green Sunfish	Inverte-brates
% Water	%w/w	71%	70%	73%	98%
% Lipid (wet wt.)	%w/w	7.9%	3.5%	2.0%	0.13%
% Lipid (dry wt.)	%w/w	27%	12%	7.4%	6.6%
Aroclor 1242 (wet)	mg/kg	0.55	0.70	0.66	N.I.
Aroclor 1242 (dry)	mg/kg	1.9	2.3	2.4	N.I.
Aroclor 1248 (wet)	mg/kg	1.1	N.I.	N.I.	0.17
Aroclor 1248 (dry)	mg/kg	3.8	N.I.	N.I.	8.6
Aroclor 1254 (wet)	mg/kg	0.77	0.59	1.0	N.I.
Aroclor 1254 (dry)	mg/kg	2.6	2.0	3.8	N.I.
Aroclor 1260 (wet)	mg/kg	0.55	N.I.	0.33	0.05
Aroclor 1260 (dry)	mg/kg	1.9	N.I.	1.2	2.7
Total PCB (wet) *	mg/kg	3.0	1.3	2.0	0.24
Total PCB (dry) *	mg/kg	10	4.3	7.4	11
Total PCB (wet) **	mg/kg	2.5	1.4	2.0	0.12
Total PCB (dry) **	mg/kg	8.7	4.5	7.5	6.0
TOC (wet wt) @	%w/w	15%	>24%	19%	0.16%
TOC (dry wt) @	%w/w	51%	>80%	70%	8%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
N.R. - Not Required
@ - Analysis performed by Environmental Laboratories, Inc.

Analysis Certified By: _____
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DATE RECEIVED: December 23, 1986
February 2, 1987
CLIENT P.O. #: DACW23-84-D-0012
DACW23-87-M-4056
D/A PROJECT #: 5671.12
5161.02
DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		6357-20	7033-01	7033-02	7033-03
		Area A	A-1-2	A-2-3	A-1-4
SAMPLE DESCRIPTION		Zoo Plankton	Gizzard Shad	Alewife	Yellow Perch
% Water	%w/w	99.8%	69%	76%	73%
% Lipid (wet wt.)	%w/w	0.02%	11%	3.5%	5.2%
% Lipid (dry wt.)	%w/w	12%	35%	14%	19%
Aroclor 1242 (wet)	mg/kg	N.I.	3.0	0.56	0.85
Aroclor 1242 (dry)	mg/kg	N.I.	9.5	2.3	3.1
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	N.I.	0.80	0.71	1.0
Aroclor 1254 (dry)	mg/kg	N.I.	2.6	3.0	3.8
Aroclor 1260 (wet)	mg/kg	N.I.	0.44	0.18	0.53
Aroclor 1260 (dry)	mg/kg	N.I.	1.4	0.75	2.0
Total PCB (wet) *	mg/kg	<0.02	4.2	1.4	2.4
Total PCB (dry) *	mg/kg	<10	14	5.8	8.9
Total PCB (wet) **	mg/kg	<0.02	3.2	1.3	1.7
Total PCB (dry) **	mg/kg	<10	10	5.4	6.3
TOC (wet wt) @	%w/w	0.08%	>25%	18%	>21%
TOC (dry wt) @	%w/w	40%	>80%	75%	>80%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
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DATE RECEIVED: February 2&6, 1987

CLIENT P.O. #: DACW23-87-M-4056

D/A PROJECT #: 5161.02

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		7033-04	7033-05	7033-06	7033-07
SAMPLE DESCRIPTION		C-1-4+ C-2-2 Gizzard Shad	B-2-1+ B-1-1 Green Sunfish	B-4-6+ B-5-7 Pumpkin-seed Sunfish	B-4-2+B -4-3+B-4 -1+B-5-3 +B-5-5 Yellow Perch
% Water	%w/w	64%	77%	76%	77%
% Lipid (wet wt.)	%w/w	17%	1.8%	2.2%	4.1%
% Lipid (dry wt.)	%w/w	48%	8.1%	9.0%	18%
Aroclor 1242 (wet)	mg/kg	2.5	0.60	1.1	1.9
Aroclor 1242 (dry)	mg/kg	6.8	2.6	4.4	8.1
Aroclor 1248 (wet)	mg/kg	0.17	N.I.	N.I.	N.I.
Aroclor 1248 (dry)	mg/kg	0.48	N.I.	N.I.	N.I.
Aroclor 1254 (wet)	mg/kg	0.85	0.68	1.0	2.4
Aroclor 1254 (dry)	mg/kg	2.4	2.9	4.2	10
Aroclor 1260 (wet)	mg/kg	0.30	0.11	0.22	0.39
Aroclor 1260 (dry)	mg/kg	0.84	0.49	0.94	1.7
Total PCB (wet) *	mg/kg	3.8	1.4	2.3	4.7
Total PCB (dry) *	mg/kg	10	6.0	9.6	20
Total PCB (wet) **	mg/kg	3.1	1.6	1.5	3.0
Total PCB (dry) **	mg/kg	8.6	7.0	6.2	13
TOC (wet wt) @	%w/w	25%	7.6%	13%	16%
TOC (dry wt) @	%w/w	.70%	33%	53%	70%

* - Sum of Individual Aroclors
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DATE RECEIVED: February 17, 1987

CLIENT P.O. #: DACW23-87-M-4056

D/A PROJECT #: 5161.02

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		7037-01	7037-02	7048-28	7048-29
		C-1-6	C-1-10	B-5	B-10
SAMPLE DESCRIPTION		Yellow Perch	Alewife	Sediment	Sediment
% Water	%w/w	75%	79%	41%	44%
% Lipid (wet wt.)	%w/w	2.7%	1.7%	N.R.	N.R.
% Lipid (dry wt.)	%w/w	11%	8.1%	N.R.	N.R.
Aroclor 1242 (wet)	mg/kg	0.52	0.77	1.7	0.33
Aroclor 1242 (dry)	mg/kg	2.1	3.6	2.9	0.59
Aroclor 1248 (wet)	mg/kg	N.I.	N.I.	N.I.	0.07
Aroclor 1248 (dry)	mg/kg	N.I.	N.I.	N.I.	0.12
Aroclor 1254 (wet)	mg/kg	0.58	0.63	0.38	0.10
Aroclor 1254 (dry)	mg/kg	2.3	3.0	0.65	0.18
Aroclor 1260 (wet)	mg/kg	0.17	0.14	0.11	0.06
Aroclor 1260 (dry)	mg/kg	0.67	0.65	0.18	0.10
Total PCB (wet) *	mg/kg	1.3	1.5	2.2	0.55
Total PCB (dry) *	mg/kg	5.2	7.2	3.7	0.98
Total PCB (wet) **	mg/kg	1.0	1.6	0.15	0.05
Total PCB (dry) **	mg/kg	4.0	7.6	0.25	0.08
TOC (wet wt) @	%w/w	17%	11%	2.9%	0.36%
TOC (dry wt) @	%w/w	69%	52%	4.9%	0.65%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
N.R. - Not Required
@ - Analysis performed by Environmental Laboratories, Inc.

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DATE RECEIVED: February 17, 1987
CLIENT P.O. #: DACW23-87-M-4056
D/A PROJECT #: 5161.02
DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.		7048-30
SAMPLE DESCRIPTION		C1 + C3 Peri-phyton
% Water	%w/w	96%
% Lipid (wet wt.)	%w/w	0.05%
% Lipid (dry wt.)	%w/w	1.2%
Aroclor 1242 (wet)	mg/kg	<0.04
Aroclor 1242 (dry)	mg/kg	<1.0
Aroclor 1248 (wet)	mg/kg	N.I.
Aroclor 1248 (dry)	mg/kg	N.I.
Aroclor 1254 (wet)	mg/kg	<0.04
Aroclor 1254 (dry)	mg/kg	<1.0
Aroclor 1260 (wet)	mg/kg	N.I.
Aroclor 1260 (dry)	mg/kg	N.I.
Total PCB (wet) *	mg/kg	<1.0
Total PCB (dry) *	mg/kg	<1.0
Total PCB (wet) **	mg/kg	<0.04
Total PCB (dry) **	mg/kg	<1.0
TOC (wet wt) @	%w/w	0.52%
TOC (dry wt) @	%w/w	13%

* - Sum of Individual Aroclors
** - Quantified from "Mixed Standards"
N.I. - None Identified
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ATTN: Mr. Jan Miller

DATE RECEIVED: October 24, 1986

CLIENT P.O. #: DACW23-84-D-0012

D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.	6294-83	6297-18	6297-25	Proced-
	Sediment	Alewives	Yellow	ural
SAMPLE DESCRIPTION	A	C-1-9 C-2-8	Perch C-2-6	Blank
Matrix Spike-%Recovery	24%	94%	170%	
Matrix Spike/Duplicate %Recovery	26%	40%	170%	
Relative % Difference	8%	81%	0%	
Total PCB (mg/l)				<0.001

Analysis Certified By:

James F. Dallmeyer
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DATE RECEIVED: December 23, 1986

CLIENT P.O. #: DACW23-84-D-0012

D/A PROJECT #: 5671.12

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO.	6357-10 A-1-5	Proced-ural	Proced-ural
SAMPLE DESCRIPTION	Yellow Perch	Spike	Blank
Matrix Spike-%Recovery	64%	98%	
Matrix Spike/Duplicate %Recovery	92%		
Relative % Difference	34%		
Total PCB (mg/l)			<0.001

Analysis Certified By:

James F. Dallmeyer
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ATTN: Mr. Jan Miller

DATE RECEIVED: February 2,27/87

CLIENT P.O. #: DACW23-84-M-4056

D/A PROJECT #: 5161.02

DATE OF REPORT : April 7, 1987
(revised report)

D/A SAMPLE NO. SAMPLE DESCRIPTION	Procedural Blank Spike	7033-04 C-1-4+ C-2-2 Gizzard Shad Spike	7048-29 B-10 Sediment Spike	Procedural Blank
Matrix Spike-%Recovery	101%	81%	80%	
Matrix Spike/Duplicate %Recovery	102%	70%	120%	
Relative % Difference	1%	14%	40%	
Total PCB (mg/l)				<0.001

Analysis Certified By:

James F. Dallmeyer
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APPENDIX D:

FISH TISSUE CHEMICAL ANALYSES BY THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY ON FISH COLLECTED DURING THE 1986 BASELINE STUDY

The Illinois Environmental Protection Agency (IEPA) analyzed twelve samples of fish tissue from the materials collected during this study. Four of these samples were split quality assurance checks of ground fish tissue prepared by Daily Analytical Laboratories (DAL). The remaining eight samples were whole fish (larger sport fish) requested by the Illinois Department of Conservation for the purpose of evaluating health risks of fish consumption by sport fishermen utilizing Calumet Harbor. The IEPA chemical analyses were more extensive than the DAL tests, and included pesticide scans as well as PCB's. These data are listed in Table D-1.

The results of the four quality assurance split samples analyzed by both IEPA and DAL for percent lipid and PCB content are listed in Table D-2. Both quantitation methods used by DAL produced, on average, higher estimates for PCB than the did the IEPA analyses, while DAL estimates of percent lipid content were lower, on average, than IEPA estimates. When the PCB data for the twelve IEPA samples are normalized for lipid content, however, an average of 29 ppm PCB in lipid is obtained, which compares very well the DAL average of 28 ppm PCB in lipid for 28 fish and crayfish samples.

Scattergrams with regression statistics for IEPA data and for all harbor fish and crayfish data (IEPA + DAL) are shown in figures D-1 and D-2, respectively. Despite variability inherent in the fish populations, as well as that due to sampling and measurement error, lipid normalization using regression techniques or averaging produce useful descriptions of trends in PCB accumulation in aquatic biota.

Table D-1: Organic contaminant analyses of composite fish samples collected from Calumet Harbor during the present study and submitted to the Illinois Environmental Protection Agency.

Species	Yellow Perch	Yellow Perch	Alewife	Gizzard Shad	Freshwater Drum	Longnose Sucker
Code Number	A-1-5	A-2-5	A-2-4	A-1-3	A-1-1	A-1-10
No. of fish	10	10	10	19	3	2
Parameter			mg kg^{-1} (ppm)			
% Lipid	3.00	3.20	4.20	11.00	9.90	5.50
Total PCB's	1.20	1.20	0.64	1.90	3.30	0.78
PCB/fr. Lipid	40.00	37.50	15.24	17.27	33.33	14.18
Aldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Chlordane	<0.02	0.05	0.04	0.09	0.04	0.03
Total DDT's	0.15	0.16	0.10	0.15	0.16	0.08
Dieldrin	0.03	0.04	0.04	0.06	0.04	0.03
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hept. epoxide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Toxaphene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Methoxychlor	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hexachlorobenz.	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
G-BHC (lindane)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Alpha-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mirex	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Species	Yellow Perch	Yellow Perch	Alewife	Rainbow Trout	Brown Trout	White Sucker
Code Number	C-1-6	C-2-7	C-1-10	C-2-4	C-1-2	C-1-3
No. of fish	10	5	10	1	3	1
Parameter			mg kg^{-1} (ppm)			
% Lipid	3.80	3.20	3.00	1.80	13.00	4.10
Total PCB's	0.75	0.69	0.78	0.69	2.40	2.60
PCB/fr. Lipid	19.74	21.56	26.00	38.33	18.46	63.41
Aldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Chlordane	0.04	0.04	<0.02	<0.02	0.07	0.02
Total DDT's	0.11	0.10	0.17	0.11	0.40	0.02
Dieldrin	0.04	0.05	0.03	0.02	0.12	0.02
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hept. epoxide	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Toxaphene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Methoxychlor	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hexachlorobenz.	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
G-BHC (lindane)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Alpha-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mirex	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table D-2: Results of Quality Assurance split samples (ground fish tissue) prepared by Daily Analytical Laboratory and Submitted to the Illinois Environmental Protection Agency (IEPA) for replicate PCB analayses.

Sample		Yellow perch		Alewife	
		A-1-5	C-1-6	A-2-4	C-1-10
Laboratory	*Method	PCB's (ppm wet weight)			
Daily Analytical	1	1.00	1.30	1.70	1.50
	2	1.10	1.00	2.20	1.60
IEPA	1	1.20	0.75	0.64	0.78

Sample	Yellow perch		Alewife	
	A-1-5	C-1-6	A-2-4	C-1-10
Laboratory	% Lipid (wet weight)			
Daily Analytical	4.00	2.70	3.20	1.70
IEPA	3.00	3.80	4.20	3.00

*Method 1: Quantitation by sum of computer-evaluated Arochlor peaks
Method 2: Quantitation by comparison with standard prepared with equal portions of Arochlors 1242, 1248, 1254 and 1260

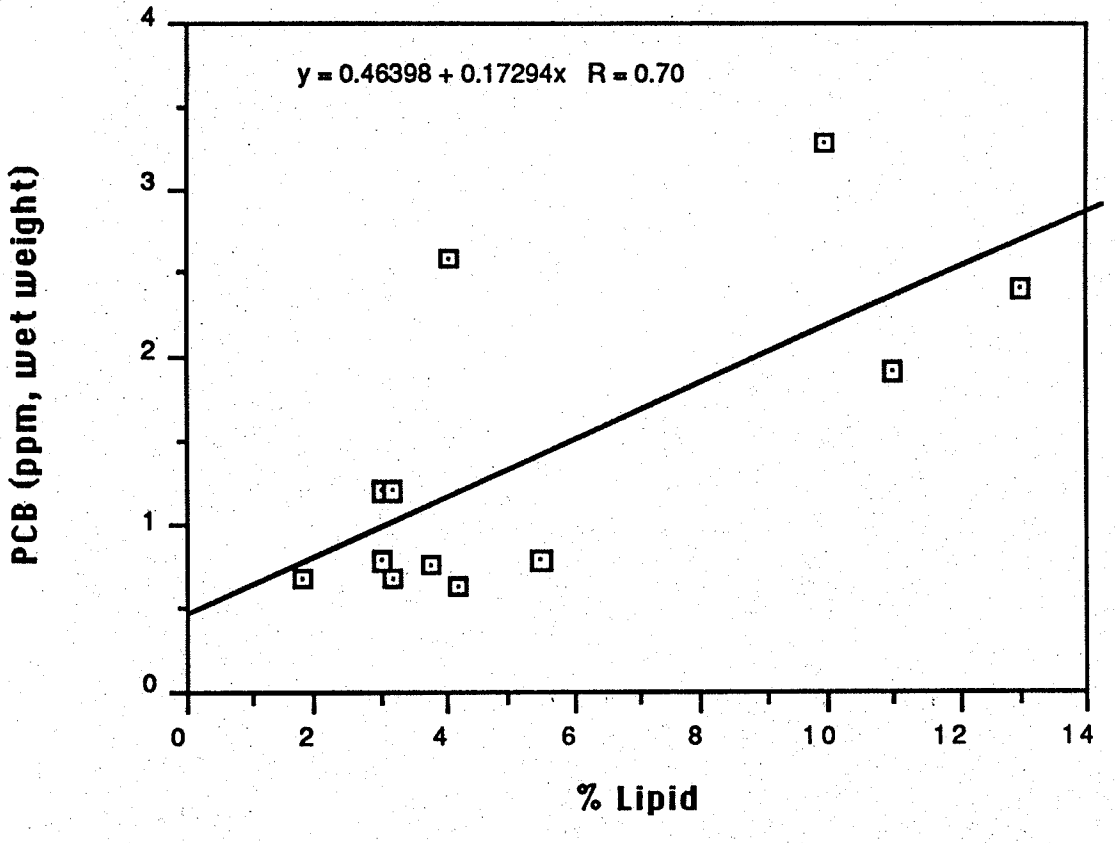

Figure D-1: Scattergram and regression line (PCB's vs. % Lipid) generated for Calumet Harbor fish composites collected during the 1986 baseline study and analyzed by IEPA.

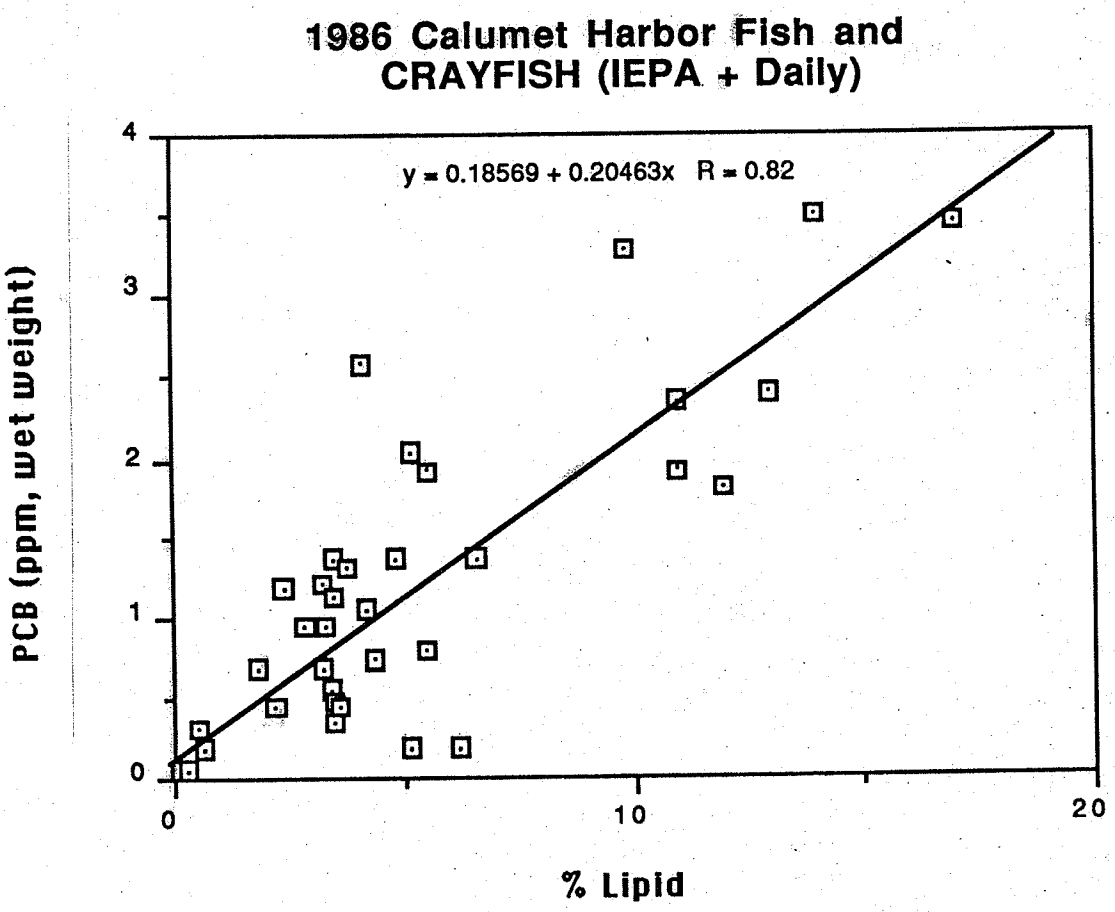

Figure D-2: Scattergram and regression line (PCB's vs. % Lipid) generated for Calumet Harbor fish and crayfish composites analyzed by IEPA and Daily Analytical Laboratory.

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