



US Army Corps
of Engineers

MISCELLANEOUS PAPER EL-91-4

POLYCHLORINATED BIPHENYL LEVELS IN THE SAGINAW CONFINED DISPOSAL FACILITY DURING DISPOSAL OPERATIONS, FALL 1987

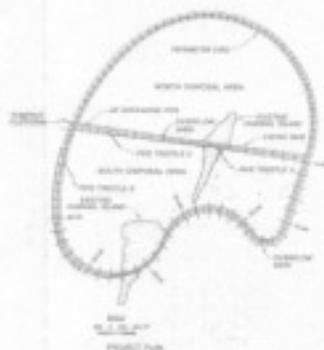
by

Tommy E. Myers

Environmental Laboratory

DEPARTMENT OF THE ARMY

Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199



January 1991

Final Report

Approved for Public Release; Distribution Unlimited

Prepared for US Army Engineer District, Detroit
Detroit, Michigan 48231-1027



Destroy this report when no longer needed. Do not return
it to the originator.

The findings in this report are not to be construed as an official
Department of the Army position unless so designated
by other authorized documents.

The contents of this report are not to be used for
advertising, publication, or promotional purposes.
Citation of trade names does not constitute an
official endorsement or approval of the use of
such commercial products.

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified				1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY				3. DISTRIBUTION /AVAILABILITY OF REPORT Approved for public release; distribution unlimited.			
2b. DECLASSIFICATION /DOWNGRADING SCHEDULE				5. MONITORING ORGANIZATION REPORT NUMBER(S)			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper EL-91-4				7a. NAME OF MONITORING ORGANIZATION			
6a. NAME OF PERFORMING ORGANIZATION USAEWES Environmental Laboratory		6b. OFFICE SYMBOL (if applicable)		7b. ADDRESS (City, State, and ZIP Code)			
6c. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199				9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8a. NAME OF FUNDING /SPONSORING ORGANIZATION USAED, Detroit		8b. OFFICE SYMBOL (if applicable)		10. SOURCE OF FUNDING NUMBERS			
8c. ADDRESS (City, State, and ZIP Code) Detroit, MI 48231-1027				PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Polychlorinated Biphenyl Levels in the Saginaw Confined Disposal Facility During Disposal Operations, Fall 1987							
12. PERSONAL AUTHOR(S) Myers, Tommy E.							
13a. TYPE OF REPORT Final report		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) January 1991		15. PAGE COUNT 99	
16. SUPPLEMENTARY NOTATION Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.							
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)				
FIELD	GROUP	SUB-GROUP	Confined disposal facility Polychlorinated biphenyls Disposal Dredged material				
19. ABSTRACT (Continue on reverse if necessary and identify by block number)							
<p>Pond water samples were collected from the Saginaw confined disposal facility (CDF), Saginaw, MI, during late summer and early fall 1987 and were analyzed for polychlorinated biphenyls (PCBs), suspended solids, and ammonia-nitrogen. During this period, sediment from the Saginaw River near Saginaw was dredged and disposed in the Saginaw CDF. The perimeter dikes at the Saginaw CDF have a prepared limestone core that was designed to be permeable. Effluent monitoring is not practical because the discharge through permeable dikes is diffuse and is quickly diluted to background concentrations. This study, therefore, focused on collection of influent and pond water samples during disposal operations, and on the use of PCB concentrations in pond water samples to estimate the amount of PCB entering the dike and possibly being released from the CDF.</p> <p style="text-align: right;">(Continued)</p>							
20. DISTRIBUTION /AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS				21. ABSTRACT SECURITY CLASSIFICATION Unclassified			
22a. NAME OF RESPONSIBLE INDIVIDUAL				22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL	

PREFACE

The work described herein was conducted for the US Army Engineer District, Detroit, by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES). Funding was provided by the Detroit District under Intra-Army Order for Reimbursable Services No. NCE-IA-88-0010. Detroit District Project Manager for the study was Ms. Pam Bedore, CENCE-CO-00.

The report was prepared by Mr. Tommy E. Myers, Water Supply and Waste Treatment Group (WSWTG), Environmental Engineering Division (EED), EL. Technical reviewers were Dr. Paul R. Schroeder, Water Resources Engineering Group (WREG), EED, and Dr. Michael R. Palermo, Research Projects Group, EED. Field sampling and sample processing were performed by Messrs. Mark E. Zappi and Sidney B. Ragsdale, WSWTG, EED; Ms. Carla Fisher and Mr. Ernie Liebetrea, CENCE-CO-0; and Ms. Bedore. Analysis of polychlorinated biphenyls and ammonia-nitrogen was performed by the Analytical Laboratory Group, EED, under the supervision of Ms. Ann B. Strong. Suspended solids determinations were performed by Mr. Thomas E. Schaefer, Jr., WREG, EED. Assistance with data reduction was provided by Ms. Kellie Huff, WSWTG, EED.

The study was conducted under the direct supervision of Mr. Norman R. Francingues, Jr., Chief, WSWTG, and under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Chief, EL.

Commander and Director of WES was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

This report should be cited as follows:

Myers, Tommy E. 1991. "Polychlorinated Biphenyl Levels in the Saginaw Confined Disposal Facility During Disposal Operations, Fall 1987," Miscellaneous Paper EL-91-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

CONTENTS

	<u>Page</u>
PREFACE	1
PART I: INTRODUCTION	3
Background	3
Objectives and Approach	4
PART II: METHODS	5
Sampling Procedures	5
Determination of PCB Distribution Coefficients	6
Chemical Analysis	7
PART III: RESULTS AND DISCUSSION	8
Dredging and Disposal Operations	8
Coordination of Sampling with Disposal Operations	9
Characterization of Influent	10
Pond Water Response to Disposal Operations	11
Prediction with Modified Elutriate Test	16
Prediction with Simple Equilibrium Partitioning Equations	18
Containment Efficiency	29
PART IV: CONCLUSIONS	33
REFERENCES	34
TABLES 1-6	
FIGURES 1-16	
APPENDIX A: POLYCHLORINATED BIPHENYL DATA	A1
APPENDIX B: SEQUENTIAL BATCH LEACH DATA	B1

POLYCHLORINATED BIPHENYL LEVELS IN THE SAGINAW CONFINED
DISPOSAL FACILITY DURING DISPOSAL OPERATIONS, FALL 1987

PART I: INTRODUCTION

Background

1. An Interagency Work Group is evaluating the effectiveness of confined disposal facilities (CDFs) in the Great Lakes for retaining contaminants in polluted dredged material. The group includes representatives of the US Army Engineer (USAE) Division, North Central; Region V of the US Environmental Protection Agency (USEPA); and Regions III and V of the US Fish and Wildlife Service (USFWS). One class of contaminants in the Saginaw River, Michigan, about which the Interagency Work Group has expressed concern is polychlorinated biphenyls (PCBs). These are hydrophobic organic contaminants that are of concern because of their wide distribution and persistence in the environment (National Research Council 1979).

2. The USAE District, Detroit, operates and maintains a CDF for disposal of sediments from the Federal navigational channel in the Saginaw River near Saginaw, MI (see Figure 1). The Saginaw CDF is a 1.13 million-square meter facility that is divided into north and south disposal cells of nearly equal size. Figure 2 shows a plan view of the Saginaw CDF. The perimeter dikes have a prepared limestone core that was designed to be permeable and to function as a filter for the discharge. An overflow weir allows direct discharge from the south cell when and if the dikes become clogged. The weir was not used during this study.

3. Although many studies have been conducted on the behavior of PCBs in the Great Lakes (Mackay et al. 1983), few field data on PCBs in CDFs in the Great Lakes have been collected. The USAE District, Detroit, requested the Environmental Engineering Division of the Environmental Laboratory, US Army Engineer Waterways Experiment Station (WES), to conduct a field study of PCB concentrations in dredged material influents and pond water entering the permeable dikes at the Saginaw CDF and to evaluate selected screening-level procedures for preproject estimation of dissolved PCB concentrations in CDFs.

Objectives and Approach

4. The objectives of this study were to compare field data on PCBs in the Saginaw CDF with values predicted by the modified elutriate test and simple equations based on equilibrium partitioning and to estimate the amount of PCB moving into and possibly through the dike during disposal operations at the Saginaw CDF.

5. The approach involved collection of influent and pond water samples during disposal operations, pond water samples before disposal operations commenced, and pond water samples after disposal operations ceased. Effluent monitoring was not practical because the discharge from a permeable dike CDF is a diffuse source that is often quickly diluted to background concentrations. Analysis of samples for suspended solids, ammonia-nitrogen, and PCBs provided the basis for evaluating selected procedures for preproject estimation of dissolved PCB in the Saginaw CDF and estimating the amount of PCB entering the dike during disposal operations.

PART II: METHODS

Sampling Procedures

Influent

6. Influent slurry exiting the CDF pipe trestle was sampled using the "J" sampling apparatus described by Montgomery (1978). This apparatus diverts a stream of slurry into a collection vessel. Approximately 22 l of dredged material slurry was collected in 38-l stainless steel pots and transported to a field laboratory at the Saginaw Area Office, USAE District, Detroit. At the field laboratory, slurry samples for total solids were placed in 1-l polypropylene bottles. Samples for dissolved ammonia-nitrogen and PCBs were centrifuged in stainless steel centrifuge tubes at $6,500 \times g$ for 30 min. The supernate was then filtered through precombusted ($400^{\circ} C$) Whatman GF/D glass fiber prefilters and precombusted Gelman AE glass fiber filters with a nominal pore size of 1.0μ . Ammonia-nitrogen samples were placed in 125-ml polypropylene bottles, and PCB samples were placed in 1.9-l amber glass jugs. Dredged material solids were removed from the centrifuge tubes and placed in 1-l glass jars with aluminum foil-lined caps. Prior to use, glass jars and jugs for storage of PCB samples were washed with soap and water, rinsed with tap water, rinsed five times with distilled-deionized water, and rinsed twice with reagent-grade acetone. The stainless steel pots were similarly cleaned prior to use. Samples were shipped on ice by overnight delivery to WES for analysis.

Pond water

7. Predisposal and postdisposal samples. Predisposal pond water samples collected 1 day before dredging and disposal operations commenced and postdisposal pond water samples collected at 1-week intervals after disposal operations ceased were obtained from three widely spaced locations in the south cell. Water from middepth was mixed in a 38-l stainless steel pot to make one composite sample. Figure 2 shows the approximate locations from which water was obtained for the composite samples. Each composite sample consisted of approximately 11 l of water from locations 1 and 2 and 8 l of water from location 3, for a total composite volume of 30 l. Less water was collected at location 3 because the water there was shallower than at the other locations. Water depths at locations 1 and 2 were 1.8 to 2.5 m; at location 3, the water depth was less than 1 m. Three such composites were

collected for characterization of preexisting conditions. Three composite pond water samples were also collected for characterization of postdisposal conditions, except that the postdisposal composites were collected at 1-week intervals and, thus, were not replicates.

8. The stainless steel pots containing the composite samples were transported to the field laboratory for processing. Whole water samples for PCB and suspended solids were collected and placed in 1.9-ℓ amber glass jugs and 1-ℓ polypropylene bottles, respectively. Samples for dissolved ammonia-nitrogen and PCBs were prepared by centrifugation and filtration as described previously for processing of influent samples and placed into 1-ℓ polypropylene bottles and 1.9-ℓ amber glass jugs, respectively. Prior to use, glass jars and jugs and stainless steel pots were cleaned as previously described. Samples were shipped on ice by overnight delivery to WES for analysis.

9. Pond water samples during disposal operations. During disposal operations, pond water samples were collected at two locations along the south cell perimeter dike as shown in Figure 2. These locations were in zones of significant dike seepage as indicated by a dye study at the Saginaw CDF (Schroeder and McEnroe 1988). Sampling was conducted on the inside of the dike at approximately 2 m into the pond. Twenty-three liters of water was collected at each location by compositing equal volumes of water from near the bottom, middepth, and surface in equal proportions in 38-ℓ stainless steel pots. Samples were transported to the field laboratory and processed as previously described for the processing of the predisposal and postdisposal samples.

Determination of PCB Distribution Coefficients

10. The PCB distribution coefficients were determined in a four-cycle sequential batch leach test. The method used in this study is a slight modification of the procedures described elsewhere (Environmental Laboratory 1987, Myers and Brannon 1988). A 4:1 water-to-sediment ratio and a shaking time of 24 hr were used in the sequential batch leach tests for Saginaw River sediment. Twenty-four stainless steel centrifuge tubes (sufficient for three replicates), double rinsed with acetone, were loaded with sufficient sediment and deoxygenated, distilled-deionized water to obtain a 4:1 water-to-sediment dry weight ratio. All operations were conducted under a nitrogen atmosphere. The tubes were placed in a rotary tumbler (Garrett et al. 1984) and turned end

over end at 40 rpm for 24 hr. After agitation on the tumbler, the samples were removed from the tumbler, centrifuged for 30 min at 6500 × g, and filtered under a nitrogen atmosphere through precombusted (400° C) Whatman GF/D glass fiber prefilters and precombusted Gelman AE glass fiber filters (nominal pore size of 1.0 μ). A subsample of filtered leachate was set aside for analysis of dissolved organic carbon. The remainder of the leachate was acidified with 1 ml of concentrated hydrochloric acid to prevent iron precipitation and scavenging of PCBs from solution by iron precipitates. These samples were then stored at 4° C in the dark in acetone-rinsed 2-l glass bottles until extracted for PCB analysis. All extractions were completed within 30 days of sample collection.

11. After each cycle of agitation and phase separation, leachate was replaced with fresh deoxygenated, distilled-deionized water, and the procedure previously described for agitation and phase separation was repeated. Four cycles of the batch leach test summarized in Table 1 were conducted.

Chemical Analysis

PCBs and organic carbon

12. Water and sediment samples were analyzed for concentrations of PCB aroclors, total PCB (quantified using a multi-aroclor standard), and 60 selected PCB congeners. The PCB congener identification key used in this report is given in Table 2. Concentrations of PCBs in sediment samples were determined following Soxhlet extraction, Florosil cleanup, and quantification in a Hewlett Packard 5880A gas chromatograph equipped with an electron capture detector and dual Supelco capillary columns, DB-5 and SPB-608. Concentrations of PCB compounds in water samples following methylene chloride extraction were determined on the same equipment as for sediment samples. Sediment total organic carbon and dissolved organic carbon in water samples were determined using an Oceanographic International 524B organic carbon analyzer.

Suspended solids and ammonia-nitrogen

13. Total solids in influent slurry samples and suspended solids in water samples were determined in triplicate according to gravimetric procedures given by the US Environmental Protection Agency (USEPA 1983). Ammonia-nitrogen as NH₃-N was determined on a Technicon AutoAnalyzer according to the USEPA (1983) procedures.

PART III: RESULTS AND DISCUSSION

Dredging and Disposal Operations

14. Dredging and disposal operations began on 12 August 1987 and ended on 13 September 1987. Dredged material from two areas of the Saginaw River (Figure 3) was disposed in the Saginaw CDF during this study. Sediments from Area I in the upper reach were slightly coarser than sediments from Area II in the entrance channel (Palermo and Randall 1989). Sediments from both areas were classified as silt (MH) according to the Unified Soil Classification System. Sediment was dredged, transported, and placed in the Saginaw CDF by the hopper dredge *Dodge Island*. Each cycle of loading and pumpout included travel time for the dredge from the area being dredged to the CDF. Thus, disposal events were intermittent. Total cycle time varied, depending on which area of the river the dredge was working, river traffic, weather, sediment properties, and other factors.

15. At the time of the study, the north cell of the Saginaw CDF was filled, and the west half of the south cell was nearly filled. Initially, dredged material from Area I was pumped into the CDF through pipe Trestle B (Figure 2). During this operation a large mound of dredged material solids formed immediately in front of the discharge pipe and forced influent to flow back toward the northwest corner of the south cell through brush and other vegetation instead of draining directly into the CDF pond. The cross dike forced the flow to turn east in order to reach the CDF pond. The vegetation in the northwest corner of the south cell became partially submersed with dredged material as disposal operations continued, forcing the influent to split into two eastward flows that went around the mound that had formed in front of the discharge pipe. These flows spread across a delta of dredged material from previous disposal operations before entering the CDF pond.

16. Eventually, the discharge point was changed to pipe Trestle A (Figure 2). At pipe Trestle A, influent flowed across a delta of dredged material solids that formed beneath the discharge pipe. During disposal operations, the delta would build as solids were deposited and then slump into the pond. This process of deposition and slumping slowly enlarged the delta of dredged material solids around Trestle A.

Coordination of Sampling with Disposal Operations

17. Sample collection dates and times are given in Table 3. Pond water samples for characterization of preexisting conditions were collected on 11 August, 1 day before disposal operations began. Postdisposal pond water samples were collected at 1-week intervals beginning approximately 1 week after disposal operations ended.

18. Since sediments from Area I were known from previous sampling by the Detroit District to have low contamination levels relative to Area II, pond water samples were collected primarily during disposal of dredged material from Area II. Most of the material disposed during the period 12-30 August was dredged from Area I. Influent and pond water samples were collected on 15 August (Table 3) to provide information on Area I influent solids and pond water quality during disposal of Area I sediments.

19. On 31 August, two loads from Area I were disposed in the CDF, and then dredging operations switched from Area I to Area II. From 31 August through 2 September, 25 loads of material from Area II were dredged and disposed in the Saginaw CDF. Total volume disposed from 31 August through 2 September was 30,095 cu m. Average cycle time was 2.3 hr per load, and average pumpout time was 20 min per load. Dredged material (Areas I and II) was discharged through pipe Trestle A. During this operation, 8 influent samples and 16 pond water samples were collected (Table 3). The first influent sample collected on 31 August was collected during disposal of the material from Area I. During disposal operations, pond water sampling lagged influent sampling by approximately 2 hr (Table 3). Since inflows were pulsed, the hydraulic retention time in the CDF was probably longer than 2 hr. Consequently, influent and pond water samples were "snapshots" of existing conditions and do not necessarily correspond on a 2-hr basis to the same mass of water.

20. On 3 September, the dredge began working Area I again. Additional sediment was also dredged from Area II before dredging and disposal operations were completed on 13 September. No influent or pond water samples were collected during disposal operations after 2 September.

Characterization of Influent

PCBs

21. Influent solids. Aroclor and total PCB concentrations in influent solids are presented in Table A1 (Appendix A) for dredged material from Area I and in Table A3 (Appendix A) for dredged material from Area II. Aroclors 1216, 1232, 1248, and 1254 were generally below the detection limit (0.01 mg/kg) in the influent solids from Areas I and II. Concentrations of Aroclors 1242 and 1260 in influent solids from Areas I and II ranged from <0.01 to 0.93 mg/kg. The averages for total PCB in influent solids were 0.26 mg/kg for Area I and 0.90 mg/kg for Area II. Thus, the PCB concentrations in influent solids for dredged material from Area II were slightly higher than for dredged material from Area I.

22. The PCB congener concentrations in influent solids are presented in Tables A2 and A4 (Appendix A) for dredged material from Areas I and II, respectively. Average PCB congener concentrations in influent solids from Areas I and II are shown in Figure 4. Many of the 60 PCB congeners analyzed in this study were not detected in the influent solids samples. Only those PCB congeners with an average concentration above the detection limit (0.002 mg/kg) are shown in Figure 4. More PCB congeners were present in influent solids from Area II than from Area I, and for those PCB congeners present in influent solids from both areas, the concentrations were generally higher in influent solids from Area II than in influent solids from Area I. Figure 4 shows that di-, tri-, and tetrachlorobiphenyls were the most abundant PCB congeners in Area I and II influent solids. The PCB congener in highest concentration for the congeners analyzed in this study was C15, 4,4'-dichlorobiphenyl.

23. Influent water. Since influent water was separated from influent solids by centrifugation and filtration, the data for influent water represent dissolved parameter concentrations. Dissolved aroclor concentrations in dredged material influent during disposal of dredged material from Areas I and II were near or below the detection limit (0.0002 mg/l) in most of the samples (Tables A5 and A7, Appendix A). Most of the values for total PCB for influent water were slightly above the detection limit. (Total PCB is a chemical parameter quantitated using a multi-aroclor standard; total PCB is not the sum of the PCB congeners, nor is total PCB a sample type.) Average influent water

total PCB concentration was 0.0005 mg/l for dredged material from both Areas I and II.

24. Dissolved PCB congener concentrations in dredged material influent are presented in Tables A6 and A8 (Appendix A) for dredged material from Areas I and II, respectively. Average PCB congener concentrations in influent water for Areas I and II are presented in Figure 5. The data in Figure 5 show that influent water from Area I contains more detectable PCB congeners than influent water from Area II. The concentrations of PCB congeners C52 and C101 were enriched in Area I influent water relative to Area II influent water, and the concentrations of PCB congeners C15 and C18 were enriched in Area II influent water relative to Area I influent water.

Total solids and dissolved ammonia-nitrogen

25. Table 4 presents total solids and dissolved ammonia-nitrogen results for all the influent samples collected. Most of the samples contained more than 100 g/l total solids. However, there were some samples with less than 50 g/l total solids. Dredged material slurries usually contain more than 100 g/l total solids. Palermo and Randall (1989) also reported some low solids concentrations during their study of hopper overflow during the same dredging and disposal operation on the Saginaw River.

26. Ammonia-nitrogen data showed that influent concentrations of dissolved $\text{NH}_3\text{-N}$ were controlled by solids concentration. Samples with low solids content were also low in $\text{NH}_3\text{-N}$ relative to the dissolved $\text{NH}_3\text{-N}$ in samples with high solids content. In those samples containing more than 100 g/l total solids, dissolved $\text{NH}_3\text{-N}$ concentrations were between 35 and 51 mg/l. In those samples containing less than 50 g/l total solids, dissolved $\text{NH}_3\text{-N}$ concentrations were between 4 and 15 mg/l. The reason ammonia-nitrogen concentrations were of interest in this study is discussed in the following section on pond water response to disposal operations.

Pond Water Response to Disposal Operations

Dissolved ammonia-nitrogen

27. Dissolved ammonia-nitrogen was used as an indicator of the adequacy of the sampling design for measuring pond water response to disposal operations. Since dredged material contains significant amounts of ammonia-nitrogen and ammonia-nitrogen is highly soluble, dissolved $\text{NH}_3\text{-N}$ concentrations in CDFs usually increase during disposal operations (Hoeppel,

Myers, and Engler 1978). Properly placed sampling locations should show this increase.

28. For the sampling period 31 August through 2 September, pond water dissolved $\text{NH}_3\text{-N}$ concentrations at Stations A and B ranged from 0.9 to 6.1 mg/l (Figure 6). These data show that during disposal operations, dissolved $\text{NH}_3\text{-N}$ concentrations at Stations A and B were two orders of magnitude higher than dissolved $\text{NH}_3\text{-N}$ concentrations in samples collected prior to disposal. Dissolved $\text{NH}_3\text{-N}$ concentrations in the three composite predisposal pond water samples were below 0.03 mg/l (Table 5). Although these data are not sufficient to show that Stations A and B were the best locations that could have been selected, the data show that the sampling locations selected were adequate for measuring the impact of dredged material disposal on water quality at the inside face of the dike.

29. Dissolved $\text{NH}_3\text{-N}$ concentrations in pond water samples collected after disposal operations were completed showed a sharp drop from 2.07 mg/l in the first sample collected to 0.23 mg/l in second sample collected (Table 5). The dissolved $\text{NH}_3\text{-N}$ concentration in the final sample collected was slightly lower than the concentration in the previous sample. The data show that 3 weeks after disposal operations ended, the dissolved $\text{NH}_3\text{-N}$ concentration in the pond was approximately an order of magnitude higher than the predisposal concentration.

Suspended solids

30. Suspended solids concentrations at Stations A and B are shown in Figure 7. In general, suspended solids concentrations were higher at Station A than at Station B. Dissolved $\text{NH}_3\text{-N}$ concentrations were also generally higher at Station A than at Station B (Figure 6). The suspended solids concentrations in the three composite samples collected prior to disposal ranged from 166 to 189 mg/l (Table 5). Thus, the concentration of suspended solids in the pond water was lower during disposal operations than immediately prior to disposal operations. The data in Figure 7 also indicate a trend for decreasing suspended solids concentrations during the sampling period.

31. The suspended solids data show that the pond water at the inside face of the dike during disposal was approximately 1,000 times lower in solids content than the influent slurry. Several processes can account for this reduction in solids: removal by mounding and delta formation, dilution by pond water, and sedimentation in the pond. Dilution of the influent solids concentration by pond water accounts for less than 5 percent of the total

reduction in solids concentration. Although some sedimentation in the pond probably took place, the field observations of mounding and delta formation suggest that most of the reduction in solids concentration was due to solids removal before the influent reached the CDF pond.

32. The decrease in pond water suspended solids during disposal operations relative to the predisposal condition was probably related to disappearance of an algae bloom that was visually evident on the day predisposal samples were collected. This bloom disappeared by the time sampling for disposal impacts began. Thus, it is possible that most of the solids in the predisposal pond water samples were biological solids, while most of the solids in the during-disposal pond water samples were dredged material solids.

33. Suspended solids concentrations in pond water samples collected after disposal operations were completed show a slight increase between the first and final samples collected (Table 5). This may indicate an increase in biological solids, resuspension of bottom sediment, or simply random variation either in sampling or suspended solids in the CDF.

PCBs

34. Aroclor and total PCB versus PCB congener-specific analysis. Quantification of PCBs as aroclors or total PCB (using multi-aroclor standard) assumes that sample chromatograms are similar to standard aroclor chromatograms and that the degree of similarity is sufficient to warrant quantification as aroclor equivalents. This assumption is often questionable for environmental samples (Neely 1983; McFarland, Clarke, and Gibson 1986; Schwartz, Stalling, and Rice 1987). The prevalence of di-, tri-, and tetrachlorobiphenyls and the absence of many higher chlorine-substituted biphenyls in Figure 4 suggests that PCB aroclors as originally manufactured probably do not exist in Saginaw River sediments. Thus, usage of aroclor and total PCB equivalents may be misleading.

35. In addition, PCB congener-specific analysis can provide more information about the level and type of PCB contamination than aroclor and total PCB analysis because the detection limit is lower and PCB congeners are specific chemicals. At the WES, the detection limit for PCB congener-specific analysis of water samples is 20 times lower than the detection limit for aroclor and total PCB analysis. A PCB congener is a specific chemical compound with associated physical and chemical properties. Aroclors are mixtures of chemical compounds (PCB congeners) with widely varying physical and chemical properties that affect the fate of these chemicals once they enter the

environment. For these reasons, PCB congeners are better indices of environmental fate and transport processes than aroclors or total PCB. Therefore, PCB congener-specific data are emphasized in the remainder of this report. The entire aroclor, total PCB, and PCB congener data set is presented in Appendix A.

36. Data set reduction. Analysis of pond water samples in this study for PCBs generated a large, cumbersome data set consisting of three characteristic sample types (predisposal, disposal, and postdisposal), two parameter types (whole water and dissolved), and 60 PCB congeners. The data set for pond water samples exceeded 2,700 entries, and when the data for influents are included, the number of entries exceeds 3,800. A data set this large is difficult to interpret without some means of reducing the data to a manageable form. Two methods were used in this study. One involved comparison of PCB congener distributions using average values, and the other involved evaluation of the CDF in terms of a selected PCB congener.

37. Average PCB congener distributions. Average PCB congener concentrations in whole water samples from the CDF pond are presented in Figures 8 and 9. As shown in Figure 8, postdisposal PCB congener concentrations were increased relative to predisposal PCB congener concentrations. The PCB levels in samples collected during dredged material disposal were also increased relative to PCB levels in predisposal pond water samples. On average, PCB contamination was highest in the pond water samples collected during disposal of dredged material from Area I. Average pond water PCB congener concentrations during disposal of dredged material from Area II were lower than the average PCB concentrations in pond water collected during disposal of dredged material from Area I and in postdisposal samples. The increase in PCBs in the postdisposal pond water relative to PCB levels at Stations A and B during disposal of dredged material from Area II indicates that PCBs in the pond water increased during the disposal operations that followed the monitoring period of 31 August through 2 September. The differences between average whole water PCB congener concentrations during disposal must be interpreted with caution because the influent and pond water samples as previously discussed represent snapshots of conditions. The differences may be due to differences in influent PCB concentrations, but not necessarily the influent concentrations that were measured.

38. Average dissolved PCB congener concentrations in pond water samples are shown in Figures 10 and 11. As for whole water PCB concentrations,

average dissolved PCB congener concentrations were higher for postdisposal samples than for predisposal (Figure 10) and disposal samples (Figure 11). Unlike the whole water PCB data, the lowest (not the highest) dissolved PCB concentrations were measured in samples collected during disposal of dredged material from Area I. Differences between predisposal and disposal dissolved PCB concentrations are small and probably not significant since the data were near the detection limit in all these samples. The differences between post-disposal data and disposal dissolved PCB congener data are probably large enough to indicate an increase in dissolved PCB during the disposal operations that followed the monitoring period of 31 August through 2 September.

39. The whole water and dissolved PCB congener concentrations measured in this study were generally near or below the chemical analytical detection limit (0.00001 mg/l). The maximum whole water concentration was 0.00028 mg/l PCB congener C15 in pond water from Station A during disposal of Area I dredged material. The maximum dissolved concentration was 0.00009 mg/l PCB congener C15 in the first pond water composite sample collected after disposal operations were completed. Because most of the PCB congener data are below or near the chemical analytical detection limit, any changes that occurred during disposal were probably masked by the abundance of below-detection limit values in the data set.

40. Evaluation using PCB congener C15. The ideal PCB congener for studying the release of PCBs from dredged material to CDF pond water is a PCB congener that (a) is present in the sediment, (b) is not present in the pond water before disposal operations begin, (c) is present in the pond water during disposal, and (d) is the most abundant PCB congener in the sediment. Congener C15 (4,4'-dichlorobiphenyl) satisfies these requirements for the disposal operations monitored in this study.

41. Dissolved PCB congener C15 concentrations in pond water and influent water during disposal operations from 31 August through 2 September are shown in Figure 12. As indicated in Figure 12, trends in pond water and influent water dissolved PCB congener C15 concentrations were similar. Comparison of influent dissolved $\text{NH}_3\text{-N}$ concentrations to pond water dissolved $\text{NH}_3\text{-N}$ concentrations indicates a 20-fold dilution of influent water during disposal operations. Dilution of influent water should have reduced PCB concentrations to below the detection limit. Since the concentrations of dissolved PCB congener C15 in influent and pond waters were approximately the

same, some process other than dilution of influent dissolved PCB must be affecting dissolved pond water PCB concentrations.

42. Desorption from pond water suspended solids could affect pond water dissolved PCB concentrations. However, trends in dissolved PCB congener C15 at Stations A and B do not match trends in suspended solids at Stations A and B (Figure 7) very well. Peaks in suspended solids concentrations occurred approximately 2 hr earlier than peaks in dissolved PCB congener C15 concentrations. Further, although suspended solids concentrations were lower at Station B than at Station A, dissolved PCB congener C15 concentrations were higher at Station B.

43. Concentrations of PCB congener C15 in whole water samples from Stations A and B are shown in Figure 13. Trends in whole water PCB congener C15 concentrations are similar to trends in suspended solids concentrations (Figure 7), and as with suspended solids, concentrations at Station A were generally higher than at Station B. The correspondence between concentrations in whole water and dissolved PCB congener C15 concentrations was also weak, indicating that some component of the whole water samples other than suspended solids is affecting dissolved PCB congener C15 concentrations. The literature (Gschwend and Wu 1985, Brownawell 1986) indicates that this component may be PCB bound to nonfilterable organic colloids.

44. One problem with analyzing trends in the dissolved PCB concentrations in this study is that the data are near or at the chemical analytical detection limit in most of the samples. Chemical analytical techniques are least precise when the parameter being measured is near the detection limit. For this reason, differences between values near the detection limit are usually less reliable than differences between values that are much higher than the detection limit. It is difficult, therefore, to properly evaluate the significance of the small differences indicated in Figures 12 and 13.

Prediction with Modified Elutriate Test

Background

45. The modified elutriate test was developed as part of the Long-Term Effects of Dredging Operations (LEDO) research program of the US Army Corps of Engineers (Palermo 1986). The test involves measurement of both dissolved and total concentrations of contaminants in the elutriate. A separate column settling test, developed to evaluate the settling design for CDFs, is used to

determine the suspended solids concentration in effluent during hydraulic disposal. Results from both the modified elutriate and settling column tests are then used to predict total concentrations of contaminants in the effluent. Settling tests were not conducted in this study.

46. Data from five field evaluations on maintenance dredging projects confirmed that the test is a reliable and conservative predictor of heavy metal concentrations in effluents (Palermo 1988, Palermo and Thackston 1988). Sediment from one site, Black Rock Harbor, Connecticut, contained high enough concentrations of PCBs (14.3 mg/kg total PCB) for PCBs to be found in the effluent during disposal operations. The total PCB concentration in the effluent from the Black Rock Harbor CDF was 0.0099 mg/l, versus a predicted value of 0.013 mg/l.

47. Additional verification work was conducted at the New Bedford Harbor Superfund site, New Bedford, MA (Palermo and Thackston, in preparation). The PCB concentrations in sediments from the Acushnet River Estuary at the New Bedford Harbor Superfund site range from a few milligrams per kilogram to over 1,000 mg/kg (Averett 1988). A pilot-scale CDF involving 1,680 cu m of contaminated material was constructed as part of a pilot study to demonstrate dredging and disposal alternatives. The total PCB concentration in the composite sample used for modified elutriate testing was 2,167 mg/kg (Averett 1988). The modified-elutriate prediction for dissolved total PCB (0.0075 mg/l) was very close to the field value (0.0045 mg/l), indicating that the modified elutriate test was conservative by a factor of 1.6.

Saginaw results

48. Modified elutriate tests were conducted by Palermo and Randall (1989) on sediment from Area II. Figure 14 shows the average total and dissolved PCB congener concentrations reported by Palermo and Randall (1989) for the modified elutriate. The average concentrations of 16 PCB congeners in the total elutriate were above the detection limit, compared to a total of 13 PCB congeners in whole water samples from Stations A and B during disposal of Area II sediment. Nine of the sixteen PCB congeners detected in the total elutriate were also detected in whole water samples from Stations A and B during disposal of Area II sediment. The average concentrations of four PCB congeners (C8, C49, C50, and C86) were above the detection limit in whole water samples at Stations A and B but were not predicted by the modified elutriate test. The concentrations of these PCB congeners were only slightly above the detection limit, however.

49. Whole water predicted and observed PCB congener concentrations were about the same for the PCB congeners detectable in both the modified elutriate and in pond water samples. The predicted whole water concentration for PCB congener C15 (0.00002 mg/l) was slightly lower than observed average values for Stations A and B (0.00004 and 0.00006 mg/l, respectively) during disposal of Area II sediment. Congener C52 was the second most abundant PCB congener in whole water samples from the pond during disposal. The predicted concentration for PCB C52 was slightly higher (0.00007 mg/l) than the average values for Stations A and B (0.000026 and 0.000036 mg/l, respectively).

50. The modified elutriate test predicted dissolved concentrations above the detection limit for four PCB congeners. Dissolved concentrations of six PCB congeners were above the detection limit in the pond water samples collected during disposal of Area II sediment. Predicted and observed dissolved PCB congener concentrations were only slightly above the detection limit, and were about the same for the PCB congeners detectable in both modified elutriate and pond water samples.

51. The modified elutriate results in this study are consistent with the verification studies of Palermo (1988) and Palermo and Thackston (1988) which involved sediments with higher contamination levels and used total PCB as the parameter of interest. The data in this study showed that the modified elutriate test produced useful estimates of PCB congener concentrations in CDF pond water.

Prediction with Simple Equilibrium Partitioning Equations

Background

52. Development of a simple procedure(s) suitable for screening-level evaluation of PCBs in CDFs was one of the original objectives of the Inter-Agency Work Group on CDFs in the Great Lakes. The guidelines for the development effort were that the procedure be simple and inexpensive and that it not require data collection beyond the routine sampling and testing normally conducted for dredging projects. The procedure or set of procedures was to be used as a template for evaluation of the relative pollutant potential of the 29 CDFs in the Great Lakes under US jurisdiction. In this section, equilibrium partitioning concepts are used to develop simple equations for estimating dissolved PCB congener concentrations in CDF pond water. The

predictive equations are simple and easily carried out by hand or on a calculator.

Equilibrium partitioning theory

53. Equilibrium partitioning describes the tendency of a chemical to move from one environmental compartment to another (Mackay 1979, Thibodeaux 1979). A chemical introduced into one environmental compartment will eventually become present in other compartments due to differences in chemical potential, the driving force for mass transfer. The introduction of PCB-contaminated solids into a bottle of clean water, for example, will result in the appearance of PCB in the aqueous phase. The PCBs will desorb, and the aqueous phase concentration will increase until equilibrium is reached. The system is in equilibrium when no further changes in concentration of PCB in either phase occur.

54. According to equilibrium partitioning theory, the ratio of the mass fraction of PCB in the solid phase to the mass fraction in the aqueous phase at equilibrium is a fixed value referred to as the partitioning coefficient. The partitioning coefficient is, thus, defined as follows:

$$K_p = \frac{(M_{cs}/M_s)}{(M_{cw}/M_w)} \quad (1)$$

where

K_p = partitioning coefficient, dimensionless

M_{cs} = mass of PCB in the solid phase, kg

M_s = mass of solids, kg

M_{cw} = mass of PCB in the aqueous phase, kg

M_w = mass of water, kg

55. The mass fractions in Equation 1 can be replaced with phase PCB concentrations without any loss of generality so that Equation 1 becomes

$$K_p = \left(\frac{C_{se}}{C_{we}} \right) \quad (2)$$

where

K_p = partitioning coefficient, l/kg

C_{se} - PCB concentration in the solid phase at equilibrium, mg/kg

C_{we} - PCB concentration in the aqueous phase at equilibrium, mg/l

In Equation 2, it is assumed that the density of water is 1 kg/l. Bottle-type experiments are often used to determine partitioning coefficients.

56. In many applications of equilibrium partitioning, Equation 2 is rearranged to yield

$$C_{we} = \left(\frac{C_{se}}{K_p} \right) \quad (3)$$

To use Equation 3, the equilibrium solid phase concentration as well as the partitioning coefficient must be known.

57. In some situations, it is the initial solid phase PCB concentration, not the equilibrium solid phase PCB concentration, that is known. The aqueous phase PCB concentration can still be calculated if the solids concentration and the partitioning coefficient are known. The PCB mass remaining on the solid phase is the initial mass minus the mass that has desorbed. The PCB mass remaining on the solids is given by

$$C_s M_s = C_{so} M_s - C_w M_w \quad (4)$$

where

C_{so} = initial solid phase PCB concentration, mg/kg

C_w = PCB concentration in the aqueous phase, mg/l

58. Dividing by M_s and substituting volume of water for mass of water yields

$$C_s = C_{so} - C_w \left(\frac{V_w}{M_s} \right) \quad (5)$$

where V_w is the volume of water, in liters.

59. In Equation 5, the term V_w/M_s is the reciprocal of the solids concentration. Denoting the solids concentration as S , Equation 5 becomes

$$C_s = C_{so} - \left(\frac{C_w}{S} \right) \quad (6)$$

60. Equation 6 is a mass balance equation and is not limited to equilibrium conditions. It applies immediately after solids are introduced, when equilibrium is reached, and all time in between. Once equilibrium has been reached, $C_w = C_{we}$ and $C_s = C_{se}$, and since Equation 2 applies, C_{se} can be replaced with $C_{se} = K_p C_{we}$. Making these substitutions in Equation 6 and rearranging yields

$$C_{we} = \left[\frac{C_{so}}{K_p + \frac{1}{S}} \right] \quad (7)$$

Equation 7 relates the aqueous phase PCB concentration to the initial solid phase PCB concentration, the partitioning coefficient, and the solids concentration. It describes equilibrium conditions in a closed system containing only two phases, solids and water. Equation 7 yields aqueous phase concentrations identical to those provided by a CDF spreadsheet model that is under development by the USEPA (McCutcheon, Ambrose, and Martin 1988).

61. The equilibrium partitioning and mass balance equations can be used to gain insight into how equilibrium partitioning affects solid and aqueous phase PCB concentrations when PCB-contaminated solids are introduced into a water column. As the amount of contaminated solids added to the system decreases, Equation 7 shows that the aqueous phase PCB concentration also decreases. A decrease is required because the source of PCB in the system is the contaminated solids. The amount of PCB released from the solid phase is controlled by the partitioning coefficient and the solids concentration. The higher the distribution coefficient and the higher the solids concentration, the less change in the initial solid phase PCB concentration. Combination and rearrangement of Equations 6 and 7 yield

$$\frac{C_{se}}{C_{so}} = 1 - \left[\frac{1}{K_p S + 1} \right] \quad (8)$$

62. Equation 8 is an equilibrium equation for a closed system containing only contaminated solids and water. Equation 8 shows that the concentration of PCB remaining in the solid phase as a fraction of the initial solid phase PCB concentration depends on the product of the partitioning coefficient and the solids concentration. So long as the product of the partitioning coefficient and the solids concentration is large, C_{se} will be approximately equal to C_{so} . As shown in Figure 15, for K_p equal to a constant value, C_{se}/C_{so} decreases as the solids concentration decreases. As K_p increases, more dilution of the solids concentration is required to effect a significant change in the solid phase PCB concentration. For example, when $K_p = 10,000 \text{ l/kg}$, the solids concentration has to be diluted to less than 1 g/l before there is a significant decrease in the solid phase PCB concentration.

63. Equation 8 has important implications for calculating dissolved PCB concentrations when equilibrium is assumed. If the partitioning coefficient is large, the solids concentration must be small in order for the solid phase PCB concentration at equilibrium to be significantly different from the initial solid phase PCB concentration. When there is little change in the solid phase PCB concentration, C_{se} is approximately equal to C_{so} , and Equation 3 can be approximated by

$$C_{we} = \left(\frac{C_{so}}{K_p} \right) \quad (9)$$

64. Sometimes there is confusion about which equation (Equation 3, 7, or 9) to use to calculate an aqueous phase PCB concentration. All three equations require a value for the partitioning coefficient, but Equation 7 yields a lower value for the aqueous phase concentration than the other two equations. Whenever the equilibrium solid phase PCB concentration is known or can be assumed, Equation 3 should be used since the equilibrium assumption is the only restriction on Equation 3. Caution must be exercised in applying Equation 7 to open systems since it was developed for addition of contaminated solids to a closed system containing clean water. The restrictions on Equation 9 are the equilibrium assumption and the requirement for a large value for the product of the partitioning coefficient and the solids concentration. In many situations involving dredged material disposal, the bulk sediment PCB

concentration can be used for the initial solid phase PCB concentration, and Equations 7 and 9 may be appropriate depending on site-specific conditions.

Partitioning/distribution coefficients

65. Operational definition. The term partitioning coefficient will be replaced in the remainder of this report with the term "distribution coefficient." This change in terminology is needed to avoid implying that the dissolved PCB concentrations measured in this study are truly dissolved and that a single chemical is being partitioned in two homogeneous phases. Dredged material usually contains a variety of chemicals that compete for sorption sites associated with a heterogeneous solid phase composed of sand, silt, clay, and insoluble organic carbon. Equations 3, 7, and 9 as previously presented do not account for these complexities. Thus, a change in terminology that is consistent with the complexity of the system is needed.

66. This change in terminology has practical implications and is not purely cosmetic. Distribution coefficients can vary depending on the solids-liquid separation technique that is used to separate dissolved and particulate PCB. Although it may be possible to determine a partitioning coefficient for truly dissolved PCB using head-space partitioning techniques, most distribution coefficients are determined in batch experiments that require solids-liquid separation. For this reason, the coefficients and the dissolved phase are operationally defined by the solids-liquid separation technique that is used. The distribution coefficients and dissolved phase in this study were defined by centrifugation followed by filtration through 1.0- μ glass fiber filters. Since a portion of colloidal matter in sediments and natural waters is smaller than 1.0 μ , the dissolved PCB concentrations in this report include PCB sorbed to colloidal organic matter and other materials that pass a 1.0- μ glass fiber filter.

67. Measured saginaw distribution coefficients. Single-point distribution coefficients (Environmental Laboratory 1987) were calculated from data obtained in a four-cycle sequential batch leach test conducted on a composite sample of influent solids collected during disposal of Area II sediment. The PCB distribution coefficients are presented in Tables 6 and B4 (Appendix B). The sequential batch leach data from which the distribution coefficients in this study were obtained are presented in Appendix B. Distribution coefficients ranged from 583 to 11,096 l/kg . The "greater than" values in Table B4 indicate PCB congeners that were present in the composite influent solids sample but did not leach in detectable amounts. The greater than values are

based on the detection limit (0.00001 mg/l). Most of the greater than values are for PCB congeners with a high degree of chlorine substitution, usually six chlorine atoms or more. Highly substituted PCBs are less likely to leach due to their lower solubilities and higher sorption affinities.

Application of simple equilibrium partitioning equations

68. Evaluation of contaminant transport in a CDF is complex, involving a variety of physical, chemical, and biological processes. Ideally, all processes should be included in an evaluation. The level of detail that is employed depends on the human and computer resources that are available and the type of evaluation needed. For the type of evaluations in this report, the problem of estimating PCB concentrations in CDF pond water was simplified using equilibrium partitioning concepts.

69. Figure 16 shows dissolved PCB congener concentrations predicted by Equations 7 and 9. The distribution coefficients in Table B4 and the influent solids PCB congener concentrations for dredged material from Area II (Figure 4) were used to calculate the results shown in Figure 16. A solids concentration of 100 mg/l was used in Equation 7. Comparison of Figures 11 and 16 shows that Equation 7 underestimated and Equation 9 overestimated dissolved PCB congener concentrations in the Saginaw CDF pond water during disposal of dredged material from Area II.

70. Equation 7 predicted that six PCB congeners (C15, C18, C28, C49, C52, and C77) would be present in detectable concentrations. The average concentrations of four of these PCB congeners (C15, C18, C49, and C52) were above the detection limit at Station A and/or B. Equation 7 was within a factor of two of the observed average concentrations for PCB congeners C18, C49, and C52 and within a factor of three for PCB congener C15. Equation 7 underestimated concentrations for PCB congeners C50 and C101 and overestimated concentrations for PCB congeners C28 and C77.

71. Equation 9 predicted that 17 PCB congeners would be present in detectable concentrations. All six of the PCB congeners whose average concentrations were above the detection limit in pond water samples from Stations A and/or B were predicted to be detectable by Equation 9. For four of these PCB congeners (C49, C50, C52, and C101), the values predicted by Equation 9 were within a factor of 2 of the observed concentrations. Equation 9 underestimated PCB congener C15 concentration by a factor of three and overestimated PCB congener C18 concentration by a factor of eight. Eleven PCB

congeners were predicted to be present in detectable concentrations that were not detectable in pond water samples.

72. Comparison of predicted versus observed dissolved PCB congener concentrations indicates that Equations 7 and 9 can be used to bracket estimated dissolved PCB congener concentrations between probable maximum and minimum values. Both equations provided predictions that were generally within a factor of two to three of the observed concentrations. Equation 9 tended to overestimate observed concentrations, and Equation 7 tended to underestimate observed concentrations.

Predicted distribution coefficients

73. If distribution coefficients for PCBs in polluted dredged material could be accurately estimated with minimal information on the sediment to be dredged and disposed, then simple equilibrium-partitioning equations could be used for screening purposes without the complex laboratory testing associated with sequential batch leach tests. Empirical equations that relate distribution coefficients to sediment organic carbon and octanol-water partitioning coefficients are available for predicting field distribution coefficients (Karickhoff, Brown, and Scott 1979; Means et al. 1980; Karickhoff 1981; Schwarzenbach and Westall 1981; Chiou, Porter, and Schmedding 1983; Abdul and Gibson 1986). These relationships were developed mainly through laboratory batch adsorption tests using soils, sediments, and aquifer materials and various classes of organic chemicals. The applicability of these relationships for desorption of contaminants from polluted sediments is uncertain.

74. Predicted distribution coefficients for 24 PCB congeners that were calculated using the relationships of Karickhoff (1981), Means et al. (1980), Schwarzenbach and Westall (1981), and Chiou, Porter, and Schmedding (1983) are presented in Table 6. The number of PCB congeners in Table 6 is only 24 because the availability of PCB congener-specific octanol-water partitioning coefficients is limited. The PCB congener octanol-water partitioning coefficients reported by Rapaport and Eisenreich (1984) were used to calculate predicted distribution coefficients. The fraction of sediment organic carbon used in the calculations was 0.0242. Distribution coefficients measured in this study are also presented in Table 6 for comparison.

75. The agreement between predicted and measured varies but is generally poor. Although distribution coefficients could, in some instances, be roughly approximated using literature relationships, predicted values in several instances were larger than measured values by an order of magnitude or

more. Several factors may be contributing to the disagreement between predicted and measured distribution coefficients. Candidate factors are listed below.

- a. Chemical equilibrium in the sequential batch leach test used to determine PCB congener distribution coefficients for dredged material from the Saginaw River was not achieved.
- b. Available relationships do not model release of PCB residing in intraparticle pores of dredged material solids.
- c. Desorption is different from adsorption; that is, there is a sorption hysteresis.
- d. Solids-liquid separation techniques used in the studies conducted to develop the empirical relationships differed from the solids-liquid separation technique used in this study.
- e. The liquid-solids ratio in the sequential batch leach test used to determine PCB congener distribution coefficients for dredged material from the Saginaw River was different from the liquid-solids ratio used in the studies conducted to develop the empirical relationships.

76. An explanation based on factor a, chemical nonequilibrium, is not consistent with the data. If the batch leachates in this study were not at chemical equilibrium with the sediment solids, the PCB congener concentrations would be lower than the equilibrium value. At equilibrium, the leachate PCB congener concentrations would be higher, and as a result the measured distribution coefficient would be lower than those reported, and the disagreement between predicted and observed would be even larger.

77. An explanation based on factor b implies that although sorption is a reversible process, there is more than one type of sorption site. One type is represented by sites on the surface of solid particles, and another type by those sites on the wall of intraparticle pores. Contaminant that is sorbed to particle surfaces desorbs according to equilibrium partitioning theory. Contaminant that is sorbed in the intraparticle pores is leached by a two-step process involving desorption from the pore wall followed by diffusion to the particle surface. An explanation based on intraparticle pore phenomena can be interpreted as a physical nonequilibrium explanation (Brusseau and Rao 1989). An explanation based on physical nonequilibrium, like an explanation based on chemical nonequilibrium, is not consistent with the data. If physical nonequilibrium affected the measured distribution coefficients, equilibrium leachate PCB congener concentrations would be higher and, hence, distribution coefficients even lower than those measured in this study.

78. An explanation based on factor c can be applied to polluted sediments for which a hysteresis in adsorption-desorption processes exists. Hysteresis exists when the distribution between sorbed and dissolved phases is different for adsorption-dominated and desorption-dominated processes (Hill, Myers, and Brannon 1988). This means that a unique distribution coefficient that applies to both adsorption and desorption is unlikely. Since the predicted values are based on relationships developed during adsorption-dominated testing and the observed values are based on data obtained during desorption-dominated testing, an explanation based on factor c could be possible. However, the available data on hysteresis effects (Mustafa and Gamar 1972, Di Toro and Horzempa 1982, Corwin and Farmer 1984) show that distribution coefficients for desorption are larger than distribution coefficients for adsorption. If hysteresis effects were occurring, the measured distribution coefficients should be larger than the predicted distribution coefficients. Thus, an explanation based on factor c is not consistent with the data in Table 6.

79. Factor d , differences in solids-liquids separation techniques, probably accounts for some of the differences in predicted and observed K_d values as well as differences among predicted values. Schwarzenbach and Westall (1981) used simple settling, and Chiou, Porter, and Schmedding (1983) used an unspecified centrifugation technique. The equations developed by Means et al. (1980) and Karickhoff (1981) are based on a centrifugation technique (12,000 g for 10 min) that would be expected to remove more colloidal particles than are removed in the centrifugation-filtration technique used in this study. Because differences in solids-liquid separation techniques result in varying amounts of microparticles and/or organic macromolecules that remain in the "dissolved" phase, observed distribution coefficients will vary. Thus, differences in predicted and observed distribution coefficients may be related to differences in the way the dissolved phase has been operationally.

80. The solids-liquid separation technique used in this study probably overestimates the amount of colloidal-bound PCB that moves in the environment as if dissolved. But this cannot be said with certainty. Standard leach tests for hazardous waste use 0.45- μ filtration to define dissolved, but most 0.45- μ membrane filters sorb PCBs. In addition, use of a 0.45- μ boundary for dissolved is primarily for standardization and convenience. An information base for developing an operational definition of dissolved that discriminates between those materials transported in the environment as if dissolved and

those that do not behave as if dissolved is not available. Solids-liquid separation for processing environmental samples containing PCBs is an area in which additional research is needed.

81. An explanation based on factor e suggests that distribution coefficients vary with liquid-solids ratio. As discussed in Hill, Myers, and Brannon (1988), distribution coefficients have been shown to be inversely related to the solids concentration in batch sorption tests. This dependency on liquid-solids ratio has been explained as dilution of soluble organic carbon at low solids concentration (Gschwend and Wu 1985). If Gschwend and Wu (1985) are correct, at low liquid-solids ratios, contaminant concentrations in the dissolved phase are higher than predicted by K_d values measured at high liquid-solids ratios because there is less dilution of dissolved organic carbon-bound contaminant at low liquid-solids ratios. Chiou, Porter, and Schmedding (1983) used an unspecified liquid-solids ratio. Schwarzenbach and Westall (1981) used liquid-solids ratios between 2:1 and 6:1. The Means et al. (1980) and Karickhoff (1981) relationships are based on batch tests conducted at 10:1 and 20:1 liquid-solids ratios. The liquid-solids ratio used to measure distribution coefficients in Saginaw River dredged material solids was 4:1. Thus, a liquid-solids ratio explanation may apply to some of the data in Table 6.

82. Factors a, b, and c have been used to explain nonideal sorption of contaminants to sediments and soils (Brusseau and Rao 1989). Although these factors may affect the partitioning of PCBs in the Saginaw CDF, they cannot account for the differences in measured and predicted distribution coefficients shown in Table 6. Factors d and e alone or in combination probably account for the differences in predicted and observed distribution coefficients. Additional testing of polluted dredged material from a number of different sites will be needed before the applicability of the available relationships to polluted dredged material can be fully evaluated. Thus, laboratory determination of distribution coefficients is still needed.

Equilibrium partitioning versus modified elutriate test

83. Two procedures for predicting PCB concentrations in CDF pond water have been presented. One uses the modified elutriate test; the other is based on equilibrium partitioning. Predictions based on modified elutriate testing and equilibrium partitioning were similar and within an order of magnitude of observed PCB concentrations in pond water from the Saginaw CDF. In most

cases, the predictions were within a factor of two to three of the observed values. Thus, the data in this report indicate that both approaches are suitable for reconnaissance-level evaluations of PCB losses from CDFs.

84. There are advantages and disadvantages for each approach. Modified elutriate testing can provide information on metals as well as organics while equilibrium partitioning is primarily limited to hydrophobic organics. Because the modified elutriate test is empirical and equilibrium partitioning is theoretical, equilibrium partitioning has more general application than modified elutriate testing. For example, distribution coefficients can be used to describe leaching of hydrophobic organics from dredged material in a CDF after filling is completed as well as to estimate concentrations of hydrophobic organics in CDF pond water during disposal operations.

85. In this study, both approaches involved laboratory testing. The modified elutriate test is simpler and easier to conduct than is the sequential batch leach test used to determine distribution coefficients. Empirical relationships are available for estimating distribution coefficients so that equilibrium partitioning could be used in reconnaissance-level evaluations without laboratory testing. However, the applicability of the available empirical relationships to polluted dredged material, has not been established. Criteria for selection of the proper empirical relationship for estimating distribution coefficients remain a critical research need for developing the simple equilibrium partitioning equation presented in this report as a screening tool.

Containment Efficiency

86. Containment efficiency (CEF) is defined as follows:

$$CEF = \sum_1^n \frac{(\text{Rate of mass in})_j - (\text{Rate of mass out})_j}{(\text{Rate of mass in})_j} \quad (10)$$

where j is the PCB congener index, and n is the number of PCB congeners. This equation was applied to disposal of dredged material from Area II during the period 31 August to 2 September.

87. The rate of mass in is given by

$$(\text{Rate of mass in})_j = C_{s,j} S_i Q_i + C_{iw,j} Q_i \left[1 - \frac{S_i}{G} \right] \quad (11)$$

where

$C_{s,j}$ = concentration of j^{th} PCB congener in the influent solids from Area II, mg/kg

S_i = solids concentration in the influent during disposal of dredged material from Area II, kg/l

Q_i = influent flow during disposal of dredged material from Area II, l/day

$C_{iw,j}$ = concentration of j^{th} PCB congener in the influent water from Area II, mg/l

G = density of solids in influent, kg/l

88. The rate of mass out is given by

$$(\text{Rate of mass out})_j = C_{pw,j} Q_o \quad (12)$$

where

$C_{pw,j}$ = concentration of j^{th} PCB congener in the pond water during disposal of dredged material from Area II, mg/l

Q_o = flow out of the CDF during disposal of dredged material from Area II, l/day

89. Equations 10, 11, and 12 were solved using average values for disposal operations during the period 31 August through 2 September. During this 3-day period, 30,095 cu m of dredged material from Area II was disposed in the Saginaw CDF. Thus, the average flow into the CDF during this period was 10 million liters per day. Assuming steady flow and no storage of water in the CDF during this period and using average values for PCB congener concentrations in the influent and pond water, Equations 10, 11, and 12 simplify to the following:

$$CEF = \frac{C_{s,j} S_i + (C_{iw,j} - C_{pw,j}) \left[1 - \frac{S_i}{G} \right]}{C_{s,j} S_i + C_{iw,j} \left[1 - \frac{S_i}{G} \right]} \quad (13)$$

90. Equation 13 was solved using the average influent solids concentration (0.130 kg/l) for dredged material from Area II, an assumed solids density of 2.5 kg/l, and average values for influent and pond water PCB congener concentrations during disposal of dredged material from Area II. Two types of calculations were made, one based on average whole water PCB congener concentrations in pond water during disposal operations, and one based on average dissolved PCB congener concentrations in pond water during disposal operations. For each PCB congener, the maximum of the average concentrations at Stations A and B was used.

91. The CEF based on average whole water PCB congener concentrations in pond water was 0.9982. This CEF assumes that the dike is transparent to dissolved and particulate PCB; that is, there is no sorption or filtration of PCBs by the dike. The CEF based on average dissolved PCB congener concentrations in pond water was 0.9993. This CEF assumes only dissolved PCB passes through the dike.

92. The calculation based on average whole water PCB congener concentrations in the pond water entering the dike is probably a good lower bound on the containment efficiency of the CDF. Thus, for the 60 PCB congeners that were analyzed, the Saginaw CDF retained during disposal operations at least 99.82 percent of the PCB mass that was disposed in the CDF. Assuming no sorption of dissolved PCB and no filtration of particulate PCB, approximately 2.6 g per day of PCB was released through the dike during the period 31 August through 2 September 1987. The dissolved PCB release through the dike, assuming no sorption, was approximately 1 g per day.

93. The calculation based on average dissolved PCB congener concentrations may or may not be a good upper bound on the containment efficiency of the CDF. This calculation assumes that all of the particulate PCB and none of the dissolved PCB are removed by the dike. Although some particulate PCB is probably removed by the dike, 100 percent removal by the dike is not likely. In addition, there is probably some removal of dissolved PCB.

94. To pass through the dike, a parcel of water must take a long and tortuous path during which there is a potential for attenuation of contaminant transport by adsorption, filtration, and bioabsorption/biodegradation. Bioabsorption/biodegradation in biological films is the mechanism by which attached growth biological treatment systems treat domestic and/or industrial wastewaters. The algae blooms that occasionally occur in the Saginaw CDF indicate that conditions may be right for development of biological films in the dike. If the dike acts as a treatment structure, the PCB releases previously calculated overestimate PCB release. Removal of organic contaminants in CDF pond water by permeable dikes, however, has not been investigated, and the potential significance of the dike as a treatment structure is unknown.

PART IV: CONCLUSIONS

95. Monitoring at the Saginaw confined disposal facility indicated that 99.82 to 99.93 percent of the polychlorinated biphenyl disposed in the CDF was retained during disposal operations, depending on the assumptions used to calculate contaminant loss. During a 3-day period of monitoring, the release of combined dissolved and particulate PCB was approximately 2.6 g per day assuming no sorption, filtration, or bioabsorption/biodegradation in the dike. The release of dissolved PCB was approximately 1.0 g per day assuming that particulate PCB was removed by the dike.

96. Predictions of PCB congener concentrations in CDF pond water based on modified elutriate testing and simple equilibrium partitioning equations were similar and within an order of magnitude of observed concentrations. The data in this study corroborate results from previous studies showing the modified elutriate test to be a good predictor of PCB concentrations in effluent from CDFs. The data in this study also showed that two simple equilibrium partitioning equations could be used to estimate dissolved PCB concentrations, provided the equilibrium distribution coefficient is known.

97. Empirical relationships from the literature overestimated PCB congener distribution coefficients for dredged material from the Saginaw River, in some instances by an order of magnitude or more. Differences in observed and predicted values were probably due to differences in laboratory procedures used to obtain distribution coefficients. In particular, distribution coefficients vary depending on the operational definition of "dissolved phase."

REFERENCES

- Abdul, A. S., and Gibson, T. L. 1986. "Equilibrium Batch Experiments with Six Polycyclic Aromatic Hydrocarbons and Two Aquifer Materials," Hazardous Waste and Hazardous Materials, Vol 3, No. 2, pp 125-137.
- Averett, D. E. 1988. "New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 3, Characterization and Elutriate Testing of Acushnet River Estuary Sediment," Technical Report EL-88-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Brownawell, B. J. 1986. "The Role of Colloidal Organic Matter in the Marine Geochemistry of PCBs," Ph.D. thesis, Massachusetts Institute of Technology/Woods Hole Oceanographic Institution, WHOI-86-19, Woods Hole, MA.
- Brusseau, M. L., and Rao, P. S. C. 1989. "Sorption Nonideality During Organic Contaminant Transport in Porous Media," Critical Reviews in Environmental Control, Vol 19, No. 1, pp 33-99.
- Chiou, C. T., Porter, P. E., and Schmedding, D. W. 1983. "Partition Equilibria of Nonionic Organic Compounds Between Soil Organic Matter and Water," Environmental Science and Technology, Vol 17, No. 4, pp 227-231.
- Corwin, D. L., and Farmer, W. J. 1984. "Nonsingle-Valued Adsorption-Desorption of Bromacil and Diquat by Freshwater Sediments," Environmental Science And Technology, Vol 18, No. 7, pp 507-514.
- Di Toro, D. M., and Horzempa, L. M. 1982. "Reversible and Resistant Components of PCB Adsorption-Desorption: Isotherms," Environmental Science and Technology, Vol 16, No. 9, pp 594-602.
- Environmental Laboratory. 1987. "Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana; Vol II," Miscellaneous Paper EL-87-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Garrett, B. C., Jackson, D. R., Schwartz, W. E., and Warner, J. S. 1984. "Solid Waste Leaching Procedure: Draft Technical Resource Document for Public Comment," SW-924, Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, DC.
- Gschwend, P. M., and Wu, S. 1985. "On the Constancy of Sediment-Water Partition Coefficients of Hydrophobic Organic Pollutants," Environmental Science and Technology, Vol 19, No. 1, pp 90-96.
- Hill, D. O., Myers, T. E., and Brannon, J. M. 1988. "Development and Application of Techniques for Predicting Leachate Quality in Confined Disposal Facilities: Background and Theory," Miscellaneous Paper D-88-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Hoeppel, R. E., Myers, T. E., and Engler, R. M. 1978. "Physical and Chemical Characterization of Dredged Material Influent and Effluent in Confined Disposal Areas," Technical Report D-78-24, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Karickhoff, S. W. 1981. "Semi-Empirical Estimation of Sorption of Hydrophobic Pollutants on Natural Sediments and Soils," Chemosphere, Vol 10, No. 9, pp 833-846.
- Karickhoff, S. W., Brown, D. S., and Scott, T. A. 1979. "Sorption of Hydrophobic Pollutants on Natural Sediments," Water Research, Vol 13, pp 241-248.

- Mackay, D., Paterson, S., Eisenreich, S. J., and Simmons, M. S. 1983. Physical Behavior of PCBs in the Great Lakes. Ann Arbor Science, Ann Arbor, MI.
- Mackay, D. 1979. "Finding Fugacity Feasible," Environmental Science and Technology, Vol 13, No. 10, pp 1218-1223.
- McCutcheon, S. C., Ambrose, R. B., and Martin, J. L. 1988. "Analysis of Disposal Alternatives for Dredge Spoils Contaminated by Hydrophobic Chemicals," Environmental Research Laboratory, US Environmental Protection Agency, Athens, GA.
- McFarland, V. A., Clarke, J. U., and Gibson, A. B. 1986. "Changing Concepts and Improved Methods for Evaluating the Importance of PCBs as Dredged Sediment Contaminants," Miscellaneous Paper D-86-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Means, J. C., Wood, S. G., Hassett, J. J., and Banwart, W. L. 1980. "Sorption of Polynuclear Aromatic Hydrocarbons by Sediments and Soils," Environmental Science and Technology, Vol 14, No. 12, pp 1524-1528.
- Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-76-56, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Mustafa, M. A., and Gamar, Y. 1972. "Adsorption and Desorption of Diuron as a Function of Soil Properties," Soil Science Society of America Proceedings, Vol 36, pp 561-565.
- Myers, T. E., and Brannon, J. M. 1988. "New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 5, Evaluation of Leachate Quality," Technical Report EL-88-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- National Research Council. 1979. Polychlorinated Biphenyls. National Academy of Science, Washington, DC.
- Neely, W. B. 1983. "Reactivity and Environmental Persistence of PCB Isomers," Physical Behavior of PCBs in the Great Lakes, D. Mackay et al., eds., Ann Arbor Science, Ann Arbor, MI.
- Palermo, M. R. 1986. "Development of a Modified Elutriate Test for Estimating the Quality of Effluent from Confined Dredged Material Disposal Areas," Technical Report D-86-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R. 1988. "Field Evaluations of the Quality of Effluent from Confined Dredged Material Disposal Areas," Technical Report D-88-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R., and Randall, R. E. 1989. "Evaluation of Hopper Loading and Overflow for Saginaw River, Michigan," Miscellaneous Paper D-89-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R., Shafer, R. A., Brannon, J. M., Myers, T. E., Truitt, C. L., Zappi, M. E., Skogerboe, J. G., Sturgis, T. C., Wade, R., Gunnison, D., Griffin, D. M., Jr., Tatem, H., Portzer, S., and Adamec, S. A. 1989. "Evaluation of Dredged Material Disposal Alternatives for US Navy Homeport at Everett, Washington," Technical Report EL-89-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

- Palermo, M. R., and Thackston, E. L. 1988. "Verification of Predictions of Dredged Material Effluent Quality," Journal of Environmental Engineering, American Society of Civil Engineers, Vol 114, No. 6.
- Palermo, M. R., and Thackston, E. L. "Confined Disposal Area Effluent Quality for New Bedford Superfund Pilot Dredging," Proceedings, Corps of Engineers Eighth Seminar on Water Quality (in preparation), 6-8 February 1990, Las Vegas, NV.
- Rapaport, R. A., and Eisenreich, S. J. 1984. "Chromatographic Determination of Octanol-Water Partition Coefficients (K_{ow} 's) for 58 Polychlorinated Biphenyl Congeners," Environmental Science and Technology, Vol 18, No. 3, pp 163-170.
- Schroeder, P. R., and McEnroe, B. M. 1988. "Dye Tracer Study at the Saginaw Bay, Michigan, Confined Disposal Facility," Miscellaneous Paper EL-88-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Schwartz, T. R., Stalling, D. L., and Rice, C. L. 1987. "Are Polychlorinated Biphenyl Residues Adequately Described by Aroclor Mixture Equivalents? Isomer-Specific Principal Components Analysis of Such Residues in Fish and Turtles," Environmental Science and Technology, Vol 21, No. 1, pp 72-76.
- Schwarzenbach, R. P., and Westall, J. 1981. "Transport of Nonpolar Organic Compounds from Surface Water to Groundwater; Laboratory Sorption Studies," Environmental Science and Technology, Vol 15, No. 11, pp 1360-1367.
- Thibodeaux, L. J. 1979. Chemodynamics, John Wiley and Sons, New York.
- US Environmental Protection Agency. 1983. "Methods for Chemical Analysis of Water and Wastes," EPA/600/4-79/020 (rev. March 1983), Environmental Monitoring and Support Laboratory, Cincinnati, OH.

Table 1
Test Sequence for Sequential Batch Leaching of Anaerobic
Saginaw Sediment for PCB Analysis

Step	Description
1	Load sediment into 450-ml stainless steel centrifuge tubes. Add sufficient water to each tube to bring final water-to-sediment ratio to 4:1. Sufficient stainless steel tubes must be loaded to obtain enough leachate for analysis.
2	Place mixtures in a rotary mixer and turn at 40 rpm for 24 hr.
3	Centrifuge for 30 minutes at 6500 × g.
4	Filter leachate through a Whatman GD/F glass fiber prefilter followed by passage through a Gelman AE glass fiber filter of 1.0- μ nominal pore size.
5	Acidify leachate with 1 ml of HCL. Store leachate in acetone-rinsed glass bottles.
6	Repeat steps 2, 3, 4, and 5, setting aside a small amount of leachate prior to acidification for analysis of dissolved organic carbon.

Note: The anaerobic integrity of the sample was maintained during sample addition to centrifuge tube, shaking, centrifugation, and filtration.

Table 2

PCB Congener Identification Key Used in This Report

<u>IUPAC* Number</u>	<u>Compound</u>
C07	2,4-Dichlorobiphenyl
C08	2,4'-Dichlorobiphenyl
C15	4,4'-Dichlorobiphenyl
C18	2,2',5-Trichlorobiphenyl
C28	2,4,4'-Trichlorobiphenyl
C31	2,4',5-Trichlorobiphenyl
C40	2,2',3,3'-Tetrachlorobiphenyl
C44	2,2',3,5'-Tetrachlorobiphenyl
C49	2,2',4,5'-Tetrachlorobiphenyl
C50	2,2',4,6-Tetrachlorobiphenyl
C52	2,2',5,5'-Tetrachlorobiphenyl
C54	2,2',6,6'-Tetrachlorobiphenyl
C60	2,3,4,4'-Tetrachlorobiphenyl
C70	2,3',4',5-Tetrachlorobiphenyl
C77	3,3',4,4'-Tetrachlorobiphenyl
C82	2,2',3,3',4-Pentachlorobiphenyl
C86	2,2',2,3,4-Pentachlorobiphenyl
C87	2,2',3,4,5'-Pentachlorobiphenyl
C97	2,2',3',4,5-Pentachlorobiphenyl
C101	2,2',4,5,5'-Pentachlorobiphenyl
C103	2,2',4,5',6-Pentachlorobiphenyl
C105	2,3,3',4,4'-Pentachlorobiphenyl
C114	2,3,4,4',5-Pentachlorobiphenyl
C118	2,3',4,4',5-Pentachlorobiphenyl
C121	2,3',4,5',6-Pentachlorobiphenyl
C128	2,2',3,3',4,4'-Hexachlorobiphenyl
C129	2,2',3,3',4,5-Hexachlorobiphenyl
C136	2,2',3,3',6,6'-Hexachlorobiphenyl
C137	2,2',3,4,4',5-Hexachlorobiphenyl
C138	2,2',3,4,4',5'-Hexachlorobiphenyl
C141	2,2',3,4,5,5'-Hexachlorobiphenyl
C143	2,2',3,4,5,6'-Hexachlorobiphenyl
C151	2,2',3,5,5',6-Hexachlorobiphenyl
C153	2,2',4,4',5,5'-Hexachlorobiphenyl
C154	2,2',4,4',5,6'-Hexachlorobiphenyl
C156	2,3,3',4,4',5-Hexachlorobiphenyl
C159	2,3,3',4,5,5'-Hexachlorobiphenyl
C167	2,3',4,4',5,5'-Hexachlorobiphenyl
C170	2,2',3,3',4,4',5-Heptachlorobiphenyl
C171	2,2',3,3',4,4',6-Heptachlorobiphenyl
C173	2,2',3,3',4,5,6-Heptachlorobiphenyl
C180	2,2',3,4,4',5,5'-Heptachlorobiphenyl
C182	2,2',3,4,4',5,6'-Heptachlorobiphenyl
C183	2,2',3,4,4',5',6-Heptachlorobiphenyl
C185	2,2',3,4,5,5',6-Heptachlorobiphenyl
C187	2,2',3,4',5,5',6-Heptachlorobiphenyl
C189	2,3,3',4,4',5,5'-Heptachlorobiphenyl
C191	2,3,3',4,4',5',6-Heptachlorobiphenyl
C194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl
C195	2,2',3,3',4,4',5,6-Octachlorobiphenyl
C196	2,2',3,3',4,4',5,6'-Octachlorobiphenyl
C200	2,2',3,3',4,5',6,6'-Octachlorobiphenyl
C201	2,2',3,3',4,5,5',6'-Octachlorobiphenyl
C202	2,2',3,3',5,5',6,6'-Octachlorobiphenyl
C203	2,2',3,4,4',5,5',6-Octachlorobiphenyl
C205	2,3,3',4,4',5,5',6-Octachlorobiphenyl
C206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl
C207	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl
C208	2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl
C209	2,2',3,3',4,4',5,5',6,6',-Decachlorobiphenyl

* International Union of Pure and Applied Chemists.

Table 3
Sample Collection

<u>Sample Type</u>	<u>Sample No.</u>	<u>Date</u>	<u>Hour</u>
<u>Predisposal Pond Water</u>			
Composite (triplicate)	1, 2, & 3	8/11/87	
Influent			
Area I	1	8/15/87	0640
	2	8/31/87	1810
Area II	1	8/31/87	2000
	2	9/1/87	1130
	3	9/1/87	1425
	4	9/1/87	1735
	5	9/1/87	1930
	6	9/1/87	2330
	7	9/2/87	1710
<u>Pond Water During Disposal</u>			
Area I disposal			
Sta A	1	8/15/87	0800
Sta A & B	2	8/31/87	2000
Area II disposal (Sta A & B)	1	8/31/87	2230
	2	9/1/87	1230
	3	9/1/87	1530
	4	9/1/87	1930
	5	9/1/87	2230
	6	9/2/87	0200
	7	9/2/87	1900
<u>Postdisposal Pond Water</u>			
Composite	1	9/21/87	
	2	9/28/87	
	3	10/5/87	

Table 4
Total Solids and Dissolved Ammonia-Nitrogen in
Dredged Material Influent, Saginaw CDF

<u>Area</u>	<u>Sample No.</u>	<u>Total Solids g/l</u>	<u>Dissolved Ammonia-Nitrogen mg/l</u>
I	1	11.7	4.07
	2	49.4	14.40
II	1	30.7	10.90
	2	158.0	50.90
	3	170.8	56.00
	4	138.4	40.00
	5	148.1	35.70
	6	150.8	46.10
	7	111.3	33.80

Table 5
Suspended Solids and Dissolved Ammonia-Nitrogen in Predisposal and
Postdisposal Pond Water, Saginaw CDF

<u>Sample Type</u>	<u>Sample No.</u>	<u>Suspended Solids mg/l</u>	<u>Dissolved Ammonia-Nitrogen mg/l</u>
Predisposal	1	188.0	0.03
	2	166.0	0.03
	3	189.0	0.02
Postdisposal	1	48.4	2.07
	2	52.7	0.23
	3	75.3	0.19

Table 6

Measured and Predicted PCB Congener Distribution
Coefficients for Saginaw Dredged Material (l/kg)*

Congener (IUPAC No.)	Source**				
	1	2	3	4	5
7	BDL†	1,987	2,330	490	423
8	703	1,253	1,470	351	279
15	11,096	658	771	221	156
18	632	3,533	4,144	741	712
28	2,100	4,878	5,720	935	953
31	3,031	4,878	5,720	935	953
40	>1,100	3,616	4,240	754	727
44	3,315	6,430	7,541	1,141	1,224
49	2,956	16,528	19,383	2,253	2,872
52	2,438	12,253	14,369	1,816	2,192
60	>1,200	6,890	8,080	1,200	1,302
70	1,708	16,913	19,835	2,290	2,933
82	600	13,748	16,123	1,973	2,432
87	642	23,347	27,380	2,889	3,925
97	583	46,583	54,631	4,751	7,330
101	1,286	117,012	137,226	9,220	16,853
118	598	131,290	153,970	10,017	18,702
128	>200	90,830	106,521	7,683	18,404
129	BDL	208,080	244,026	13,956	28,358
136	2,333	32,228	37,795	3,644	5,253
137	BDL	510,777	599,013	26,640	63,863
138	1,192	274,803	321,689	17,027	36,406
141	BDL	387,463	454,398	21,835	49,747
153	733	560,056	656,805	28,467	69,408

* Literature K_d values calculated using K_{ow} values reported by Rapaport and Eisenreich (1984). $f_{oc} = 0.0242$.

** Data sources:

1-See Appendix B for description of data.

2-Karickhoff (1981).

3-Means et al. (1980).

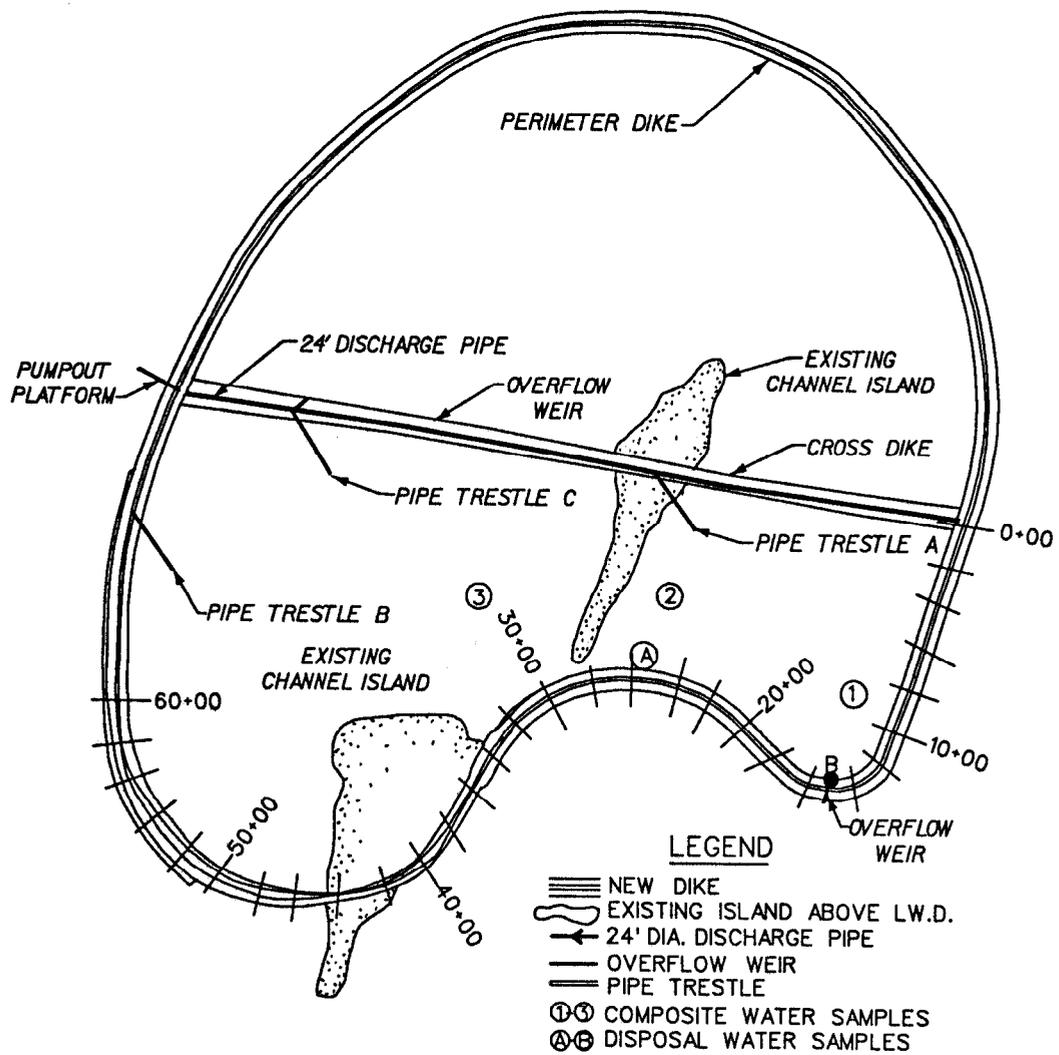
4-Schwarzenbach and Westall (1981).

5-Chiou, Porter, and Schmedding (1983).

† Below detection limit in Saginaw River dredged material solids.



Figure 1. Vicinity map for Saginaw CDF
 (from Schroeder and McEnroe 1988)



SCALE
 61 0 61 122 m

PROJECT PLAN

Figure 2. Saginaw confined disposal facility
 (from Schroeder and McEnroe 1988)

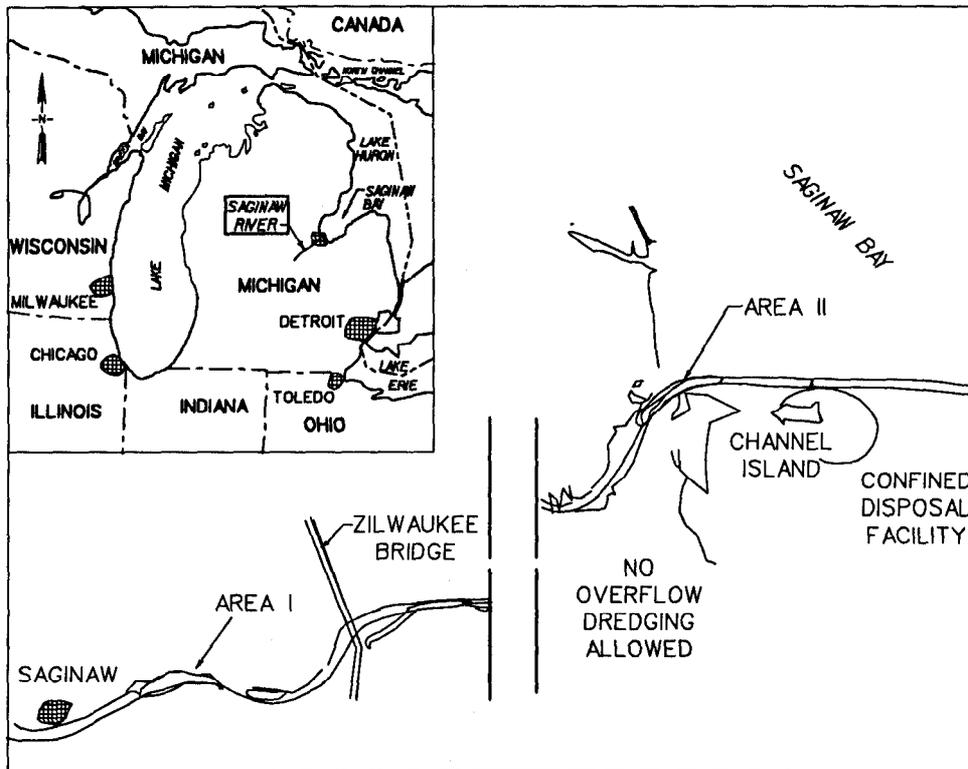
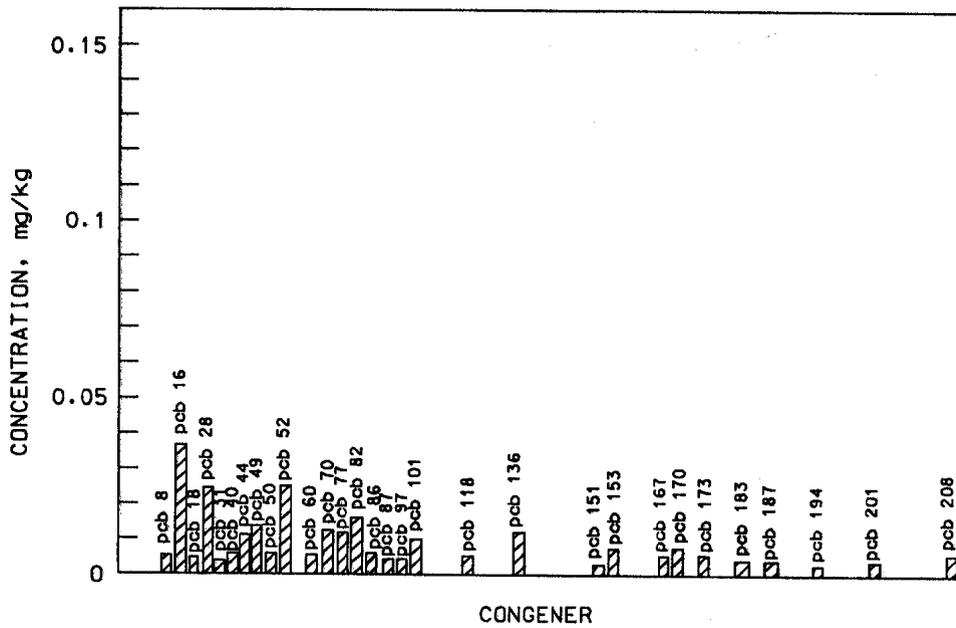
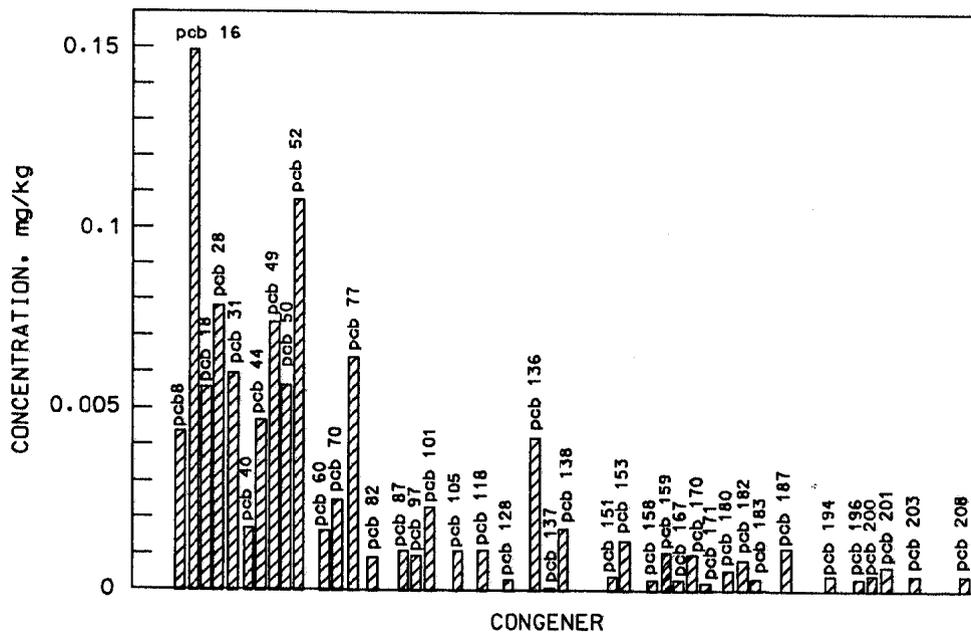


Figure 3. Saginaw River, Michigan (note Areas I and II)
 (from Palermo and Randall 1989)

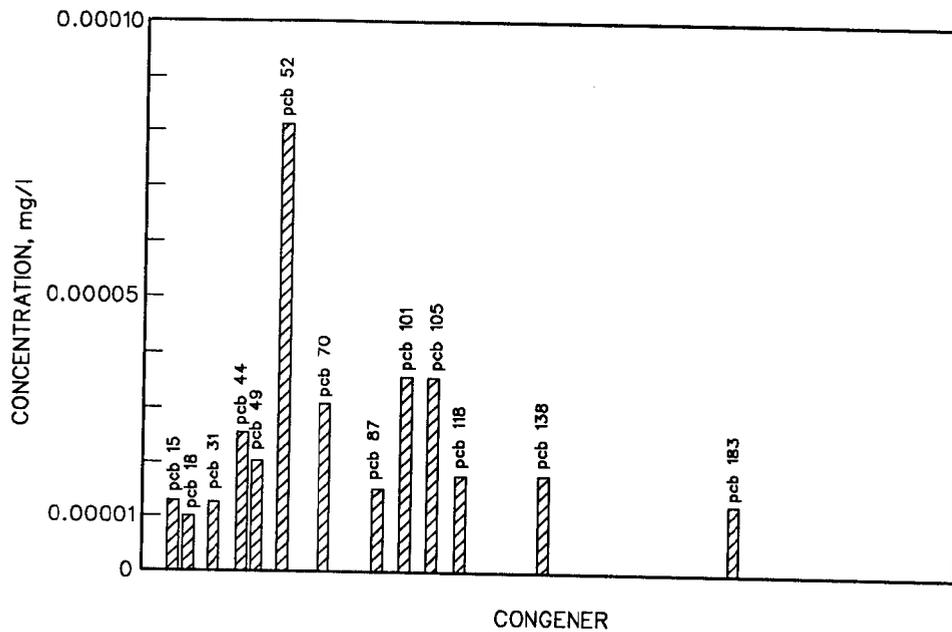


a. Area I

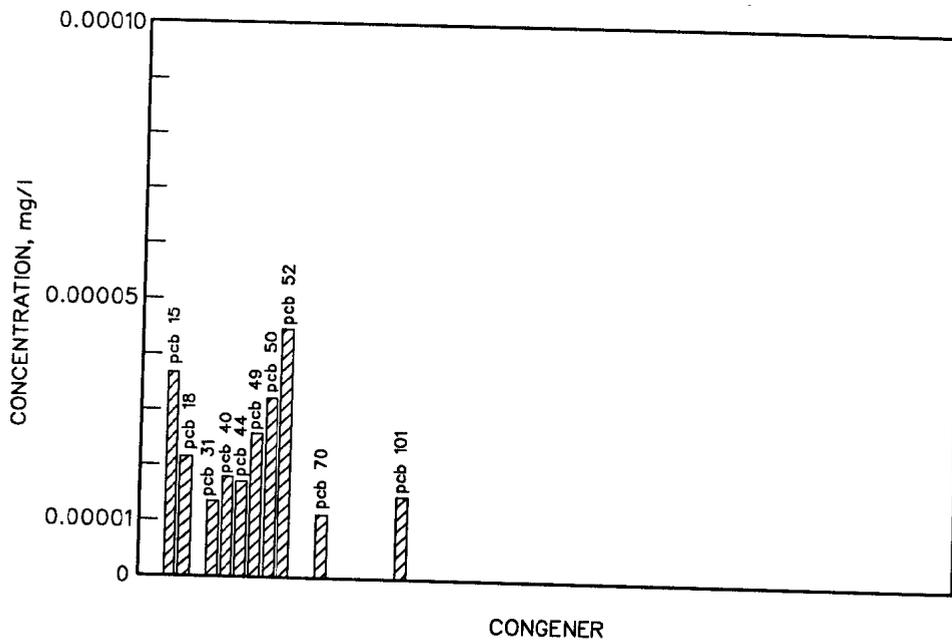


b. Area II

Figure 4. Average PCB congener concentrations in influent solids



a. Area I



b. Area II

Figure 5. Average PCB congener concentrations in influent water (filtered)

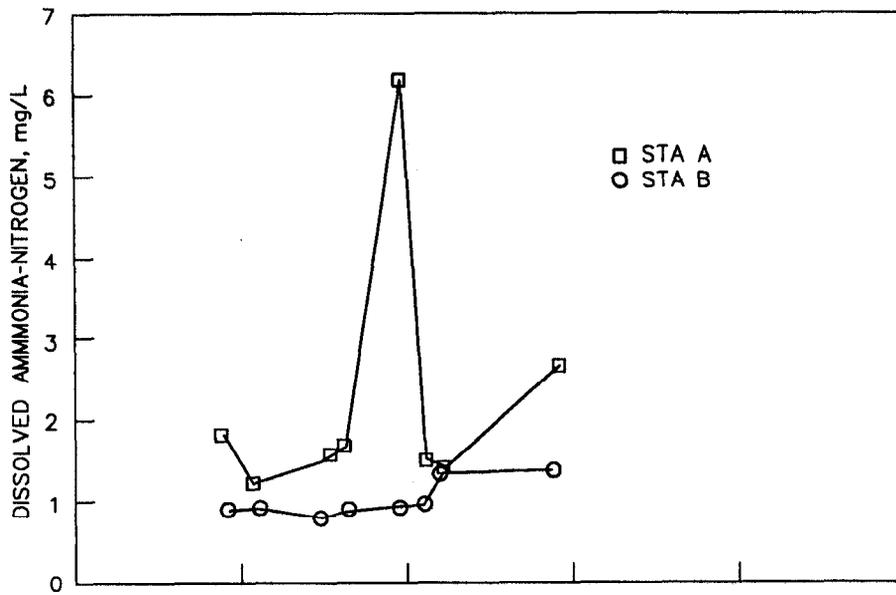


Figure 6. Pond water dissolved ammonia-nitrogen concentrations during disposal operations

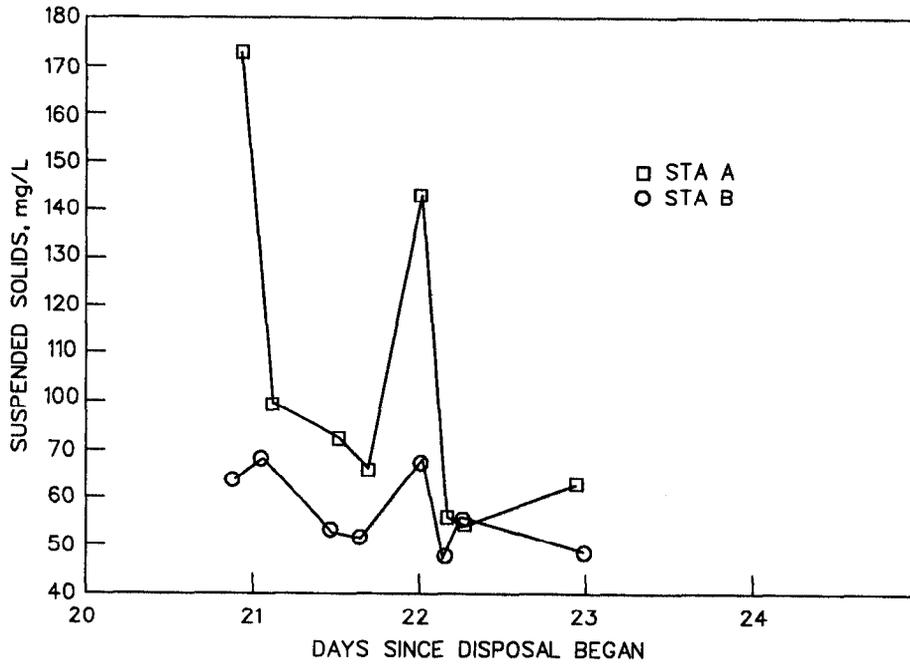
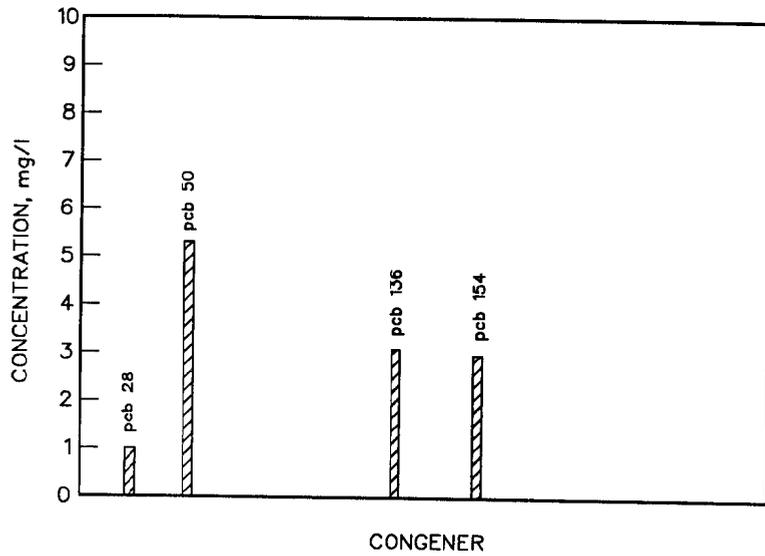
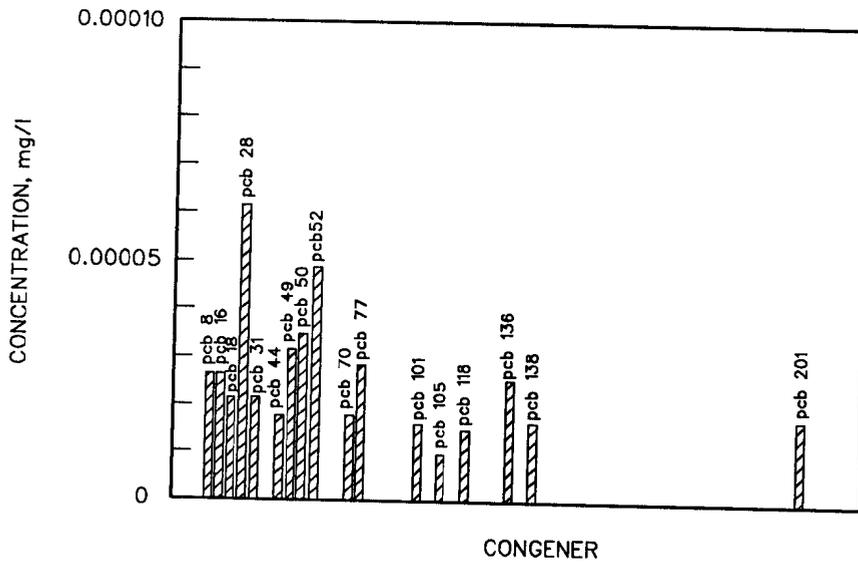


Figure 7. Pond water suspended solids concentrations during disposal operations

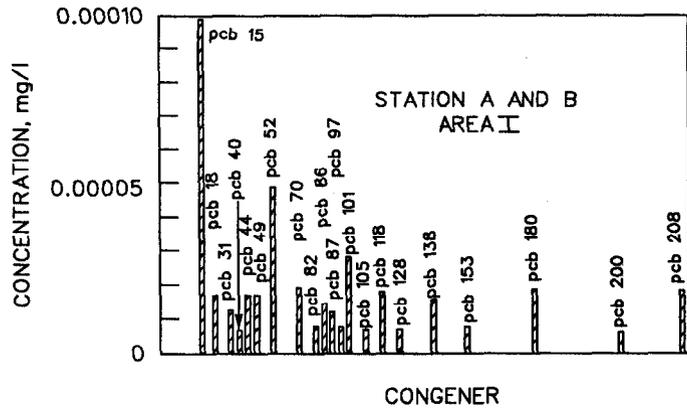


a. Predisposal

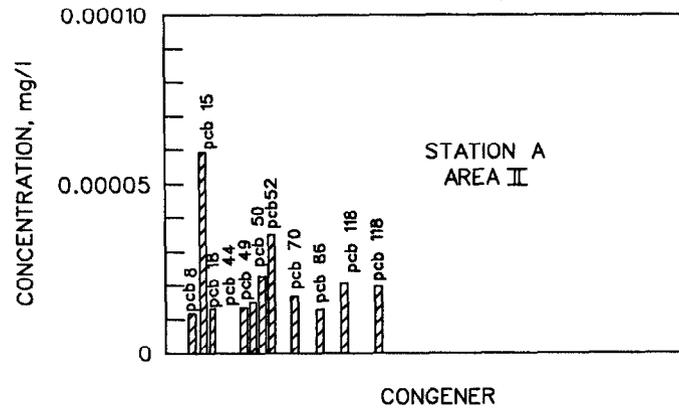


b. Postdisposal

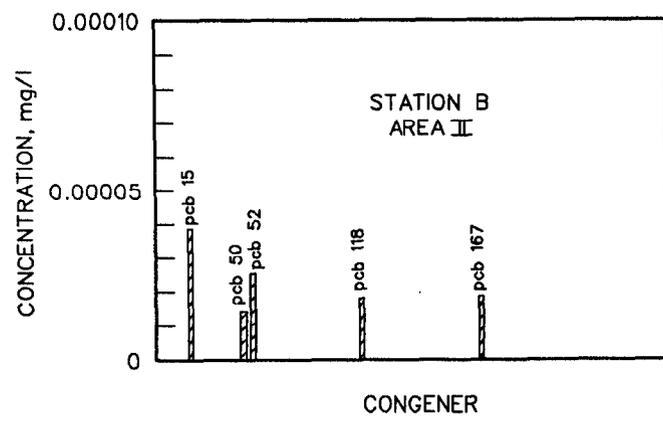
Figure 8. Average pond water PCB congener concentrations in whole water samples



a. Stations A and B, Area I

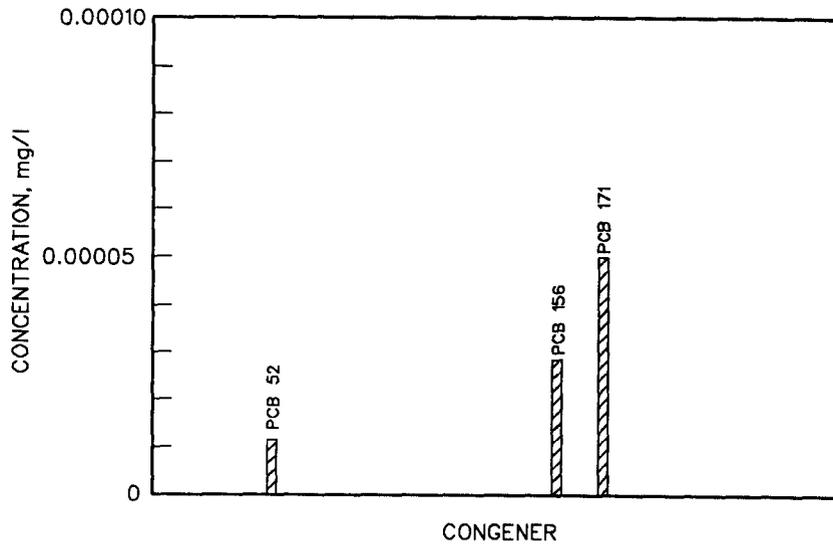


b. Station A, Area II

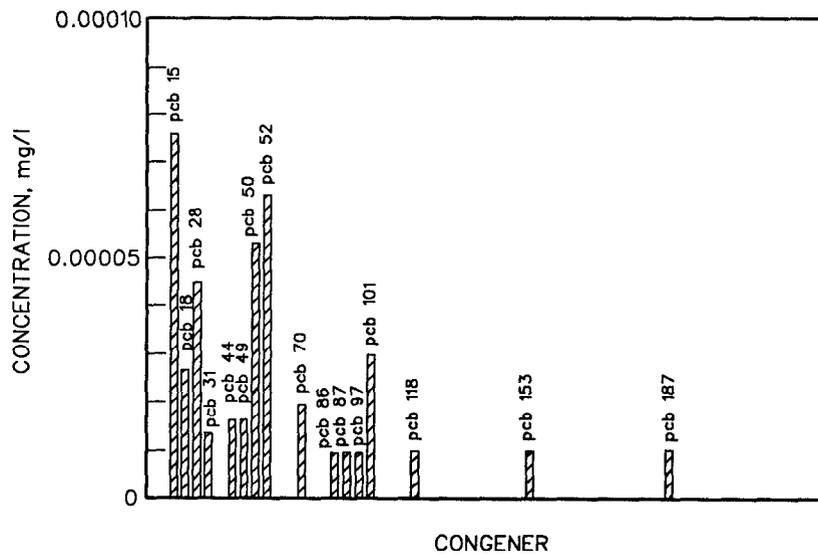


c. Station B, Area II

Figure 9. Average pond water PCB congener concentrations in whole water samples during disposal operations

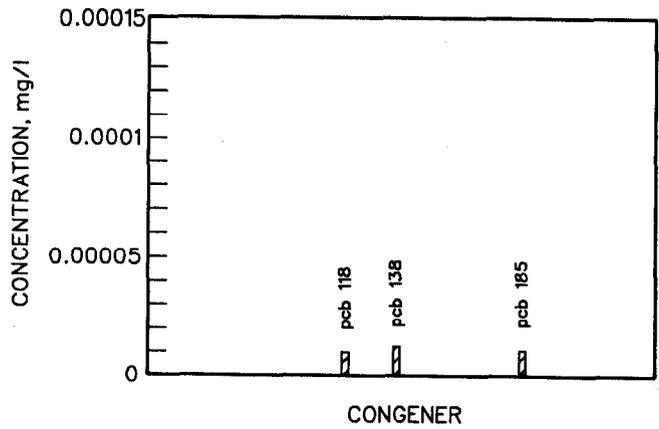


a. Predisposal

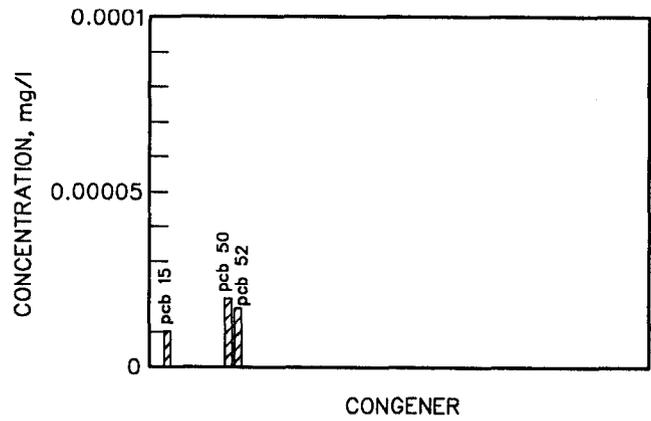


b. Postdisposal

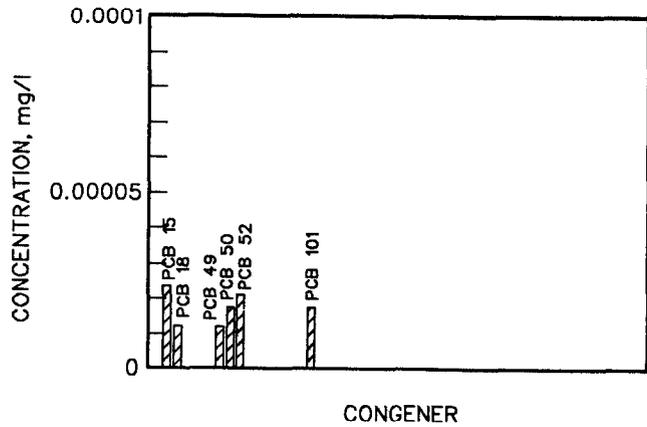
Figure 10. Average pond water dissolved PCB congener concentrations



a. Stations A and B, Area I



b. Station A, Area II



c. Station B, Area II

Figure 11. Average dissolved PCB congener concentrations during disposal operations

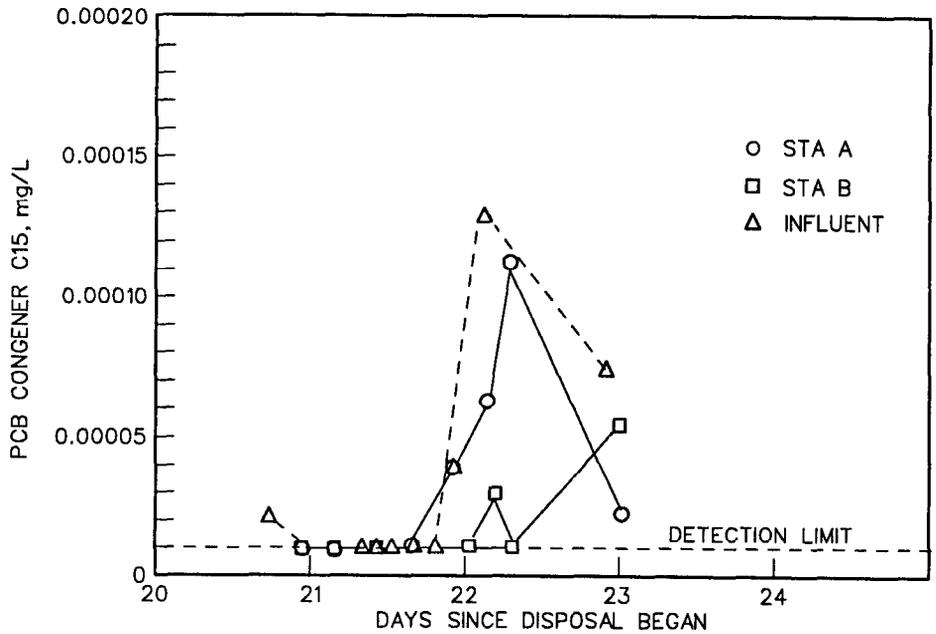


Figure 12. Dissolved PCB congener C15 concentrations in influent and pond water during disposal operations

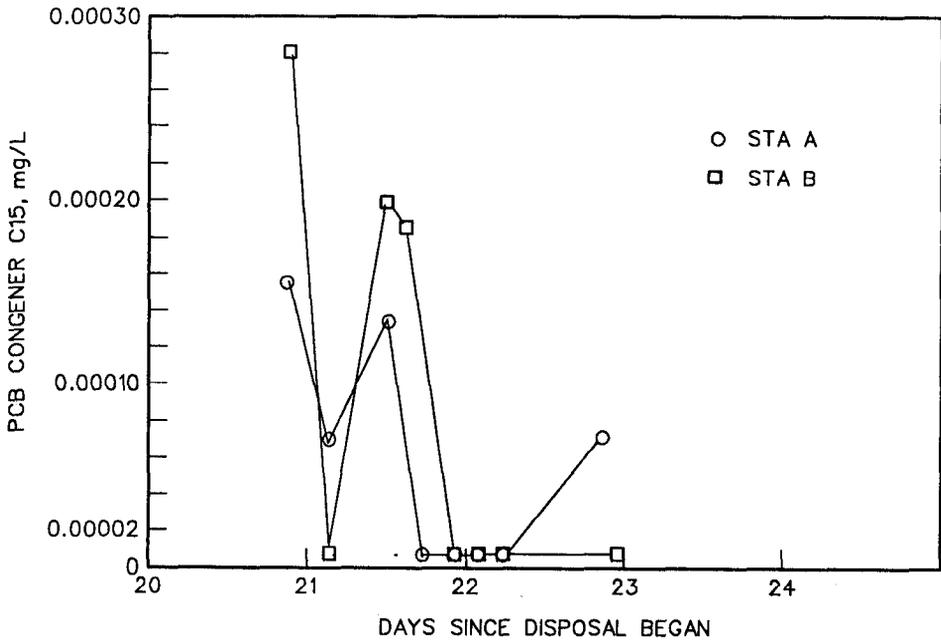
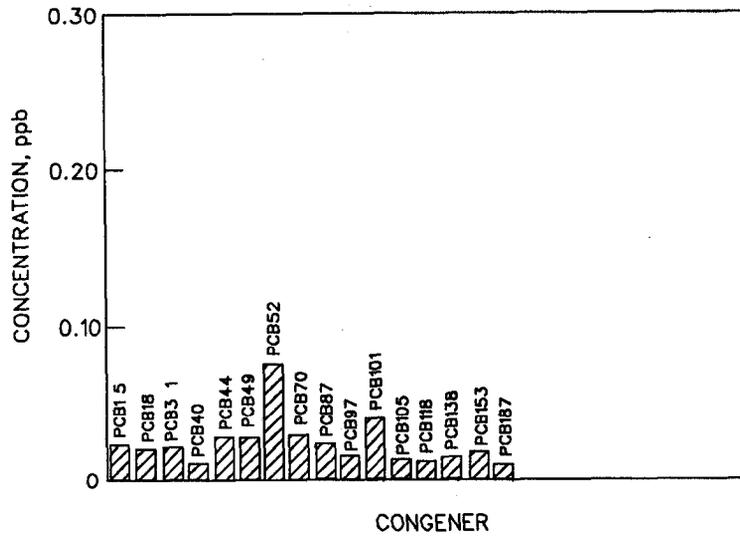
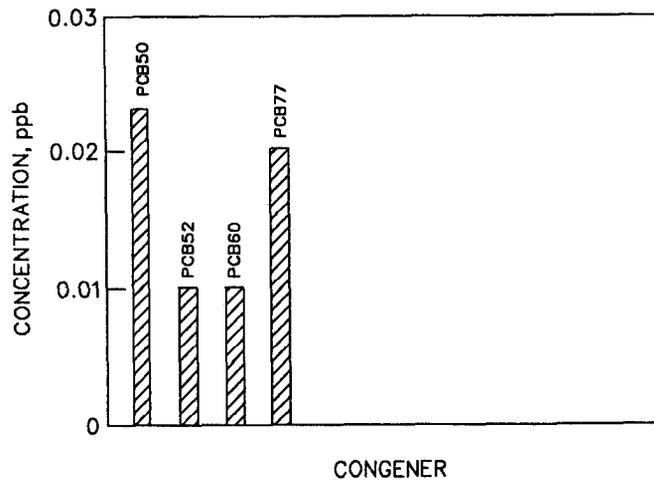


Figure 13. Whole water PCB congener C15 concentrations in pond water during disposal operations



a. Whole water



b. Dissolved

Figure 14. Average PCB congener concentrations in the modified elutriate test for Area II sediment

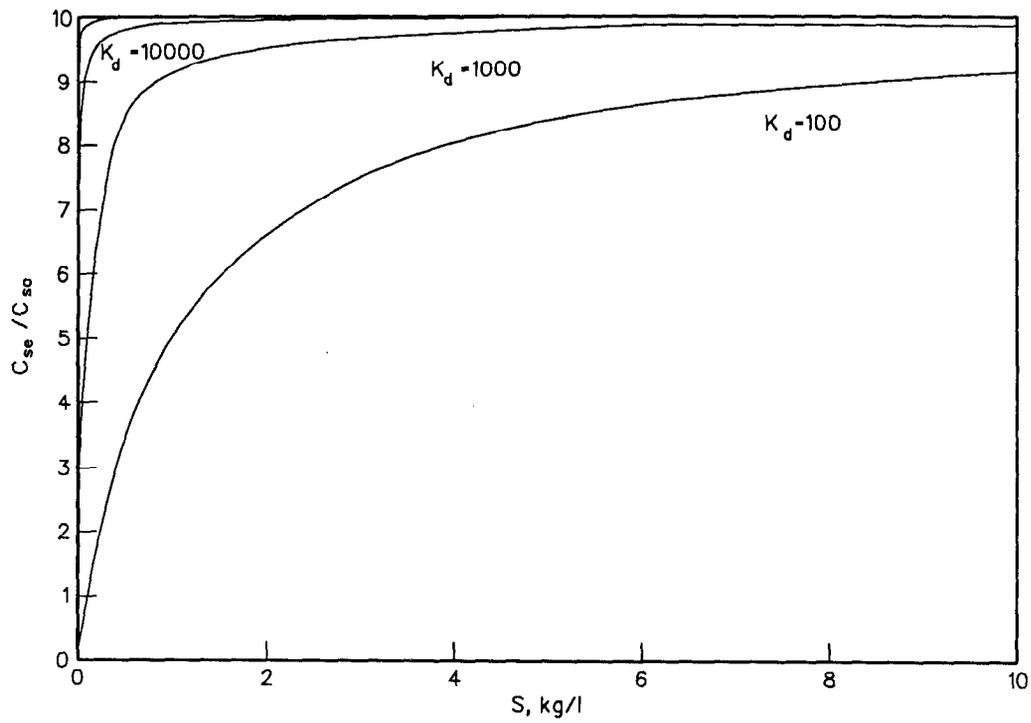
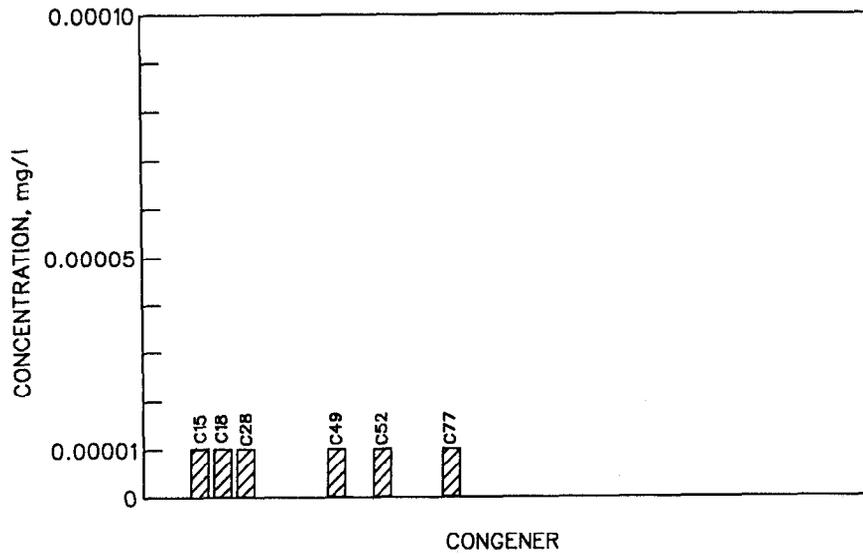
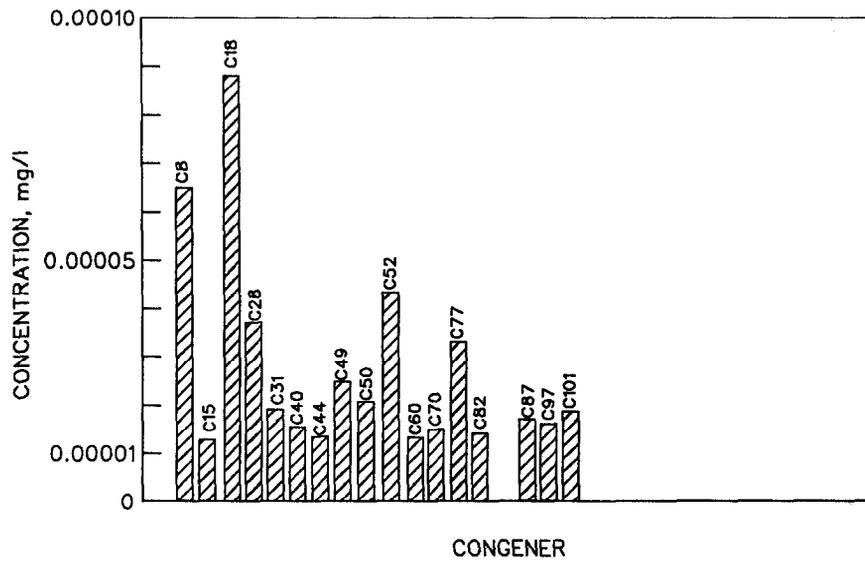


Figure 15. Fraction of initial solid phase PCB concentration remaining versus solids concentration



a. Equation 7 prediction



b. Equation 9 prediction

Figure 16. Predicted dissolved PCB congener concentrations for equilibrium partitioning equations

APPENDIX A: POLYCHLORINATED BIPHENYL DATA

1. This appendix contains the entire PCB data set, including aroclors, total PCB, and PCB congeners. The tables are organized as follows:

No.	Description
A1	Aroclors and Total PCB in Influent Solids During Disposal of Area I Dredged Material
A2	PCB Congeners in Influent Solids During Disposal of Area I Dredged Material
A3	Aroclors and Total PCB in Influent Solids During Disposal of Area II Dredged Material
A4	PCB Congeners in Influent Solids During Disposal of Area II Dredged Material
A5	Aroclors and Total PCB in Influent Water During Disposal of Area I Dredged Material
A6	PCB Congeners in Influent Water During Disposal of Area I Dredged Material
A7	Aroclors and Total PCB in Influent Water During Disposal of Area II Dredged Material
A8	PCB Congeners in Influent Water During Disposal of Area II Dredged Material
A9	Predisposal Pond Water Aroclors and Total PCB in Whole Water Samples
A10	Predisposal Pond Water PCB Congeners in Whole Water Samples
A11	Predisposal Dissolved Aroclors and Total PCB in Pond Water Samples
A12	Predisposal Dissolved PCB Congeners in Pond Water Samples
A13	Whole Water Aroclors and Total PCB in Pond Water During Disposal of Area I Dredged Material
A14	Whole Water PCB Congeners in Pond Water During Disposal of Area I Dredged Material
A15	Dissolved Aroclors and Total PCB in Pond Water During Disposal of Area I Dredged Material
A16	Dissolved PCB Congeners in Pond Water During Disposal of Area I Dredged Material

No.	Description
A17	Whole Water Aroclors and Total PCB in Pond Water at Station A During Disposal of Area II Dredged Material
A18	Whole Water PCB Congeners in Pond Water at Station A During Disposal of Area II Dredged Material
A19	Dissolved Aroclors and Total PCB in Pond Water at Station A During Disposal of Area II Dredged Material
A20	Dissolved PCB Congeners in Pond Water at Station A During Disposal of Area II Dredged Material
A21	Whole Water Aroclors and Total PCB in Pond Water at Station B During Disposal of Area II Dredged Material
A22	Whole Water PCB Congeners in Pond Water at Station B During Disposal of Area II Dredged Material
A23	Dissolved Aroclors and Total PCB in Pond Water at Station B During Disposal of Area II Dredged Material
A24	Dissolved PCB Congeners in Pond Water at Station B During Disposal of Area II Dredged Material
A25	Postdisposal Pond Water Aroclors and Total PCB in Whole Water Samples
A26	Postdisposal Pond Water PCB Congeners in Whole Water Samples
A27	Postdisposal Dissolved Aroclors and Total PCB in Pond Water Samples
A28	Postdisposal Dissolved PCB Congeners in Pond Water Samples

Table A1

Aroclors and Total PCB in Influent Solids During Disposal of
Area I Dredged Material (mg/kg)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>
1016	<0.01	<0.01
1221	<0.01	<0.01
1232	<0.01	<0.01
1242	0.09	0.24
1248	<0.01	<0.01
1254	<0.01	<0.01
1260	<0.01	0.12
Total PCB	0.09	0.43

Table A2

PCB Congeners in Influent Solids During Disposal of Area I
Dredged Material (mg/kg)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>
PCB 7	<0.002	<0.002
PCB 8	0.009	<0.002
PCB 15	0.014	0.052
PCB 18	0.007	<0.002
PCB 28	0.012	0.033
PCB 31	0.004	<0.002
PCB 40	<0.002	0.008
PCB 44	0.003	0.017
PCB 49	0.005	0.021
PCB 50	0.009	<0.002
PCB 52	0.009	0.036
PCB 54	<0.002	<0.002
PCB 60	<0.002	0.011
PCB 70	0.004	0.019
PCB 77	0.003	0.027
PCB 82	<0.002	0.006
PCB 86	0.002	0.008
PCB 87	<0.002	0.006
PCB 97	<0.002	0.006
PCB101	0.003	0.014
PCB103	<0.002	<0.002
PCB105	<0.002	<0.002
PCB114	<0.002	<0.002
PCB118	<0.002	0.007
PCB121	<0.002	<0.002
PCB128	<0.002	0.002
PCB129	<0.002	<0.002
PCB136	0.004	0.017

(Continued)

Table A2 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>
PCB137	<0.002	<0.002
PCB138	<0.002	<0.002
PCB141	<0.002	<0.002
PCB143	<0.002	<0.002
PCB151	<0.002	0.003
PCB153	<0.002	0.013
PCB154	<0.002	<0.002
PCB156	<0.002	<0.002
PCB159	<0.002	<0.002
PCB167	<0.002	0.009
PCB170	<0.002	0.013
PCB171	<0.002	<0.002
PCB173	<0.002	0.01
PCB180	<0.002	<0.002
PCB182	<0.002	<0.002
PCB183	<0.002	0.005
PCB185	<0.002	<0.002
PCB187	<0.002	0.008
PCB189	<0.002	<0.002
PCB191	<0.002	<0.002
PCB194	<0.002	0.003
PCB195	<0.002	<0.002
PCB196	<0.002	<0.002
PCB200	<0.002	<0.002
PCB201	<0.002	0.006
PCB202	<0.002	<0.002
PCB203	<0.002	0.002
PCB205	<0.002	<0.002
PCB206	<0.002	<0.002
PCB207	<0.002	<0.002
PCB208	<0.002	0.009
PCB209	<0.002	<0.002

Table A3
Aroclors and Total PCB in Influent Solids During
Disposal of Area II Dredged Material (mg/kg)

Aroclor	Sample						
	1	2	3	4	5	6	7
1016	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1221	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1232	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1242	0.71	0.87	0.62	0.74	0.74	0.93	0.82
1248	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1254	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1260	0.11	0.11	0.1	0.11	0.06	0.18	0.08
Total PCB	0.83	0.96	0.74	0.85	0.86	1.14	0.89

Table A4
PCB Congeners in Influent Solids During Disposal of
Area II Dredged Material (mg/kg)

Congener	Sample						
	1	2	3	4	5	6	7
PCB 7	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB 8	0.037	0.039	0.033	0.042	0.054	0.043	0.070
PCB 15	0.135	0.152	0.129	0.15	0.183	0.155	0.155
PCB 18	0.048	0.057	0.042	0.052	0.074	0.052	0.065
PCB 28	0.062	0.084	0.062	0.076	0.096	0.089	0.088
PCB 31	0.055	0.062	0.048	0.058	0.071	0.062	0.061
PCB 40	0.016	0.022	0.010	0.013	0.018	0.024	0.017
PCB 44	0.040	0.056	0.034	0.042	0.056	0.053	0.051
PCB 49	0.065	0.086	0.058	0.070	0.082	0.083	0.080
PCB 50	0.060	0.037	0.056	0.062	0.043	0.069	0.070
PCB 52	0.098	0.122	0.085	0.097	0.119	0.127	0.114
PCB 54	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB 60	0.014	0.017	0.013	0.017	0.021	0.019	0.017
PCB 70	0.022	0.029	0.021	0.026	0.033	0.030	0.028
PCB 77	0.025	0.071	0.057	0.066	0.072	0.095	0.064
PCB 82	0.010	0.007	0.008	0.009	0.010	0.014	0.006
PCB 86	<0.002	<0.002	<0.002	<0.002	0.011	<0.002	<0.002
PCB 87	0.010	0.012	0.008	0.009	0.013	0.014	0.012
PCB 97	0.008	0.010	0.008	0.009	0.011	0.013	0.010
PCB101	0.025	0.025	0.021	0.023	0.024	0.034	0.022
PCB103	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB105	0.008	0.012	0.009	0.011	0.013	0.015	0.011
PCB114	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB118	0.010	0.012	0.009	0.010	0.011	0.014	0.011
PCB121	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB128	0.004	<0.002	0.003	0.003	0.003	0.005	0.004

(Continued)

Table A4 (Concluded)

Congener	Sample						
	1	2	3	4	5	6	7
PCB129	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB136	0.041	0.043	0.036	0.041	0.044	0.059	0.040
PCB137	0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.002
PCB138	0.014	0.021	0.017	0.023	0.021	0.027	<0.002
PCB141	<0.002	0.002	<0.002	<0.002	0.003	0.003	<0.002
PCB143	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB151	0.004	0.004	0.003	0.004	0.004	0.005	0.003
PCB153	0.013	0.016	0.012	0.013	0.011	0.021	0.011
PCB154	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB156	<0.002	<0.002	0.006	0.005	0.004	<0.002	<0.002
PCB159	0.010	0.010	0.009	0.013	0.007	0.015	0.008
PCB167	0.003	<0.002	0.002	0.003	<0.002	0.003	<0.002
PCB170	0.011	0.011	0.006	0.007	0.010	0.013	0.009
PCB171	<0.002	<0.002	0.006	<0.002	<0.002	<0.002	<0.002
PCB173	<0.002	0.002	0.002	0.002	<0.002	<0.002	0.002
PCB180	0.006	0.004	0.006	0.006	0.002	0.010	0.002
PCB182	0.007	0.008	0.007	0.007	0.005	0.012	0.006
PCB183	0.003	0.004	0.004	0.005	0.004	0.005	0.003
PCB185	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB187	0.009	0.011	0.008	0.009	0.009	0.015	0.009
PCB189	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB191	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB194	0.003	0.004	0.003	0.003	0.002	0.005	0.003
PCB195	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB196	0.003	0.003	0.002	<0.002	<0.002	0.005	<0.002
PCB200	0.004	0.004	0.003	0.004	0.003	0.005	0.003
PCB201	0.006	0.008	0.004	0.005	0.005	0.010	0.005
PCB202	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB203	0.003	0.004	0.003	0.003	0.003	0.007	0.002
PCB205	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB206	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002
PCB207	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
PCB208	0.004	0.004	0.002	0.004	0.003	0.004	<0.002
PCB209	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002

Table A5

Aroclors and Total PCB in Influent Water During Disposal of Area I
Dredged Material (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>
1016	<0.0002	<0.0002
1221	<0.0002	<0.0002
1232	<0.0002	<0.0002
1242	0.0009	<0.0002
1248	<0.0002	<0.0002
1254	<0.0002	<0.0002
1260	<0.0002	<0.0002
Total PCB	0.0009	<0.0002

Table A6

PCB Congeners in Influent Water During Disposal of Area I
Dredged Material (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>
PCB 7	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001
PCB 15	<0.00001	0.00002
PCB 18	0.00001	0.00001
PCB 28	<0.00001	<0.00001
PCB 31	0.00002	<0.00001
PCB 40	<0.00001	<0.00001
PCB 44	0.00004	0.00001
PCB 49	0.00003	0.00001
PCB 50	<0.00001	<0.00001
PCB 52	0.00015	0.00001
PCB 54	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001
PCB 70	0.00005	0.00001
PCB 77	<0.00001	<0.00001
PCB 82	<0.00001	0.00001
PCB 86	<0.00001	<0.00001
PCB 87	0.00002	0.00001
PCB 97	0.00001	<0.00001
PCB101	0.00006	0.00001
PCB103	<0.00001	<0.00001
PCB105	0.00002	<0.00001
PCB114	0.00001	<0.00001
PCB118	0.00003	<0.00001
PCB121	<0.00001	<0.00001
PCB128	<0.00001	<0.00001
PCB129	<0.00001	<0.00001
PCB136	<0.00001	<0.00001

(Continued)

Table A6 (Concluded)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>
PCB137	<0.00001	<0.00001
PCB138	0.00003	<0.00001
PCB141	<0.00001	<0.00001
PCB143	<0.00001	<0.00001
PCB151	<0.00001	<0.00001
PCB153	<0.00001	<0.00001
PCB154	<0.00001	<0.00001
PCB156	<0.00001	<0.00001
PCB159	<0.00001	0.00001
PCB167	<0.00001	<0.00001
PCB170	<0.00001	<0.00001
PCB171	<0.00001	<0.00001
PCB173	<0.00001	<0.00001
PCB180	<0.00001	<0.00001
PCB182	<0.00001	0.00001
PCB183	<0.00001	0.00002
PCB185	<0.00001	<0.00001
PCB187	<0.00001	<0.00001
PCB189	<0.00001	<0.00001
PCB191	<0.00001	<0.00001
PCB194	<0.00001	<0.00001
PCB195	<0.00001	<0.00001
PCB196	<0.00001	<0.00001
PCB200	<0.00001	<0.00001
PCB201	<0.00001	<0.00001
PCB202	<0.00001	<0.00001
PCB203	<0.00001	<0.00001
PCB205	<0.00001	<0.00001
PCB206	<0.00001	<0.00001
PCB207	<0.00001	<0.00001
PCB208	<0.00001	<0.00001
PCB209	<0.00001	<0.00001

Table A7
Aroclors and Total PCB in Influent Water During Disposal of
Area II Dredged Material (mg/l)

Aroclor	Sample					
	1	2	3	4	5	6
1016	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1242	<0.0002	0.0003	0.0003	0.0002	0.0004	0.0009
1248	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	0.0002	0.0011	0.0002	0.0003	0.0011

Table A8
PCB Congeners in Influent Water During Disposal of
Area II Dredged Material (mg/l)

Congener	Sample						
	1	2	3	4	5	6	7
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 15	0.00001	<0.00001	<0.00001	<0.00001	0.00004	0.00012	0.00007
PCB 18	0.00001	0.00001	<0.00001	<0.00001	0.00003	0.00005	0.00004
PCB 28	<0.00001	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	0.00001	0.00001	0.00001	0.00001	0.00003	0.00002
PCB 40	<0.00001	0.00002	0.00001	0.00001	0.00002	0.00003	0.00003
PCB 44	0.00001	0.00001	0.00001	0.00001	0.00002	0.00003	0.00003
PCB 49	0.00001	0.00002	0.00001	0.00002	0.00003	0.00004	0.00005
PCB 50	<0.00001	0.00003	0.00003	0.00003	0.00001	0.00009	0.00003
PCB 52	0.00001	0.00003	0.00003	0.00002	0.00004	0.00010	0.00008
PCB 54	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	0.00001
PCB 70	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.00003	0.00002
PCB 77	<0.00001	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 82	0.00001	<0.00001	0.00001	<0.00001	0.00001	0.00002	0.00001
PCB 86	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001
PCB 87	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.00002	0.00001
PCB 97	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.00002	0.00001
PCB101	<0.00001	<0.00001	0.00001	<0.00001	0.00001	0.00004	0.00003
PCB103	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	0.00001
PCB105	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB118	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	0.00002	0.00001
PCB121	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	0.00001	0.00001
PCB128	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001

(Continued)

Table A9
Predisposal Pond Water Aroclors and Total PCB
in Whole Water Samples (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	<0.0002	<0.0002	<0.0002
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	0.0003	0.0005

Table A10
Predisposal Pond Water PCB Congeners in
Whole Water Samples (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	<0.00001	<0.00001
PCB 18	<0.00001	<0.00001	<0.00001
PCB 28	0.00001	0.00001	0.00001
PCB 31	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001
PCB 44	<0.00001	<0.00001	<0.00001
PCB 49	<0.00001	<0.00001	<0.00001
PCB 50	0.00006	0.00005	0.00005
PCB 52	<0.00001	<0.00001	<0.00001
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	<0.00001	<0.00001
PCB 86	<0.00001	<0.00001	<0.00001
PCB 87	<0.00001	<0.00001	<0.00001
PCB 97	<0.00001	<0.00001	<0.00001
PCB 101	<0.00001	<0.00001	<0.00001
PCB 103	<0.00001	<0.00001	<0.00001
PCB 105	<0.00001	<0.00001	<0.00001
PCB 114	<0.00001	<0.00001	<0.00001
PCB 118	<0.00001	<0.00001	<0.00001
PCB 121	<0.00001	<0.00001	<0.00001
PCB 128	<0.00001	<0.00001	<0.00001
PCB 129	<0.00001	<0.00001	<0.00001
PCB 136	<0.00001	0.00005	0.00004

(Continued)

Table A10 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB 137	<0.00001	<0.00001	<0.00001
PCB 138	<0.00001	<0.00001	<0.00001
PCB 141	<0.00001	<0.00001	<0.00001
PCB 143	<0.00001	<0.00001	<0.00001
PCB 151	<0.00001	<0.00001	<0.00001
PCB 153	<0.00001	<0.00001	<0.00001
PCB 154	0.00003	0.00003	0.00003
PCB 156	<0.00001	<0.00001	<0.00001
PCB 159	<0.00001	<0.00001	<0.00001
PCB 167	<0.00001	<0.00001	<0.00001
PCB 170	<0.00001	<0.00001	<0.00001
PCB 171	<0.00001	<0.00001	<0.00001
PCB 173	<0.00001	<0.00001	<0.00001
PCB 180	<0.00001	<0.00001	<0.00001
PCB 182	<0.00001	<0.00001	<0.00001
PCB 183	<0.00001	0.00002	<0.00001
PCB 185	<0.00001	<0.00001	<0.00001
PCB 187	<0.00001	<0.00001	<0.00001
PCB 189	<0.00001	<0.00001	<0.00001
PCB 191	<0.00001	<0.00001	<0.00001
PCB 194	<0.00001	<0.00001	<0.00001
PCB 195	<0.00001	<0.00001	<0.00001
PCB 196	<0.00001	<0.00001	<0.00001
PCB 200	<0.00001	<0.00001	<0.00001
PCB 201	<0.00001	<0.00001	<0.00001
PCB 202	<0.00001	<0.00001	<0.00001
PCB 203	<0.00001	<0.00001	<0.00001
PCB 205	<0.00001	<0.00001	<0.00001
PCB 206	<0.00001	<0.00001	<0.00001
PCB 207	<0.00001	<0.00001	<0.00001
PCB 208	<0.00001	<0.00001	<0.00001
PCB 209	<0.00001	<0.00001	<0.00001

Table A11
Predisposal Dissolved Aroclors and Total PCB in
Pond Water Samples (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	<0.0002	0.0002	<0.0002
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	0.0002	<0.0002

Table A12
Predisposal Dissolved PCB Congeners in Pond Water Samples (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	0.00001	<0.00001
PCB 18	<0.00001	<0.00001	<0.00001
PCB 28	0.00001	0.00001	<0.00001
PCB 31	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001
PCB 44	<0.00001	0.00001	<0.00001
PCB 49	<0.00001	0.00001	<0.00001
PCB 50	0.00001	<0.00001	<0.00001
PCB 52	0.00001	0.00002	<0.00001
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	<0.00001	<0.00001
PCB 86	<0.00001	<0.00001	<0.00001
PCB 87	<0.00001	<0.00001	<0.00001
PCB 97	<0.00001	<0.00001	<0.00001
PCB101	<0.00001	<0.00001	<0.00001
PCB103	<0.00001	<0.00001	<0.00001
PCB105	<0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001
PCB118	<0.00001	<0.00001	<0.00001
PCB121	<0.00001	<0.00001	<0.00001
PCB128	<0.00001	<0.00001	<0.00001
PCB129	<0.00001	<0.00001	<0.00001
PCB136	<0.00001	<0.00001	<0.00001
PCB137	<0.00001	<0.00001	<0.00001

(Continued)

Table A12 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB138	<0.00001	<0.00001	<0.00001
PCB141	<0.00001	<0.00001	<0.00001
PCB143	<0.00001	<0.00001	<0.00001
PCB151	<0.00001	<0.00001	<0.00001
PCB153	<0.00001	<0.00001	<0.00001
PCB154	<0.00001	<0.00001	<0.00001
PCB156	0.00004	0.00004	<0.00001
PCB159	<0.00001	<0.00001	<0.00001
PCB167	<0.00001	<0.00001	<0.00001
PCB170	<0.00001	<0.00001	<0.00001
PCB171	0.00007	0.00006	0.00002
PCB173	<0.00001	<0.00001	<0.00001
PCB180	<0.00001	<0.00001	<0.00001
PCB182	<0.00001	<0.00001	<0.00001
PCB183	<0.00001	<0.00001	<0.00001
PCB185	<0.00001	<0.00001	<0.00001
PCB187	<0.00001	<0.00001	<0.00001
PCB189	<0.00001	<0.00001	<0.00001
PCB191	<0.00001	<0.00001	<0.00001
PCB194	<0.00001	<0.00001	<0.00001
PCB195	<0.00001	<0.00001	<0.00001
PCB196	<0.00001	<0.00001	<0.00001
PCB200	<0.00001	<0.00001	<0.00001
PCB201	<0.00001	<0.00001	<0.00001
PCB202	<0.00001	<0.00001	<0.00001
PCB203	<0.00001	<0.00001	<0.00001
PCB205	<0.00001	<0.00001	<0.00001
PCB206	<0.00001	<0.00001	<0.00001
PCB207	<0.00001	<0.00001	<0.00001
PCB208	<0.00001	<0.00001	<0.00001
PCB209	<0.00001	<0.00001	<0.00001

Table A13

Whole Water Aroclors and Total PCB in Pond Water During Disposal of
Area I Dredged Material (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	<0.0002	0.001	0.0005
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	0.0013	0.0005

Table A14

Whole Water PCB Congeners in Pond Water During Disposal of
Area I Dredged Material (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	0.00028	0.00015
PCB 18	<0.00001	0.00005	0.00002
PCB 28	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	0.00003	0.00002
PCB 40	<0.00001	0.00001	0.00001
PCB 44	<0.00001	0.00004	0.00003
PCB 49	<0.00001	0.00004	0.00003
PCB 50	<0.00001	<0.00001	<0.00001
PCB 52	<0.00001	0.00013	0.00008
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	0.00005	0.00003
PCB 77	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	0.00002	0.00001
PCB 86	<0.00001	0.00003	0.00003
PCB 87	<0.00001	0.00003	0.00002
PCB 97	<0.00001	0.00002	0.00001
PCB101	<0.00001	0.00007	0.00005
PCB103	<0.00001	<0.00001	<0.00001
PCB105	0.00001	0.00001	0.00001
PCB114	<0.00001	<0.00001	<0.00001
PCB118	0.00001	0.00004	0.00003
PCB121	<0.00001	<0.00001	<0.00001
PCB128	<0.00001	0.00002	<0.00001
PCB129	<0.00001	<0.00001	<0.00001

(Continued)

Table A14 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
PCB136	<0.00001	<0.00001	<0.00001
PCB137	<0.00001	0.00001	0.00001
PCB138	0.00002	0.00003	0.00002
PCB141	<0.00001	<0.00001	<0.00001
PCB143	<0.00001	<0.00001	<0.00001
PCB151	<0.00001	0.00001	<0.00001
PCB153	<0.00001	0.00002	0.00001
PCB154	<0.00001	<0.00001	<0.00001
PCB156	<0.00001	<0.00001	<0.00001
PCB159	<0.00001	0.00001	<0.00001
PCB167	<0.00001	<0.00001	<0.00001
PCB170	<0.00001	<0.00001	<0.00001
PCB171	<0.00001	<0.00001	<0.00001
PCB173	<0.00001	<0.00001	<0.00001
PCB180	<0.00001	0.00001	0.00007
PCB182	<0.00001	<0.00001	<0.00001
PCB183	<0.00001	0.00001	<0.00001
PCB185	<0.00001	<0.00001	<0.00001
PCB187	<0.00001	0.00001	0.00001
PCB189	<0.00001	<0.00001	<0.00001
PCB191	<0.00001	0.00001	<0.00001
PCB194	<0.00001	<0.00001	<0.00001
PCB195	<0.00001	<0.00001	<0.00001
PCB196	<0.00001	<0.00001	<0.00001
PCB200	<0.00001	0.00002	<0.00001
PCB201	<0.00001	<0.00001	<0.00001
PCB202	<0.00001	<0.00001	<0.00001
PCB203	<0.00001	<0.00001	0.00001
PCB205	<0.00001	<0.00001	<0.00001
PCB206	<0.00001	<0.00001	<0.00001
PCB207	<0.00001	<0.00001	<0.00001
PCB208	<0.00001	0.00001	0.00007
PCB209	<0.00001	<0.00001	<0.00001

Table A15

Dissolved Aroclors and Total PCB in Pond Water During
Disposal of Area I Dredged Material (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	<0.0002	<0.0002	<0.0002
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	<0.0002	<0.0002

Table A16

Dissolved PCB Congeners in Pond Water During
Disposal of Area I Dredged Material (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	<0.00001	<0.00001
PCB 18	<0.00001	<0.00001	<0.00001
PCB 28	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001
PCB 44	<0.00001	<0.00001	<0.00001
PCB 49	<0.00001	0.00001	<0.00001
PCB 50	<0.00001	<0.00001	<0.00001
PCB 52	<0.00001	<0.00001	<0.00001
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	0.00001	<0.00001
PCB 86	<0.00001	<0.00001	<0.00001
PCB 87	<0.00001	<0.00001	<0.00001
PCB 97	<0.00001	<0.00001	<0.00001
PCB101	<0.00001	0.00001	<0.00001
PCB103	<0.00001	<0.00001	<0.00001
PCB105	0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001
PCB118	0.00002	<0.00001	<0.00001
PCB121	<0.00001	<0.00001	<0.00001
PCB128	<0.00001	<0.00001	<0.00001
PCB129	<0.00001	<0.00001	<0.00001
PCB136	<0.00001	<0.00001	<0.00001

(Continued)

Table A16 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2A</u>	<u>Sample 2B</u>
PCB137	<0.00001	<0.00001	<0.00001
PCB138	0.00002	0.00001	<0.00001
PCB141	<0.00001	<0.00001	<0.00001
PCB143	<0.00001	<0.00001	<0.00001
PCB151	<0.00001	<0.00001	<0.00001
PCB153	<0.00001	<0.00001	<0.00001
PCB154	<0.00001	<0.00001	<0.00001
PCB156	<0.00001	<0.00001	<0.00001
PCB159	<0.00001	0.00001	<0.00001
PCB167	<0.00001	<0.00001	0.00001
PCB170	<0.00001	<0.00001	<0.00001
PCB171	<0.00001	<0.00001	<0.00001
PCB173	<0.00001	<0.00001	<0.00001
PCB180	<0.00001	<0.00001	<0.00001
PCB182	<0.00001	<0.00001	<0.00001
PCB183	<0.00001	<0.00000	<0.00001
PCB185	0.00002	<0.00001	<0.00001
PCB187	<0.00001	<0.00001	<0.00001
PCB189	<0.00001	<0.00001	<0.00001
PCB191	<0.00001	<0.00001	<0.00001
PCB194	<0.00001	<0.00001	<0.00001
PCB195	<0.00001	<0.00001	<0.00001
PCB200	<0.00001	<0.00001	<0.00001
PCB201	<0.00001	<0.00001	<0.00001
PCB202	<0.00001	<0.00001	<0.00001
PCB203	<0.00001	<0.00001	<0.00001
PCB205	<0.00001	<0.00001	<0.00001
PCB206	<0.00001	<0.00001	<0.00001
PCB207	<0.00001	<0.00001	<0.00001
PCB208	<0.00001	<0.00001	<0.00001
PCB209	<0.00001	<0.00001	<0.00001

Table A17

Whole Water Aroclors and Total PCB in Pond Water at Station A
During Disposal of Area II Dredged Material (mg/l)

Aroclor	Sample						
	1	2	3	4	5	6	7
1016	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1242	<0.0011	<0.0007	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1248	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Total PCB	<0.0011	<0.0009	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002

Table A18

Whole Water PCB Congeners in Pond Water at Station A
During Disposal of Area II Dredged Material (mg/l)

Congener	Sample						
	1	2	3	4	5	6	7
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 8	0.00005	0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001
PCB 15	0.0002	0.00019	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 18	0.00005	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00002
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 40	0.00001	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 44	0.00005	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 49	0.00005	0.00003	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB 50	0.00004	0.00001	0.00002	0.00003	0.00002	0.00003	0.00002
PCB 52	0.00016	0.00005	<0.00001	<0.00001	<0.00001	<0.00001	0.00002
PCB 54	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 70	0.00006	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 82	0.00002	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 86	0.00004	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 87	0.00004	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 97	0.00003	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB101	0.00008	0.00004	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB103	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB105	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB118	0.00004	<0.00001	0.00002	0.00002	0.00002	0.00003	<0.00001
PCB121	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB128	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001

(Continued)

Table A19

Dissolved Aroclors and Total PCB in Pond Water at Station A
During Disposal of Area II Dredged Material (mg/l)

Aroclor	Sample						
	1	2	3	4	5	6	7
1016	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1242	<0.0002	0.0003	0.0002	<0.0002	0.0002	<0.0002	0.0003
1248	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Total PCB	0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004

Table A20

Dissolved PCB Congeners in Pond Water at Station A During
Disposal of Area II Dredged Material (mg/l)

Congener	Sample						
	1	2	3	4	5	6	7
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	<0.00001	<0.00001	0.00001	0.00003	<0.00001	0.00005
PCB 18	<0.00001	<0.00001	<0.00001	0.00001	0.00002	<0.00001	0.00002
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB 40	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 44	<0.00001	0.00001	<0.00001	<0.00001	0.00002	<0.00001	0.00002
PCB 49	<0.00001	0.00003	<0.00001	<0.00001	0.00002	<0.00001	0.00002
PCB 50	<0.00001	0.00004	0.00002	<0.00001	0.00004	<0.00001	0.00006
PCB 52	<0.00001	0.00003	<0.00001	<0.00001	0.00006	0.00001	0.00006
PCB 54	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	0.00001	<0.00001	<0.00001	0.00002	<0.00001	0.00002
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00008
PCB 82	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 86	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001
PCB 87	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB 97	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB101	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	<0.00001	0.00002
PCB103	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB105	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001
PCB118	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB121	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001

(Continued)

Table A21

Whole Water Aroclors and Total PCB in Pond Water at Station B
During Disposal of Area II Dredged Material (mg/l)

Aroclor	Sample						
	1	2	3	4	5	6	7
1016	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1242	<0.0002	0.0002	<0.0002	<0.0002	0.0002	<0.0002	0.0003
1248	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	0.0002

Table A22

Whole Water PCB Congeners in Pond Water at Station B
During Disposal of Area II Dredged Material (mg/l)

Congener	Sample						
	1	2	3	4	5	6	7
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 15	0.00006	0.00012	<0.00001	<0.00001	<0.00001	<0.00001	0.00007
PCB 18	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00003
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	0.00002	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB 40	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 44	<0.00001	0.00002	<0.00001	<0.00001	0.00001	<0.00001	0.00002
PCB 49	<0.00001	0.00002	<0.00001	<0.00001	0.00002	<0.00001	0.00002
PCB 50	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001	0.00006
PCB 52	<0.00001	0.00004	<0.00001	<0.00001	0.00005	<0.00001	0.00007
PCB 54	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00002
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB 86	0.00001	0.00002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 87	<0.00001	0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00001
PCB 97	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB101	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	0.00002
PCB103	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB105	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00001
PCB118	0.00002	0.00002	0.00002	<0.00001	0.00005	<0.00001	0.00001
PCB121	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001

(Continued)

Table A23

Dissolved Aroclors and Total PCB at Station B During Disposal of
Area II Dredged Material (mg/l)

Aroclor	Sample					
	1	2	4	5	6	7
1016	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1242	<0.0002	<0.0002	<0.0002	0.0004	0.0003	<0.0002
1248	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Total PCB	<0.0002	<0.0002	<0.0002	0.0005	0.0002	<0.0002

Table A24

Dissolved PCB Congeners in Pond Water at Station B During
Disposal of Area II Dredged Material (mg/l)

Congener	Sample					
	1	2	4	5	6	7
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 15	<0.00001	<0.00001	0.00004	0.00006	0.00011	0.00002
PCB 18	<0.00001	<0.00001	0.00002	0.00003	0.00005	0.00001
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 31	<0.00001	<0.00001	<0.00001	0.00002	0.00003	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001	<0.00001	0.00003	<0.00001
PCB 44	<0.00001	<0.00001	0.00001	0.00002	0.00003	<0.00001
PCB 49	<0.00001	<0.00001	0.00001	0.00003	0.00005	0.00001
PCB 50	<0.00001	0.00002	0.00001	0.00005	0.00005	0.00002
PCB 52	0.00001	<0.00001	0.00002	0.00008	0.00008	0.00001
PCB 54	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 70	<0.00001	<0.00001	0.00001	0.00003	0.00003	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB 82	<0.00001	<0.00001	<0.00001	0.00001	0.00001	<0.00001
PCB 86	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001
PCB 87	<0.00001	<0.00001	0.00001	0.00002	0.00001	<0.00001
PCB 97	<0.00001	<0.00001	<0.00001	0.00001	0.00001	<0.00001
PCB101	<0.00001	<0.00001	0.00001	0.00004	0.00004	<0.00001
PCB103	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB105	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001	0.00001	0.00001	0.00001
PCB118	<0.00001	<0.00001	<0.00001	0.00002	0.00001	<0.00001
PCB121	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	<0.00001

(Continued)

Table A24 (Concluded)

<u>Congener</u>	<u>Sample</u>						
	<u>1</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	
PCB128	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB129	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB136	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB137	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB138	<0.00001	<0.00001	<0.00001	0.00001	0.00001	<0.00001	
PCB141	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB143	<0.00001	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	
PCB151	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB153	<0.00001	<0.00001	<0.00001	0.00002	0.00002	<0.00001	
PCB154	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB156	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB159	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	
PCB167	<0.00001	<0.00001	<0.00001	0.00003	<0.00001	<0.00001	
PCB170	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB171	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB173	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB180	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	
PCB182	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB183	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	<0.00001	
PCB185	<0.00001	<0.00001	<0.00001	0.00001	<0.00001	<0.00001	
PCB187	<0.00001	<0.00001	<0.00001	0.00001	0.00001	<0.00001	
PCB189	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB191	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB194	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB195	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB196	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB200	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB201	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB202	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB203	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB205	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB206	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB207	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	
PCB208	<0.00001	<0.00001	<0.00001	0.00004	<0.00001	<0.00001	
PCB209	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	

Table A25

Postdisposal Pond Water Aroclors and Total PCB
in Whole Water Samples (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	0.0011	0.0003	<0.0002
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	0.0014	0.0003	<0.0002

Table A26

Postdisposal Pond Water PCB Congeners in Whole Water Samples (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	0.00007	<0.00001	<0.00001
PCB 15	0.00007	<0.00001	<0.00001
PCB 18	0.00005	0.00001	<0.00001
PCB 28	0.00012	0.00006	<0.00001
PCB 31	0.00004	0.00002	<0.00001
PCB 40	0.00001	<0.00001	<0.00001
PCB 44	0.00004	0.00001	<0.00001
PCB 49	0.00007	0.00002	<0.00001
PCB 50	0.00007	0.00003	<0.00001
PCB 52	0.00010	0.00004	<0.00001
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	<0.00001	<0.00001	<0.00001
PCB 70	0.00004	0.00001	<0.00001
PCB 77	0.00006	0.00002	<0.00001
PCB 82	0.00001	<0.00001	<0.00001
PCB 86	0.00002	<0.00001	<0.00001
PCB 87	0.00001	<0.00001	<0.00001
PCB 97	0.00002	<0.00001	<0.00001
PCB101	0.00004	<0.00001	<0.00001
PCB103	<0.00001	<0.00001	0.00001
PCB105	0.00001	0.00001	0.00001
PCB114	<0.00001	<0.00001	<0.00001
PCB118	0.00003	0.00001	<0.00001
PCB121	<0.00001	<0.00001	<0.00001
PCB128	<0.00001	<0.00001	<0.00001
PCB129	<0.00001	<0.00001	<0.00001
PCB136	0.00005	0.00002	<0.00001
PCB137	<0.00001	<0.00001	<0.00001

(Continued)

Table A26 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB138	0.00002	0.00002	0.00001
PCB141	<0.00001	<0.00001	<0.00001
PCB143	<0.00001	<0.00001	<0.00001
PCB151	<0.00001	<0.00001	<0.00001
PCB153	0.00002	<0.00001	<0.00001
PCB154	<0.00001	<0.00001	<0.00001
PCB156	<0.00001	<0.00001	<0.00001
PCB159	<0.00001	<0.00001	<0.00001
PCB167	<0.00001	<0.00001	<0.00001
PCB170	<0.00001	<0.00001	<0.00001
PCB171	<0.00001	<0.00001	<0.00001
PCB173	<0.00001	<0.00001	<0.00001
PCB180	0.00002	<0.00001	<0.00001
PCB182	<0.00001	<0.00001	<0.00001
PCB183	<0.00001	<0.00001	<0.00001
PCB185	0.00002	<0.00001	<0.00001
PCB187	<0.00001	<0.00001	<0.00001
PCB189	<0.00001	<0.00001	<0.00001
PCB191	<0.00001	<0.00001	<0.00001
PCB194	<0.00001	<0.00001	<0.00001
PCB195	<0.00001	<0.00001	<0.00001
PCB196	0.00002	<0.00001	<0.00001
PCB200	<0.00001	<0.00001	<0.00001
PCB201	0.00001	<0.00001	0.00004
PCB202	<0.00001	<0.00001	<0.00001
PCB203	<0.00001	<0.00001	<0.00001
PCB205	<0.00001	<0.00001	<0.00001
PCB206	<0.00001	<0.00001	<0.00001
PCB207	<0.00001	<0.00001	<0.00001
PCB208	<0.00001	<0.00001	<0.00001
PCB209	<0.00001	<0.00001	0.00002

Table A27
Predisposal Dissolved Aroclor and Total PCB in
Pond Water Samples (mg/l)

<u>Aroclor</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
1016	<0.0002	<0.0002	<0.0002
1221	<0.0002	<0.0002	<0.0002
1232	<0.0002	<0.0002	<0.0002
1242	0.0004	0.0006	0.0002
1248	<0.0002	<0.0002	<0.0002
1254	<0.0002	<0.0002	<0.0002
1260	<0.0002	<0.0002	<0.0002
Total PCB	0.0004	0.0008	0.0003

Table A28
Postdisposal Dissolved PCB Congeners in Pond Water
Samples (mg/l)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB 7	<0.00001	<0.00001	<0.00001
PCB 8	<0.00001	<0.00001	<0.00001
PCB 15	0.00009	0.00008	0.00006
PCB 18	0.00003	0.00003	0.00002
PCB 28	0.00007	0.00006	<0.00001
PCB 31	0.00002	0.00001	0.00001
PCB 40	<0.00001	<0.00001	<0.00001
PCB 44	0.00002	0.00002	0.00001
PCB 49	0.00002	0.00002	0.00001
PCB 50	0.00007	0.00006	0.00003
PCB 52	0.00008	0.00008	0.00003
PCB 54	<0.00001	<0.00001	<0.00001
PCB 60	0.00001	0.00001	<0.00001
PCB 70	0.00002	0.00003	0.00001
PCB 77	<0.00001	<0.00001	<0.00001
PCB 82	0.00001	0.00001	<0.00001
PCB 86	0.00001	0.00001	0.00001
PCB 87	0.00001	0.00001	0.00001
PCB 97	0.00001	0.00001	0.00001
PCB101	0.00004	0.00003	0.00002
PCB103	<0.00001	<0.00001	<0.00001
PCB105	0.00001	<0.00001	<0.00001
PCB114	<0.00001	<0.00001	<0.00001
PCB118	0.00001	0.00001	0.00001
PCB121	<0.00001	<0.00001	<0.00001
PCB128	<0.00001	<0.00001	<0.00001
PCB129	<0.00001	<0.00001	<0.00001

(Continued)

Table A28 (Concluded)

<u>Congener</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 3</u>
PCB136	<0.00001	<0.00001	<0.00001
PCB137	<0.00001	<0.00001	<0.00001
PCB138	0.00001	<0.00001	<0.00001
PCB141	<0.00001	<0.00001	<0.00001
PCB143	<0.00001	<0.00001	<0.00001
PCB151	<0.00001	<0.00001	<0.00001
PCB153	0.00001	0.00001	<0.00001
PCB154	<0.00001	0.00001	<0.00001
PCB156	0.00001	<0.00001	<0.00001
PCB159	<0.00001	<0.00001	<0.00001
PCB167	<0.00001	<0.00001	<0.00001
PCB170	<0.00001	<0.00001	<0.00001
PCB171	<0.00001	<0.00001	<0.00001
PCB173	<0.00001	<0.00001	<0.00001
PCB180	<0.00001	<0.00001	<0.00001
PCB182	<0.00001	<0.00001	<0.00001
PCB183	<0.00001	<0.00001	<0.00001
PCB185	<0.00001	<0.00001	<0.00001
PCB187	0.00001	<0.00001	0.00001
PCB189	<0.00001	<0.00001	<0.00001
PCB191	<0.00001	<0.00001	<0.00001
PCB194	<0.00001	<0.00001	<0.00001
PCB195	<0.00001	<0.00001	<0.00001
PCB196	<0.00001	<0.00001	<0.00001
PCB200	<0.00001	<0.00001	<0.00001
PCB201	<0.00001	<0.00001	<0.00001
PCB202	<0.00001	<0.00001	<0.00001
PCB203	<0.00001	<0.00001	<0.00001
PCB205	<0.00001	<0.00001	<0.00001
PCB206	<0.00001	<0.00001	<0.00001
PCB207	<0.00001	<0.00001	<0.00001
PCB208	<0.00001	<0.00001	<0.00001
PCB209	<0.00001	<0.00001	<0.00001

Introduction

1. The equilibrium distribution of polychlorinated biphenyls between water and sediment solids is typically represented by a constant termed the distribution coefficient (Thibodeaux 1979*). Hill, Myers, and Brannon (1988) present the essential aspects of the theory of these distribution coefficients as they apply to confined disposal facilities.

2. Sequential batch leach tests have been used in previous studies to determine distribution coefficients for polluted sediments from Indiana Harbor, Indiana (Environmental Laboratory 1987), New Bedford Harbor, Massachusetts (Myers and Brannon 1988), and Everett Bay, Washington (Palermo et al. 1989). Some of the results of these studies as they apply to this study are summarized below.

Kinetic testing

3. Kinetic testing has been conducted in previous studies to determine the shaking time needed to achieve steady-state conditions during batch leaching tests. These tests were not designed to investigate kinetics of desorption per se but to determine if a 24-hr shake time was adequate. In each study it was shown that contaminant concentrations in leachate at shake times longer than 24 hr were either not significantly different from the concentration obtained for the 24-hr shake time or were lower. These studies provide the basis for using a 24-hr shake time in this study. The literature relationships against which the distribution coefficients determined in this study were compared were all based on batch equilibria obtained at 24 hr of shaking or less.

Liquid-solids ratio testing

4. The primary objective of sequential batch leach testing in previous studies was to estimate leachate quality for disposal alternatives involving CDFs. Because the liquid-solids ratio in dredged material following sedimentation in a CDF is approximately 1:1, testing at various liquid-solids ratios has been conducted to determine the lowest practical liquid-solids ratio for batch testing. Previous experience has shown that a 4:1 liquid-solids ratio is the lowest practical ratio for conducting batch leach tests with dredged

* See References at the end of the main text.

material. A 4:1 liquid-solids ratio was used in this study to provide a consistent basis for comparison with previous leaching studies of polluted dredged material.

Sequential versus single batch testing

5. Sequential batch leach tests have been used in previous studies of polluted sediments to evaluate the constancy of distribution coefficients. During sequential batch leaching of Indiana Harbor sediment, distribution coefficients were constant, while distribution coefficients were not constant during sequential batch leaching of Everett Bay and New Bedford Harbor sediments. The nonconstant distribution coefficients during sequential leaching of estuarine sediments were caused by dispersion of sediment colloids as salt was washed out. Since ionic strength does not change significantly during sequential leaching of freshwater sediments, distribution coefficients remain constant.

6. Although previous experience with PCB-contaminated freshwater sediment has shown that distribution coefficients are constant and could be determined without sequential leaching, this experience is limited to one sediment. As a check for deviation from previous results, a four-cycle sequential batch leach procedure was used in this study. The results confirmed previous findings.

Data Presentation

7. The sequential batch leach data tables are organized as follows:

<u>No.</u>	<u>Description</u>
B1	PCB and TOC Concentrations in Saginaw Dredged Material Used in Sequential Batch Leach Tests
B2	Steady-State PCB Solid Phase Concentrations in Saginaw Dredged Material During Sequential Leaching
B3	Steady-State PCB and DOC Aqueous Phase Concentrations in Saginaw Dredged Material During Sequential Leaching
B4	PCB Distribution Coefficients for Saginaw Dredged Material

Calculation of Distribution Coefficients

8. The PCB desorption isotherm data from the Indiana Harbor study (Environmental Laboratory 1987) tended to cluster around a single point instead of plotting as a well-defined isotherm. The sequential batch leach data for Saginaw River dredged material also showed this clustering effect. Clustering indicates large distribution coefficients that are constant. When the distribution coefficient is large and constant, the aqueous phase contaminant concentration is small and relatively constant throughout the leaching sequence due to partitioning. Clustered desorption isotherms result because the differences in aqueous phase contaminant concentrations are within the noise level of the combined variability of batch leaching and the chemical analytical procedures.

9. To calculate a meaningful distribution coefficient when clustered desorption isotherms are obtained, two assumptions are necessary. First, the bulk sediment PCB is assumed to be completely leachable, i.e., there is no fraction resistant to leaching. Second, the batch data are assumed to cluster about some value that represents the overall or net distribution coefficient for the sequential leaching. These assumptions were used to calculate distribution coefficients in this study. Each distribution coefficient in Table B4 is the mean of four single-point distribution coefficients, one for each cycle in the sequential leach procedure.

Table B1

PCB and Total Organic Carbon Concentrations in Saginaw River
Dredged Material Used in Sequential Batch Leach Tests

<u>Parameter</u>	<u>Concentration</u> <u>mg/kg</u>
PCB 7	<0.002
PCB 8	0.035
PCB 15	0.219
PCB 18	0.076
PCB 28	0.084
PCB 31	0.069
PCB 40	0.011
PCB 44	0.039
PCB 49	0.057
PCB 50	0.080
PCB 52	0.079
PCB 54	<0.002
PCB 60	0.012
PCB 70	0.023
PCB 77	0.037
PCB 82	0.006
PCB 86	<0.002
PCB 87	0.007
PCB 97	0.007
PCB 101	0.018
PCB 103	0.005
PCB 105	0.007
PCB 114	<0.002
PCB 118	0.007
PCB 121	<0.002
PCB 128	0.002
PCB 129	<0.002
PCB 136	0.028
PCB 137	<0.002
PCB 138	0.013
PCB 141	<0.002
PCB 143	<0.002
PCB 151	0.002
PCB 153	0.009
PCB 154	<0.002
PCB 156	0.003
PCB 159	0.006
PCB 167	<0.002
PCB 170	0.005
PCB 171	<0.002
PCB 173	<0.002
PCB 180	0.005
PCB 182	0.003
PCB 183	0.002
PCB 185	<0.002

(Continued)

Table B1 (Concluded)

<u>Parameter</u>	<u>Concentration</u> <u>mg/kg</u>
PCB 187	0.006
PCB 189	<0.002
PCB 191	<0.002
PCB 194	0.002
PCB 195	0.002
PCB 196	0.002
PCB 200	<0.002
PCB 201	0.003
PCB 202	<0.002
PCB 203	0.003
PCB 205	<0.002
PCB 206	<0.002
PCB 207	<0.002
PCB 208	<0.002
PCB 209	<0.002
Aroclor 1016	<0.01
Aroclor 1221	<0.01
Aroclor 1232	<0.01
Aroclor 1242	0.93
Aroclor 1248	<0.01
Aroclor 1254	<0.01
Aroclor 1260	0.08
Total PCB	0.87
Total organic carbon	24,232

Table B2

Steady-State PCB Solid Phase Concentrations (mg/kg) in Saginaw River
Dredged Material During Sequential Batch Leaching

Parameter	Sequential Leach Number				
	1	2	3	4	
PCB 07		Not present			
PCB 08	0.0350	0.0346	0.0345	0.0343	
PCB 15	0.2189	0.2188	0.2187	0.2187	
PCB 18	0.0759	0.0758	0.0758	0.0757	
PCB 28	0.0839	0.0839	0.0839	0.0839	
PCB 31	0.0689	0.0688	0.0688	0.0687	
PCB 40		Not released			
PCB 44	0.0390	0.0389	0.0389	0.0388	
PCB 49	0.0569	0.0569	0.0568	0.0567	
PCB 50	0.0799	0.0798	0.0797	0.0795	
PCB 52	0.0789	0.0787	0.0786	0.0784	
PCB 54		Not present			
PCB 60		Not released			
PCB 70	0.0230	0.0229	0.0229	0.0228	
PCB 77	0.0370	0.0370	0.0369	0.0369	
PCB 82	0.0060	0.0060	0.0060	0.0060	
PCB 86	0.0060	0.0060	0.0060	0.0060	
PCB 87	0.0060	0.0060	0.0059	0.0059	
PCB 97	0.0070	0.0070	0.0069	0.0069	
PCB 101	0.0180	0.0179	0.0179	0.0178	
PCB 103		Not released			
PCB 105	0.0070	0.0070	0.0070	0.0069	
PCB 114		Not present			
PCB 118	0.0070	0.0070	0.0069	0.0068	
PCB 121		Not present			
PCB 128		Not released			
PCB 129		Not present			
PCB 136	0.0280	0.0280	0.0280	0.0279	
PCB 137		Not present			
PCB 138	0.0130	0.0129	0.0129	0.0129	
PCB 141		Not present			
PCB 143		Not present			
PCB 151		Not released			
PCB 153	0.0090	0.0090	0.0089	0.0088	
PCB 154		Not present			
PCB 156		Not released			
PCB 159		Not released			
PCB 167		Not present			
PCB 170		Not released			
PCB 171		Not present			
PCB 173		Not present			
PCB 180		Not released			
PCB 182		Not released			
PCB 183		Not released			
PCB 185		Not present			

(Continued)

Table B2 (Concluded)

Parameter	Sequential Leach Number			
	1	2	3	4
PCB 187		Not released		
PCB 189		Not present		
PCB 191		Not present		
PCB 194		Not released		
PCB 195		Not released		
PCB 196		Not released		
PCB 200		Not present		
PCB 201		Not released		
PCB 202		Not present		
PCB 203		Not released		
PCB 205		Not present		
PCB 206		Not present		
PCB 207		Not present		
PCB 208		Not present		
PCB 209		Not present		
Aroclor 1016		Not present		
Aroclor 1221		Not present		
Aroclor 1232		Not present		
Aroclor 1242	0.9293	0.9272	0.9261	0.9237
Aroclor 1248		Not present		
Aroclor 1254		Not present		
Aroclor 1260		Not released		
Total PCB	0.8692	0.8675	0.8668	0.8644

Table B3

Steady-State PCB and Dissolved Organic Carbon Aqueous Phase Concentrations [mg/L (standard error)]
in Saginaw River Dredged Material During Sequential Leaching

Parameter	Sequential Leach Number			
	1	2	3	4
C07	<0.00001	<0.00001	<0.00001	<0.00001
C08	0.00007(0.000007)	0.00010(0.00005)	0.00003(0.00002)	0.00003(0.00003)
C15	0.00004(0.00002)	0.00002(0.00002)	0.000003(0.000003)	<0.00001
C18	0.00002(0.00003)	0.00002(0.000009)	0.000007(0.000003)	0.00002(0.000007)
C28	0.00001(0.00001)	<0.00001	<0.00001	<0.00001
C31	0.00001(0.000007)	0.00003(0.000003)	0.00002(0.00)	0.00003(0.000003)
C40	<0.00001	<0.00001	<0.00001	<0.00001
C44	0.00001(0.000006)	0.00001(0.000003)	0.000007(0.000003)	0.00001(0.000003)
C49	0.00002(0.000009)	0.00002(0.00001)	0.00001(0.000006)	0.00002(0.000007)
C50	0.00002(0.00001)	0.00003(0.00002)	0.00003(0.000007)	0.00004(0.00002)
C52	0.00002(0.00001)	0.00005(0.000009)	0.00003(0.000007)	0.00005(0.00003)
C54	<0.00001	<0.00001	<0.00001	<0.00001
C60	<0.00001	<0.00001	<0.00001	<0.00001
C70	0.000007(0.000003)	0.00002(0.000003)	0.00001(0.000003)	0.00002(0.000007)
C77	<0.00001	0.00007(0.000007)	0.000007(0.000007)	<0.00001
C82	0.000007(0.000003)	<0.00001	<0.00001	0.000003(0.000003)
C86	0.000003(0.000003)	<0.00001	<0.00001	<0.00001
C87	<0.00001	0.00001(0.00)	0.000003(0.000003)	0.00001(0.000006)
C97	<0.00001	0.00001(0.00)	0.000003(0.000003)	0.00001(0.000007)
C101	0.000007(0.000003)	0.00001(0.000006)	0.000003(0.000003)	0.00003(0.00001)
C103	<0.00001	<0.00001	<0.00001	<0.00001
C105	<0.00001	0.00001(0.00)	<0.00001	0.000007(0.000003)
C114	<0.00001	<0.00001	<0.00001	<0.00001
C118	<0.00001	0.00001(0.00)	0.00001(0.00)	0.00002(0.000006)
C121	<0.00001	<0.00001	<0.00001	<0.00001
C128	<0.00001	<0.00001	<0.00001	<0.00001
C129	<0.00001	<0.00001	<0.00001	<0.00001
C136	<0.00001	0.000007(0.000007)	0.000003(0.000003)	0.000003(0.000003)
C137	<0.00001	<0.00001	<0.00001	<0.00001
C138	0.000003(0.000003)	0.00001(0.00)	<0.00001	0.00001(0.000006)
C141	<0.00001	<0.00001	<0.00001	<0.00001
C143	<0.00001	<0.00001	<0.00001	<0.00001
C151	<0.00001	<0.00001	<0.00001	<0.00001
C153	0.000007(0.000003)	0.000003(0.000003)	0.000007(0.000003)	0.00002(0.00001)
C154	<0.00001	<0.00001	<0.00001	<0.00001
C156	<0.00001	<0.00001	<0.00001	<0.00001
C159	<0.00001	<0.00001	<0.00001	<0.00001
C167	<0.00001	<0.00001	<0.00001	<0.00001
C170	<0.00001	<0.00001	<0.00001	<0.00001
C171	<0.00001	<0.00001	<0.00001	<0.00001
C173	<0.00001	<0.00001	<0.00001	<0.00001
C180	<0.00001	<0.00001	<0.00001	<0.00001
C182	<0.00001	<0.00001	<0.00001	<0.00001
C183	<0.00001	<0.00001	<0.00001	<0.00001
C185	<0.00001	<0.00001	<0.00001	<0.00001
C187	<0.00001	<0.00001	<0.00001	<0.00001
C189	<0.00001	<0.00001	<0.00001	<0.00001
C191	<0.00001	<0.00001	<0.00001	<0.00001
C194	<0.00001	<0.00001	<0.00001	<0.00001
C195	<0.00001	<0.00001	<0.00001	<0.00001
C196	<0.00001	<0.00001	<0.00001	<0.00001
C200	<0.00001	<0.00001	<0.00001	<0.00001
C201	<0.00001	<0.00001	<0.00001	<0.00001
C202	<0.00001	<0.00001	<0.00001	<0.00001
C203	<0.00001	<0.00001	<0.00001	<0.00001
C205	<0.00001	<0.00001	<0.00001	<0.00001
C206	<0.00001	<0.00001	<0.00001	<0.00001
C207	<0.00001	<0.00001	<0.00001	<0.00001
C208	<0.00001	<0.00001	<0.00001	<0.00001
C209	<0.00001	<0.00001	<0.00001	<0.00001
Aroclor 1016	<0.0002	<0.0002	<0.0002	<0.0002
Aroclor 1221	<0.0002	<0.0002	<0.0002	<0.0002
Aroclor 1232	<0.0002	<0.0002	<0.0002	<0.0002
Aroclor 1242	0.0002(0.00009)	0.0005(0.00003)	0.0003(0.00007)	0.0006(0.0002)
Aroclor 1248	<0.0002	<0.0002	<0.0002	<0.0002
Aroclor 1254	<0.0002	<0.0002	<0.0002	<0.0002
Aroclor 1260	<0.0002	<0.0002	<0.0002	<0.0002
Total PCB	0.0002(0.0001)	0.0004(0.00003)	0.0002(0.00009)	0.0006(0.0002)
DOC	21.0(1.0)	18.9(3.8)	13.8(0.1)	18.5(0.9)

Table B4

PCB Distribution Coefficients for Saginaw River Dredged Material

<u>Parameter</u>	<u>Distribution Coefficient</u> (<u>l/kg</u>)
PCB 7	Not present
PCB 8	703
PCB 15	11,096
PCB 18	632
PCB 28	2,100
PCB 31	3,031
PCB 40	>1,100
PCB 44	3,315
PCB 49	2,956
PCB 50	2,660
PCB 52	2,438
PCB 54	Not present
PCB 60	>1,200
PCB 70	1,780
PCB 77	1,850
PCB 82	600
PCB 86	Not present
PCB 87	642
PCB 97	583
PCB 101	1,286
PCB 103	>500
PCB 105	700
PCB 114	Not present
PCB 118	598
PCB 121	Not present
PCB 128	>200
PCB 129	Not present
PCB 136	2,333
PCB 137	Not present
PCB 138	1,192
PCB 141	Not present
PCB 143	Not present
PCB 151	>200
PCB 153	733
PCB 154	Not present
PCB 156	>300
PCB 159	>600
PCB 167	Not present
PCB 170	>500
PCB 171	Not present
PCB 173	Not present
PCB 180	>500
PCB 182	>300
PCB 183	>200
PCB 185	Not present
PCB 187	>600

(Continued)

Table B4 (Concluded)

<u>Parameter</u>	<u>Distribution Coefficient (ℓ/kg)</u>
PCB 189	Not present
PCB 191	Not present
PCB 194	>200
PCB 195	>200
PCB 196	>200
PCB 200	Not present
PCB 201	>300
PCB 202	Not present
PCB 203	>300
PCB 205	Not present
PCB 206	Not present
PCB 207	Not present
PCB 208	Not present
PCB 209	Not present
Aroclor 1016	Not present
Aroclor 1221	Not present
Aroclor 1232	Not present
Aroclor 1242	2,757
Aroclor 1248	Not present
Aroclor 1254	Not present
Aroclor 1260	>400
Total PCB	2,639

19. ABSTRACT (Continued).

Ammonia-nitrogen concentrations in the CDF pond water increased, as expected, during disposal operations relative to predisposal concentrations, and suspended solids concentrations in the CDF pond water decreased during disposal operations relative to predisposal concentrations. Pond water suspended solids concentrations did not increase during disposal operations, as might be expected, because most of the solids in the influent dredged material were removed by deposition on previously existing dredged material deltas and deltas that formed beneath the dredged material discharge pipe during disposal operations.

The PCB concentrations were relatively low in the dredged material and in the pond water samples. Total PCB in the influent solids averaged 0.90 mg/kg. The CDF pond water total PCB ranged from <0.0002 to 0.0011 mg/l in whole water samples and from <0.0002 to 0.0004 mg/l in filtered samples. Total PCB in most of the whole water and filtered samples was below the detection limit of 0.0002 mg/l total PCB.

Polychlorinated biphenyl congener-specific analysis (60 congeners) was used to obtain better quantification of PCBs than could be obtained using aroclor or total PCB analysis. The PCB congener-specific data showed that pond water PCB levels were slightly increased relative to pond water PCB levels prior to disposal operations. Congener C15 (4,4'-dichlorobiphenyl) was the most abundant PCB congener in the dredged material influent solids and in the pond water. Congener C15 concentrations in CDF pond water ranged from <0.00001 to 0.00028 mg/l in whole water samples and from <0.00001 to 0.00009 mg/l in filtered samples. Congener C15 concentrations in predisposal samples were below the detection limit (0.00001 mg/l).

Two procedures for predicting dissolved PCB concentrations in CDF pond water were evaluated--the modified elutriate test and simple equilibrium partitioning between suspended solids and pond water. Predictions based on modified elutriate testing and simple equilibrium partitioning using site-specific distribution coefficients were similar, and generally within a factor of 2 to 3 of the observed concentrations.

Based on PCB congener concentrations in pond water samples collected near the dike, dissolved PCB release during disposal operations was approximately 1.0 g/day, and combined dissolved and particulate PCB release was 2.6 g/day. These estimates assume that the dike is transparent to PCB transport, that is, sorption, filtration, and bioabsorption/biodegradation in the dike are not accounted for. The containment efficiency of the Saginaw CDF during disposal operations was 99.82 percent, assuming the dike is transparent to transport of both dissolved and particulate PCB in the pond water, and 99.93 percent assuming the dike conducts dissolved PCB only. These assumptions constitute a worst-case scenario that neglects filtration and sorption in the dike.