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EVALUATION OF HOPPER LOADING AND OVERFLOW
FOR SAGINAW RIVER, MICHIGAN

by

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Preface

This report describes an evaluation of hopper dredge loading and overflow characteristics on the Saginaw River, Michigan. This work 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-87-0057, 13 March 1987, and No. NCE-IA-88-0005, 19 October 1987. The Detroit District Project Manager for the study was Ms. Pam Bedore. Publication of the report was funded through the Dredging Operations Technical Support Program (DOTS). Dr. Robert M. Engler was Program Manager of DOTS.

The report was prepared by Dr. Michael R. Palermo, Research Projects Group, Environmental Engineering Division (EED), EL, and Dr. Robert E. Randall, Texas A&M University, who participated under an Intergovernmental Personnel Act Agreement. Dr. Robert N. Havis, Water Resources Engineering Group (WREG), EED, developed the study plan. The field sampling and a portion of the testing for this study were performed by Canton Analytical Laboratory, Ypsilanti, MI, under contract to the Detroit District. Assistance in field monitoring and field processing of samples was provided by Mr. Mark E. Zappi and Mr. Sydney B. Ragsdale, Water Supply and Waste Treatment Group (WSWTG), EED; Dr. Havis; and Ms. Bedore. The analysis of PCBs was performed by the Analytical Laboratory Group (ALG), EED, under the supervision of Ms. Ann B. Strong. Technical review of this report was provided by Ms. Bedore; Mr. Donald F. Hayes, WREG, EED; Mr. Tommy E. Myers, WSWTG, EED; and Mr. Alan M. Teeter, Estuaries Division, Hydraulics Laboratory, WES. Dr. Palermo served as WES study coordinator.

This study was conducted under the direct supervision of Dr. Raymond L. Montgomery, Chief, EED, and under the general supervision of Dr. John Harrison, Chief, EL.

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

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Conversion Factors, Non-SI to SI (Metric)
Units of Measurement

Non-SI units of measurement used in this report can be converted to SI
(metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
tons (2,000 pounds, mass)	907.1847	kilograms

EVALUATION OF HOPPER LOADING AND OVERFLOW FOR
SAGINAW RIVER, MICHIGAN

Introduction

Background

1. The US Army Engineer District, Detroit, maintains a navigation channel with authorized depths of 22 to 27 ft* in the Saginaw River near Saginaw, MI. A location map and layout of the channels is shown as Figure 1. In recent years, the concentrations of metals and polychlorinated biphenyls (PCBs) in the sediments from some reaches of the channel have exceeded criteria for unrestricted open-water disposal adopted by Region V of the US Environmental Protection Agency (USEPA). The sediments that exceed these criteria are placed in the confined disposal facility (CDF) shown in Figure 1. The upper reaches of the channel contain generally sandy sediments, while the lower reaches of the channel contain generally fine-grained sediments.

2. A hopper dredge is normally used to dredge the Saginaw channel. Hopper dredges are self-propelled ships equipped with propulsion machinery, hoppers for dredged material storage, and dredge pumps. Dredged material is hydraulically raised through trailing dragarms in contact with the channel bottom and is discharged into the hoppers. The material is then held in the hoppers until placed at the disposal site. While most hopper dredges are equipped with bottom doors or split hulls for release of material at open-water sites, some are equipped for pumpout of material to CDFs (US Army Corps of Engineers 1983).

3. Hopper dredges pump material until the hoppers are filled and may continue to pump past the point of hopper overflow to increase the load. During this overflow process, solids are retained in the hopper while low-density supernatant overflows back into the waterway. When dredging coarse-grained sediments (sediments with high percentages of sand) or consolidated clay sediments, the potential for load increase during hopper overflow is high. For fine-grained maintenance sediments (unconsolidated silts and clays), there is

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

less potential for load increase during hopper overflow. The practice of overflow to achieve a higher density load is sometimes referred to as economic loading.

4. Overflow of the hopper is sometimes practiced when dredging the Saginaw channel to increase the load of solids for transport to the disposal area. The Detroit District has initiated a policy of no overflow in reaches of the channel where sediment PCB concentrations exceed 10 mg/kg (dry weight). However, there is concern over the possible impact of overflow from hopper dredging operations when sediments are dredged from other reaches of the channel where sediment PCB concentrations are less than 10 mg/kg.

Purpose and scope

5. The purpose of this report is to describe the results of an evaluation of hopper loading and overflow characteristics on the Saginaw River. The evaluation was conducted during August and September 1987 and was designed to evaluate the effectiveness of increasing the hopper load during overflow and to determine the physical and chemical characteristics of the overflow for the Saginaw project. The study was a cooperative effort between the US Army Engineer District, Detroit, and the US Army Engineer Waterways Experiment Station (WES).

6. Area I, shown in Figure 1, was identified by the Detroit District as representative of upstream reach conditions (generally coarse sediments). Area II, also shown in Figure 1, was identified as representative of downstream reach conditions (generally fine sediments). Three hopper loading cycles were monitored and sampled for the study during routine maintenance dredging operations, one in Area I and two in Area II. The loading characteristics of the dredge before and during overflow were monitored using onboard instrumentation. Samples of inflow, hopper contents, and overflow were collected during filling and overflow and analyzed for both physical and chemical characteristics. Samples were also taken in the channel water column to define the plume characteristics for both overflow and nonoverflow conditions. Since sediments in the upper reach of the project were known to have very low levels of contamination, chemical testing was limited to samples collected in the lower reach.

Dredging Equipment and Operations

Dredging operations

7. The North American Trailing Company was the dredging contractor for maintenance of the Saginaw project during this study. The split-hull hopper dredge *Dodge Island*, shown in Figure 2, performed the work. The *Dodge Island* has a hopper capacity of 3,600 cu yd, a suction pipe diameter of 27 in., and a discharge pipe diameter of 24 in. The dredge is equipped to pump out residual water in the hopper prior to filling and to pump out the loaded hoppers into designated disposal areas. Movable water jets mounted above the hopper can be used to aid pumpout of coarser materials from the hopper. Overflow can be discharged over the sides of the hopper or through adjustable-height, funnel-shaped weirs arranged inside the hopper which discharge below the vessel. A schematic diagram of the overflow weirs and inflow boxes is shown as Figure 3. The *Dodge Island* is equipped with loading instrumentation that provides a continuous record of hopper load as a function of time.

8. Three loading cycles were monitored and sampled for this study. Loads 18 and 19 were taken on 18 August in the lower or downstream reach of the project (within Area II indicated on Figure 1). Load 119 was taken on 11 September in the upstream reach of the project (within Area I indicated on Figure 1). Load 119 was taken within the reach with generally coarser sediments, so an increase in load with overflow was expected. Loads 18 and 19 were taken within the reach of generally finer sediments, and therefore a lesser increase in load was expected. Load 19 was taken with no overflow.

9. No special controls were exercised over the dredging operations for this study. The dredging was conducted as the contractor normally would, within the constraints of the water quality certification and according to the contractor's judgment to maximize economic loading. Within the upper reach of the project (generally coarser material and longer haul distance), the contractor allowed the hoppers to overflow to achieve economic load. Within the lower reach in which overflow was allowed (generally finer material and shorter haul distance), the contractor preferred not to overflow for "economic reasons," but was requested to overflow for a limited time for purposes of this study. However, the overflow period was limited to approximately 6 min. This severely limited not only the amount of overflow data for the lower reach but also the conclusions that can be drawn from the study.

Hopper loading characteristics

10. Area I - upstream reach. The loading diagram for Load 119 taken in Area I in the upper reach is illustrated in Figure 4. The load after pumpout of residual water was approximately 3,550 tons at 1419 hr. Dredging began at approximately 1425 hr, and the load increased gradually to 6,000 tons at 1450 hr. Overflow began at 1452 hr. Between 1452 and 1723 hr, the load varied as dredging continued. The load had increased to 6,550 tons at 1723 hr when overflow dredging was stopped. These results show overflow did increase the load, but the load increase was highly variable. The cause of hopper load variability may be due to decanting of water by adjusting weir heights within the hopper, changing sediment conditions at the draghead due to draghead elevation, changing sediment characteristics, or bottom bathymetry.

11. A tabular summary of load during the overflow dredging cycle for Load 119 is presented as Table 1. These results show that the percent load increase was highly variable and ranged between 4.1 and 55.1 percent during an overflow period of approximately 90 min. As described above, the variability of load increase could be due to decanting water by adjusting the weir heights within the hopper. For this test, the overflow resulted in a final increase in load of 22.5 percent.

12. Area II - downstream reach. Figure 5 shows the loading chart for Loads 18 and 19 taken in Area II in the lower reach. At chart time 1207 hr, the dredge began pumpout of residual water in preparation for the dredging process. Dredging began at 1212 hr when the load minimum was 3,400 tons. Between 1212 and 1300 hr, the load varied as dredging continued. The load had increased to 6,500 tons at 1,300 hr, at which time the dredge began sailing to the disposal site. The load chart for Load 19 (which was not sampled) is also shown at the top of Figure 5. This cycle did not overflow, but the loading line is similar to that for Load 18.

13. Since Area II sediments were considered fine-grained, it was expected that overflow would not significantly increase the hopper load because the fine-grained material would not settle out in the hopper. The loading data confirm that no increase in the load was attained with overflow for this load. However, the overflow period was very short (approximately 6 min) and perhaps was too short to establish an effect.

Dredged Material and Overflow Characteristics

Sample collection and testing

14. Sampling, testing for physical characteristics, and chemical analysis for all parameters except PCBs were performed by Canton Analytical Laboratory (CAL), Ypsilanti, MI, under contract to the Detroit District. Detailed test data are contained in a report prepared by CAL (1987). All samples except those for PCB analyses were taken directly to the CAL for testing. Samples for PCB analyses were collected by CAL and immediately delivered to Corps personnel for processing. Processing consisted of phase separation by centrifugation and filtration using glass filters, performed at the Saginaw Area Office. The separated samples were then transported to the WES Analytical Laboratory Group. Prior to analysis, the volumes of settled sediment and supernatant water were measured on the sediment samples. A total water analysis was conducted on the supernatant water, and a sediment analysis (dry weight concentration) was conducted on the sediment sample. The detailed test data for these samples are presented in Appendix A of this report.

Sediment and water characterization

15. In situ sediment. Grab samples of in situ sediments from Areas I and II were taken with a Ponar dredge sampler. Fifteen stations evenly distributed throughout each reach were sampled. Material from all stations in Area I was composited for physical characterization. Material from Area II stations was composited into three samples for physical characterization, sediment chemical inventory, and elutriate testing. Results for Atterberg limits and sediment chemical inventory are shown in Table 2 and Figure A1 (Appendix A).

16. The mean total PCB concentration in the Area II composite sediment samples was 0.67 mg/kg, which would qualitatively classify the sediment as nonpolluted with respect to total PCB according to USEPA Region V criteria. The metals concentrations shown in Table 2 would qualitatively classify the sediment as moderately to heavily polluted with respect to metals according to USEPA Region V criteria.

17. The grain size distribution ranges for the composite sediment samples from Area I and II are illustrated in Figure 6. Both areas appear to have very similar distributions, having a sand fraction of 20 to 38 percent (coarser than the No. 200 sieve) with the remainder silts and clays. Sediment

from both areas would be classified as silt (MH) based on the Unified Soil Classification System. The D_{50} (grain size for which 50 percent of the particles by weight are finer) varied from 0.017 to 0.035 mm for Area I and from 0.017 to 0.025 mm for Area II. Thus, the data indicate that the sediments in Area I are only slightly coarser than those in Area II. Therefore, it is doubtful that the sediment types in the two areas are different enough to compare the effect of overflow dredging in a sandy and silty area.

18. Background water. A water sample was taken from Area II to provide an estimate of background chemical concentrations and for use in elutriate testing. The sample was taken with a Kemmerer sampler at a depth in the water column 3 ft above the bottom. Background chemical concentrations are shown in Table 3 and Figure A2.

Physical characteristics of inflow and overflow

19. Sampling. Samples of hopper inflow and overflow were taken using a bucket suspended by a rope. The samples were then transferred to appropriate containers for transport to the laboratory. Inflow sampling intervals were set at 3 min from the start of dredging. Overflow sample intervals were set at 5 min for Area I (upstream) and 1 min for Area II (downstream) due to the anticipated periods of overflow.

20. Solids concentrations. The observed suspended solids concentrations for inflow and overflow for Areas I and II are plotted in Figures 7 and 8, respectively. For Area I (Load 119 in the upper reach), the concentration of inflow varied, with an average value of 76 g/l. The concentrations of overflow showed less variability, with an average of 48 g/l, or 63 percent of the inflow concentration. The generally higher concentrations in inflow as compared with overflow indicate some retention of solids in the hopper, consistent with the loading data. For Area II (Load 18 in the lower reach), the concentration of inflow varied, with an average of 64 g/l. The overflow was limited to only a few minutes, but averaged 37 g/l, 60 percent of the inflow concentration. However, the period of overflow was too short to support any hard conclusions regarding retention of suspended solids during overflow.

21. Grain size distributions. The grain size distributions for overflow samples for both areas are shown in Figure 9 and were found to be similar, having a sand fraction of 0 to 38 percent (coarser than No. 200 sieve). The D_{50} for Area I overflow was approximately 0.008 mm, while the D_{50} for

overflow for Area II was approximately 0.009 mm. These values are finer as compared to the D_{50} of sediment samples. This indicates retention of coarser particles in the hopper during overflow for both Area I and Area II.

Chemical characteristics of inflow and overflow

22. The concentrations of metals and PCB congeners were measured for composite samples of inflow and overflow for the Area II reach only. The metals data are available in the Canton Analytical Laboratory (1987) report. Metals concentrations are reported in terms of total water concentrations. The PCB analyses were performed by WES and were determined for sediment, total water, and dissolved phases for individual PCB congeners.

23. Metals. The total concentrations of metals for inflow and overflow, expressed in milligrams per litre, are shown in Table 4. Three composite samples of inflow were taken. Due to the short duration of overflow, only one composite sample was taken. These data indicate that, for the metals, overflow concentrations ranged from 61 to 75 percent of the inflow concentrations. Since these parameters are closely associated with the suspended solids, the low retention of metals in the hopper is consistent with the retention of suspended solids.

24. PCBs. Analyses for 60 PCB congeners were conducted on the sediment, total water, and dissolved phases of the inflow and overflow samples. Sediment concentrations were determined by analysis of the suspended solids in the samples on a dry weight basis in milligrams per kilogram. Total water concentrations were determined by analysis of unfiltered water decanted from the samples, obtained after a period of quiescent settling, and are reported in milligrams per litre. Dissolved concentrations were determined on samples that were centrifuged and filtered through 0.1- μ fiberglass filters and are reported in milligrams per litre.

25. The PCB concentrations for all inflow and overflow samples are presented in Figures A4-A9 of Appendix A. For the total water phase, of approximately 60 PCB congeners analyzed, only the seven congeners shown in Table 5 were found in total water samples at concentrations above detection limits, and these were only slightly above detection. For the dissolved phase, no samples had concentrations above the detection limit except for four congeners slightly above the detection limit. These four were also detected in distilled water sample "blanks" prepared in the field (see Figure A3). The

data for sediment concentration (dry weight) for congeners presented in Table 5 are representative of all congeners. Although the values are low, the overflow samples had a consistently higher sediment concentration for most PCB congeners as compared with inflow. These data would indicate that PCBs are associated with the finer solids fractions discharged in the overflow. As with the metals data, low retention of PCBs in the hopper is consistent with low retention of suspended solids. However, the fact that only one sample could be taken limits the conclusions that can be drawn from the data.

Physical characteristics of hopper contents

26. Sampling. Samples of the hopper contents were taken at three stations along the length of the hopper as shown in Figure 10. Samples were taken at three depths: near surface, middepth, and near bottom. Each station was sampled near the beginning of overflow and following overflow. These samples were taken using a device consisting of a section of polyvinyl chloride (PVC) pipe attached to a pole. The PVC pipe section was closed with two rubber stoppers joined with an elastic tube that could be operated by a rope. A diagram of the sampler is shown in Figure 11. Some difficulty was experienced in collecting the samples within the time available, and at one point the sample pole broke. Therefore, samples were not collected at all stations and at all depths for all hopper loads.

27. Solids concentrations. The suspended solids concentrations for hopper contents for Areas I and II are shown plotted in Figures 12 and 13, respectively. The average solids concentrations for the hopper contents samples were approximately 47 and 29 g/l for Areas I and II, respectively. The data are questionable since the hopper contents averages are lower than the respective average inflow or overflow concentrations. The inconsistencies are likely due to the difficulties in collecting representative samples using the PVC sampling device.

28. Grain size distributions. The grain size distributions for the hopper contents in Areas I and II are illustrated in Figure 14. The D_{50} of hopper contents samples was approximately 0.04 mm for both Area I and Area II. Little difference between grain size distributions of samples taken before and after overflow was apparent.

Characteristics of plumes

29. Plume sampling. Plume samples were taken from a small boat, positioned at a fixed station behind the dredge, immediately after it passed during active operation. Samples were taken for background conditions and at time intervals of 1, 3, 5, 7, 9, 12, 15, 20, 25, and 30 min after passage of the dredge. Water depths near surface, middepth, and near bottom were sampled. The samples were taken with peristaltic pumps that ran continuously. Plumes resulting from operation with overflow were sampled in both Areas I and II. A plume resulting from operation without overflow was sampled in Area II. Samples for chemical analysis were taken for the Area II plumes only, and were composited for all depths and for time intervals corresponding to background, 1 to 5 min, 7 to 12 min, and 15 to 30 min after passage of the dredge.

30. Solids concentrations. The suspended solids concentrations of samples taken from the plumes are shown in Figures 15-17. For Area I, the initial concentration in the plume is higher than that for Area II, which is consistent with the longer overflow time. For Area II, the plume concentrations are similar for both overflow and nonoverflow conditions; however, the period of overflow was limited. The concentrations for all plumes drop to approximately 50 mg/l within 20 min of the passage of the dredge. The average background solids concentration in the water column prior to passage of the dredge was approximately 18 mg/l for both Areas I and II.

31. Chemical concentrations. The total concentrations of metals for background and plume samples in milligrams per litre are shown in Tables 6 and 7 for the overflow and nonoverflow plumes, respectively. Most of the metals remained below detection in the plumes. With the exception of manganese for the overflow plume, all parameters returned to background levels within 30 min of the passage of the dredge. Since these parameters are closely associated with the suspended solids, the reduction of metals in the plumes is consistent with reductions of suspended solids concentrations due to dispersion and settling in the water column.

32. Analyses for 60 PCB congeners were conducted on total and dissolved phases of the plume samples and are presented in Figures A10-A21 of Appendix A. The highest PCB concentration found in any plume sample was a total water concentration of 0.0024 ppm for total PCB. For the total water phase, approximately half the congeners were detected in either the background or one of the plume samples. However, there was no consistent pattern to the

concentrations. For example, many of the congeners were detected in the background sample but not in the plume samples. Most of the values were only slightly above detection. For the dissolved phase, only eight congeners were detected. Many of the detected congeners were also detected in distilled water sample "blanks" prepared in the field. For comparison, Table 8 shows the data for the same congeners listed in Table 5 for the inflow and overflow samples. The data in Table 8 are illustrative for all the plume samples. As with the metals data, low concentrations of PCB are consistent with low concentrations of suspended solids in the plumes.

Elutriate testing

33. Samples of sediment and water were used to conduct both standard and modified elutriate tests. The purpose of the standard elutriate testing was to gain data on possible application of the test for prediction of overflow contaminant concentrations. The test was conducted using standard procedures (US Army Corps of Engineers/USEPA 1977). Separate tests were conducted by Canton Analytical Laboratory for metals and by the WES Analytical Laboratory Group for PCBs. These results are presented in Appendix B. Since the data on overflow were limited to a single sample, no statistically valid comparison of overflow and elutriate data was possible.

34. The purpose of modified elutriate testing was to gain data on the potential quality of effluent from the CDF. The test was conducted using standard procedures (Palermo 1986). Separate tests were conducted by CAL for metals and by the WES for PCBs. These data will be used in a companion study pertaining to the CDF. Results are presented in Appendix B.

Conclusions and Recommendations

Conclusions

35. Based on the results of this study, the following conclusions can be made:

- a. A final gain in hopper load of 22.5 percent was realized during an overflow period of approximately 90 min for the load monitored in Area I. No gain was realized for an overflow period of approximately 6 min for the load monitored in Area II.
- b. Suspended solids data for the loads monitored indicate that approximately 40 percent of the solids was retained during overflow. Grain size data indicate some retention of coarser particles in the hopper.

- c. Retention of metals and PCBs in the hopper generally corresponds to that of solids.
- d. Concentrations of solids in both the overflow and nonoverflow plumes were reduced to near-background levels within 20 min of the passage of the dredge. Concentrations of chemical parameters were reduced to near background in a similar manner.

Recommendations

36. Based on the results of this study, the following recommendations are made:

- a. During future maintenance dredging operations, reaches of the channel with coarser sediments should be identified. The loading data for these reaches should be analyzed to better define the load gains due to overflow.
- b. The short duration of overflow in the Area II reach for this study limited the utility of the data on physical and chemical overflow characteristics for this reach. Additional evaluations of the characteristics of inflow and overflow would better define the relative retention of solids and contaminants in the hopper. If such evaluations are conducted, a modification to the dredging contract is recommended to allow the Corps Contracting Officer to control the duration of overflow for the evaluation.

References

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Table 1

Summary of Load Increases for Load 119, Area I

Time Hr	Process	Load tons	Load Increase tons	Percent Increase (Above Initial Dredging Load of 2,450 tons)
1418	Begin dredging	3,550	0	
1452	Overflow begins	6,000	2,450	
1500	Overflow continues	6,750	+750	30.6
1525	Overflow continues	6,900	+900	36.7
1600	Overflow continues	6,100	+100	4.1
1622	Overflow continues	7,150	+1,150	46.9
1635	Overflow continues	6,350	+350	14.3
1652	Overflow continues	7,350	+1,350	55.1
1723	Overflow stopped	6,550	+550	22.5

Table 2

Sediment Metals Concentrations and Related Data

Parameter	Replicate			Mean
	A	B	C	
Total solids, percent	31			
Liquid limits, percent	110	53	73	79
Plastic limits, percent	46	62	34	47
Plasticity index, percent	64	62	39	55
Ammonia, as N, mg/kg	130	160	190	160
Arsenic, total, mg/kg	12	12	11	12
Copper, total, mg/kg	48	48	45	47
Chromium, total, mg/kg	71	52	52	58
Lead, total, mg/kg	58	55	32	48
Manganese, total, mg/kg	940	680	680	767
Nickel, total, mg/kg	32	32	35	33
Zinc, total, mg/kg	550	480	480	503
Total organic carbon, mg/kg	39,700	40,400	54,600	44,900
Oil and grease, mg/kg	<5	<5	<5	<5
Total PCBs, mg/kg	0.67	0.63	0.72	0.67

Table 3
Background Water Sample Chemical Concentrations

Parameter	Concentration mg/l
Ammonia, as N	<0.1000
Arsenic, total	0.0030
Copper, total	<0.0100
Chromium, total	<0.0200
Lead, total	<0.0500
Manganese, total	<0.0600
Nickel, total	<0.0200
Zinc, total	0.0100
Total organic carbon	9.1000
Oil and grease	4.6000
Total suspended solids	40.0000

Table 4
Whole Water Metals Concentrations for Inflow and Overflow

Parameter	Whole Water Concentration		Ratio of Overflow to Inflow percent
	Mean Inflow mg/l	Overflow mg/l	
Arsenic	1.0	0.6	63.0
Copper	3.6	2.2	61.1
Chromium	3.4	2.2	64.7
Lead	3.6	2.4	66.7
Manganese	32.7	23.0	70.3
Nickel	2.1	1.4	66.7
Zinc	25.3	19.0	75.1

Table 5
Concentrations of Selected PCB Congeners in Inflow and Overflow

Parameter	Sediment		Total Water	
	Inflow mg/kg	Overflow mg/kg	Inflow mg/l	Overflow mg/l
PCB 7	<0.002	<0.002	0.00020	<0.00001
PCB 28	0.06500	0.11000	0.00008	0.00002
PCB 40	0.00500	<0.002	0.00001	0.00002
PCB 50	0.01900	0.11000	0.00007	0.00006
PCB 77	0.03100	0.05500	0.00010	0.00010
PCB 136	0.02800	0.04700	0.00007	0.00007
PCB 180	0.00300	0.00700	<0.00001	0.00001

Table 6
Plume Water Quality for Load 18 with Overflow, Area II

Parameter	Background	Concentration, mg/l		
		1-5 min	7-12 min	15-30 min
Ammonia, as N	<0.1000	<0.1000	<0.1000	<0.1000
Total suspended solids	8.0000	92.0000	82.0000	52.0000
Arsenic, total	<0.0020	0.0020	0.0030	<0.0020
Copper, total	<0.0100	<0.0100	<0.0100	<0.0100
Chromium, total	<0.0200	<0.0200	<0.0200	<0.0100
Lead, total	<0.0500	<0.0500	<0.0500	<0.0500
Manganese, total	0.0400	0.1100	0.1000	0.0700
Nickel, total	<0.0200	<0.0200	<0.0200	<0.0200
Zinc, total	<0.0100	<0.0100	<0.0100	<0.0100
Total organic carbon	4.0000	3.6000	3.6000	4.0000

Table 7
Plume Water Quality for Load 19 Without Overflow, Area II

Parameter	Background	Concentration, mg/l		
		1-5 min	7-12 min	15-30 min
Ammonia, as N	<0.100	<0.100	<0.100	<0.100
Total suspended solids	22.000	40.000	106.000	62.000
Arsenic, total	0.002	0.004	0.003	0.002
Copper, total	<0.010	<0.010	<0.010	<0.010
Chromium, total	<0.020	<0.020	<0.020	<0.020
Lead, total	<0.050	<0.050	<0.050	<0.050
Manganese, total	0.080	0.080	0.160	0.110
Nickel, total	<0.020	<0.020	<0.020	<0.020
Zinc, total	0.060	<0.010	0.060	0.080
Total organic carbon	5.300	5.300	5.600	6.100

Table 8

Concentrations of Selected PCB Congeners for Plume Samples

Parameter	Background mg/l	Concentration at		
		Time After Dredge Passage, mg/l		
		1-5 min	7-12 min	15-30 min
Overflow plume - total water				
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001	<0.00001
PCB 50	<0.00001	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001
PCB 136	<0.00001	<0.00001	<0.00001	<0.00001
PCB 180	<0.00001	0.00001	<0.00001	0.00002
Overflow plume - dissolved				
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001
PCB 28	0.00001	<0.00001	<0.00001	<0.00001
PCB 40	0.00002	<0.00001	<0.00001	<0.00001
PCB 50	<0.00001	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001
PCB 136	<0.00001	<0.00001	<0.00001	<0.00001
PCB 180	0.00001	<0.00001	<0.00001	<0.00001
No overflow plume - total water				
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	0.00001	<0.00001
PCB 50	<0.00001	<0.00001	0.00022	0.00008
PCB 77	<0.00001	<0.00001	0.00001	<0.00001
PCB 136	<0.00001	<0.00001	<0.00001	<0.00001
PCB 180	<0.00001	<0.00001	<0.00001	<0.00001
No overflow plume - dissolved				
PCB 7	<0.00001	<0.00001	<0.00001	<0.00001
PCB 28	<0.00001	<0.00001	<0.00001	<0.00001
PCB 40	<0.00001	<0.00001	<0.00001	<0.00001
PCB 50	<0.00001	<0.00001	<0.00001	<0.00001
PCB 77	<0.00001	<0.00001	<0.00001	<0.00001
PCB 136	<0.00001	<0.00001	<0.00001	<0.00001
PCB 180	<0.00001	<0.00001	<0.00001	<0.00001

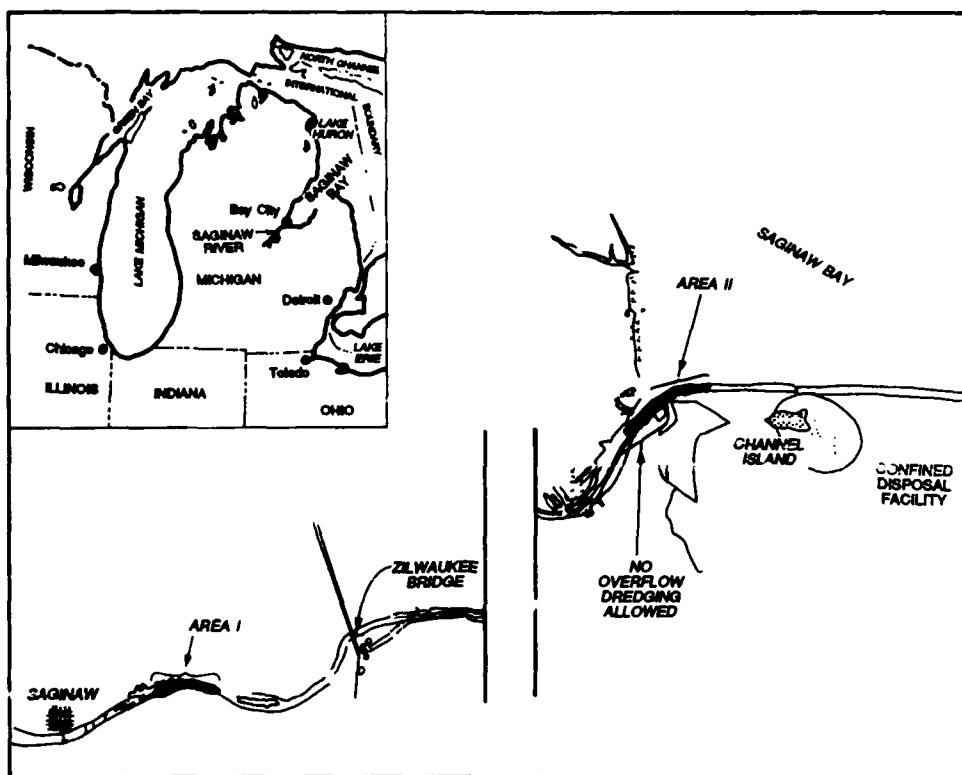


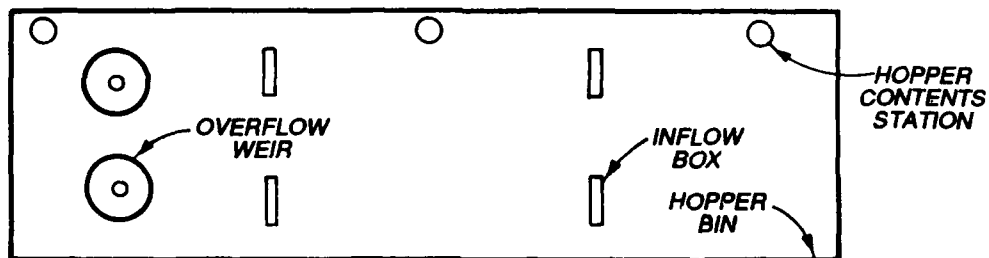
Figure 1. Saginaw River, Michigan (note Study Areas I and II)



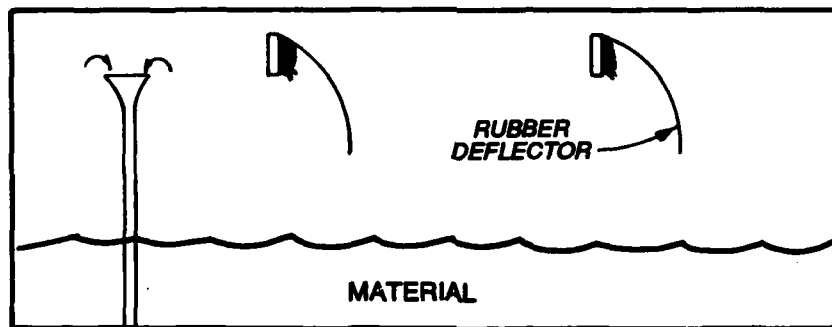
Figure 2. Hopper dredge Dodge Island

BOW

STERN



PLAN VIEW



SIDE VIEW

SUBMERGED
DISCHARGE

RUBBER
DEFLECTOR

Figure 3. Schematic of hopper bins

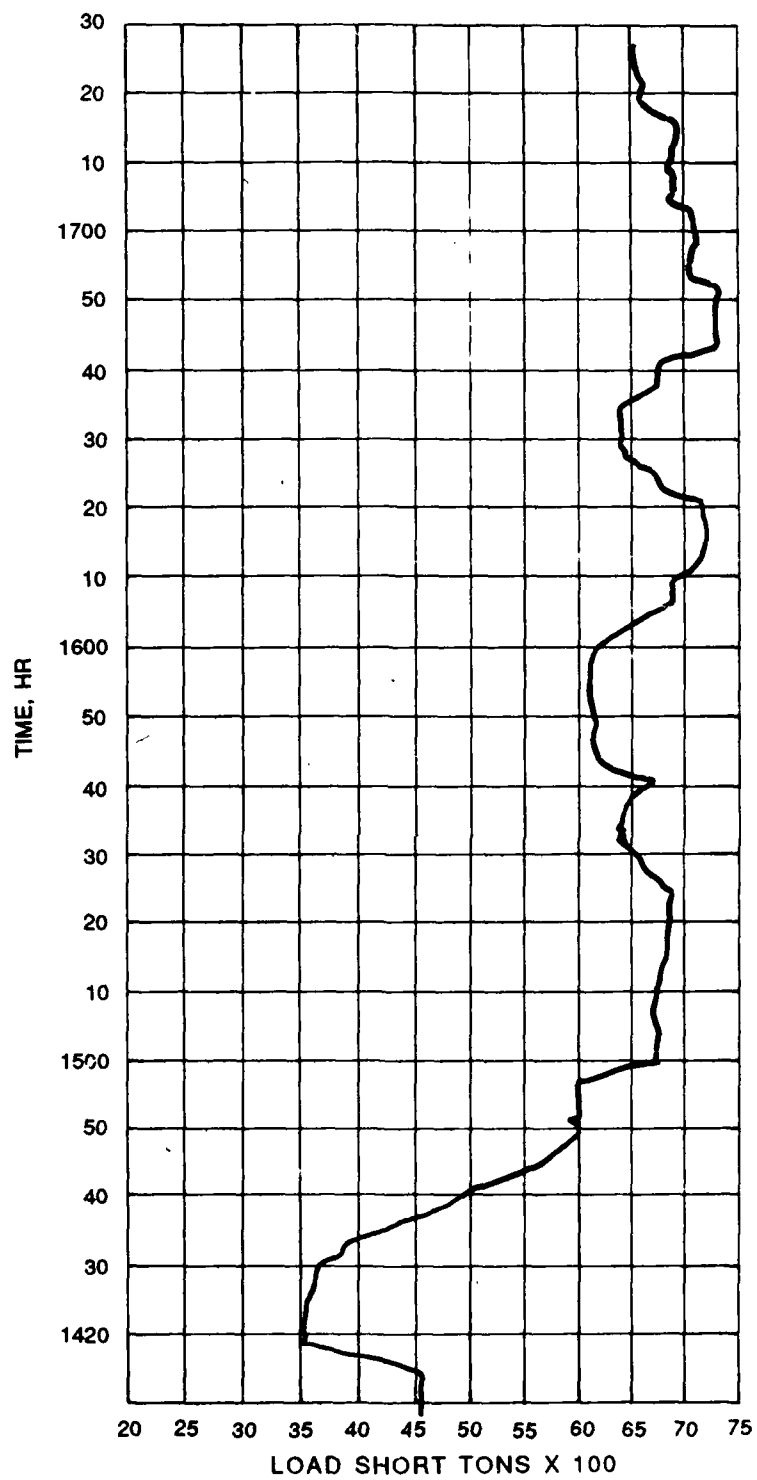


Figure 4. Load diagram for Load 119,
11 September 1987, Area I

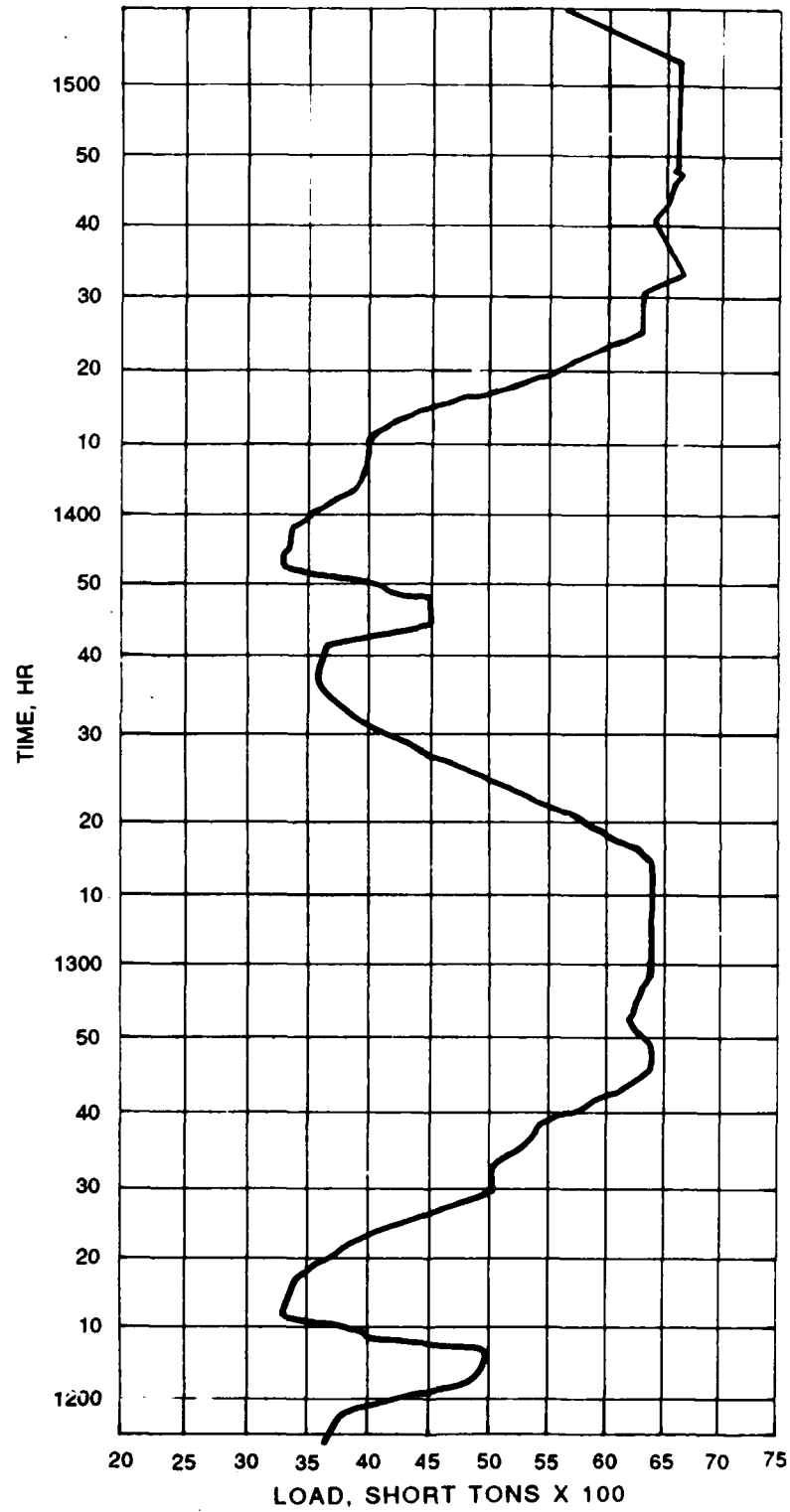


Figure 5. Load diagram for Loads 18 and 19
18 August 1987, Area II

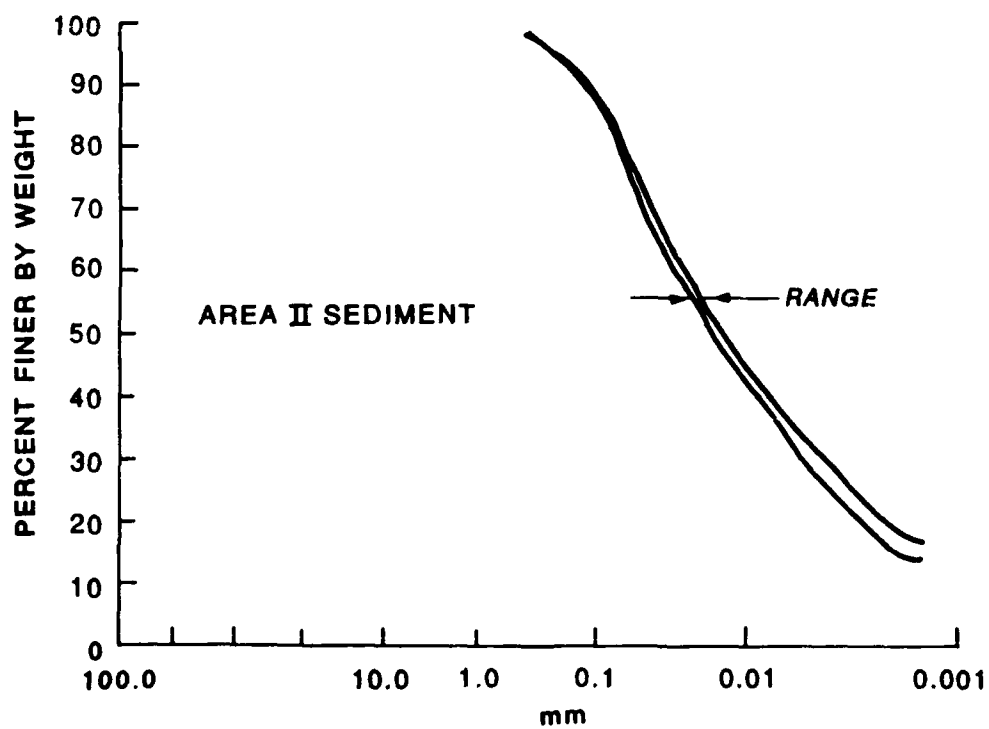
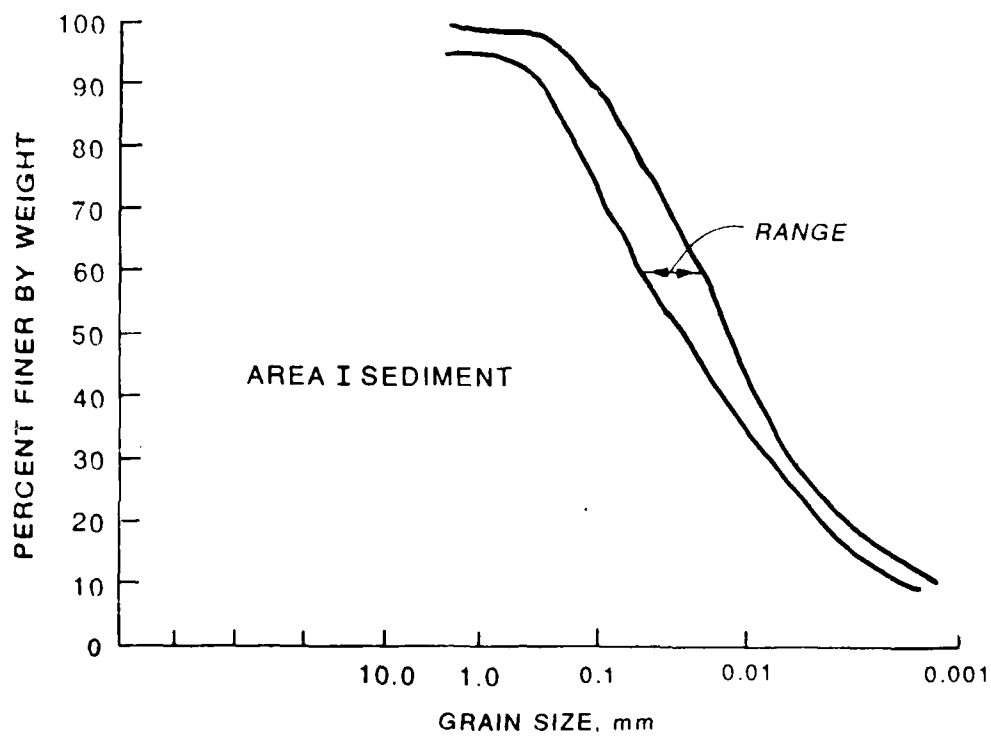


Figure 6. Grain size distributions for sediment samples

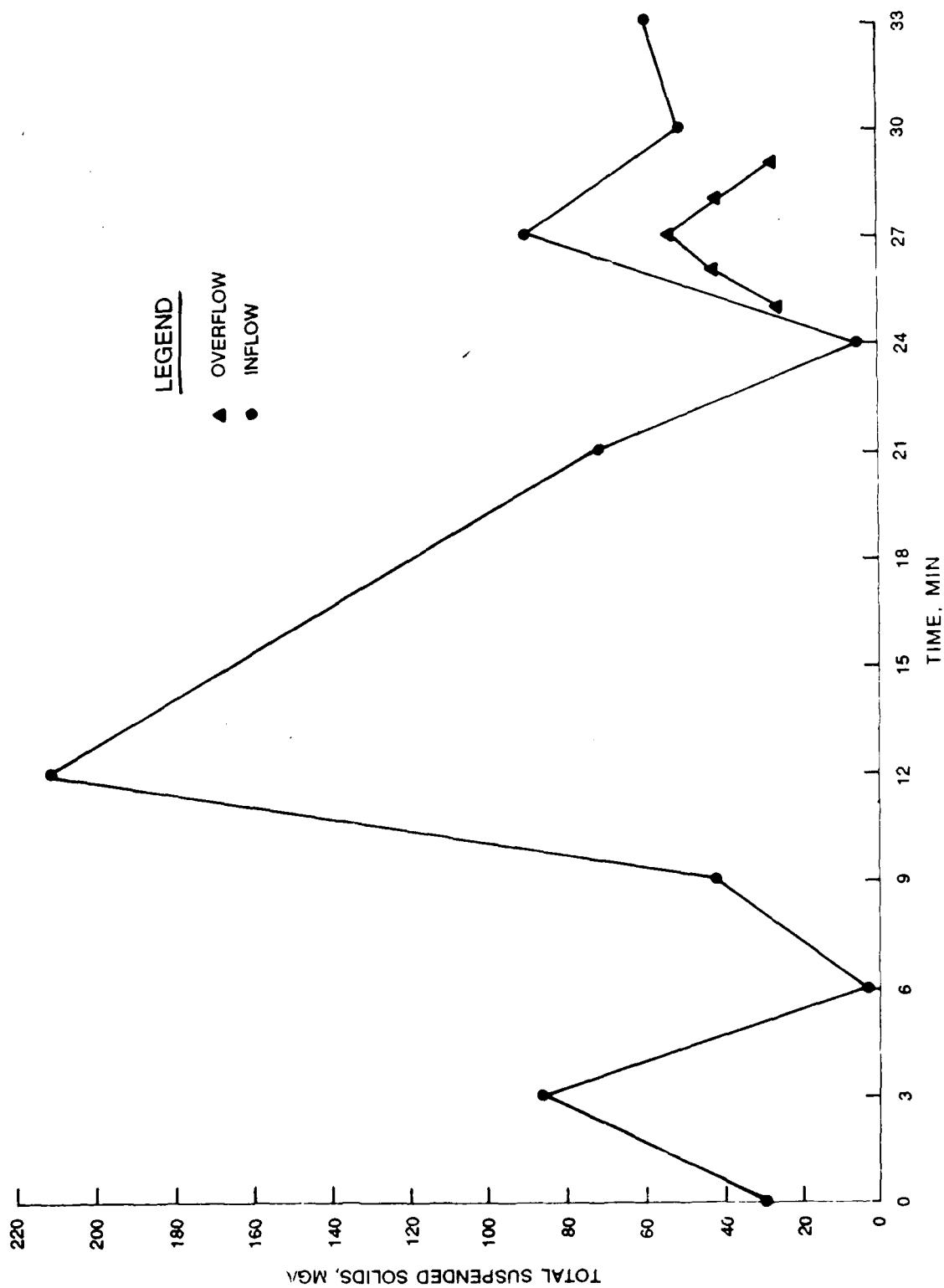


Figure 7. Inflow and overflow solids concentrations, Load 119, Area I

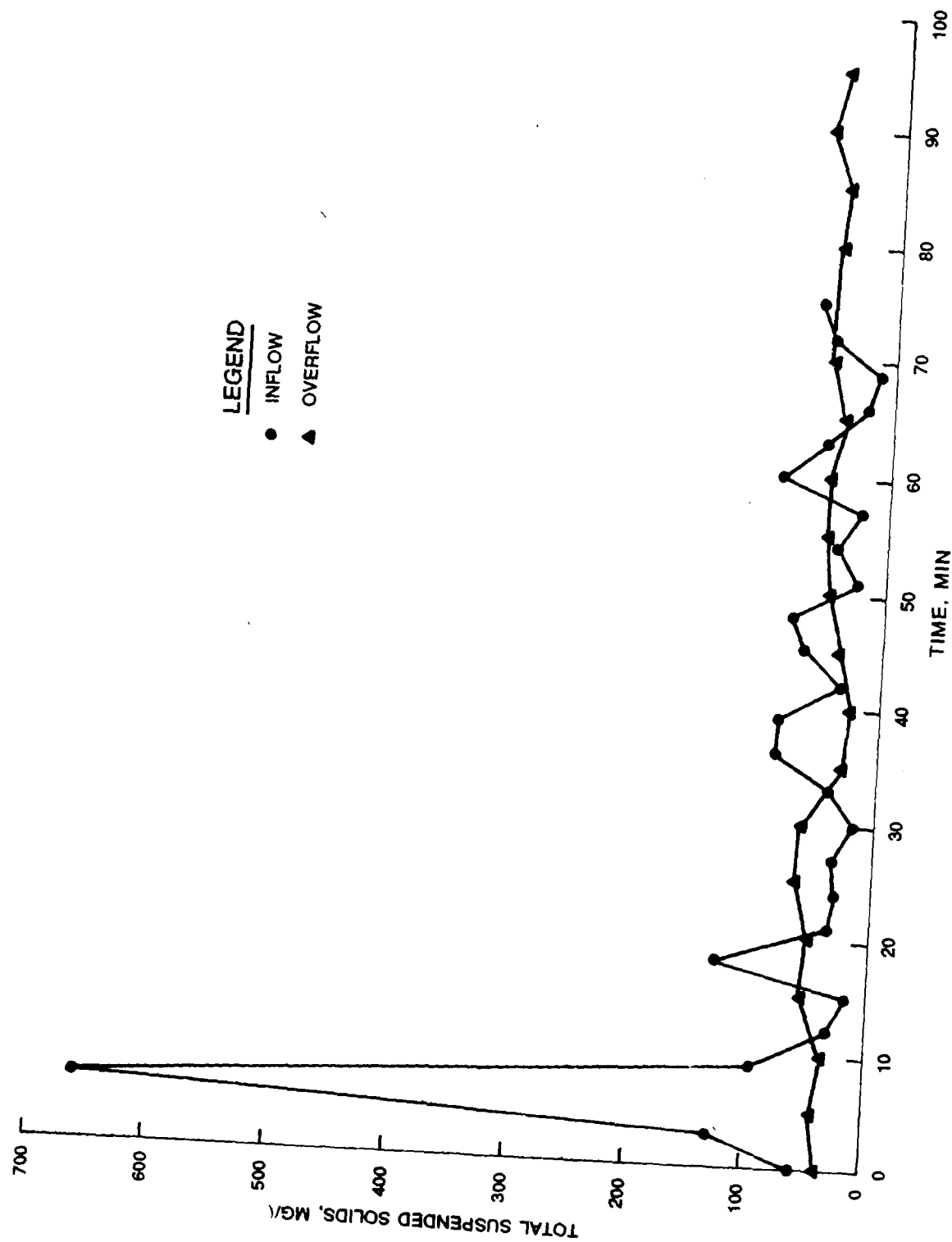


Figure 8. Inflow and overflow solids concentrations, Load 18, Area II

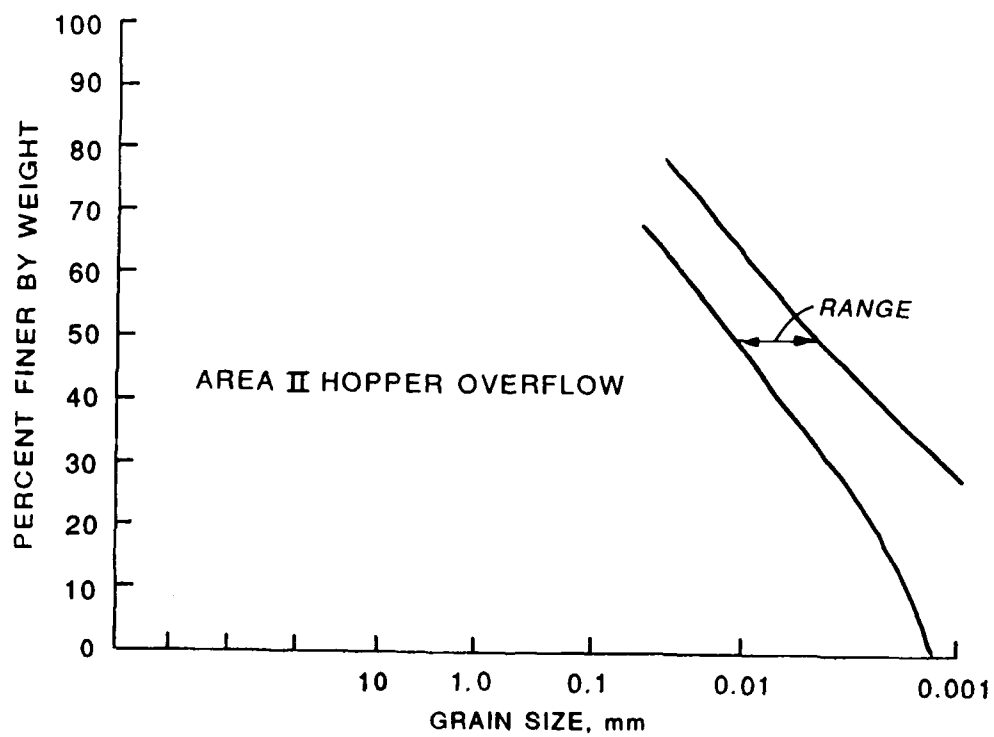
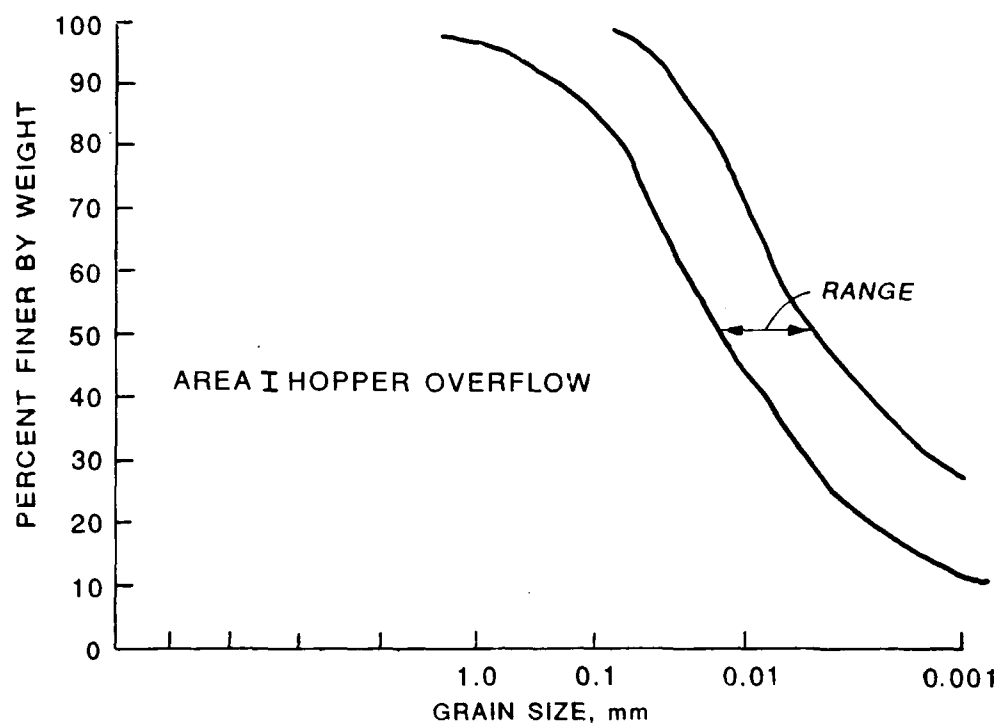


Figure 9. Grain size distributions for overflow samples

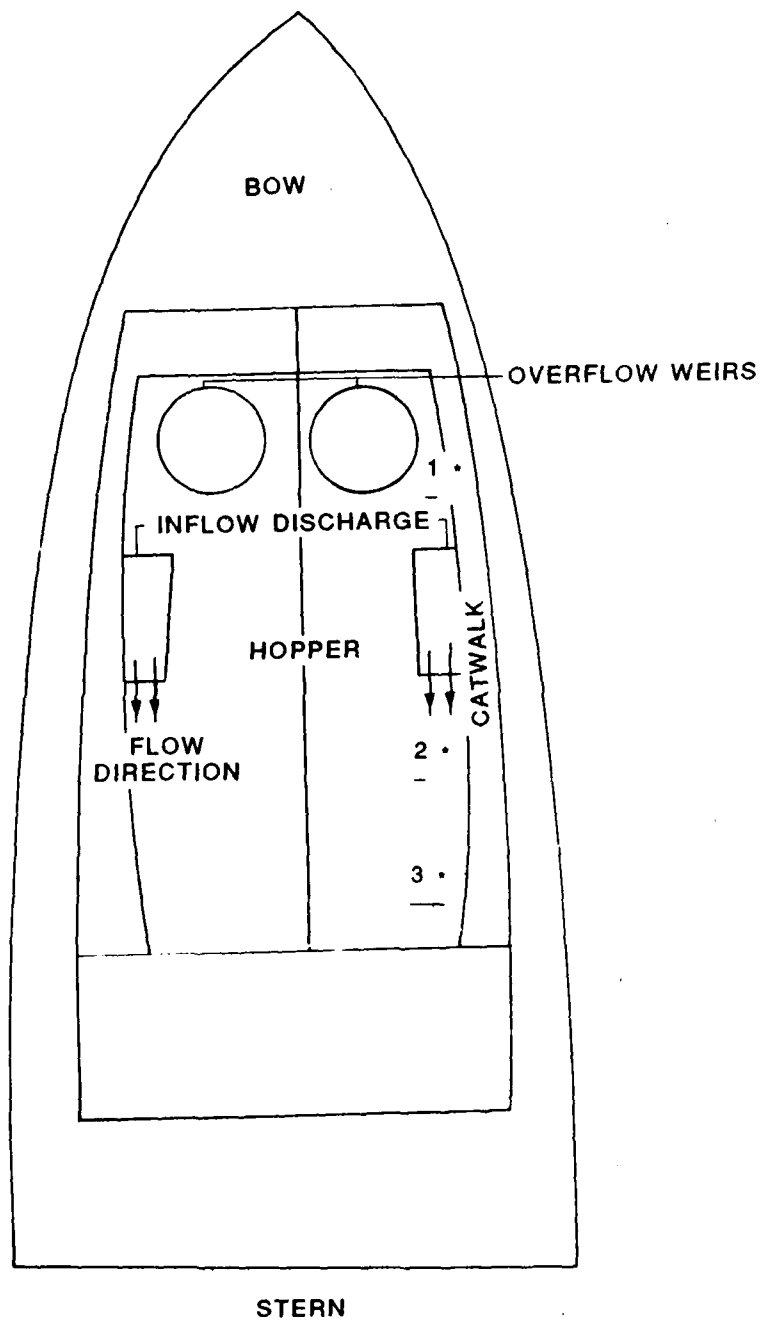


Figure 10. Sample locations for hopper contents

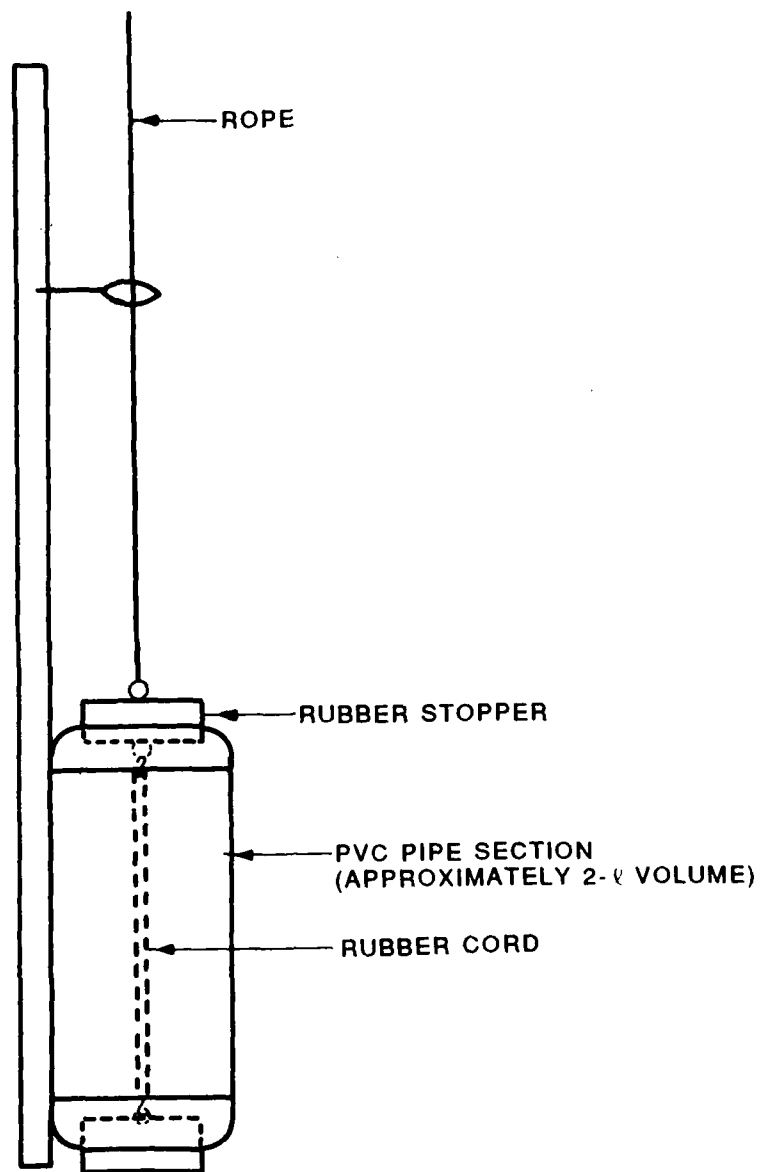


Figure 11. Diagram of PVC sampler for hopper contents

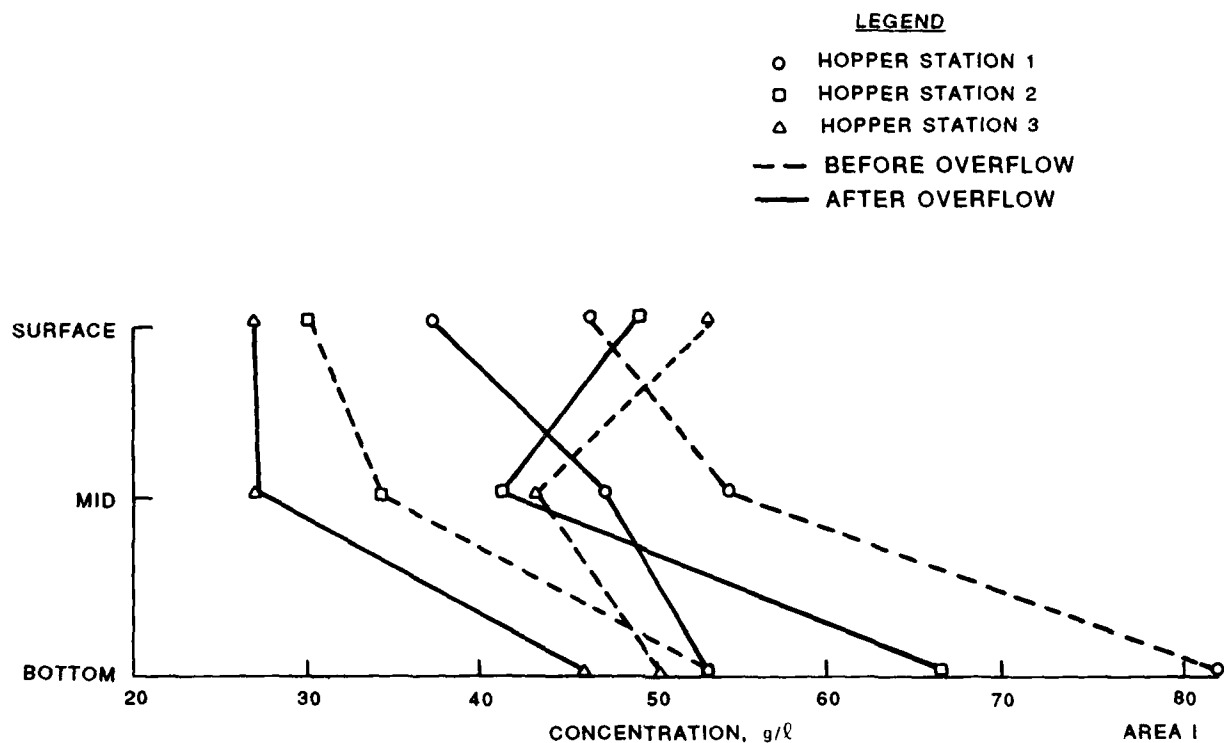


Figure 12. Hopper contents solids concentrations, Load 119, Area I

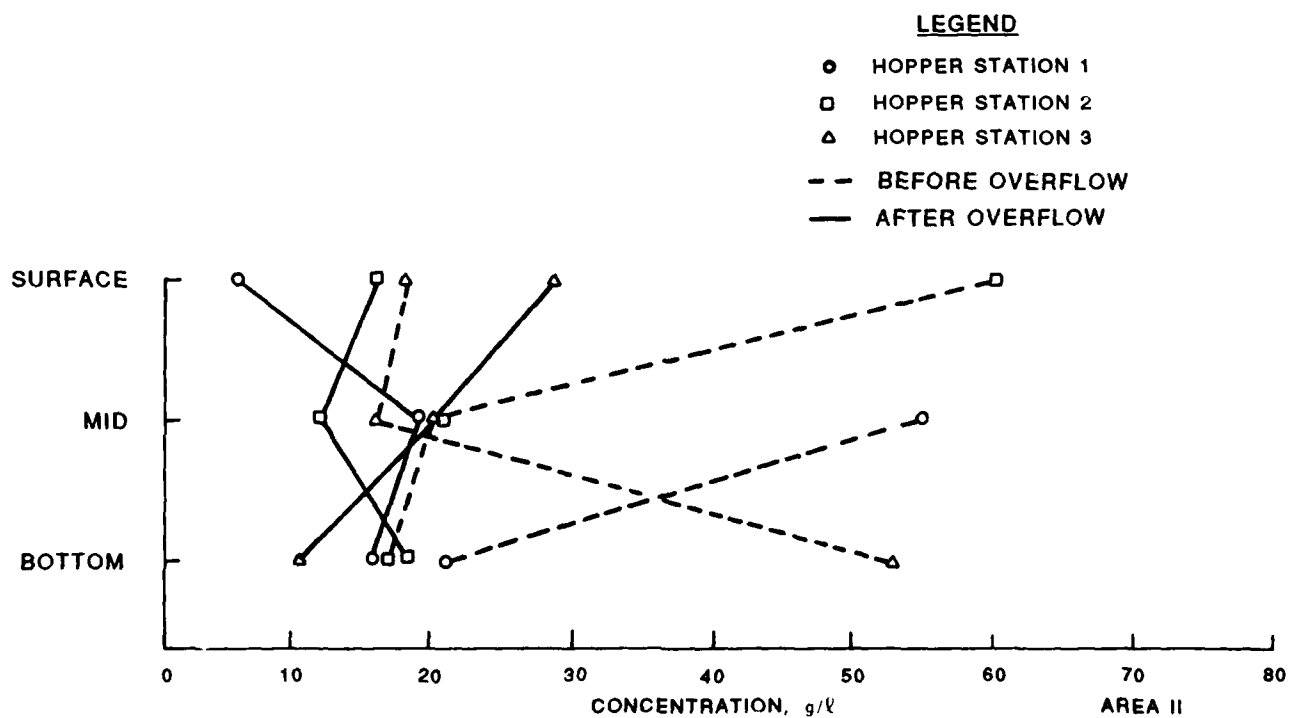


Figure 13. Hopper contents solids concentrations, Load 18, Area II

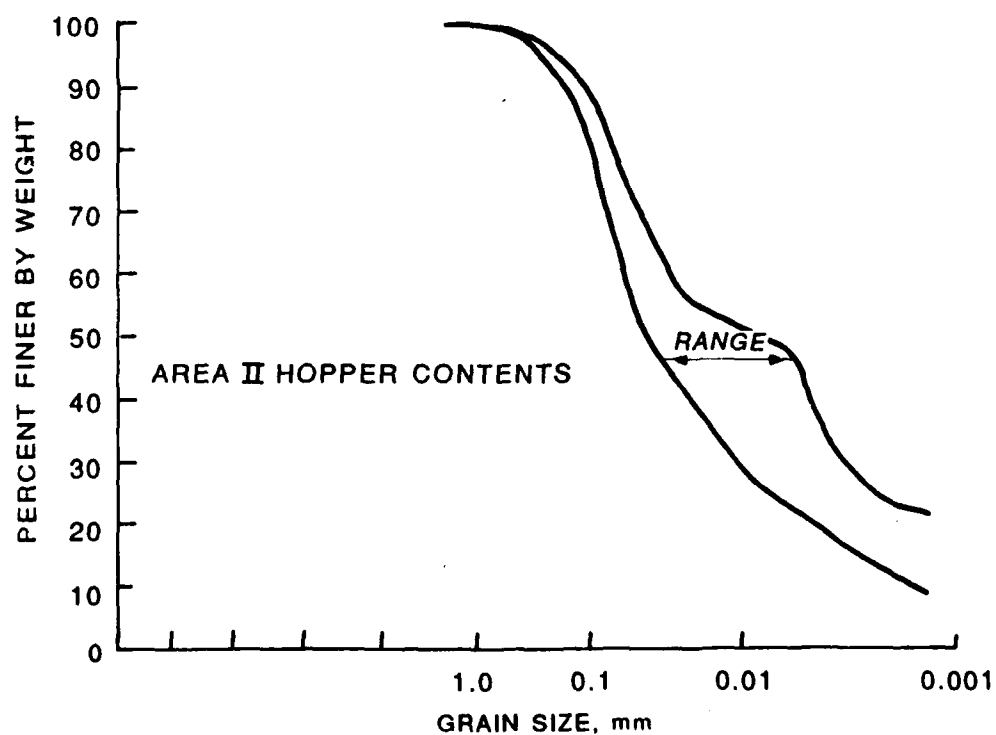
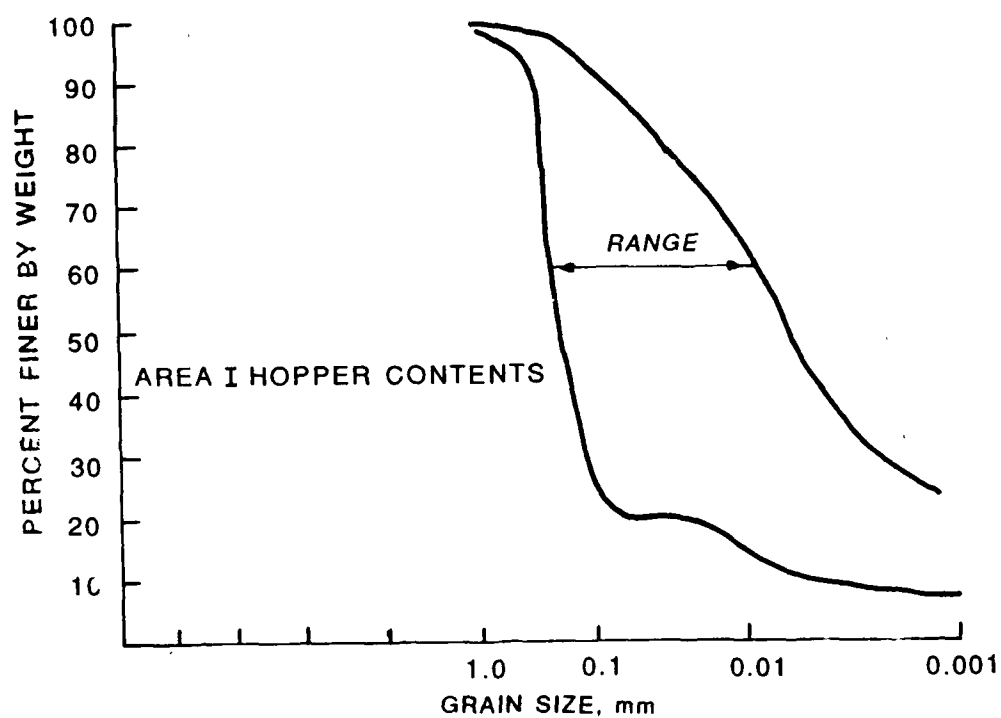


Figure 14. Grain size distributions for hopper contents

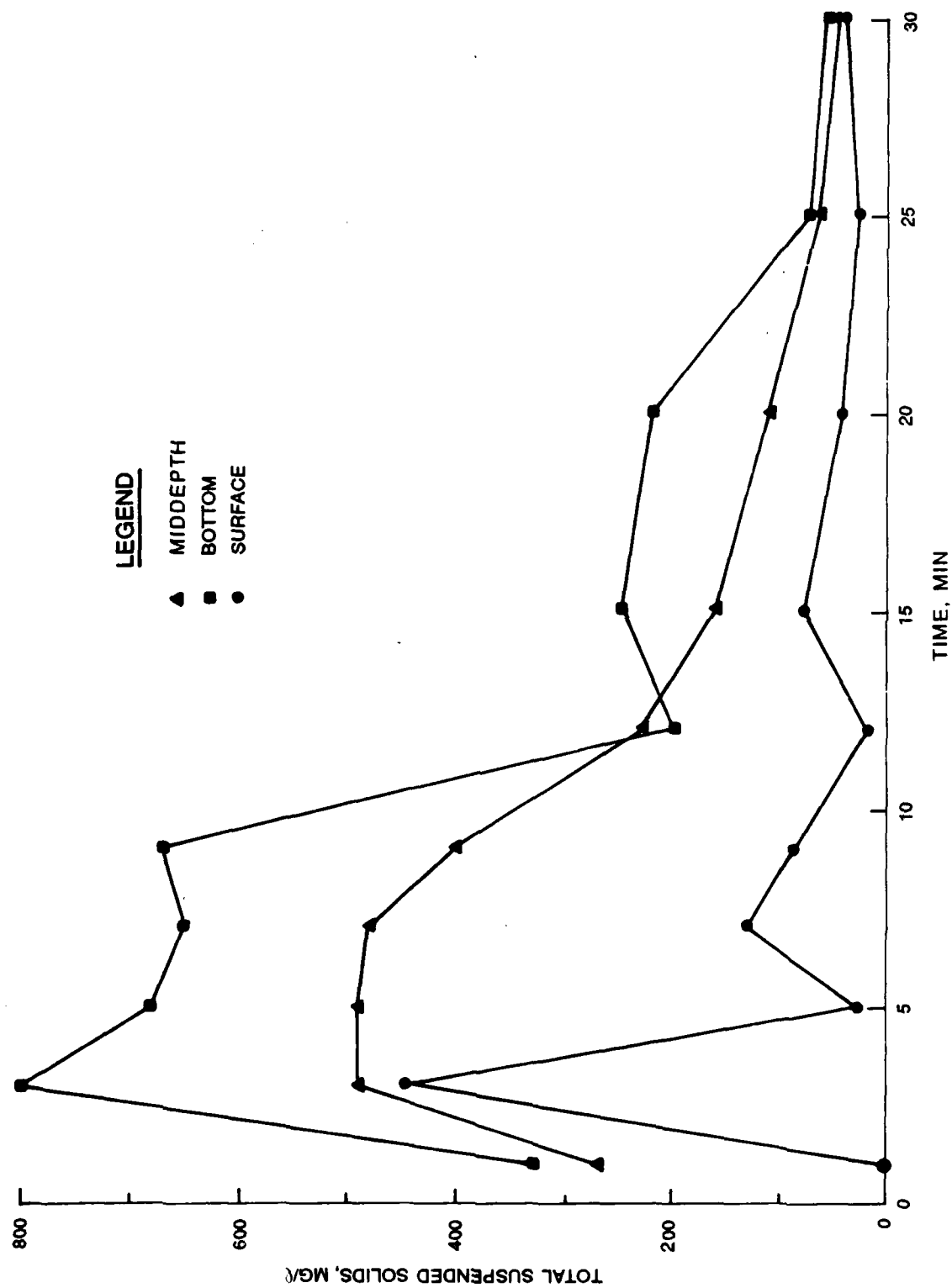


Figure 15. Plume solids concentrations, Load 119 with overflow, Area I

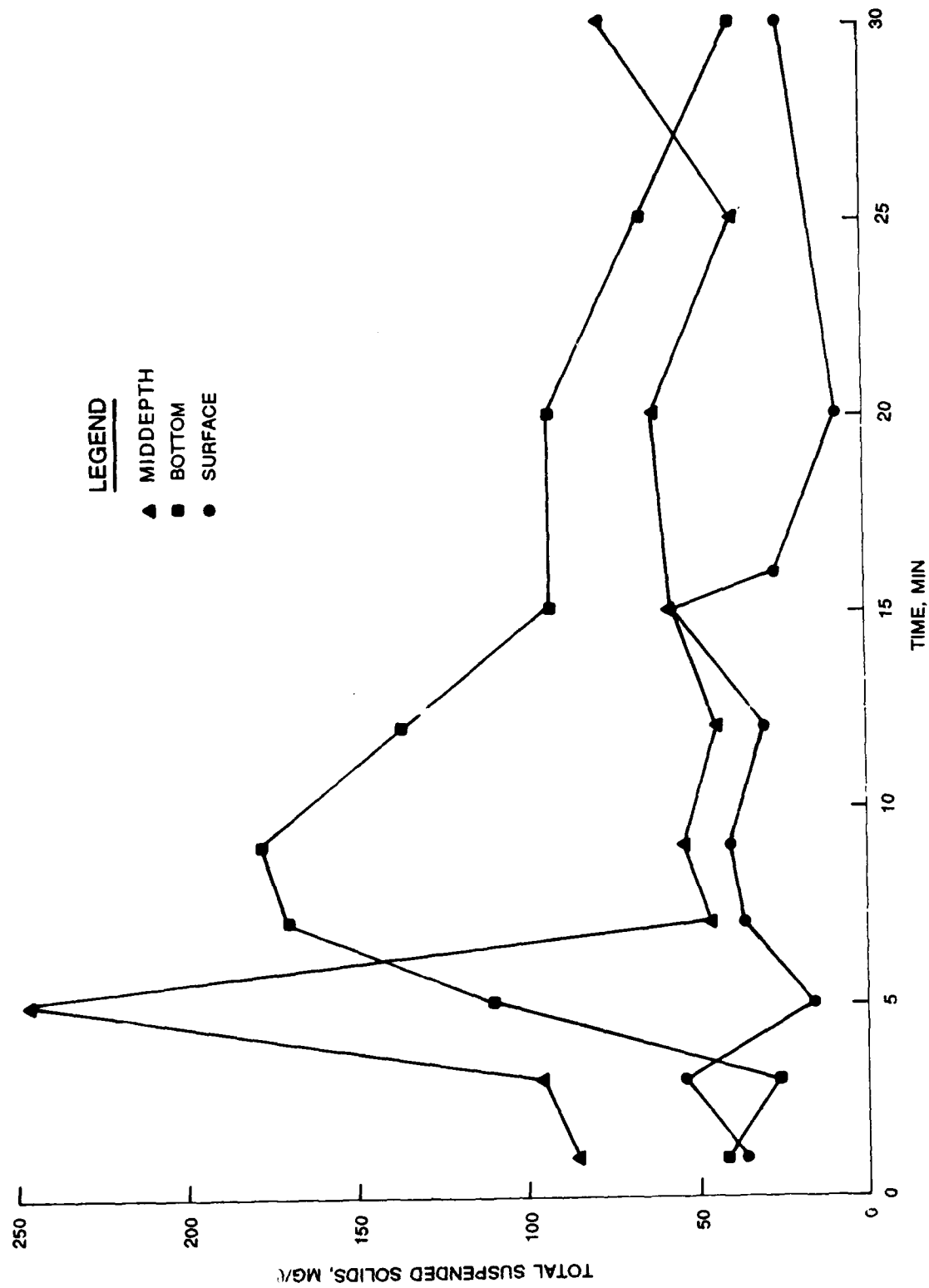


Figure 16. Plume solids concentrations, Load 18 with overflow, Area II

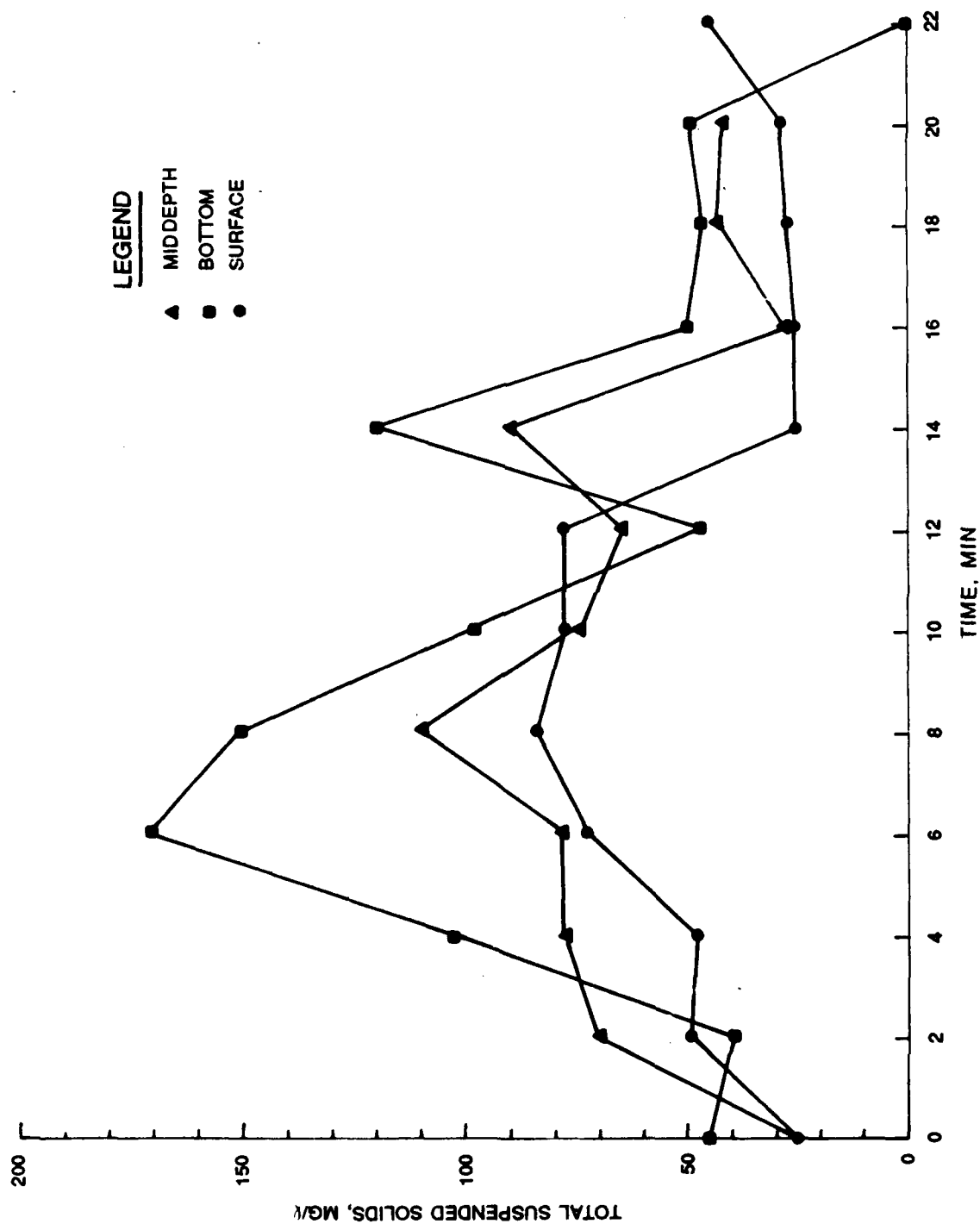
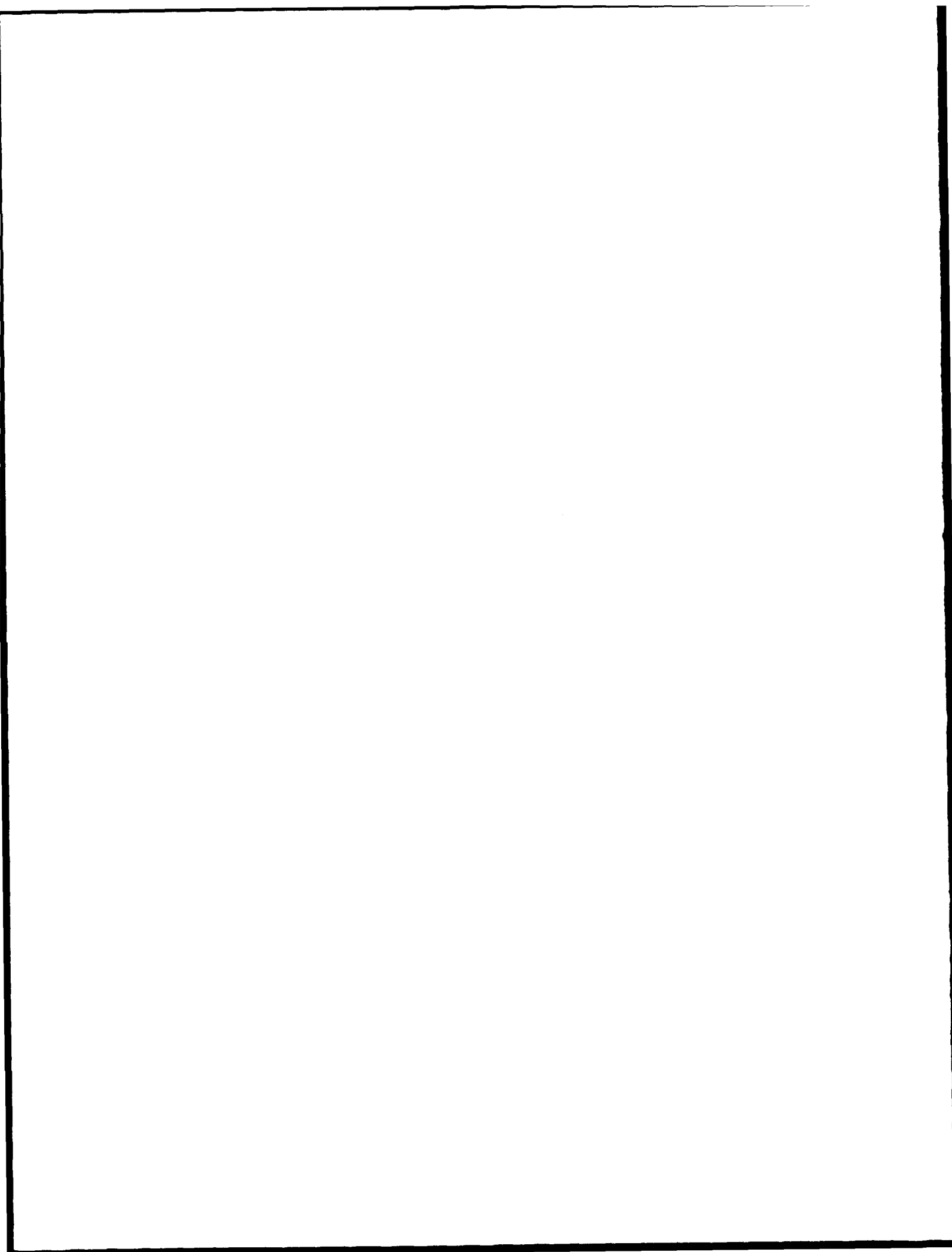
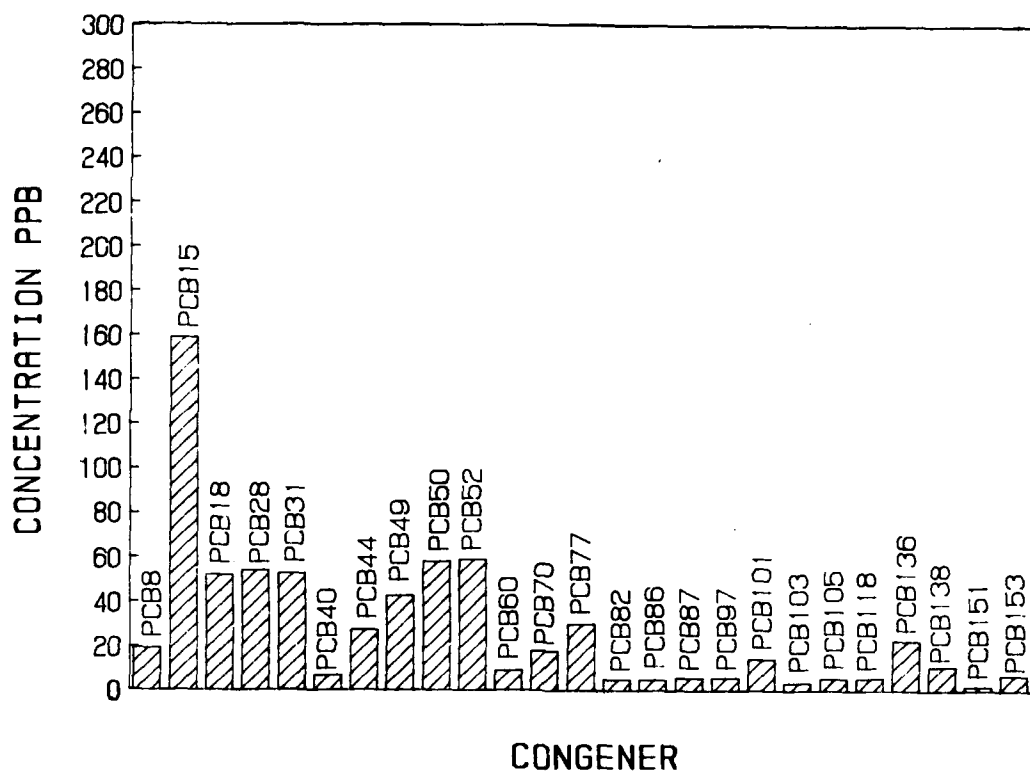


Figure 17. Plume solids concentrations, Load 19 without overflow, Area II

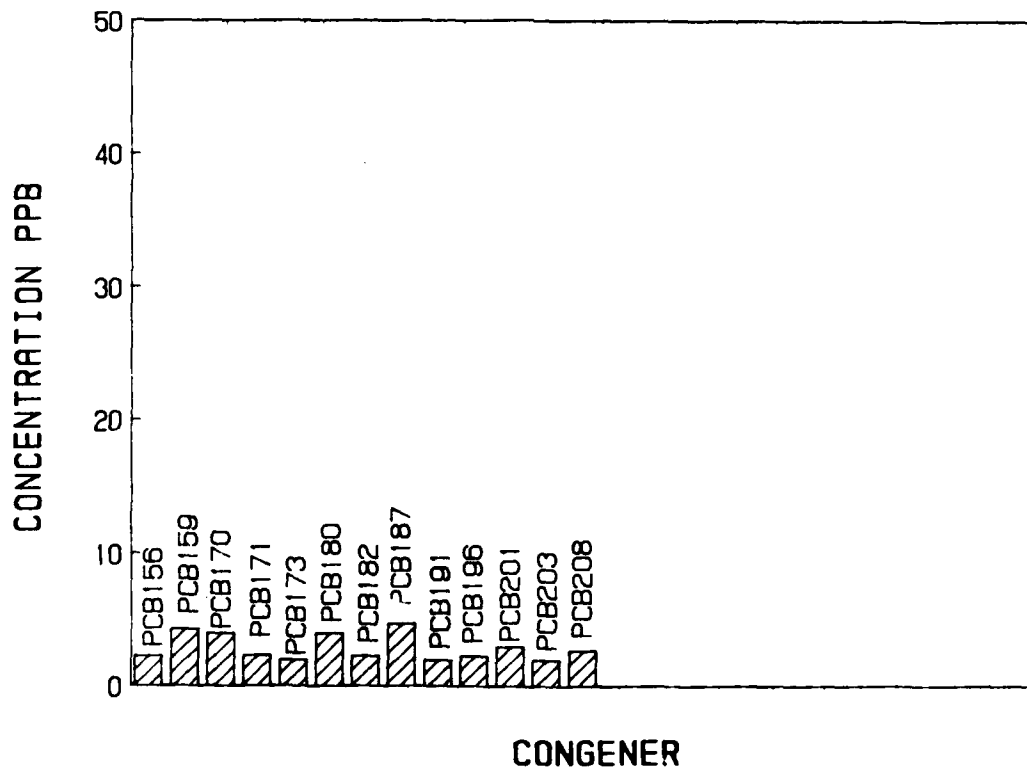


Appendix A: Laboratory Data for PCB Analysis

1. This appendix presents the results of PCB analyses conducted on sediment, water, hopper inflow, hopper overflow, plume, and distilled water blank samples. The detection limit for all PCB analyses was 0.0001 ppm. Those congeners that were detected are plotted in the bar charts in this appendix. Some of the analyses were replicated. In those instances where replicate analyses were performed, the results are labeled as average. If one or more samples of a set of replicates was above detection, and the remaining samples were below detection, the average was computed using the detection limit as the concentration for samples below detection.



a. PCB8-PCB153



b. PCB156-PCB208

Figure A1. Average sediment concentration

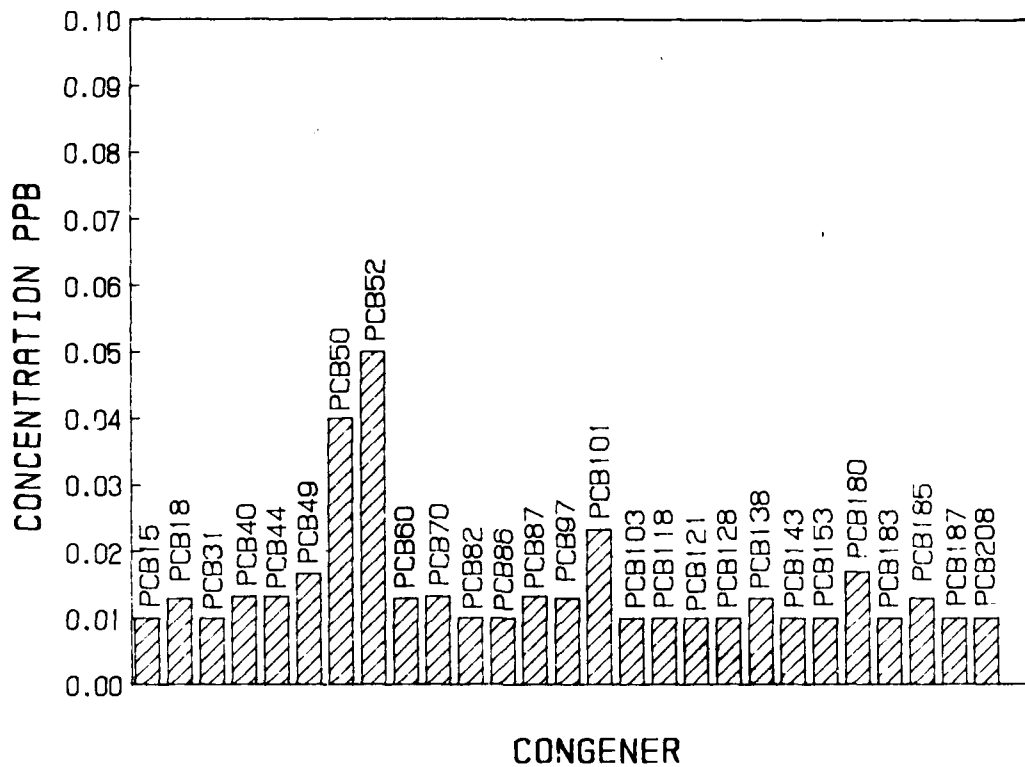


Figure A2. Average receiving water concentration

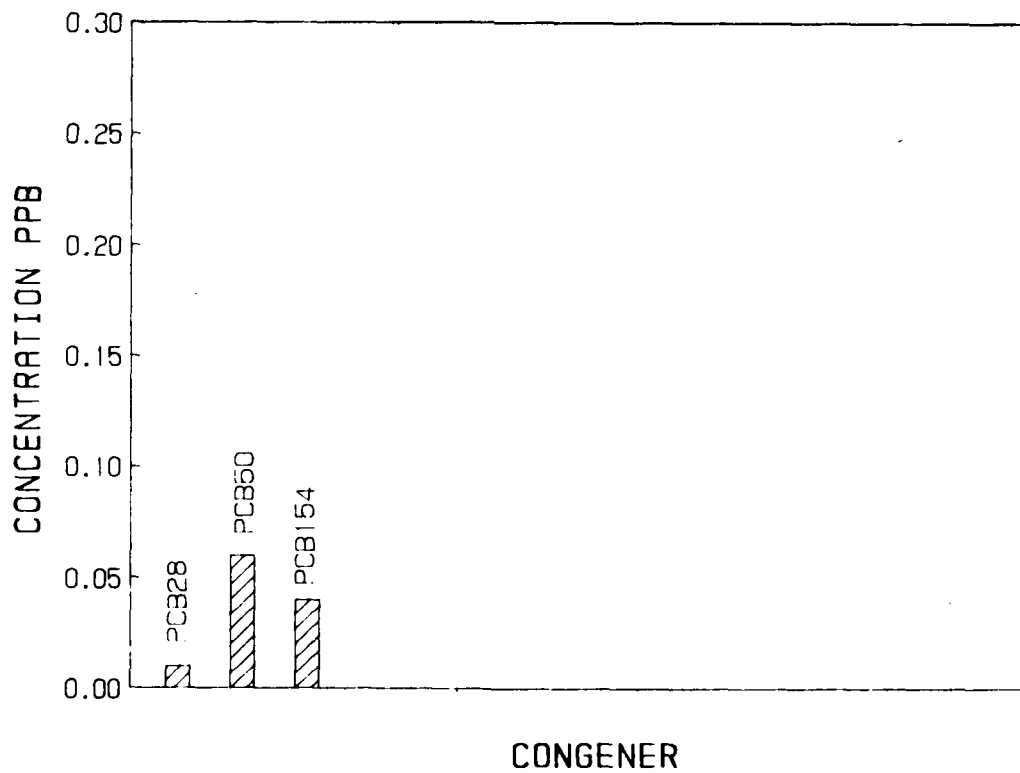
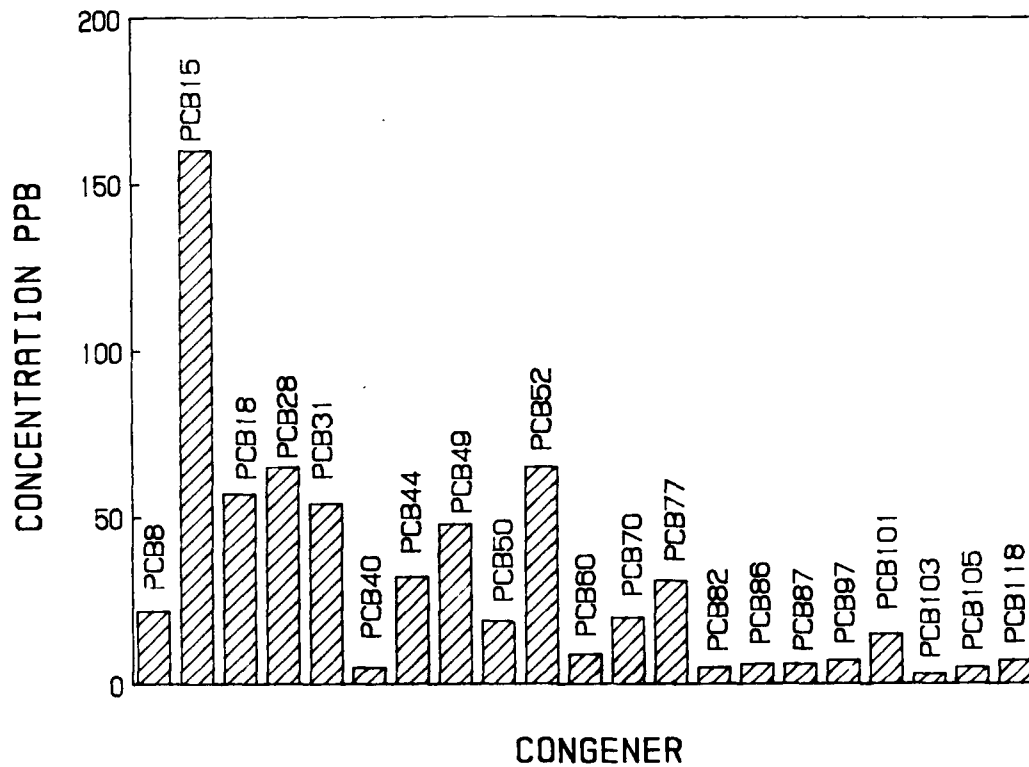
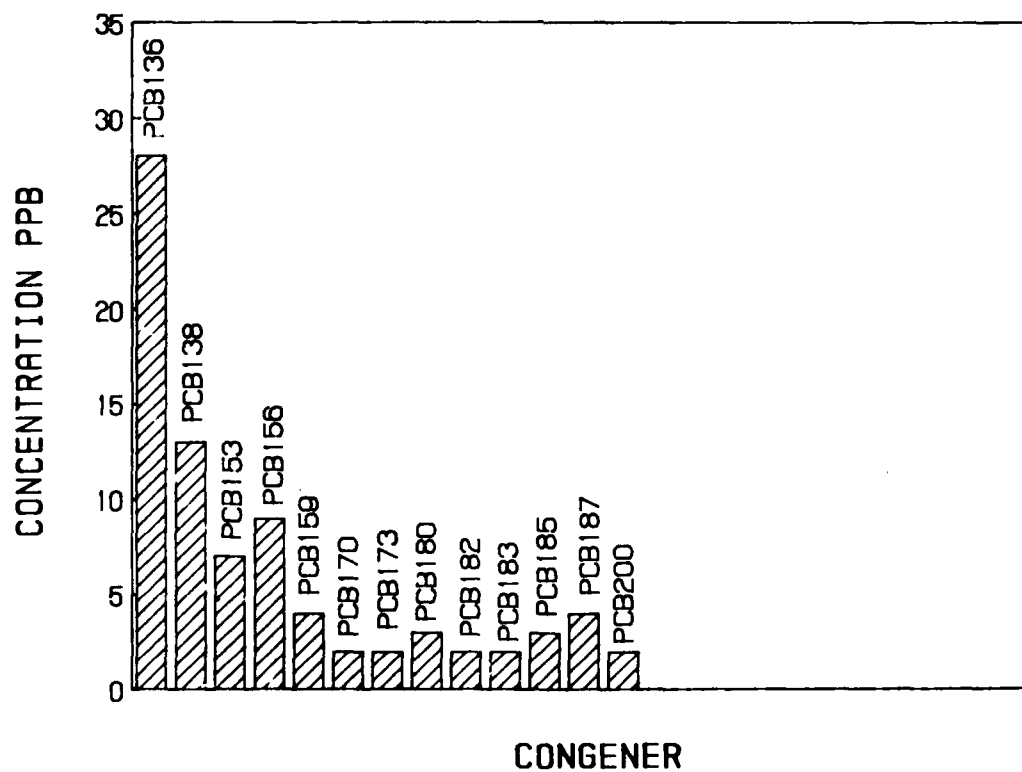


Figure A3. Hopper blank - dissolved



a. PCB8-PCB118



b. PCB136-PCB200

Figure A4. Inflow sediment

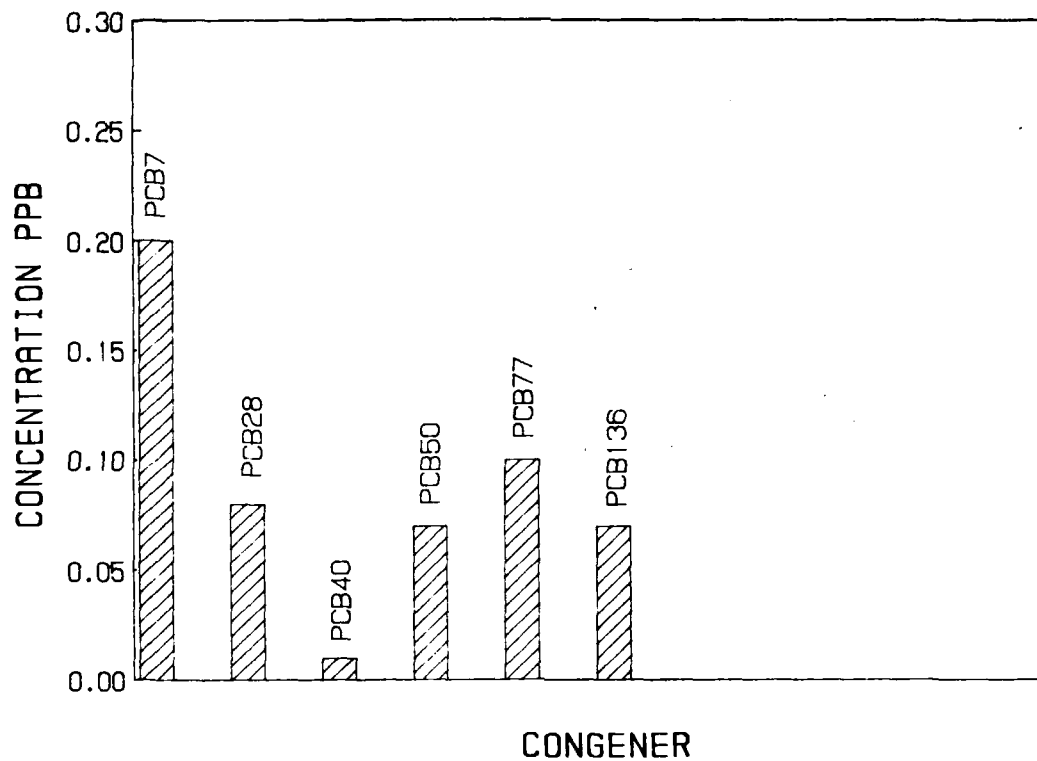


Figure A5. Hopper inflow - total

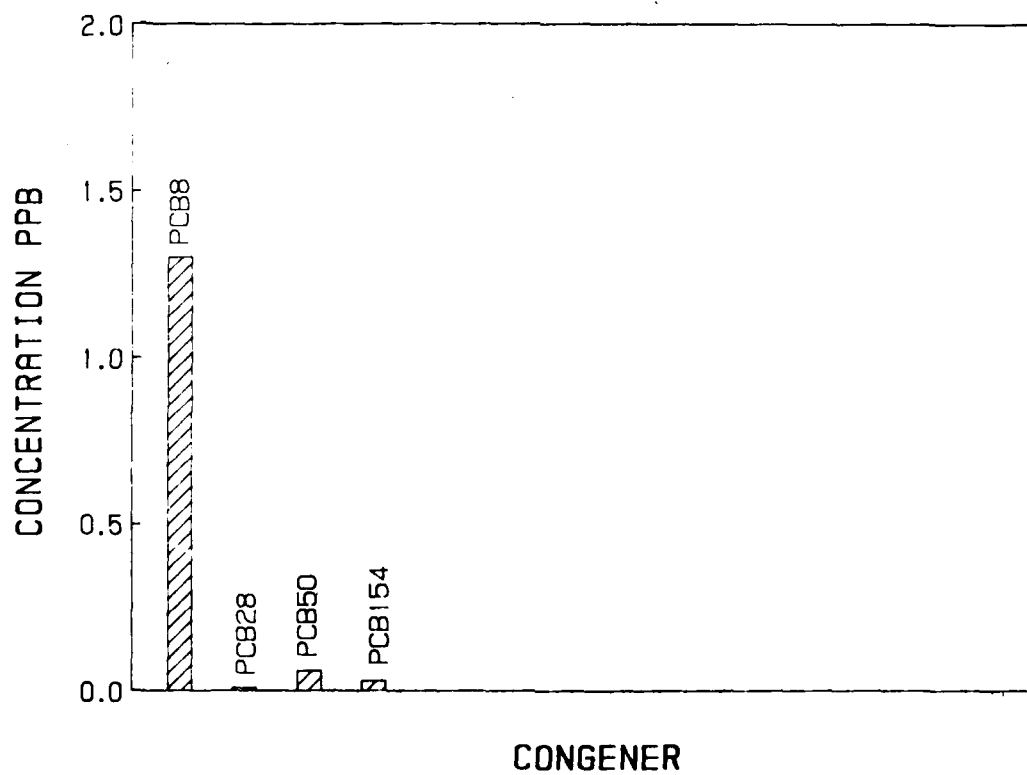
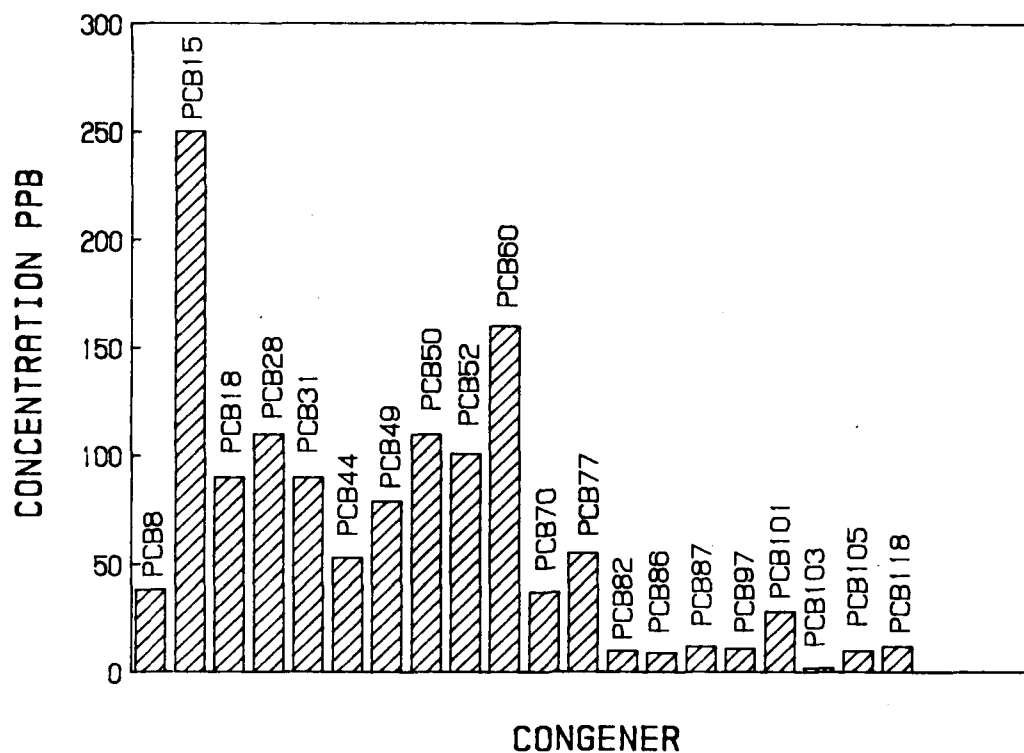
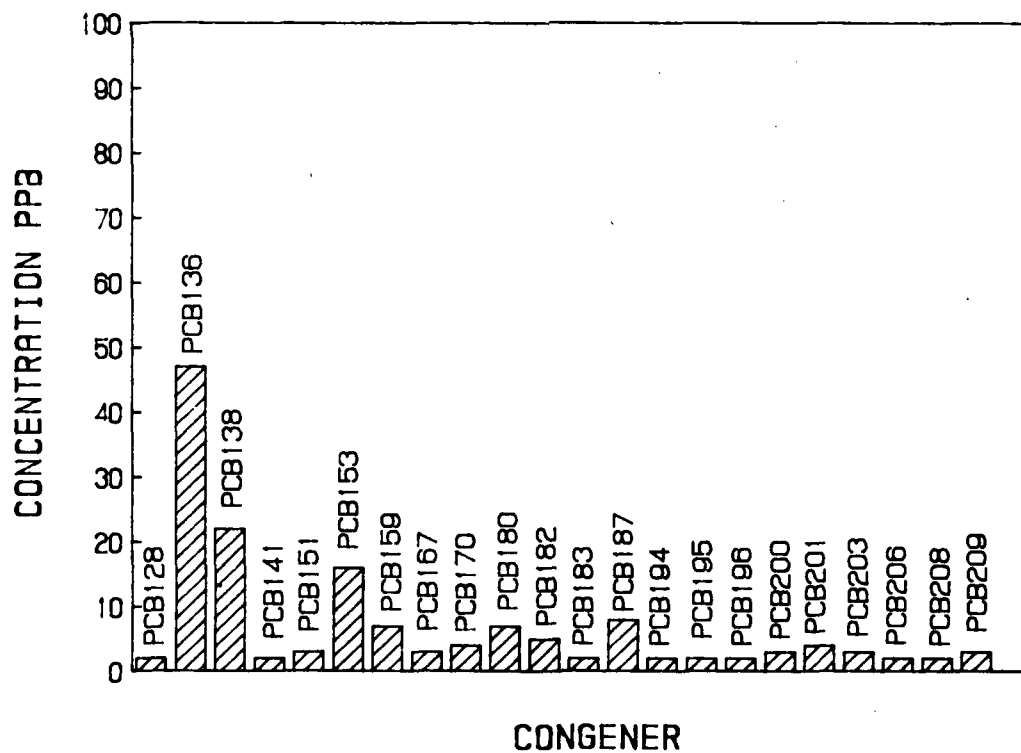


Figure A6. Hopper inflow - dissolved



a. PCB8-PCB118



b. PCB128-PCB209

Figure A7. Overflow - sediment

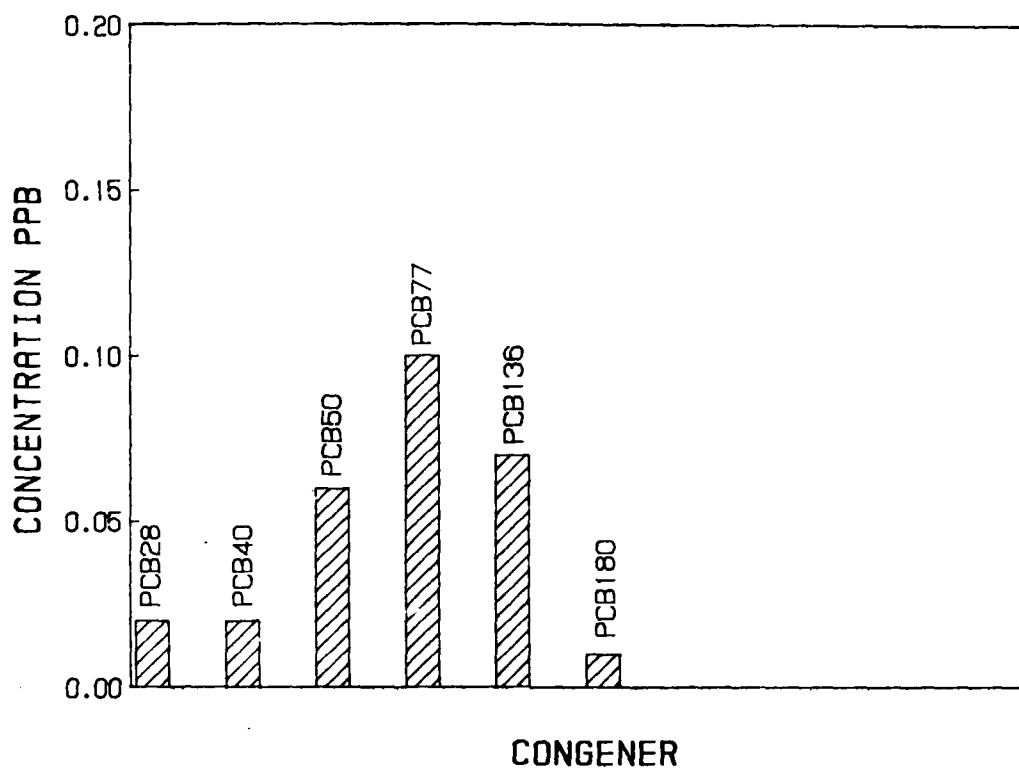


Figure A8. Hopper overflow - total

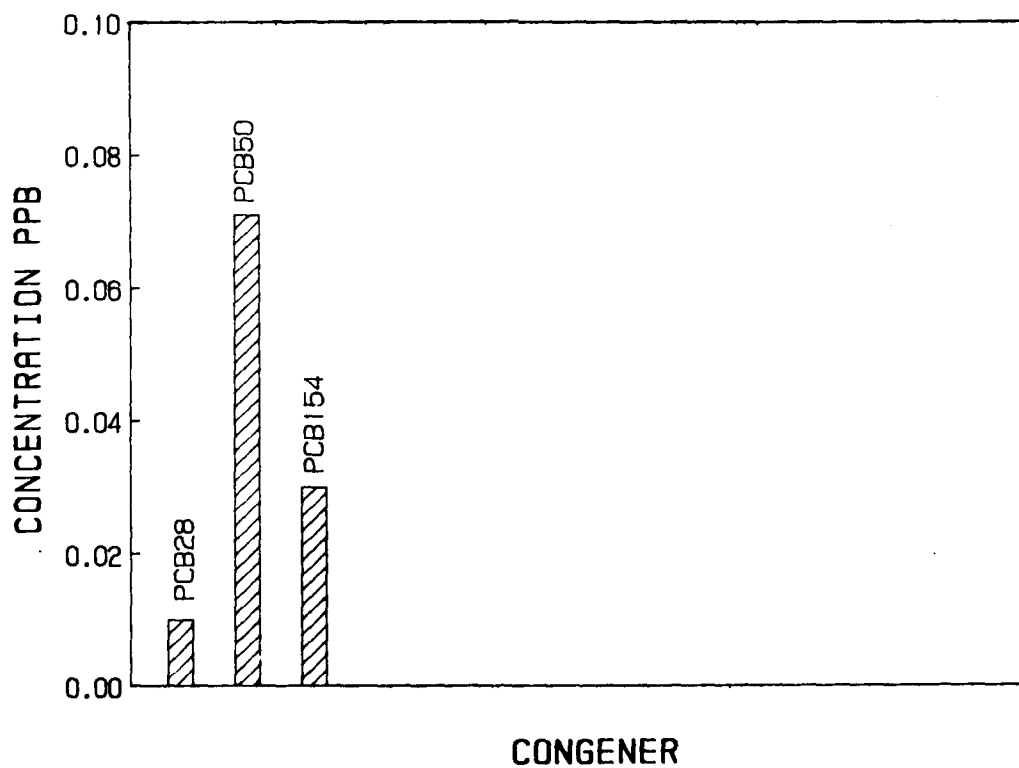


Figure A9. Hopper overflow - dissolved

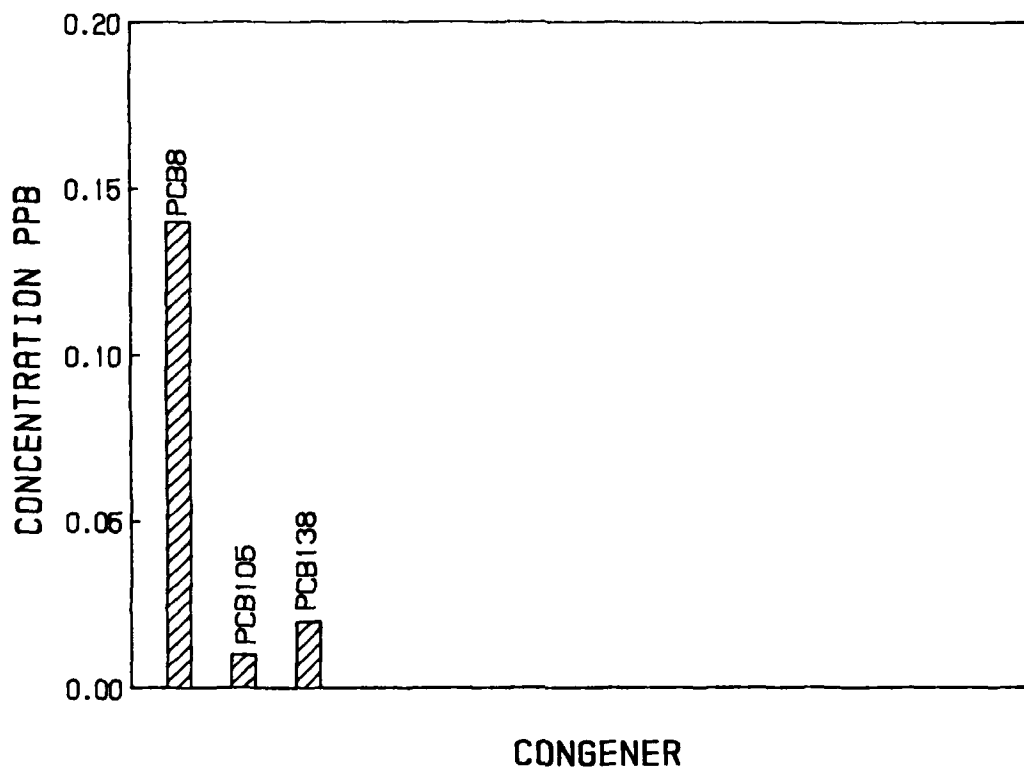


Figure A10. Plume sample A20-A total

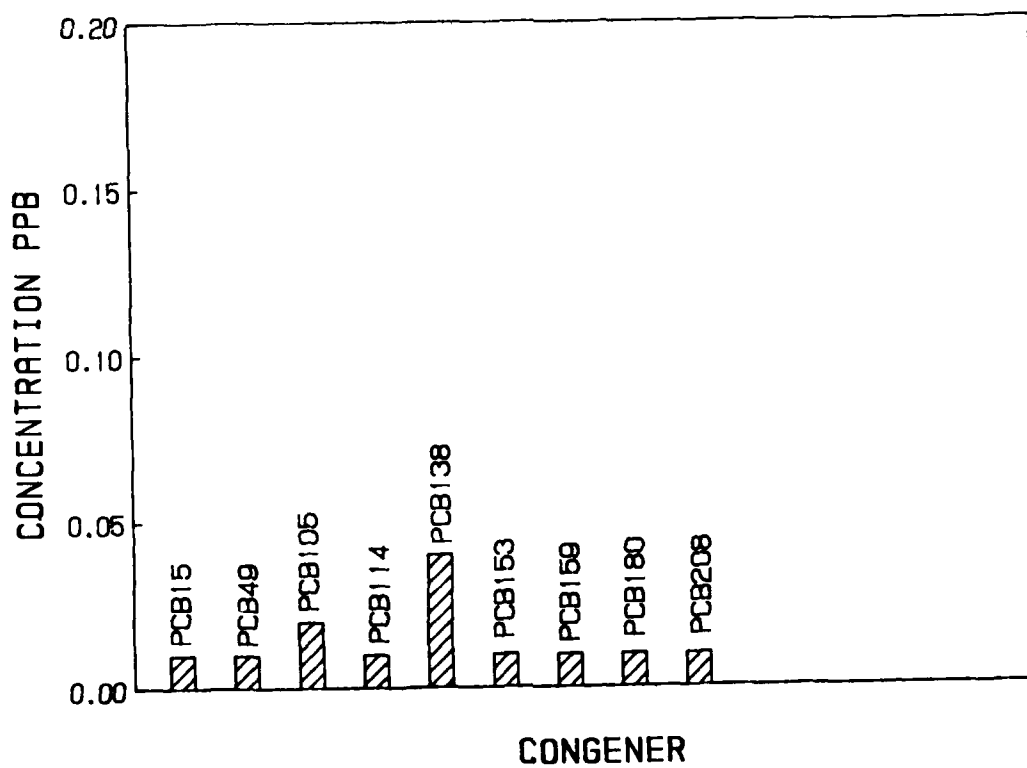


Figure A11. Plume sample A20-B total

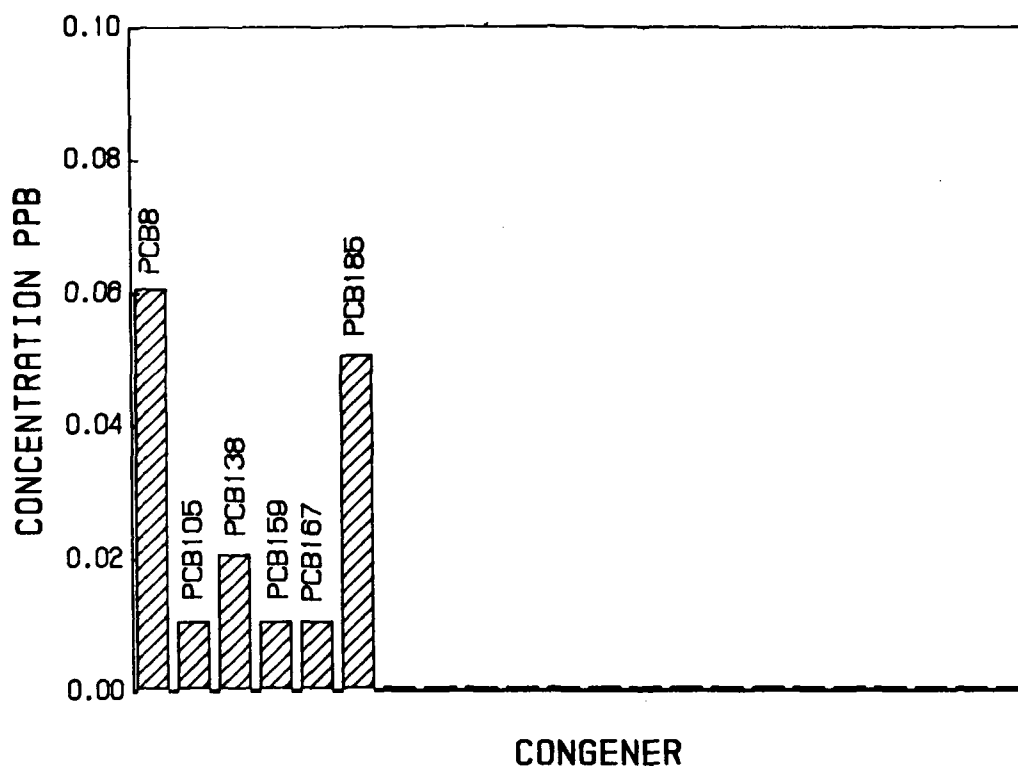


Figure A12. Plume sample A20-C total

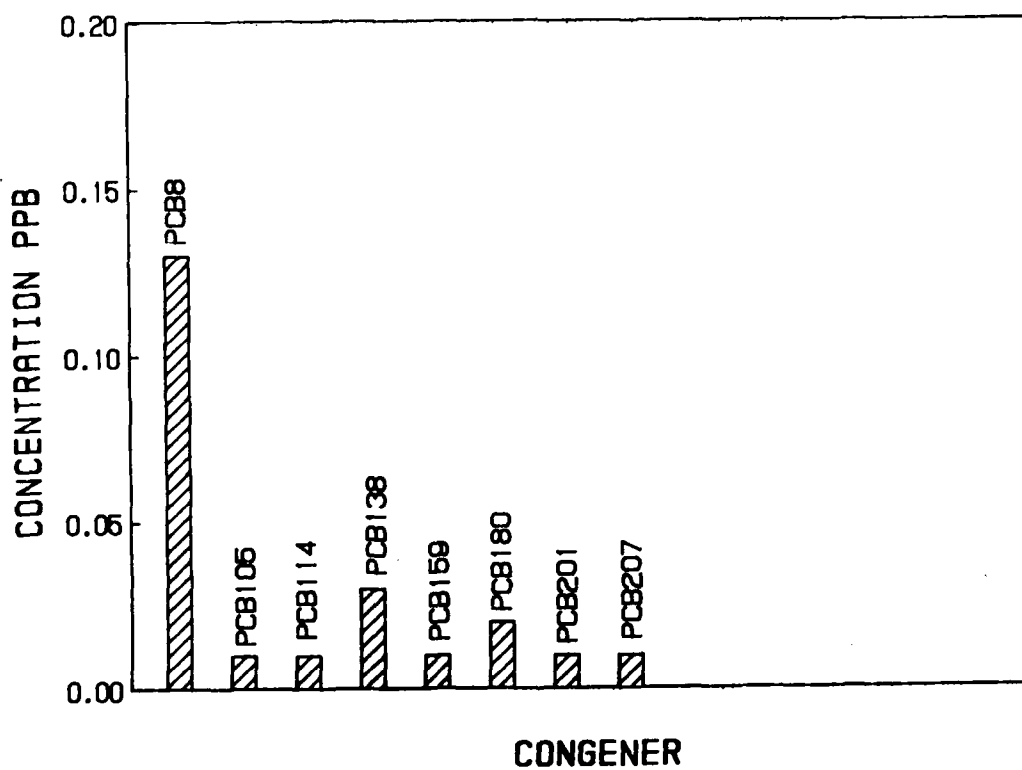


Figure A13. Plume sample A20-D total

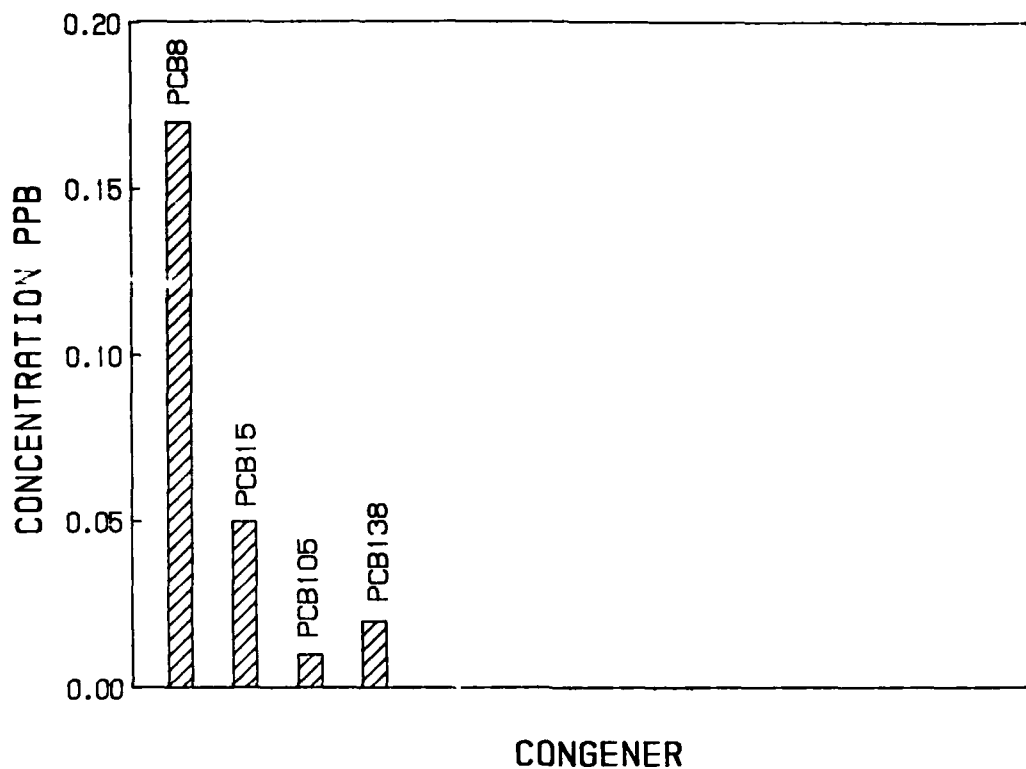


Figure A14. Plume sample A2NO-A total

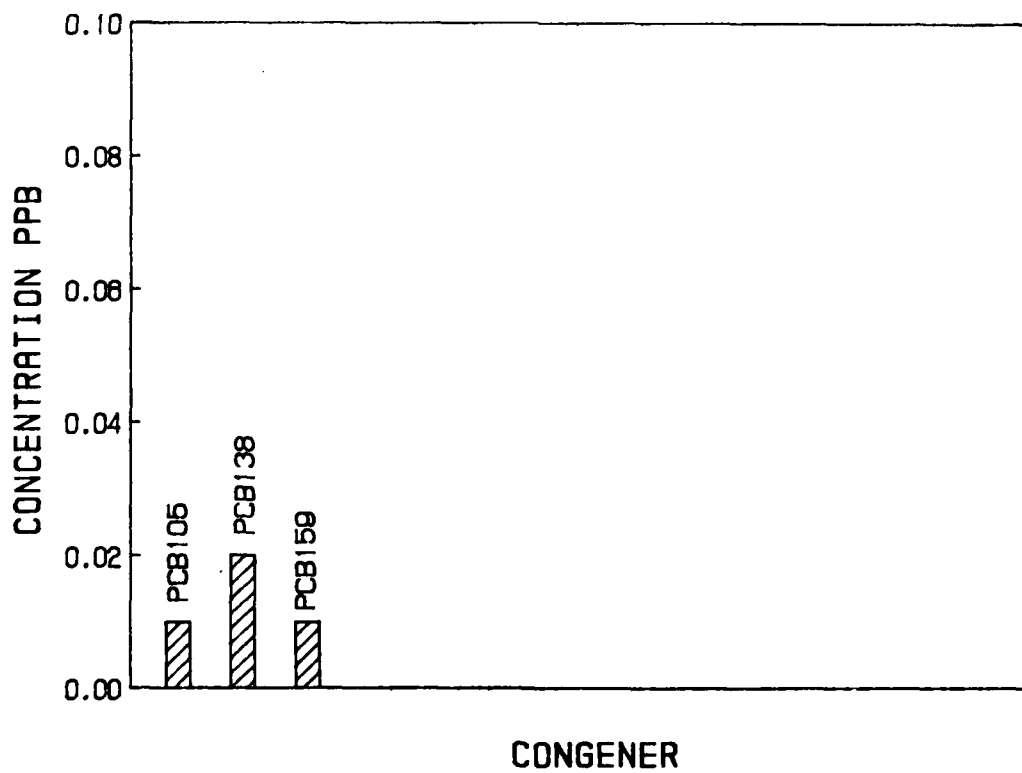


Figure A15. Plume sample A2NO-B total

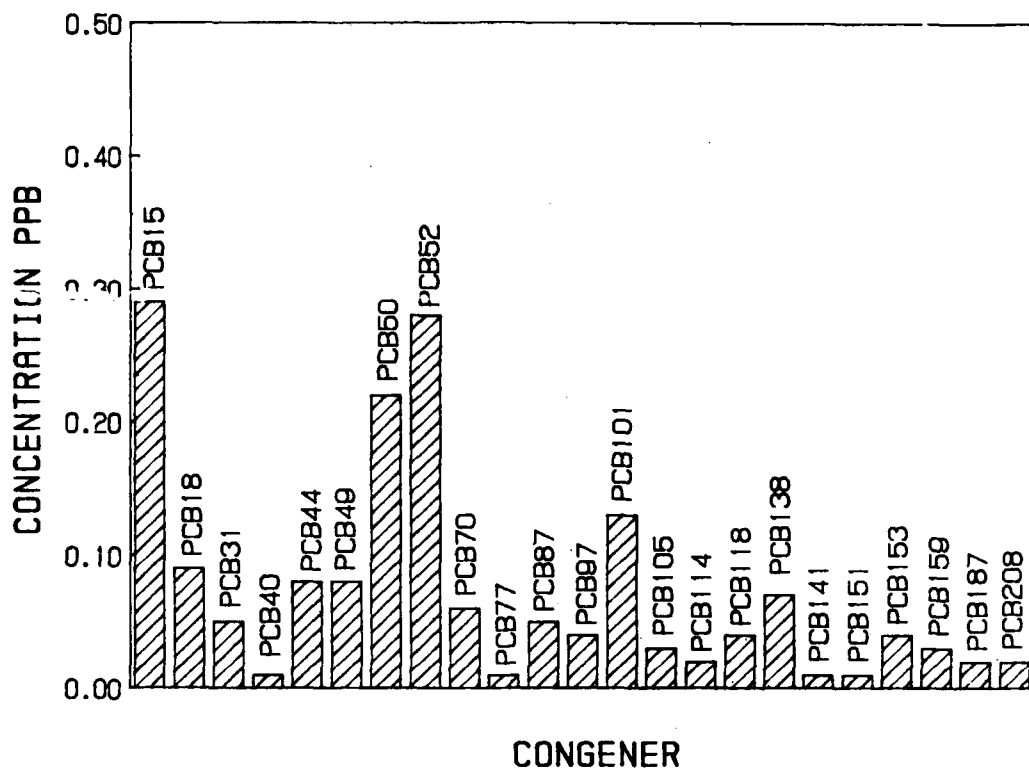


Figure A16. Plume sample A2NO-C total

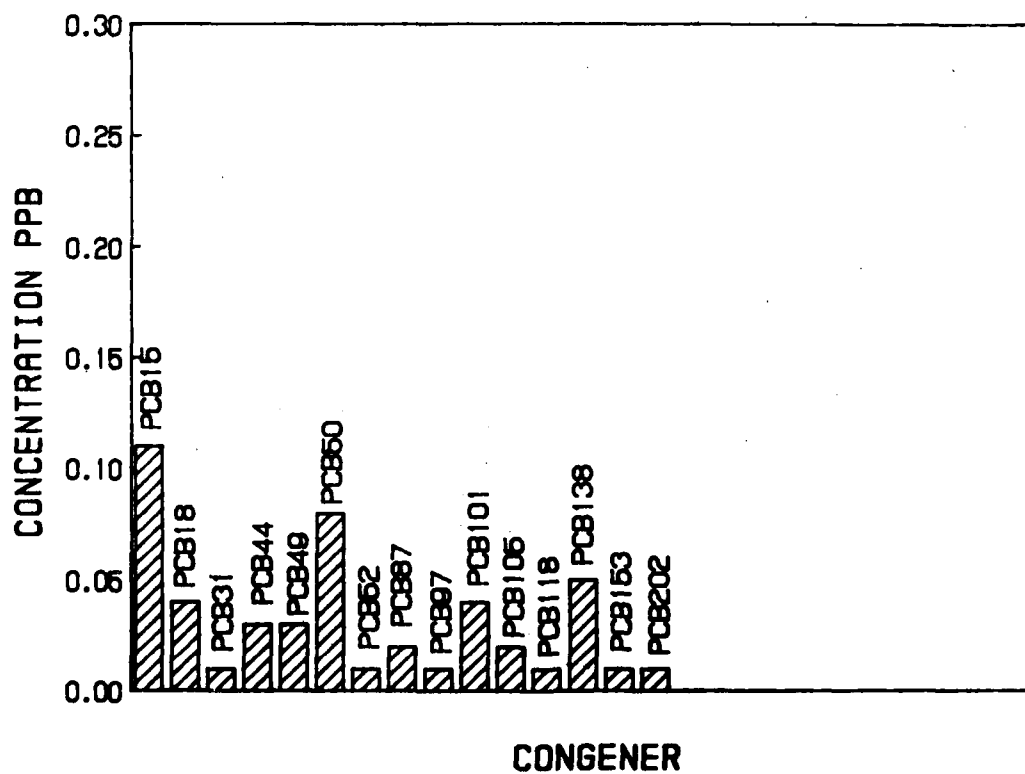


Figure A17. Plume sample A2NO-D total

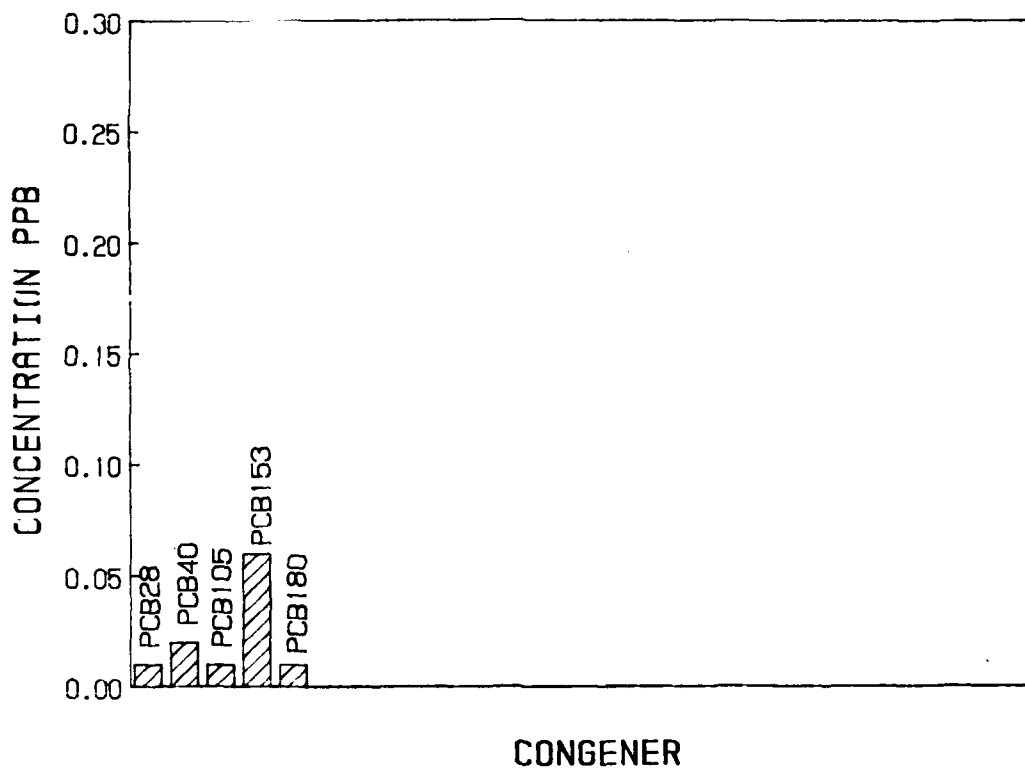


Figure A18. Plume sample A20-A dissolved

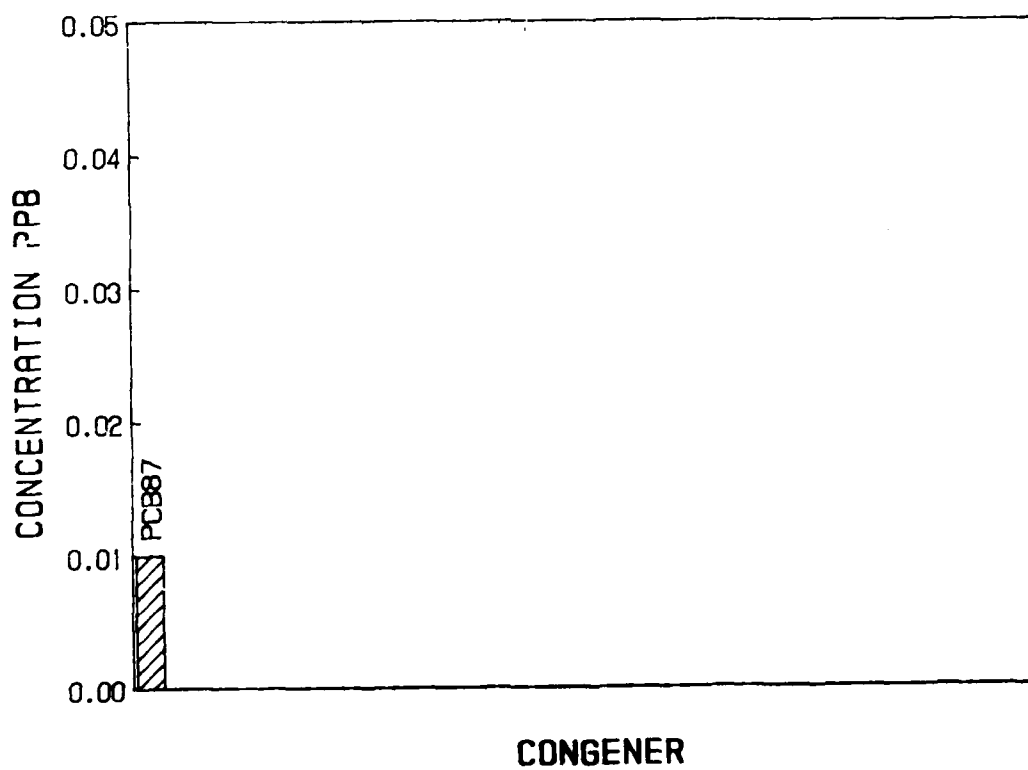


Figure A19. Plume sample A20-B dissolved

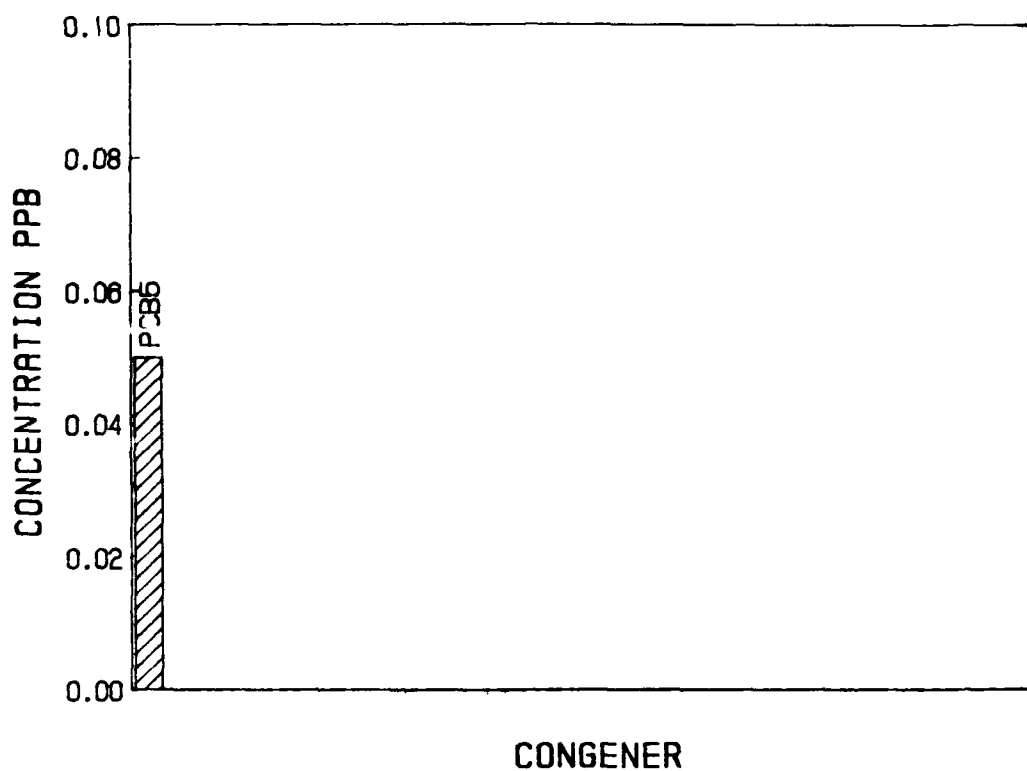


Figure A20. Plume sample A2NO-A dissolved

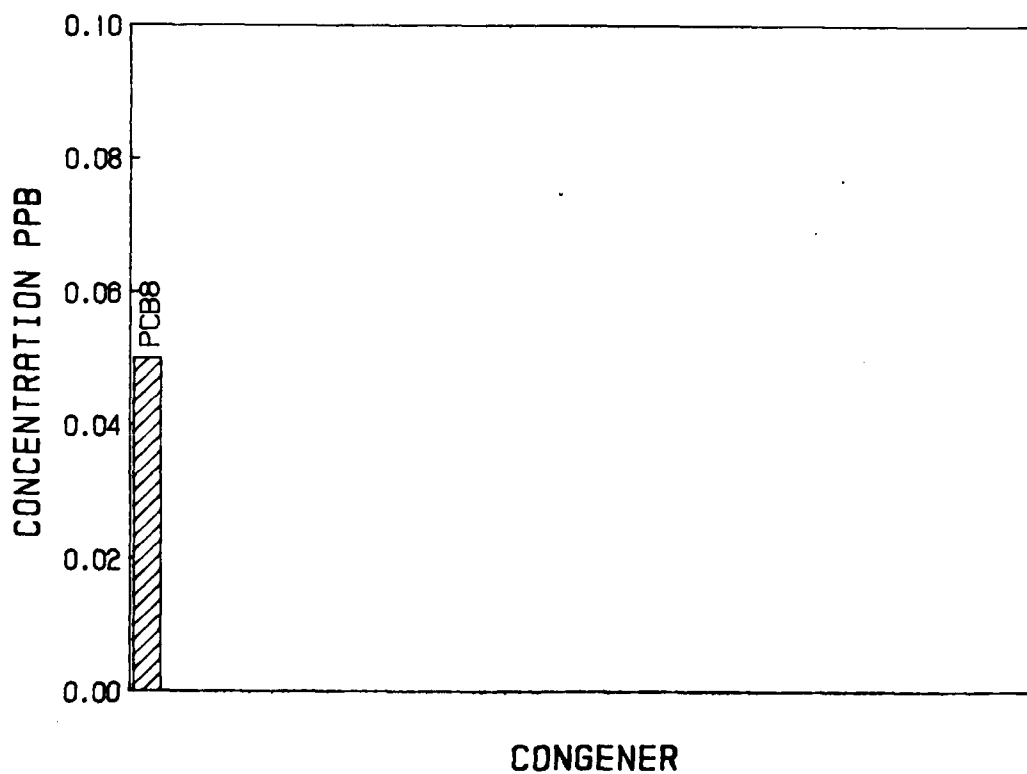


Figure A21. Plume sample A2NO-C dissolved

Appendix B: Elutriate Data

1. This appendix presents the results of PCB analyses conducted on standard and modified elutriate samples.

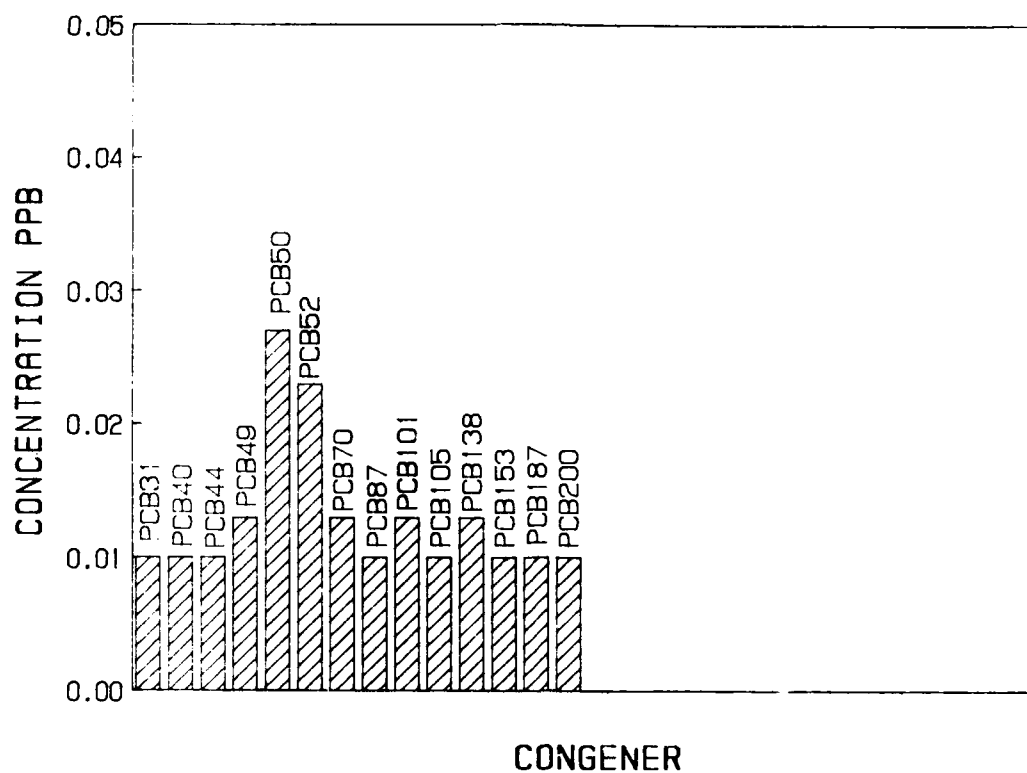


Figure B1. Average standard elutriate - total

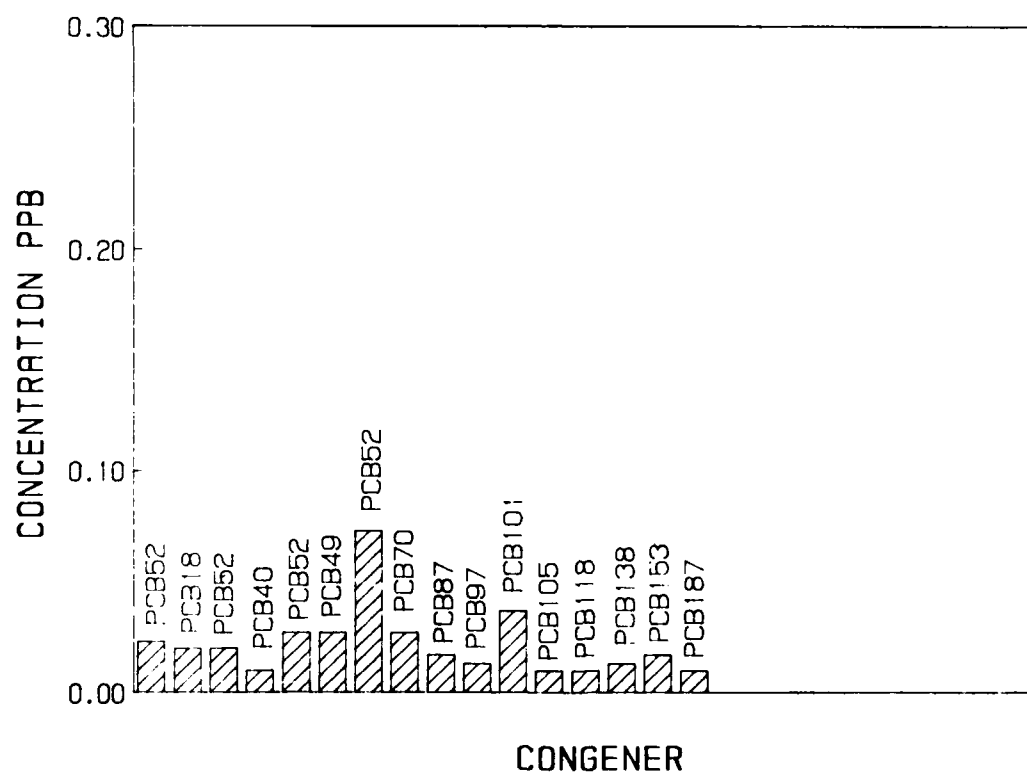


Figure B2. Average modified elutriate - total

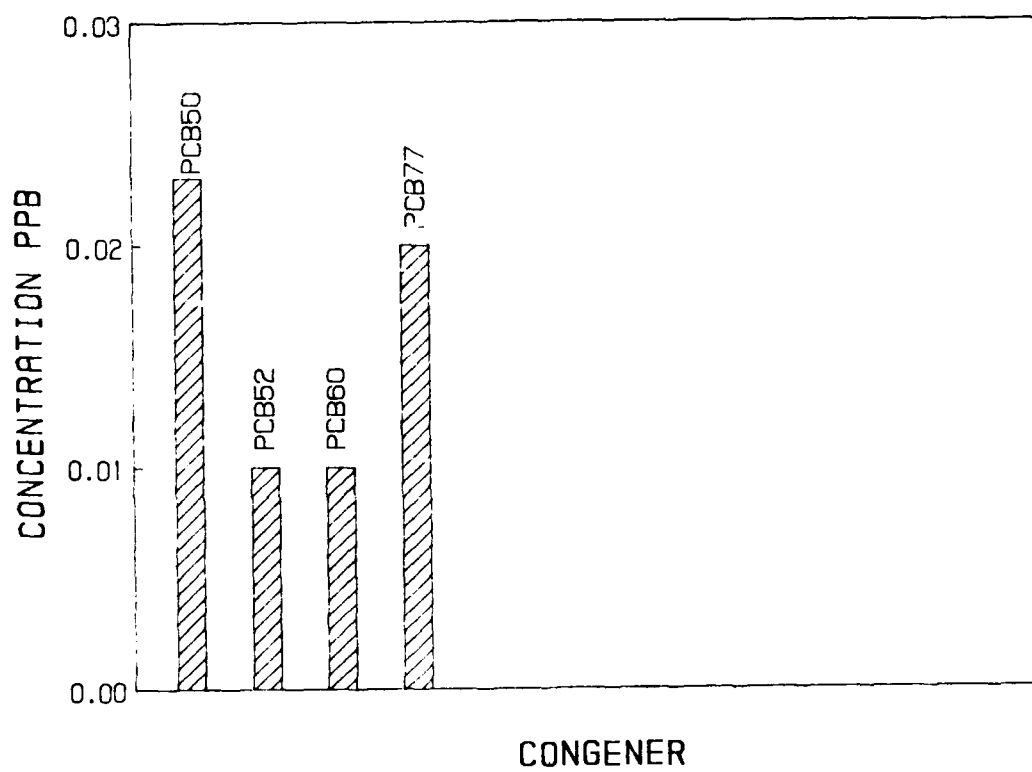


Figure B3. Average modified elutriate - dissolved