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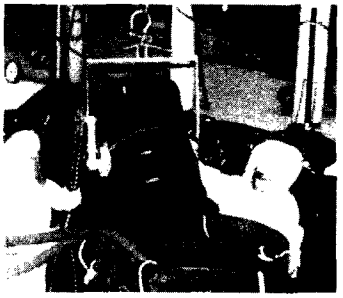

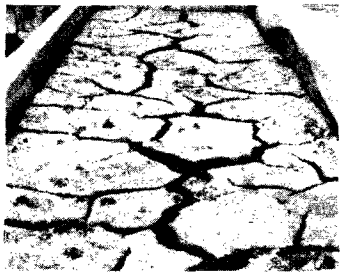

TECHNICAL REPORT EL-88-15

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

by

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March 1989

Report 3 of a Series

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NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

No. in Series	Report Title
1	Study Overview
2	Sediment and Contaminant Hydraulic Transport Investigations
3	Characterization and Elutriate Testing of Acushnet River Estuary Sediment
4	Surface Runoff Quality Evaluation for Confined Disposal
5	Evaluation of Leachate Quality
6	Laboratory Testing for Subaqueous Capping
7	Settling and Chemical Clarification Tests
8	Compatibility of Liner Systems with New Bedford Harbor Dredged Material Contaminants
9	Laboratory-Scale Application of Solidification/Stabilization Technology
10	Evaluation of Dredging and Dredging Control Technologies
11	Evaluation of Conceptual Dredging and Disposal Alternatives
12	Executive Summary

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Several of the alternatives being considered for the New Bedford Harbor Superfund Project involve dredging of contaminated sediment from the Acushnet River Estuary and placement of the contaminated dredged material in confined disposal areas. Evaluation of these alternatives requires testing sediment from the site to determine chemical and physical characteristics, settling properties, contaminant releases for various migration pathways, and treatment requirements for disposal area effluent.

The purpose of this report is to describe the estuary composite sediment sample and the hot spot sediment sample tested at the US Army Engineer Waterways Experiment Station as part of the US Army Corps of Engineers' Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives. Bulk sediment chemistry, physical characteristics, and elutriate testing for the sediments are included.

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Polychlorinated biphenyl (PCB) concentrations, reported as total PCB, in the estuary composite sediment and the hot spot sediment were 2,200 and 7,700 mg/kg, respectively. The sediments were also contaminated with heavy metals, notably copper, lead, and zinc. The Unified Soil Classification System description for both sediments was organic silt.

Both the standard elutriate test and the modified elutriate test were performed on the two sediment samples. Dissolved elutriate concentrations for PCBs and certain heavy metals exceeded Federal water quality criteria. Further analysis of contaminant release, receiving water concentrations, and transport will be required in the evaluation of alternatives for dredging and dredged material disposal.

PREFACE

This study was conducted as a part of the Acushnet River Estuary Engineering Feasibility Study (EFS) of Dredging and Dredged Material Disposal Alternatives. The US Army Corps of Engineers (USACE) performed the EFS for the US Environmental Protection Agency (USEPA), Region 1, as a component of the comprehensive USEPA Feasibility Study for the New Bedford Harbor Superfund Site, New Bedford, MA. This report, Report 3 of a series, was prepared by the US Army Engineer Waterways Experiment Station (WES) in cooperation with the New England Division (NED), USACE. Coordination and management support was provided by the Omaha District, USACE, and dredging program coordination was provided by the Dredging Division, USACE. The study was conducted between August 1985 and March 1988.

Project manager for the USEPA was Mr. Frank Ciavattieri. The NED project managers were Messrs. Mark J. Otis and Alan Randall. Omaha District project managers were Messrs. Kevin Mayberry and William Bonneau. Project managers for the WES were Messrs. Norman R. Francingues, Jr., and Daniel E. Averett.

This report was prepared by Mr. Averett, Water Supply and Waste Treatment Group (WSWTG), Environmental Engineering Division (EED), Environmental Laboratory (EL), WES. Laboratory studies were conducted by Ms. Teresa T. Holmes and Mr. Roy Wade, WSWTG. Chemical analyses for the study were performed by the Analytical Laboratory Group, EED, under the supervision of Ms. Ann Strong. Field sampling activities and engineering classification of sediments were provided by NED. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

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.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

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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:

Multiply	By	To Obtain
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
inches	2.54	centimetres
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square metres
yards	0.9144	metres

NEW BEDFORD HARBOR SUPERFUND PROJECT, ACUSHNET RIVER ESTUARY ENGINEERING FEASIBILITY STUDY OF DREDGING AND DREDGED MATERIAL DISPOSAL ALTERNATIVES

CHARACTERIZATION AND ELUTRIATE TESTING OF ACUSHNET RIVER ESTUARY SEDIMENT

PART I: INTRODUCTION

1. In August 1984, the US Environmental Protection Agency (USEPA) reported on the Feasibility Study of Remedial Action Alternatives for the Upper Acushnet River Estuary above the Coggeshall Street Bridge, New Bedford, MA (NUS Corporation 1984). The USEPA received extensive comments on the proposed remedial action alternatives from other Federal, state, and local officials, potentially responsible parties, and individuals. Responding to these comments, the USEPA chose to conduct additional studies to better define available cleanup methods. Because dredging was associated with all of the removal alternatives, the USEPA requested the US Army Corps of Engineers to conduct an Engineering Feasibility Study (EFS) of dredging and disposal alternatives. A major emphasis of the EFS was placed on evaluating the potential for contaminant releases from both dredging and disposal operations.

2. The technical phase of the EFS was completed in March 1988. However, as part of Task 8 of the EFS, the results of the study were compiled in a series of 12 reports, listed below.

- a. Report 1, "Study Overview."
- b. Report 2, "Sediment and Contaminant Hydraulic Transport Investigations."
- c. Report 3, "Characterization and Elutriate Testing of Acushnet River Estuary Sediment."
- d. Report 4, "Surface Runoff Quality Evaluation for Confined Disposal."
- e. Report 5, "Evaluation of Leachate Quality."
- f. Report 6, "Laboratory Testing for Subaqueous Capping."
- g. Report 7, "Settling and Chemical Clarification Tests."
- h. Report 8, "Compatibility of Liner Systems with New Bedford Harbor Dredged Material Contaminants."

i. Report 9, "Laboratory-Scale Application of Solidification/ Stabilization Technology."

j. Report 10, "Evaluation of Dredging and Dredging Control Technologies."

k. Report 11, "Evaluation of Conceptual Dredging and Disposal Alternatives."

l. Report 12, "Executive Summary."

This report is Report 3 of the series. The results of this study were obtained from conducting EFS Task 6, elements 1 and 2, and Task 4, element 1 (see Report 1). These study results are incorporated and used in the evaluation of conceptual dredging and dredged material disposal alternatives described in EFS Report 11.

Background

3. The EFS conducted by the USACE is based on laboratory testing protocols recommended for contaminated sediment in the "Management Strategy for Disposal of Dredged Material: Contaminant Testing and Controls" (Francingues et al. 1985). This strategy requires an initial evaluation to assess contamination potential and to identify potential disposal alternatives prior to applying the testing protocols.

4. The initial evaluation usually involves chemical characterization of the sediment. Sediment from the Acushnet River Estuary has been characterized by other investigations. The results of these investigations, compiled into a data base report by Metcalf and Eddy, Inc. (1983), led to the designation of New Bedford Harbor, which includes the Acushnet River Estuary, as a Superfund site. The primary purpose of the sediment characterization information presented in this report is to establish the background reference, or baseline, for evaluation of other testing protocols applied by the EFS.

5. Collection and compositing of sediment samples for testing at the US Army Engineer Waterways Experiment Station (WES) represents work performed for Task 5 of the EFS. These samples were tested as a part of Task 4, elements 1 and 4, and as a part of all elements of Task 6. Bulk sediment chemistry for the composite sample is the substance of Task 6, element 1, and elutriate testing was accomplished under Task 6, element 2. A complete description of the EFS is available in Report 1, "Study Overview."

6. The EFS evaluates alternatives for dredging contaminated sediment from the estuary and for disposing of the dredged material in a confined disposal facility (CDF) or in a contained aquatic disposal (CAD) facility. A CDF may be located near the shoreline with an elevation partially below the tide range, or it may be located upland with an elevation above the tide range. The CAD alternative involves excavation of a pit in the estuary for placement of contaminated dredged material in the bottom and capping of the contaminated sediment with clean sediment. Elutriate tests have been developed to predict contaminant releases during CDF filling operations and during placement of dredged material in open water. Results of the standard and modified elutriate tests for Acushnet River Estuary sediment are presented in this report. Application of elutriate tests to contaminant releases at the dredge plant and for a CAD facility will also be considered, although it is not a field-proven procedure.

Purpose and Scope

7. The purpose of this report is to describe the primary sediment samples tested at the WES for the EFS. The description will include chemical characteristics, physical characteristics or engineering classification, and elutriate testing results for the sediment samples evaluated. Two samples were tested: a composite sample representing the upper midlevel sediment polychlorinated biphenyl (PCB) concentration in the Upper Estuary and a hot spot sample selected to represent the higher sediment PCB concentration. The composite sample was tested most extensively by the EFS and was, therefore, subjected to the most extensive initial characterization. The EFS approach was to test a single composite sample rather than a series of samples because testing of a conservative (higher) PCB concentration and typical physical characteristics could be extrapolated to a majority of the Upper Estuary sediments, and also because of the expense of testing a number of different samples.

PART II: SEDIMENT SAMPLE COLLECTION

8. Sediment sample collection involved investigation of sediment PCB concentrations and physical characteristics, selection of the type of sediment for EFS testing, identification of locations within the estuary for sampling, and compositing of a 250-gal* sample for testing at the WES.

Characterization of Estuary Sediment

9. Task 2 of the EFS was conducted to assess the horizontal and vertical distributions of contaminants and sediment physical types in the estuary. Data from this characterization program were used to identify the type of sediment sample that should be subjected to laboratory testing protocols programmed for the EFS. The sediment characterization program results for Task 2 have been reported by Condike (1986).

10. The estuary sediment characterization program was based on a grid system with each sampling grid being a 250- by 250-ft cell. A 3-in. push tube sediment sample was taken from each of the approximately 150 grid cells for the estuary. Sediment cores from 31 of the grid cells were analyzed prior to selecting the samples to be tested at WES. The PCB concentrations in the top 1- to 2-ft layer of sediment (illustrated in Figure 1) ranged from 2 to 36,000 ppm. The PCB concentrations for depths greater than 2 ft were less than 2 ppm for all but one of the 31 cores analyzed.

11. Plotting of the sediment PCB concentrations on a logarithmic probability scale yielded the relationship in Figure 2. Figure 2 does not include the peak concentration detected (36,000 ppm), which has been designated as a hot spot. Two approaches were considered for selecting the sediment PCB concentration for the composite sample: evaluation of a sample with the median PCB concentration or evaluation of a sample representing 90 percent of the PCB concentrations for the cores tested. Dredging and disposal alternatives will tend to blend high and low contaminant concentrations, particularly in a CDF. However, the PCB concentrations in the northern end of the estuary are much higher than the concentrations nearer the Coggeshall Street Bridge. Dredging in the more highly contaminated sediment will extend over several months and,

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

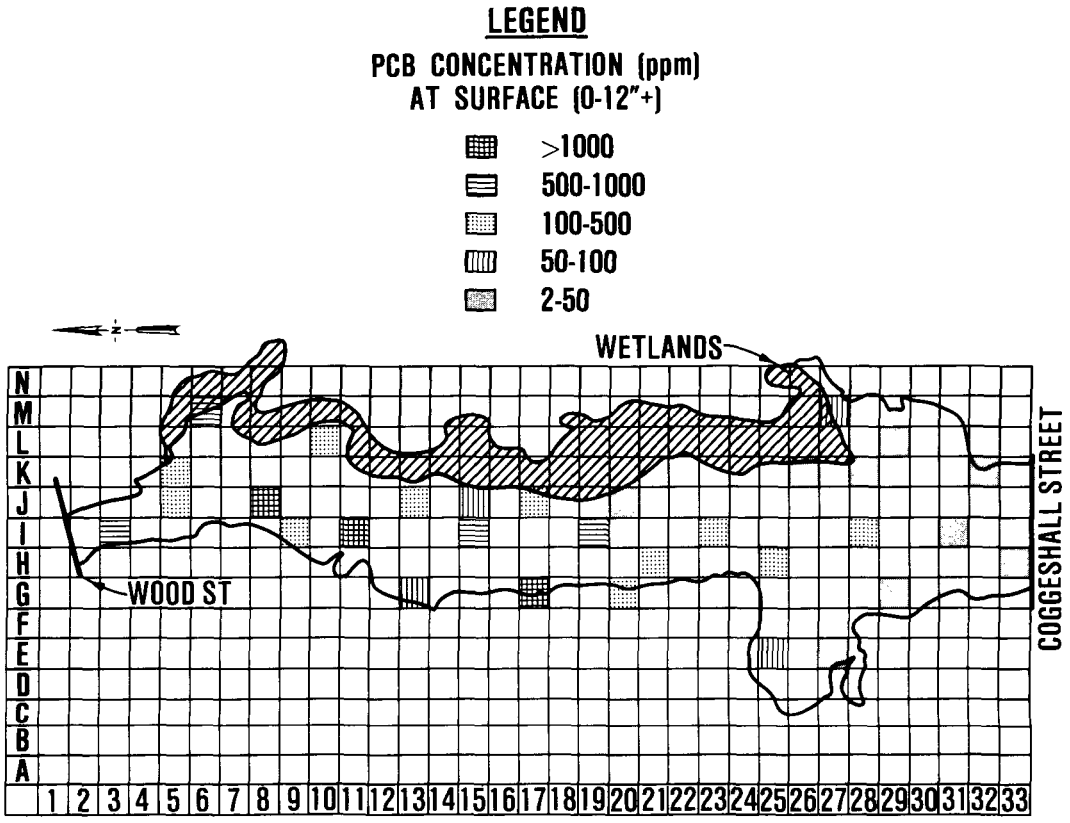

Figure 1. Sediment PCB concentrations in the Acushnet River Estuary (Condike 1986)

for most scenarios, these sediments will not be significantly diluted by less contaminated sediment. The hot spot area, where sediment PCB concentrations are extreme, such as the 36,000-ppm sample, are being considered for separate removal and disposal. Evaluation of feasibility for dredging and disposal alternatives aside from the hot spot must be applicable to the upper end of what may be called the midlevel PCB concentration. Therefore, the more conservative approach or worst case for contaminant release during dredging and disposal was selected for the composite sample. The 90-percent probability PCB concentration for the initial sediment characterization was 1,100 ppm (milligrams per kilogram).

12. Analyses of the sediment cores for heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) indicated concentrations above what could be considered background. Metal releases will be important in the evaluation of dredging and disposal alternatives. Review of metal concentrations reported by the sediment characterization study did not suggest

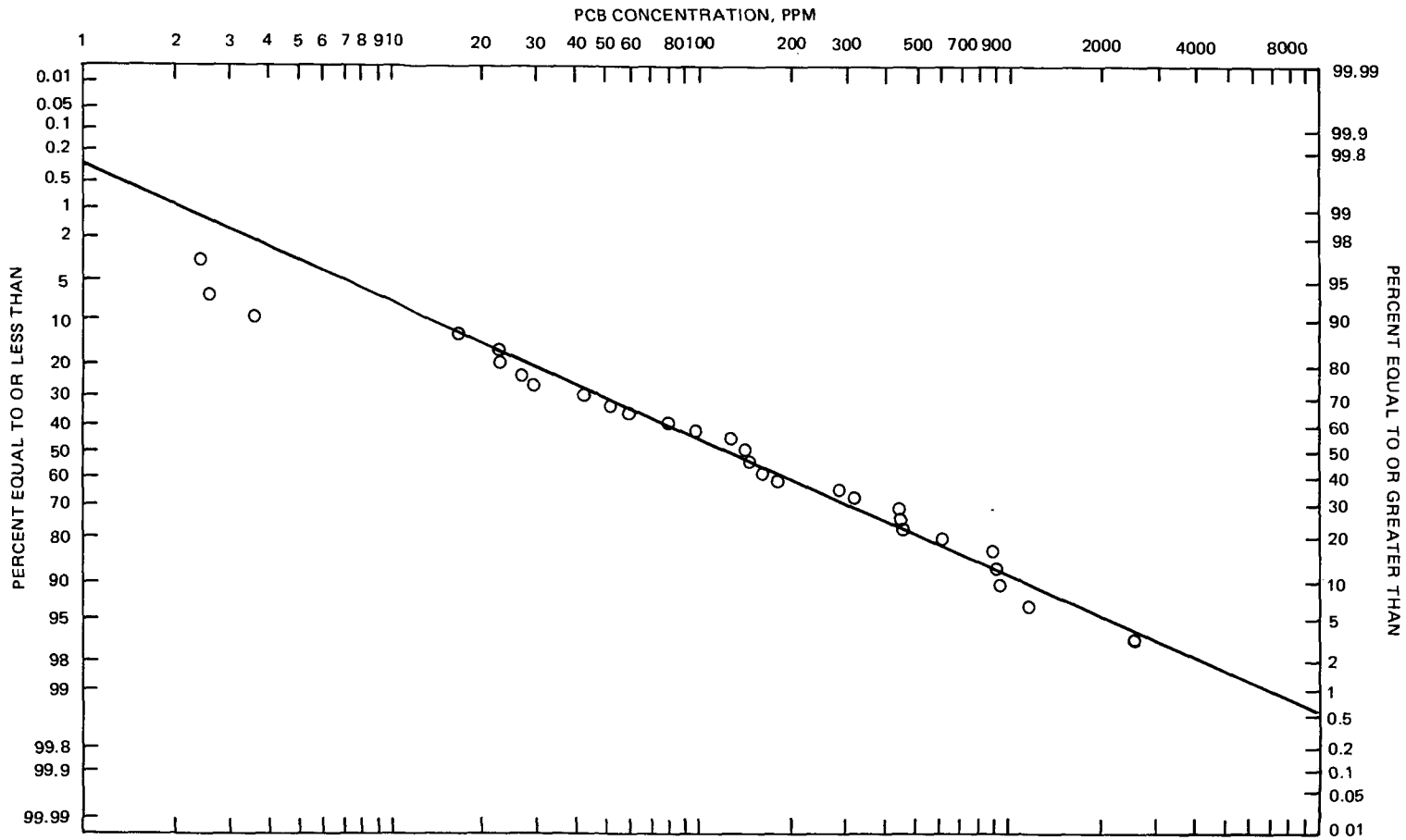

Figure 2. Observed distribution of sediment PCB concentrations in the Acushnet River Estuary

a sampling strategy different from one based on PCB analyses. Since PCB contamination is the principal contaminant identified for the cleanup, the composite sampling strategy was based on the PCB data.

13. Physical and engineering characteristics were also determined for selected sediment cores. The top 2-ft layer of sediment was classified as organic silts and organic clays with sand, sandy silts, and silty sands. Physical characteristics of the more contaminated sediments were similar and did not suggest a compositing strategy different from one based on PCB concentration.

Collection of Estuary Composite and Hot Spot Samples for Testing

14. The sediment samples considered by this report were collected from the estuary between 26 March and 8 April 1986 by HMM Associates, Inc., under contract to the US Army Engineer Division, New England (NED). A detailed report by HMM Associates, Inc. (1986), describes the sampling and compositing activities. Therefore, this report will only summarize the field sampling activity and the procedure used to prepare the estuary composite sample.

15. To achieve the target 1,100-mg/kg PCB concentration for the composite sample, the contractor was instructed to collect sediment samples to a depth of 2 ft from grids J-8, G-17, I-19, and I-23 (Figure 3). This mix was based on concentrations previously observed in sediment cores. Water samples from the estuary were also collected from these four grids for use in the elutriate and settling tests.

16. During composite sample collection, sediment samples were also collected from grid I-11 to represent the hot spot and from grids K-26, K-28, and I-31 for use in surface runoff testing. Hot spot sediment (grid I-11) was collected for potential testing since the original EFS scope did not include any separate testing of hot spot sediment. The less contaminated sediment from the area near the bridge (grids K-26, K-28, and I-31) was used for surface runoff testing because most disposal operations could include placement of a cleaner sediment on top of the CDF to minimize contamination of rainfall runoff. The surface runoff sediment is discussed in more detail in Report 4 of this series.

17. Samples were collected with a modified box corer that collected a 1-sq ft sample to a depth of 2 ft, plus or minus 4 in. The corer, weighing

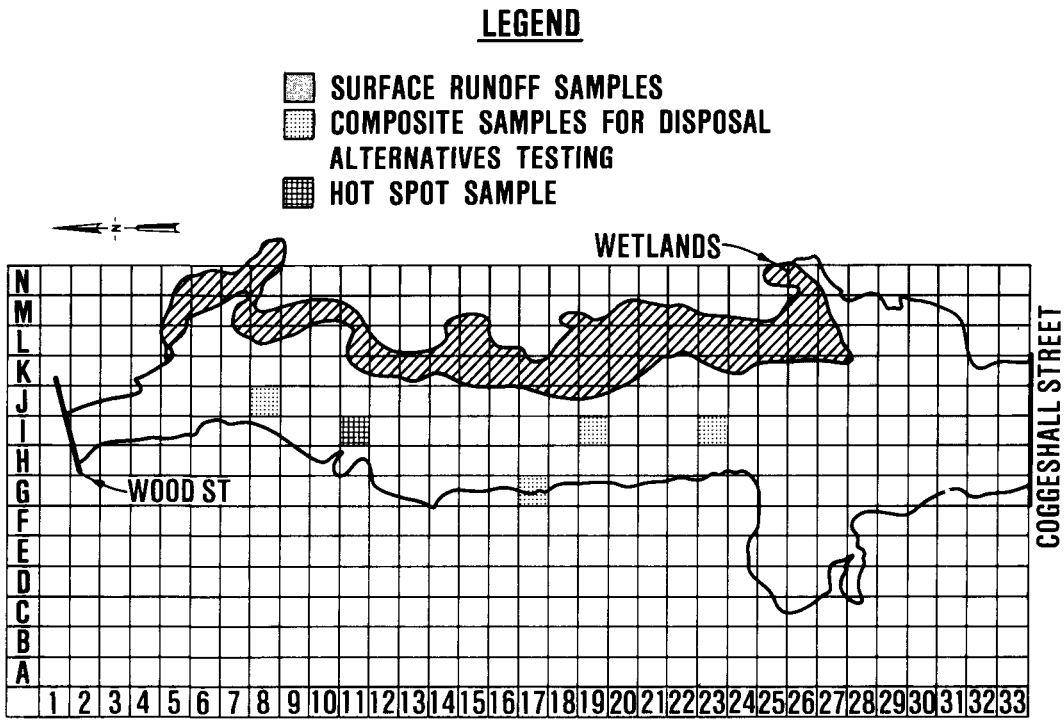

Figure 3. Locations of sampling grids for EFS

450 lb, was deployed from a mooring barge using a hydraulic winch and hydraulic A-frame. The box corer samples were placed in steel barrels and shipped to Clean Harbors Company, a hazardous waste management firm in Quincy, MA. The NED Water Quality Laboratory performed PCB analyses of the barrels collected for the composite sample and developed a formula for the mix to achieve the target concentration. Selected volumes from each sampling barrel were emptied into a single container, mixed, and then transferred to five 55-gal steel barrels. These barrels were labeled as composite samples and shipped by refrigerated truck to the WES.

18. The composite and hot spot sediment samples and the estuary water samples were received at the WES and stored at 4° C until used for the EFS testing protocols. Prior to performing any testing of the composite sample, the five composite barrels were again poured into a single container, thoroughly blended, and poured back into the barrels at WES. The purpose of this operation was to extract a representative sample for chemical characterization and to ensure that the composite sample was well mixed.

PART III: CHEMICAL AND PHYSICAL CHARACTERIZATION

Sediment Chemistry

19. Sediment samples were analyzed for PCB Aroclors, total PCB (quantitative using a multi-Aroclor standard), selected PCB congeners, polynuclear aromatic hydrocarbons (PAHs), arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Concentrations of PCB Aroclors, total PCB, PCB congeners, and PAH compounds were determined following soxhlet extraction, Florosil cleanup, and quantification in either a Hewlett Packard 5985A gas chromatograph/mass spectrophotometer equipped with a flame ionization detector (for PAHs) or a Hewlett Packard 5880A gas chromatograph equipped with an electron capture detector (for PCBs). Metals were analyzed by directly coupled plasma emission spectroscopy on a Beckman Spectraspan IIIB plasma emission spectrometer or by atomic absorption spectroscopy using a Perkin-Elmer Model 5000 atomic absorption spectrometer coupled with a Perkin-Elmer Model 500 hot graphite atomizer following appropriate sample digestion procedures (Ballinger 1979).

20. The original scope of work for the EFS included analysis only for PCB Aroclors. Aroclors are currently used for PCB water quality criteria, have been widely reported in the literature and for other New Bedford Harbor studies, and provide a measure of total PCB concentration. Congener analysis was added to the analysis schedule for EFS laboratory testing because of the limitations of Aroclor analysis in defining effects on various environmental compartments (McFarland, Clarke, and Gibson 1986), the more accurate analytical techniques for individual congeners, and the better defined physical properties for congeners.

21. The PCB congeners selected for analysis of the composite and hot spot sediments are listed in Table 1. The EFS reports will use the abbreviated congener number adopted by the International Union of Pure and Applied Chemists (IUPAC). The congeners in Table 1 were selected on the basis of toxicity, persistence, and prevalence in environmental samples. They include representatives of the PCB isomer groups di-, tri-, tetra-, penta-, hexa-, and heptachlorobiphenyl.

Estuary composite sediment sample

22. Chemical analyses of the estuary composite sediment sample and of the hot spot sediment sample for PCBs are presented in Table 2. The PCB

results for the composite sample in Table 2 show a total PCB concentration of 2,170 mg/kg on a dry weight basis. Total PCB analysis for this study calibrates the sample PCB concentration against a standard mixture of Aroclors 1242, 1254, and 1260 in equal amounts. A summation of the Aroclors found above the detection limit (A-1242 and A-1254) in these samples yields a total PCB concentration of 1,550 mg/kg. Summing the concentrations for the individual congeners analyzed gives a total PCB concentration of 1,360 mg/kg.

23. The total PCB concentration was greater than the 1,100-mg/kg (ppm) target concentration for the composite sample. However, since the targeted and the actual concentrations are the same order of magnitude and are subject to the inherent variability in sampling and analysis for PCBs, the composite sample is an appropriate sample for evaluation of dredging and disposal alternatives.

24. For the 23 congeners analyzed, 48 percent of the total was reported in the tetrachlorobiphenyl isomer. Approximately equal fractions (11 to 14 percent) were included in the di-, tri-, penta-, and hexachlorobiphenyl groups. Obviously, these percentages could change if a more exhaustive list of congeners were quantitated.

25. Table 3 displays the heavy metal analyses for the composite and hot spot sediments. Copper, lead, and zinc, the most abundant metals in New Bedford sediment, were present at concentrations of 1,730, 2,010, and 3,020 mg/kg, respectively. These concentrations exceed those normally encountered in sediments where dredging is proposed or implemented (Brannon, Plumb, and Smith 1980). Mean concentrations of heavy metals in the composite sample were greater than the mean concentration for the sediment cores analyzed by Condike (1986). Because of the comparatively low levels of arsenic, mercury, and selenium, analysis for these metals was not included in most other subsequent EFS laboratory testing.

26. The PAH concentrations in the composite sample are presented in Table 4. Mean concentrations for PAH compounds ranged from less than 4.6 mg/kg to 11.8 mg/kg. Results of the analyses for other organic pollutants in the composite sediment and the miscellaneous analyses performed are given in Appendix A. Mean percent by weight solids concentration was 36 percent. The oil and grease concentration was 28,000 ppm. Total organic carbon averaged 26,000 ppm.

Hot spot sediment sample

27. The hot spot sediment sample tested at WES was taken from one of the original sample drums (No. I-11-3) filled by HMM Associates, Inc. This 55-gal drum was sealed in the field and shipped with the composite sediment drums to WES in a refrigerated truck. The sample was stored at 4° C at the WES prior to testing. Prior to sampling for bulk analysis, the barrel was thoroughly homogenized with an electric propeller-type mixer.

28. Analyses for PCBs and heavy metals in the hot spot sample are presented in Tables 2 and 3, respectively. Average total PCB concentration (calibrated against the mixed Aroclor standard) was 7,680 mg/kg. The sum of Aroclors 1242 and 1254 was 8,400 mg/kg. (Other Aroclors were below detection limit.) The sum of the congeners evaluated was 5,440 mg/kg. Tetra- and pentachlorobiphenyl isomer groups comprised more than half of the congeners reported. The heavy metal results in Table 3 show that the hot spot concentrations for all metals, except zinc, are slightly less than the composite sample. However, mean metal concentrations in the hot spot sample are greater than the mean for sediment cores from the estuary analyzed by Condike (1986).

Sediment Physical Characteristics

29. Engineering classification of sediment is important to proper interpretation of data from other EFS testing protocols. The estuary composite sample was tested for water content, grain size analysis, Atterberg limits, and specific gravity as proposed for Task 6, element 6, of the EFS. The hot spot sample was tested for the same parameters except that the grain size analysis only determined the fractions of sand, silt, and clay. Testing was performed in accordance with Engineer Manual (EM) 1110-2-1906 (US Army Corps of Engineers 1970), except that the hot spot grain size analysis was performed using the method of Patrick (1958). The composite sample was tested by NED, and the hot spot sample was tested at WES.

30. Results of the physical testing for both sediment samples are presented in Table 5. The grain size curve for the composite sample is shown in Figure 4. The Unified Soil Classification System (USCS) description is a dark gray, sandy organic silt (OH). The hot spot sample contained more clay-sized particles and less sand but would still be classified OH. These sediment characteristics are generally typical of those reported by Condike (1986).

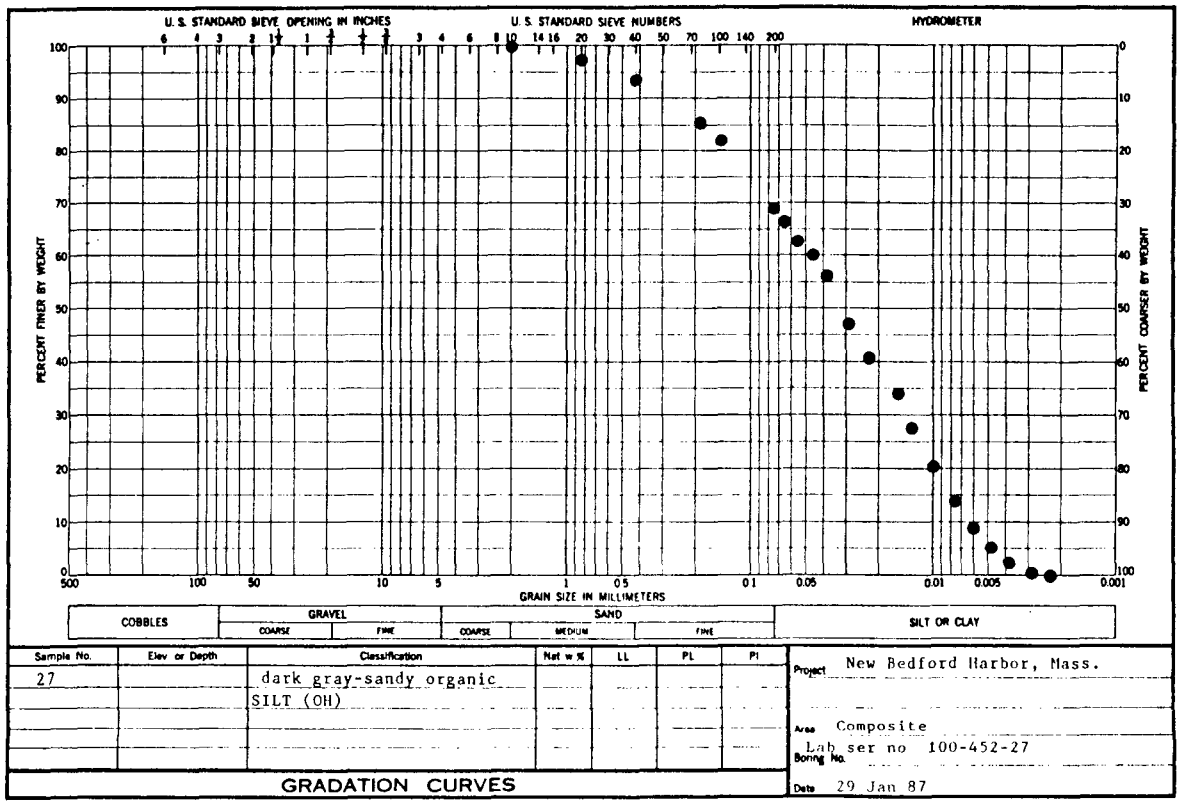

Figure 4. Grain size distribution for EFS composite sediment

PART IV: ELUTRIATE AND CONTAMINANT RELEASE TESTING

Background

Standard elutriate test

31. The standard elutriate test (Plumb 1981) has been used to estimate the release of soluble contaminants into the water column during open-water disposal operations. Disposal of the contaminated sediment from the Acushnet River Estuary in an open-water site is not currently a highly rated remedial alternative. However, contained aquatic disposal is an alternative being evaluated by the EFS. The physical and chemical processes occurring during placement of dredged material in a CAD are similar to open-water disposal. The standard elutriate test has also been reported to satisfactorily predict the release of certain soluble contaminants at or near a dredge (Ludwig, Sherrard, and Amende 1987). Therefore, standard elutriate test data will be used to estimate the release of soluble contaminants at CAD sites and will be considered for releases of soluble contaminants at the point of dredging.

Modified elutriate test

32. The modified elutriate test is a technique developed to predict the quality of effluent from confined disposal facilities during hydraulic filling or placement operations by simulating the physicochemical conditions in the CDF that affect contaminant release. Dredged material placed in a CDF separates into a thickened deposit of sediment overlain by clarified water (supernatant). Supernatant is discharged from the site as effluent during the disposal operation. Coupling the modified elutriate test data to the column settling test data and CDF retention time provides an estimate of both the dissolved and particle-associated contaminant concentrations in the effluent.

Procedures

Standard elutriate test

33. Standard elutriate tests for the EFS were performed in accordance with the procedure described in Plumb (1981). A schematic of this test procedure is shown as Figure 5. A mixture consisting of 20 percent sediment and 80 percent site water by volume was placed in a 4-ℓ graduated cylinder and mixed by bubbling compressed air through the mixture for 30 min. Compressed

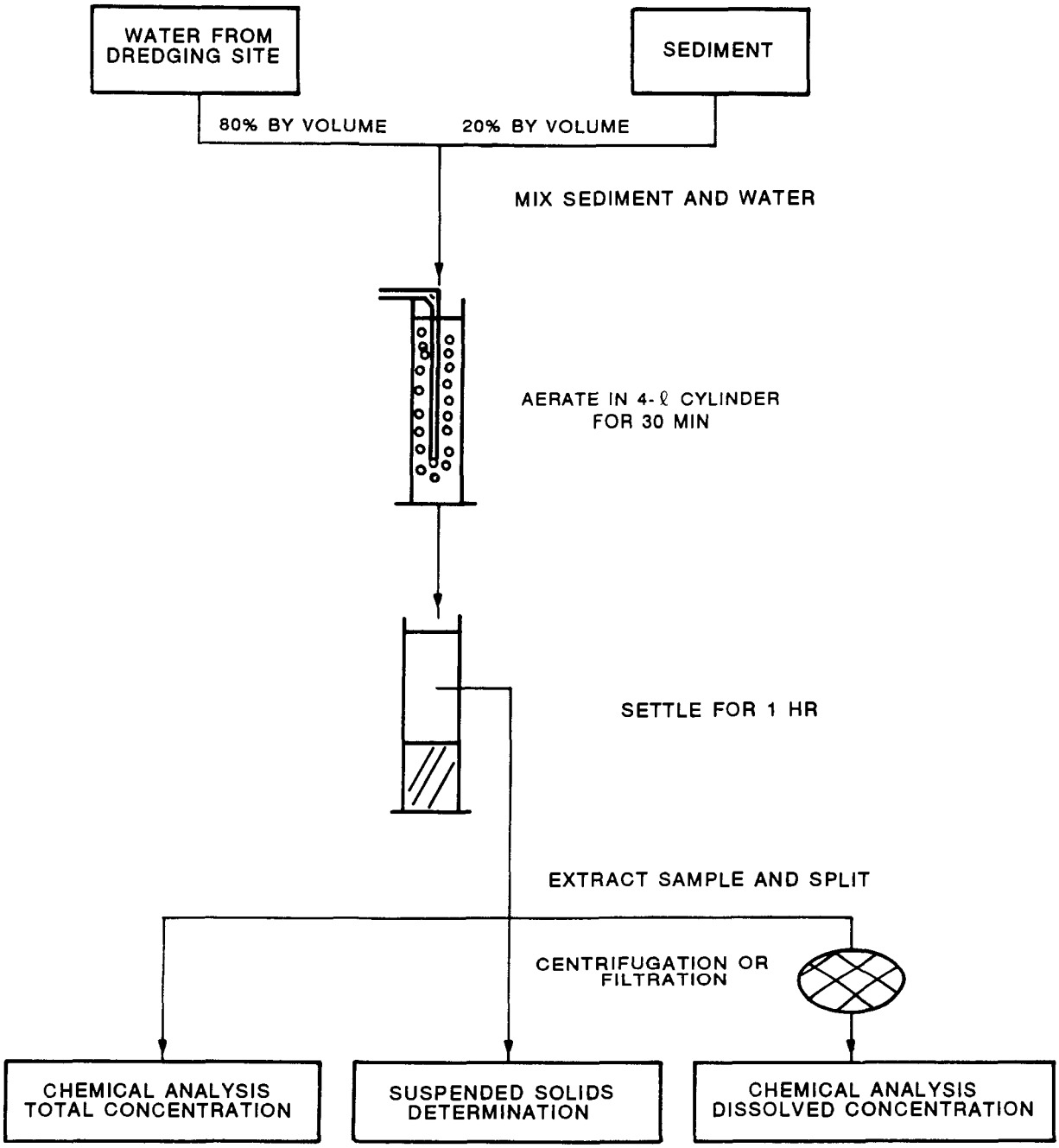

Figure 5. Schematic of standard elutriate test procedure

air mixing in lieu of mechanical shaking is recommended by the protocol when oxidizing conditions are expected at the disposal site. After the mixing phase of the test, the slurry is allowed to settle for 1 hr. The elutriate above the sediment-water interface is siphoned from the cylinder and prepared for analysis.

34. Routine application of the test requires analysis only for the soluble contaminants in the elutriate. However, this study also analyzed the whole elutriate in order to have another measure of contaminant concentration of the elutriate suspended solids. The protocol for analysis of soluble organic contaminants is to centrifuge the elutriate to remove suspended solids because of possible sorption of organics on the standard 0.45-μm filter. This procedure was followed for the composite sample, but the resulting data indicate that all suspended solids may not have been effectively removed. Later elutriate testing for the hot spot sediment used filtration through a Gelman AE glass fiber filter to remove suspended solids. This type of filter has no organic binder and is commonly used by analytical laboratories to separate soluble and suspended organic contaminants. As an added precaution, the filters were precombusted at 400° C to remove trace organic materials.

Modified elutriate test

35. Modified elutriate tests were conducted using the procedure described in Palermo (1985). A schematic of this test procedure is shown as Figure 6. Sediment and water from the dredging site were mixed into a slurry with the concentration of solids approximately equal to that expected in the CDF influent (70 to 140 g/ℓ). The slurry was placed in a 4-ℓ cylinder and aerated for 1 hr to ensure that oxidizing conditions were present during the subsequent settling phase. The aerated slurry was allowed to settle for 24 hr. After settling, the elutriate, or supernatant, was siphoned from the cylinder and analyzed for total suspended solids (TSS), dissolved contaminants, and total (before filtration or centrifugation) contaminants. The contaminants associated with the suspended solids are calculated as the difference between total and dissolved analyses divided by the TSS concentration.

Analytical methods

36. Elutriate samples were analyzed for concentrations of PCB Aroclors, total PCB, selected PCB congeners, cadmium, chromium, copper, lead, nickel, zinc, and TSS. Concentrations of PCB compounds in the elutriates were measured following methylene chloride extraction on the same equipment as

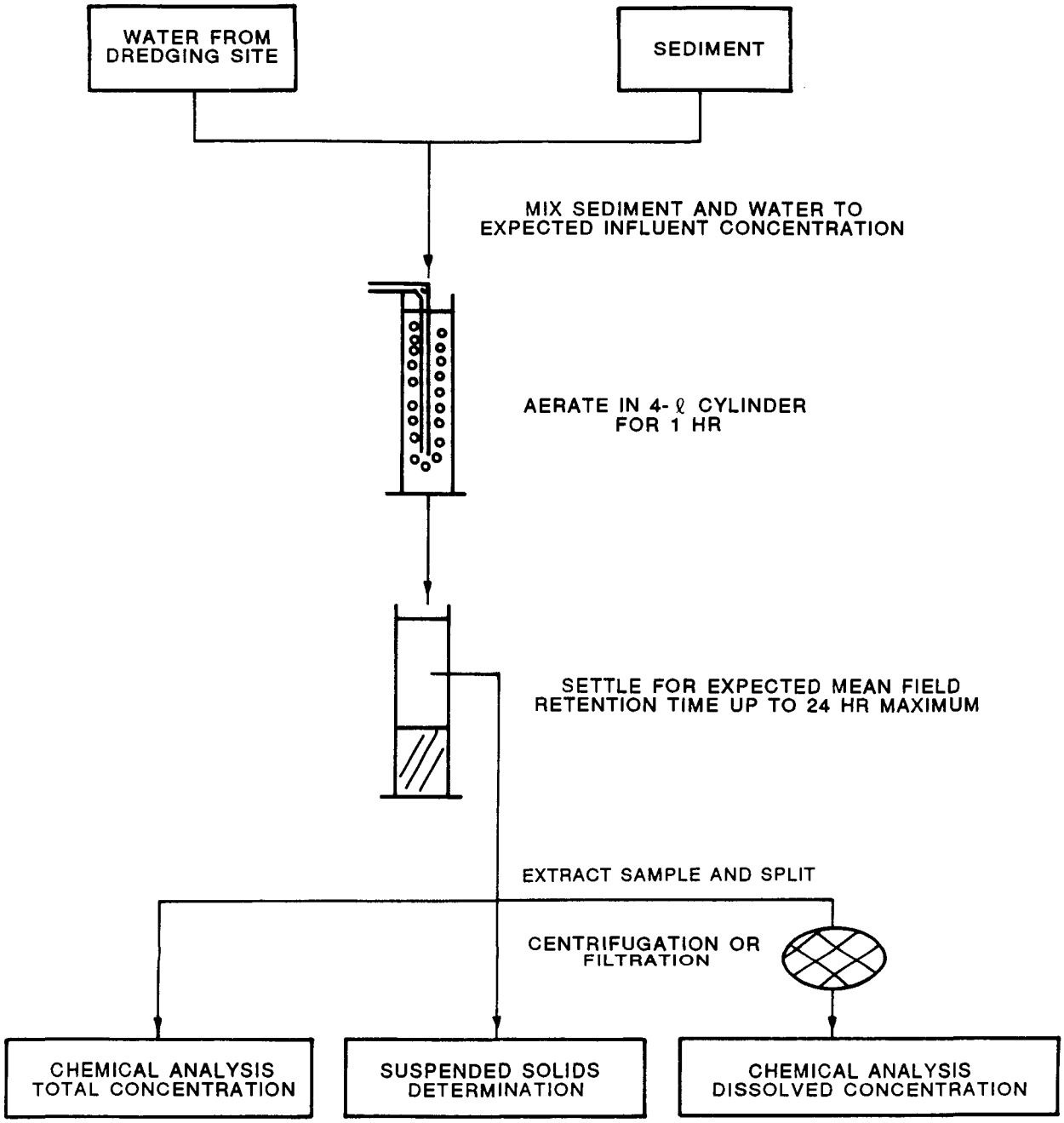

Figure 6. Schematic of modified elutriate test procedure

described for sediment characterization. Metals analyses were analyzed using the same procedures as for sediment samples. Total suspended solids were determined according to procedure No. 209C in "Standard Methods for the Examination of Water and Wastewater" (APHA, AWWA, and WPCF 1985).

Elutriate Test Results

Standard elutriate test

37. Results of the standard elutriate test for the composite sediment sample are presented in Table 6. Each of three elutriate samples was split into samples for TSS, total or whole-water PCB analyses, and dissolved PCBs. The sample for dissolved PCBs was prepared by centrifugation to remove suspended solids. The PCB congeners, Aroclors, and total PCB are reported. The analyses show that PCB concentrations in the elutriate are greater than the marine acute water quality criterion of 0.01 mg/ℓ (Table 7). Less than half of the PCB was removed by centrifugation.

38. Results of the standard elutriate test for the hot spot sediment sample are presented in Table 8. Whole and filtered elutriate samples were analyzed for PCBs and selected heavy metals. Samples for PCB analysis were filtered through a Gelman AE glass fiber filter, and samples for metal analysis were filtered through a 0.45-μm Millipore filter. Total PCB concentrations were 2.9 and 0.55 mg/ℓ for the whole and dissolved elutriate samples, respectively. Higher PCB concentrations in the hot spot elutriate compared with the estuary composite elutriate result from the higher PCB concentration in the hot spot sediment. Results shown for chromium, copper, nickel, and zinc indicate that metal concentrations were primarily associated with the particulate material in the elutriate. Statistical comparison of dissolved metal concentrations with the water quality criteria in Table 7 using a one-tailed t-test revealed that the dissolved metal concentrations in Table 8 were not significantly greater than the water quality criterion at the 0.05 level of significance. The elutriate mean dissolved copper concentration (0.0067 mg/ℓ) was greater than the acute and chronic criteria (0.0029 mg/ℓ), but the difference was not statistically significant for the test data presented. Lead and cadmium were also analyzed but are not reported because of discrepancies found in quality control checks and inconsistency with other data sets.

Modified elutriate test

39. Modified elutriate test results for the composite sediment are presented in Table 9. Solids concentration for the slurry represented was 140 g/ℓ. Results of a modified elutriate test performed at a slurry concentration of 70 g/ℓ are presented in Table 10. The lower slurry concentration produced generally lower contaminant concentrations in the elutriate and did not include the complete schedule of PCB analyses. Therefore, the discussion will focus on Table 9.

40. The total PCB concentrations shown in Table 9 are 0.22 and 0.11 mg/ℓ for the whole elutriate and the centrifuged elutriate, respectively. These concentrations are greater than the marine water quality criteria (0.01 mg/ℓ) and are also greater than the effluent quality limitations applied to wastewater discharges. Heavy metal concentrations for copper (0.057 mg/ℓ) and cadmium (0.11 mg/ℓ) were greater than the water quality criteria (0.0029 mg/ℓ for copper and 0.043 mg/ℓ for cadmium) and greater than site water (background). The high values for dissolved cadmium were inconsistent with other elutriate tests for this metal and were greater than the unfiltered sample.

41. The primary purpose of the modified elutriate test was to predict CDF effluent quality from dredging and CDF disposal. The results indicate that treatment of CDF effluent beyond suspended solids removal will be required to meet concentration-based effluent limitations. Further analysis, to be presented in Report 11, "Evaluation of Conceptual Dredging and Disposal Alternatives," will assess the mass loading impacts on water quality for CDF effluent released into the estuary.

42. Modified elutriate testing results for the hot spot sediment are shown in Table 11. Total PCB concentrations were greater than 1 mg/ℓ, which was 4 to 5 times greater than the elutriate for the composite sediment. Samples for dissolved PCB were prepared by filtering through a glass fiber filter with nominal pore size of 1 μm. Total PCBs after filtration averaged 0.46 mg/ℓ. Hydraulically dredging hot spot sediment into a CDF would produce an effluent that would require additional treatment. Dissolved heavy metal concentrations were generally lower than for the composite sediment and were greater than the acute water quality criteria only for copper.

Other Contaminant Release Investigations

43. In addition to elutriate testing, evaluations of PCB releases were also conducted as part of Task 4, element 1, of the EFS. These evaluations involved collection of water column samples during the composite sampling activity for Task 5. The scope and details of this evaluation are described in Report 2, "Sediment and Contaminant Hydraulic Transport Investigations." Samples were collected around the box coring operation to define the sediment resuspension rate by measuring TSS concentrations with time and by collecting water column samples to provide a qualitative assessment of PCB concentrations.

44. During the sampling of grids G-17 and J-8, a WES field crew collected samples at 5- and 50-yd radii around the sampling barge. Total Aroclor concentrations for grid G-17 5 yd from the barge averaged 0.0033 mg/ℓ and for grid J-8 averaged 0.11 mg/ℓ. Total suspended solids for these two sampling points averaged 43 and 112 mg/ℓ, respectively. The PCB concentration at grid J-8 is the same order of magnitude as the elutriate values for the composite sample. Sediment PCB concentrations at grid J-8 have been measured to be approximately 4,000 mg/kg and may be considered for inclusion in the hot spot.

45. Task 4 activities also included collection of a large water sample directly from the prop wash of one of the sampling boats in grid J-8. The shallow water in this area causes suspension of bottom sediments when water craft pass through the area. This sample was returned to the laboratory for the purpose of determining the fractions of the total PCB concentration associated with three ranges of particle size. The fractionation was achieved by filtration through two glass fiber filters, Whatman GF/D and GF/F, with nominal pore sizes of 2.7 and 0.7 μm, respectively. A water volume of 33.6 ℓ was filtered through a number of filters in small volumes of approximately 50 ml per filter to avoid filtration through a filter cake and loss of filter porosity. The suspended solids retained on each filter, the original water sample, and the filtrate through the 0.7-μm filter were analyzed for PCB Aroclors. Results, presented in Table 12, show that almost 99 percent of the PCBs was retained on the 2.7-μm filters. This pore size would allow most of the clay-sized particles to pass through and retain the sand and silt fractions. The PCB concentrations in the filtrates were 4 to 5 times lower than observed for the elutriate tests on the composite sample. This experiment indicates that

PCB concentrations in the water column caused by mechanical mixing of in situ highly contaminated bottom sediments with estuary water are primarily associated with sediment particles greater than 2.7 μm.

46. Another fractionation test was performed on the estuary composite sediment sample with the objective of defining the PCB fractions associated with the sand and silt fractions. Composite sediment was wet sieved through a standard No. 16 sieve (1,190-μm openings) and a standard No. 200 sieve (74-μm openings), and then filtered through 2.7- and a 0.7-μm glass fiber filters. Results of the PCB analysis of the sediment retained on each of the sieves/filters are presented in Table 13. The highest sediment PCB concentration appears to be in the material retained on the No. 16 sieve. This surprising result may be due to the notable quantity of fibrous material observed in this fraction. The fibrous material is likely organic in nature and would contribute to the PCB concentration. The sand-sized fractions (>No. 200 sieve) contained less PCB than the finer particles in the silt range. However, PCB concentrations in all fractions are in the same order of magnitude. The results of this fractionation test indicate that separately tracking PCB concentrations in estuary sediment by particle size ranges for silts and sands is not justified for evaluation of dredging and disposal alternatives.

Application of Elutriate and Contaminant Release Results

47. Elutriate and contaminant release data will be applied to contaminant release estimates to be developed in the evaluation of dredging, CDF, and CAD disposal alternatives. The alternatives and quantification of contaminant releases for specific alternatives will be described as a part of EFS Task 7 in Report 11. Contaminant release estimates require predictions of both soluble contaminant concentrations and contaminant concentrations associated with suspended sediment. Concentration values must then be applied to the volume water and the mass of suspended sediment released to the estuary and escaping through the Coggeshall Street Bridge. Sediment transport predictions are documented in EFS Report 2.

48. A summary of the elutriate test results selected for contaminant release estimates is presented in Table 14. Standard elutriate concentrations for PCBs will be used for estimates of PCB releases for the dredging and CAD operations. Hot spot values will be used for dredging the areas identified as

hot spots. Estuary composite values will be used for the remainder of the estuary. Modified elutriate concentrations for PCBs will be applied for estimates of PCB loadings from CDFs.

49. Metal concentrations for use in contaminant release estimates from all dredging and disposal components were selected based on the best data set (modified or standard, hot spot or estuary composite) for each of the metals--cadmium, copper, and lead. Data sets with average filtered concentrations greater than unfiltered concentrations were not included in Table 14. Three sets of data are included for copper. The worst case for total copper was from the hot spot modified test. These data were selected for estimating copper releases from dredging, CDF effluent, and CAD releases to the water column.

PART V: CONCLUSIONS

50. A sampling strategy based on characterization of sediment chemical and physical characteristics in the Acushnet River Estuary was developed and implemented to define appropriate characteristics of the sample to be collected and tested. The composite sediment sample collected from the Acushnet River Estuary for the laboratory testing elements of the EFS contained 2,170 mg/kg total PCB based on a mixed Aroclor standard. This concentration conservatively represents the midrange sediment PCB concentration in the Upper Estuary. A hot spot sample that was also evaluated contained 7,680 mg/kg PCB. The USCS classification for both sediments was OH.

51. Elutriate tests for the composite sediment and for the hot spot sediment indicate that elutriate concentrations for PCBs and heavy metals exceed the concentrations prescribed in Federal water quality criteria. A mass-based analysis and a review of existing contaminant concentrations in the estuary will be required to assess the concentration increases after releases from dredging and disposal operations mix with the estuary. Data from the elutriate testing will be applied to the evaluation of dredging and dredged material disposal in CDFs and in CADs.

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Table 1

PCB Congener Identification Key Used in This Report

IUPAC Number	Compound
C7	2,4-dichlorobiphenyl
C8	2,4'-dichlorobiphenyl
C28	2,4,4'-trichlorobiphenyl
C44	2,2',3,5'-tetrachlorobiphenyl
C49	2,2',4,5'-tetrachlorobiphenyl
C50	2,2',4,6-tetrachlorobiphenyl
C52	2,2',5,5'-tetrachlorobiphenyl
C70	2,3',4',5-tetrachlorobiphenyl
C77	3,3',4,4'-tetrachlorobiphenyl
C82	2,2',3,3',4-pentachlorobiphenyl
C87	2,2',3,4,5'-pentachlorobiphenyl
C97	2,2',3',4,5-pentachlorobiphenyl
C101	2,2',4,5,5'-pentachlorobiphenyl
C105	2,3,3',4,4'-pentachlorobiphenyl
C118	2,3',4,4',5-pentachlorobiphenyl
C136	2,2',3,3',6,6'-hexachlorobiphenyl
C138	2,2',3,4,4',5'-hexachlorobiphenyl
C143	2,2',3,4,5,6'-hexachlorobiphenyl
C153	2,2',4,4',5,5'-hexachlorobiphenyl
C155	2,2',4,4',6,6'-hexachlorobiphenyl
C167	2,3',4,4',5,5'-hexachlorobiphenyl
C180	2,2',3,4,4',5,5'-heptachlorobiphenyl
C185	2,2',3,4,5,5',6-heptachlorobiphenyl

Table 2

PCB Concentrations in Acushnet River Estuary Sediments (Standard Error)

Parameter*	Concentration, mg/kg Dry Weight			
	Estuary Composite**		Hot Spot†	
C7	0.56	(0.01)	3.08	(0.18)
C8	166	(3.8)	688	(171)
C28	153	(5.3)	738	(177)
C44	84.1	(3.5)	310	(29)
C49	28.0	(0.85)	233	(157)
C50	153	(5.3)	536	(61)
C52	177	(9.3)	522	(56)
C70	59.2	(3.3)	199	(22)
C77	147	(3.4)	<0.01	--
C82	24.3	(1.2)	<0.01	--
C87	8.2	(0.41)	24.6	(2.3)
C97	22.9	(1.1)	474	(38)
C101	70.4	(4.3)	424	(35)
C105	36.7	(0.88)	<0.01	--
C118	29.6	(1.3)	326	(54)
C136	17.1	(0.53)	112	(24)
C138	25.1	(0.61)	148	(24)
C143	24.7	(0.88)	159	(24)
C153	56.7	(3.1)	288	(44)
C155	50.0	(1.0)	108	(47)
C167	19.2	(2.8)	79.4	(18)
C180	7.94	(1.6)	19.4	(1.7)
C185	<1		48.4	(12)
Aroclor 1242	887	(67)	5,700	(510)
Aroclor 1254	662	(62)	2,700	(228)
Total PCB	2,167	(34)	7,680	(637)

* See Table 1 for PCB congener identification key.
** Three replicates.
† Five replicates.

Table 3

Concentrations of Metals in Acushnet River Estuary Sediments (Standard Error)

Metal	Concentration, mg/kg dry weight			
	Estuary Composite*		Hot Spot**	
Arsenic	8.66	(0.24)	NT†	--
Cadmium	35.4	(0.25)	36.2	(0.62)
Chromium	754	(9)	545	(5.8)
Copper	1,730	(21)	1,330	(14)
Lead	2,013	(239)	1,010	(8.9)
Mercury	2.59	(0.03)	NT	--
Nickel	122	(1.8)	90	(1.3)
Selenium	<0.49		NT	--
Zinc	3,020	(22)	3,360	(52)

* Three replicates.
** Five replicates.
† Not tested.

Table 4

Concentration of Polynuclear Aromatic Hydrocarbon Compounds in Upper Estuary Composite Sediment

PAH Compound	Concentration (Standard Error)* mg/kg dry weight
Naphthalene	<4.6
Acenaphthylene	<4.6
Acenaphthene	<4.6
Fluorene	<4.6
Phenanthrene	9.6 (0.3)
Anthracene	<4.6
Fluoranthene	8.7 (0.1)
Pyrene	7.1 (0.3)
Chrysene	7.5 (0.6)
Benzo (a) anthracene	7.5 (0.6)
Benzo (B) fluoranthene	11.8 (1.3)
Benzo (K) fluoranthene	11.8 (1.3)
Benzo (A) pyrene	7.6 (0.1)
Indeno(1,2,3-C D) pyrene	<4.6
Dibenzo (A H) anthracene	<4.6
Benzo (G H I) perylene	<4.6

* Triplicate analyses.

Table 5

Physical Analyses of Estuary Composite and Hot Spot Sediments

Analysis	Estuary Composite*	Hot Spot**
Percent sand (>50 μm)	39	21
Percent silt (2-50 μm)	61	67
Percent clay (<2 μm)	0	12
Liquid limit	129	131
Plastic limit	61	88
Plasticity index	68	43
Specific gravity	2.35	2.21
USCS classification	OH	OH
Soil group	Sandy organic silt	Organic silt with sand

* Performed by NED Materials Testing Laboratory (based on EM 1110-2-1906).

** Performed by WES Aquatic Processes and Effects Group. Grain size analysis performed as outlined in Patrick (1958). Other analyses performed according to EM 1110-2-1906.

Table 6

Standard Elutriate Results for Estuary Composite Sediment

	Concentration,* mg/ℓ			
	Whole Elutriate		Dissolved Elutriate**	
Parameter	Mean	(Std Err)	Mean	(Std Err)
C7	0.00014	(0.00004)	0.00007	(0.00000)
C8	0.040	(0.013)	0.020	(0.0006)
C28	0.021	(0.010)	0.025	(0.0010)
C44	0.015	(0.0048)	0.0075	(0.0003)
C49	0.0073	(0.0024)	0.0033	(0.0001)
C50	<0.00001		<0.00001	
C52	0.043	(0.013)	0.021	(0.0006)
C70	0.012	(0.0038)	0.0061	(0.0002)
C77	0.043	(0.013)	0.020	(0.0007)
C82	<0.00001		<0.00001	
C87	<0.00001		<0.00001	
C97	0.0063	(0.0019)	0.0030	(0.0001)
C101	0.016	(0.0047)	0.0079	(0.0003)
C105	<0.00001		<0.00001	
C118	0.0068	(0.0021)	0.0032	(0.0001)
C136	0.0032	(0.0010)	0.0017	(0.0002)
C138	<0.00001		<0.00001	
C143	<0.00001		<0.00001	
C153	<0.00001		<0.00001	
C155	<0.00001		<0.00001	
C167	0.0011	(0.0004)	0.00048	(0.00002)
C180	0.0013	(0.0004)	0.00060	(0.00003)
C185	0.00010	(0.00003)	0.00005	(0.00001)
A1016	<0.0002		<0.0002	
A1221	<0.0002		<0.0002	
A1232	<0.0002		<0.0002	
A1242	0.13	(0.034)	0.082	(0.010)
A1248	<0.0002		<0.0002	
A1254	0.049	(0.013)	0.029	(0.004)
A1260	<0.0002		0.0002	
Total PCB	0.23	(0.061)	0.12	(0.004)
TSS	120	(9)		

* Triplicate analyses.

** Dissolved fraction separated by centrifugation.

Table 7

Federal Water Quality Criteria for Marine Waters (USEPA 1986)

Parameter	Concentration, mg/ℓ	
	Acute	Chronic
Cd	0.043	0.0093
Cr(+6)	1.1	0.050
Cu	0.0029	0.0029
Pb	0.14	0.0056
Ni	0.075	0.0083
Zn	0.095	0.086
PCB	0.010	0.00003

Table 8

Standard Elutriate Results for Hot Spot Sediment

	Concentration, mg/ℓ *					
	Whole Elutriate		Dissolved Elutriate**		Site Water**	
Parameter	Mean	(Std Err)	Mean	(Std Err)	Mean	(Std Err)
Cr	0.058	(0.013)	0.0013	(0.0003)	<0.001	
Cu	0.116	(0.026)	0.0067	(0.0033)	<0.001	
Ni	0.013	(0.0066)	0.0037	(0.0019)	<0.001	
Zn	0.308	(0.088)	0.073	(0.022)	0.050	(0.0017)
C7	0.0006	(0.0001)				
C8	0.29	(0.038)	0.047	(0.0041)	<0.00001	
C28	0.30	(0.035)	0.10	(0.010)	<0.00001	
C44	0.092	(0.012)	0.027	(0.0027)	<0.00001	
C49	0.16	(0.019)	0.046	(0.0030)	<0.00001	
C50	0.20	(0.017)	0.068	(0.0049)	<0.00001	
C52	0.023	(0.0026)	0.0074	(0.0007)	<0.00001	
C70	0.094	(0.012)	0.044	(0.0041)	<0.00001	
C77	<0.0001		<0.0001		<0.00001	
C82	<0.0001		<0.0001		<0.00001	
C87	0.0041	(0.0014)	0.0011	(0.000033)	<0.00001	
C97	0.046	(0.0076)	0.011	(0.0006)	<0.00001	
C101	0.10	(0.013)	0.029	(0.0013)	<0.00001	
C105	0.0062	(0.0010)	0.0014	(0.0001)	<0.00001	
C118	0.065	(0.010)	0.017	(0.0010)	<0.00001	
C136	0.014	(0.0028)	0.0041	(0.0004)	<0.00001	
C138	0.019	(0.0026)	0.0052	(0.0003)	<0.00001	
C143	<0.0001		<0.0001		<0.00001	
C153	0.054	(0.0073)	0.015	(0.0006)	<0.00001	
C155	0.028	(0.0026)	0.012	(0.0011)	<0.00001	
C167	0.0034	(0.0007)	0.0008	(0.0001)	0.00001	(0.0000)
C180	0.004	(0.0009)	0.0010	(0.0001)	<0.00001	
C185	0.0004	(0.0001)	0.0003	(0.0000)	<0.00001	
A1016	<0.02		<0.002		<0.0002	
A1221	<0.02		<0.002		<0.0002	
A1232	<0.02		<0.002		<0.0002	
A1242	1.95	(0.11)	0.46	(0.021)	<0.0002	
A1248	<0.02		<0.002		<0.0002	
A1254	1.093	(0.078)	0.12	(0.0037)	<0.0002	
A1260	<0.02		<0.002		<0.0002	
Total PCB	2.89	(0.18)	0.55	(0.039)	<0.0002	
TSS	437	(3)				

* Triplicate analyses for all values.

** Filtered through 0.45-μm filter for metals and through 1-μm glass fiber filter for PCBs.

Table 9

Modified Elutriate Results for Estuary Composite Sediment

(Slurry Concentration, 140 g/ℓ)

	Concentration, mg/ℓ*				
	Whole Elutriate		Dissolved Elutriate**		
Parameter	Mean	(Std Err)	Mean	(Std Err)	Site Water
Cd	0.0075	(0.0001)	0.11	(0.007)	0.015
Cr	0.037	(0.0005)	0.029	(0.002)	0.030
Cu	0.079	(0.001)	0.057	(0.010)	0.009
Pb	0.026	(0.004)	0.011	(0.004)	0.035
Ni	0.025	(0.002)	0.12	(0.029)	0.69
Zn	0.28	(0.006)	0.40	(0.085)	0.22
C7	<0.00001		0.00003	(0.00001)	<0.00001
C8	0.030	(0.002)	<0.00001		<0.00001
C28	0.037	(0.001)	0.024	(0.012)	0.00015
C44	0.010	(0.000)	0.0029	(0.0009)	0.00005
C49	0.0036	(0.0000)	0.0026	(0.0010)	<0.00002
C50	<0.00001		0.0074	(0.0012)	0.00028
C52	0.024	(0.0005)	0.0057	(0.0013)	0.00015
C70	<0.00001		0.0031	(0.0006)	0.00008
C77	<0.00001		<0.00001		0.00031
C82	<0.00001		0.0006	(0.0002)	<0.00001
C87	0.0014	(0.0004)	0.00061	(0.00039)	0.00012
C97	0.0038	(0.0012)	0.0033	(0.0017)	0.00007
C101	0.011	(0.001)	0.0070	(0.0030)	0.00010
C105	<0.00001		<0.00001		0.00027
C118	0.010	(0.0007)	0.0016	(0.0002)	0.00010
C136	0.0032	(0.0004)	0.00063	(0.0002)	0.00014
C138	0.0037	(0.0002)	0.00061	(0.00003)	0.00014
C143	0.0034	(0.0004)	0.00053	(0.00013)	<0.00001
C153	0.0084	(0.0006)	0.0053	(0.0024)	<0.00001
C155	<0.00001		0.0021	(0.0006)	<0.00001
C167	<0.00001		0.00012	(0.00002)	<0.00001
C180	0.00078	(0.00006)	0.00046	(0.00026)	<0.00001
C185	<0.00001		<0.00001		<0.00001
A1016	<0.0002		<0.0002		<0.0002
A1221	<0.0002		<0.0002		<0.0002
A1232	<0.0002		<0.0002		<0.0002
A1242	0.14	(0.005)	0.068	(0.002)	0.0021
A1248	<0.0002		<0.0002		<0.0002
A1254	0.074	(0.004)	0.036	(0.0005)	0.0023
A1260	<0.0002		<0.0002		<0.0002
Total PCB	0.22	(0.00)	0.11	(0.00)	0.0048
TSS	320	(7)			

* Elutriates reported for duplicates. Site water reported for one sample.
** Filtered through 0.45-μm filter for metals and centrifuged for PCBs.

Table 10

Modified Elutriate Results for Estuary Composite Sediment

(Slurry Concentration, 70 g/ℓ)

	Concentration, mg/ℓ*			
	Whole Elutriate		Dissolved Elutriate**	
Parameter	Mean	(Std Err)	Mean	(Std Err)
As	<0.005		<0.005	
Cd	0.0016	(0.0002)	0.0018	(0.0002)
Cr	0.0077	(0.0041)	0.0047	(0.0018)
Cu	0.045	(0.003)	0.0020	(0.0006)
Pb	0.0037	(0.0015)	0.0020	(0.0010)
Hg	<0.0004		<0.0004	
Ni	0.0077	(0.0042)	0.011	(0.004)
Se	<0.05		<0.05	
Zn	0.13	(0.011)	0.068	(0.005)
A1016	<0.0002		<0.0002	
A1221	<0.0002		<0.0002	
A1232	<0.0002		<0.0002	
A1242	0.060	(0.001)	0.058	(0.003)
A1248	<0.0002		<0.0002	
A1254	0.068	(0.005)	0.059	(0.002)
A1260	<0.0002		<0.0002	
TSS	137	(9)		

* Triplicate analyses.

** Dissolved fraction filtered for metals, centrifuged for PCBs.

APPENDIX A: UPPER ESTUARY COMPOSITE SEDIMENT CHARACTERIZATION AND SITE WATER ANALYSES

Table A1

Metals and Organic Concentrations (Dry Weight) for Upper Estuary Composite Sediment

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
I Metals			
Arsenic	8.67	9.07	8.23
Cadmium	35.8	35.4	35.0
Chromium	768	755	739
Copper	1,760	1,740	1,690
Lead	1,759	2,491	1,789
Mercury	2.59	2.65	2.52
Nickel	125	121	119
Selenium	<0.496	<0.493	<0.496
Zinc	3,060	3,000	2,990
II Pesticides			
Aldrin	<5.0	<5.0	<5.0
α-BHC	<5.0	<5.0	<5.0
β-BHC	<5.0	<5.0	<5.0
γ-BHC	<5.0	<5.0	<5.0
Acrolein	<36	<36	<36
D-BHC	<5.0	<5.0	<5.0
Chlordane	<50	<50	<50
P,P-DDD	<5.0	<5.0	<5.0
P,P-DDE	<5.0	<5.0	<5.0
P,P-DDT	<5.0	<5.0	<5.0
Dieldrin	<0.05	0.5	0.45
α-Endosulfan	<0.05	0.13	0.11
β-Endosulfan	<0.05	<0.05	<0.05

(Continued)

(Sheet 1 of 6)

Table A1 (Continued)

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
II Pesticides (Cont.)			
Endosulfan sulfate	0.099	<0.002	<0.002
Endrin	<0.05	<0.05	<0.05
Endrin aldehyde	<0.05	<0.05	<0.05
Heptachlor	<5.0	<5.0	<5.0
Heptachlor epoxide	0.05	0.05	0.05
Toxaphene	<50	<50	<50
III Monocyclic Aromatics			
Phenol (GC)	<4.6	<4.8	<4.6
2-Chlorophenol	<4.6	<4.8	<4.6
2-Nitrophenol	<4.6	<4.8	<4.6
2,4-Dimethylphenol	<4.6	<4.8	<4.6
2,4-Dichlorophenol	<4.6	<4.8	<4.6
4-Chloro-3-Methylphenol	<4.6	<4.8	<4.6
2,4,6-Trichlorophenol	<4.6	<4.8	<4.6
Hexachlorobenzene	<4.6	<4.8	<4.6
Phenathrene	10	9.1	9.8
Anthracene	<4.6	<4.8	<4.6
Fluoranthene	8.5	8.6	8.9
2,4-Dinitrophenol	<46	<48	<46
4-Nitrophenol	<4.6	<4.8	<4.6
2-Methyl-4,6-Dinitrophenol	<46	<48	<46
Pentachlorophenol	<4.6	<4.8	<4.6
1,3-Dichlorobenzene	<4.6	<4.8	<4.6
1,4-Dichlorobenzene	5.0	5.9	6.8
1,2-Dichlorobenzene	<4.6	<4.8	<4.6

(Continued)

(Sheet 2 of 6)

Table A1 (Continued)

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
III Monocyclic Aromatics (Cont.)			
Benzene	<1.8	<1.8	<1.8
Phenol (Total)	0.715	<0.633	<0.544
2,4-Dinitrotoluene	<4.6	<4.8	<4.6
2,6-Dinitrotoluene	<4.6	<4.8	<4.6
Nitrobenzene	<4.6	<4.8	<4.6
3,3-Dichlorobenzidine	<23	<24	<23
1,2,4-Trichlorobenzene	<4.6	<4.8	<4.6
Toluene	<1.8	<1.8	<1.8
Chlorobenzene	<1.8	<1.8	<1.8
Ethylbenzene	<1.8	<1.8	<1.8
IV Halogenated Aliphatic Hydrocarbons			
Chloromethane	<3.6	<3.6	<3.6
Bromomethane	<3.6	<3.6	<3.6
Vinyl chloride	<3.6	<3.6	<3.6
Chloroethane	<3.6	<3.6	<3.6
Methylene chloride	<1.8	<1.8	<1.8
1,1-Dichloroethene	<1.8	<1.8	<1.8
Trans-1,2-Dichloroethene	<1.8	<1.8	<1.8
Chloroform	<1.8	<1.8	<1.8
Hexachlorobutadiene	<4.6	<4.8	<4.6
Hexachlorocyclopentadiene	<4.6	<4.8	<4.6
1,2-Dichloroethane	<1.8	<1.8	<1.8
1,1,1-Trichloroethane	<1.8	<1.8	<1.8
Carbon Tetrachloride	<1.8	<1.8	<1.8

(Continued)

(Sheet 3 of 6)

Table A1 (Continued)

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
IV Halogenated Aliphatic Hydrocarbons (Cont.)			
Bromodichloromethane	<1.8	<1.8	<1.8
1,2-Dichloropropane	<1.8	<1.8	<1.8
Trans-1,3-Dichloropropene	<1.8	<1.8	<1.8
Trichloroethene	<1.8	<1.8	<1.8
Dibromochloromethane	<1.8	<1.8	<1.8
Cis-1,3-Dichloropropene	<1.8	<1.8	<1.8
1,1-Dichloroethane	<1.8	<1.8	<1.8
1,1,2-Trichloroethane	<1.8	<1.8	<1.8
Bromoform	<1.8	<1.8	<1.8
1,1,2,2-Tetrachloroethane	<1.8	<1.8	<1.8
Tetrachloroethene	<1.8	<1.8	<1.8
Hexachloroethane	<4.6	<4.8	<4.6
V Polynuclear Aromatic Hydrocarbons			
Pyrene	6.4	7.5	7.3
Chrysene	6.3	8.5	7.7
Benzo(A)Anthracene	6.3	8.0	8.2
Benzo(B)Fluoranthene	9.6	14	12
Benzo(K)Fluoranthene	9.6	14	12
Benzo(A)Pyrene	7.7	7.7	7.4
2-Chloronaphthalene	<4.6	<4.8	<4.6
Acenaphthylene	<4.6	<4.8	<4.6
Acenaphthene	<4.6	<4.8	<4.6
Fluorene	<4.6	<4.8	<4.6
Indeno(1,2,3-cd) Pyrene	<4.6	<4.8	<4.6

(Continued)

(Sheet 4 of 6)

Table A1 (Continued)

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
V Polynuclear Aromatic Hydrocarbons (Cont.)			
Dibenzo (a-h) Anthracene	<4.6	<4.8	<4.6
Benzo (GHI)Perylene	<4.6	<4.8	<4.6
Naphthalene	<4.6	<4.8	<4.6
VII Halogenated Ethers			
BIS(2-Chloroisopropyl) Ether	<4.6	<4.8	<4.6
BIS(2-Chloroethyl) Ether	<4.6	<4.8	<4.6
BIS(2-Chloroethoxy) Methane	<4.6	<4.8	<4.6
2-Chloroethylvinyl Ether	<3.6	<3.6	<3.6
Dibenzofuran	<4.6	<4.8	<4.6
4-Bromophenyl Ether	<4.6	<4.8	<4.6
4-Chlorophenyl Phenyl Ether	<4.6	<4.8	<4.6
VII Nitrosamines and Miscellaneous Compounds			
Acrylonitrile	<36	<36	<36
N-Nitrosodimethylamine	<4.6	<4.8	<4.6
N-Nitrosodiphenylamine	<4.6	<4.8	<4.6
1,2-Diphenylhydrazine	<4.6	<4.8	<4.6
Benzidine	<46	<48	<46
N-Nitroso-Di-N-propylamine	<4.6	<4.8	<4.6
Isophorone	<4.6	<4.8	<4.6

(Continued)

(Sheet 5 of 6)

Table A1 (Concluded)

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
VIII Phthalate Esters			
BIS(2-ethylhexyl) phthalate	22	26	29
Di-N-Octylphthalate	<4.6	<4.8	<4.6
Butylbenzylphthalate	<4.6	<4.8	<4.6
Dibutylphthalate	<4.6	<4.8	<4.6
Diethylphthalate	<4.6	<4.8	4.6
Dimethylphthalate	<4.6	<4.8	<4.6

(Sheet 6 of 6)

Table A2

Polychlorinated Biphenyl Concentrations (Dry Weight) for Upper Estuary Composite Sediment

Analysis	Replicate 1 ppm	Replicate 2 ppm	Replicate 3 ppm
I Congeners			
C7 2,4-dichlorobiphenyl	<1.0	<1.0	<1.0
C8 2,4'-dichlorobiphenyl	164	163	170
C28 2,4,4'-trichlorobiphenyl	159	151	149
C44 2,2',3,5-tetrachlorobiphenyl	88.2	82.2	82
C49 2,2',4,5'-tetrachlorobiphenyl	28.9	27.9	27.2
C50 2,2',4,6-tetrachlorobiphenyl	159	151	149
C52 2,2',5,5'-tetrachlorobiphenyl	178	174	169
C70 2,3',4',5-tetrachlorobiphenyl	62.9	56.6	58.1
C77 3,3',4,4'-tetrachlorobiphenyl	<1	<1.0	<1
C82 2,2',3,3',4-pentachlorobiphenyl	<1.0	<1.0	<1
C87 2,2',3,4,5'-pentachlorobiphenyl	<1.0	<1.0	<1
C97 2,2',3',4,5-pentachlorobiphenyl	24.2	22.2	22.3
C101 2,2',4',5,5'-pentachlorobiphenyl	75.2	68.9	67
C105 2,3,3',4,4'-pentachlorobiphenyl	<1.0	<1	<1
C118 2,3',4,4',5-pentachlorobiphenyl	31.1	29	28.7
C136 2,2',3,3',6,6'-hexachlorobiphenyl	17.5	17.3	16.5
C138 2,2',3,4,4',5'-hexachlorobiphenyl	25.2	24.4	25.6
C143 2,2',3,4,5,6'-hexachlorobiphenyl	<1	<1.0	<1.0
C153 2,2',4,4',5,5'-hexachlorobiphenyl	58.8	53.2	58.2
C155 2,2',4,4',6,6'-hexachlorobiphenyl	<1.0	<1.0	<1.0
C167 2,3',4,4',5,5'-hexachlorobiphenyl	<1.0	<1.0	<1.0
C180 2,2',3,4,4',5,5'-heptachlorobiphenyl	9.69	6.43	7.710
C185 2,2',3,4,5,5',6-heptachlorobiphenyl	<1.0	<1.0	<1
II Aroclors			
A1016	<50	<50	<50
A1221	<50	<50	<50
A1232	<50	<50	<50
A1242	810	1,020	830
A1248	<50	<50	<50
A1254	560	650	775
A1260	<50	<50	<50
Total PCB	2,100	2,200	2,200

Table A3

Other Analyses for Upper Estuary Composite Sediment

Analysis	Replicate 1	Replicate 2	Replicate 3
Total solids, percent	35.8	35.6	36.1
Cation exchange capacity, ppm	220.0	248.0	212.0
Oil and grease, ppm	28,000.0	27,000.0	30,000.0
Total organic carbon, ppm	26,000.0	26,000.0	26,000.0

Table A4

Upper Estuary Site Water Analyses

Analysis	Grid G-17 ppm	Grid J-8 ppm	Grid I-23 ppm
I Chemical			
Arsenic	<0.005	<0.005	<0.005
Cadmium	0.0238	0.0039	0.0016
Chromium	0.003	0.002	0.002
Copper	0.005	0.005	0.003
Lead	0.120	0.089	0.119
Mercury	<0.0004	0.0070	0.0069
Nickel	<0.001	0.007	0.009
Selenium	<0.050	<0.050	<0.050
Zinc	0.049	0.312	0.044
A1016	<0.002	<0.002	<0.002
A1221	<0.002	<0.002	<0.002
A1232	<0.002	<0.002	<0.002
A1242	<0.002	<0.002	<0.002
A1248	<0.002	<0.002	<0.002
A1254	<0.002	0.128	<0.002
A1260	<0.002	<0.002	<0.002
Phenol	<0.100	<0.100	<0.100
II Physical			
Total solids	30,804	25,155	29,936
Total suspended solids	40	228	83

Table 11

Modified Elutriate Results for Hot Spot Sediment

	Concentration, mg/ℓ*					
	Whole Elutriate		Dissolved Elutriate**		Site Water	
Parameter	Mean	(Std Err)	Mean	(Std Err)	Mean	(Std Err)
Cd	0.0059	(0.0011)	0.0025	(0.0003)	0.0025	(0.0006)
Cr	0.089	(0.009)	0.0057	(0.0003)	0.002	(0.0006)
Cu	0.18	(0.019)	0.017	(0.002)	0.16	(0.002)
Pb	0.018	(0.006)	0.021	(0.001)	0.0087	(0.0007)
Ni	0.018	(0.002)	0.0077	(0.0003)	0.0023	(0.0003)
Zn	0.45	(0.033)	0.049	(0.008)	0.071	(0.030)
C07	<0.00001		0.00006	(0.00005)	<0.00001	
C08	0.085	(0.085)	0.0024	(0.0024)	0.00007	(0.00006)
C28	0.22	(0.11)	0.12	(0.010)	0.00007	(0.00001)
C44	0.076	(0.008)	0.032	(0.002)	0.00003	(0.00000)
C49	0.016	(0.0015)	0.0066	(0.0004)	0.00001	(0.00000)
C50	<0.00001		0.019	(0.019)	<0.00001	
C52	0.14	(0.02)	0.062	(0.004)	0.00008	(0.00003)
C70	0.072	(0.008)	0.027	(0.002)	0.00004	(0.00003)
C77	<0.00001		0.011	(0.009)	<0.00001	
C82	<0.00001		<0.00001		0.00002	(0.00000)
C87	0.0016	(0.0004)	<0.00001		0.00001	(0.00000)
C97	0.028	(0.002)	0.012	(0.001)	0.00003	(0.00001)
C101	0.087	(0.010)	0.038	(0.003)	0.00002	(0.00001)
C105	<0.00001		<0.00001		<0.00001	
C118	0.0050	(0.0050)	<0.00001		0.00003	(0.00000)
C136	0.011	(0.001)	0.0051	(0.0004)	0.00001	(0.00000)
C138	0.012	(0.002)	0.0050	(0.0005)	<0.00001	
C143	0.00044	(0.00043)	<0.00001		<0.00001	
C153	0.46	(0.006)	0.019	(0.002)	0.00001	(0.00000)
C155	<0.00001		<0.00001		<0.00001	
C167	0.0021	(0.0000)	<0.00001		0.00001	(0.00000)
C180	0.0012	(0.0012)	0.0011	(0.0011)	0.00001	(0.00000)
C185	0.00037	(0.00013)	0.00006	(0.00005)	<0.00001	
A1016	<0.0002		<0.0002		<0.0002	
A1221	<0.0002		<0.0002		<0.0002	
A1232	<0.0002		<0.0002		<0.0002	
A1242	0.92	(0.010)	0.34	(0.024)	0.0006	(0.0001)
A1248	<0.0002		<0.0002		<0.0002	
A1254	0.28	(0.010)	0.13	(0.003)	0.0002	(0.00003)
A1260	<0.0002		<0.0002		<0.0002	
Total PCB	1.2	(0.050)	0.46	(0.028)	0.0016	(0.0002)
TSS	148	(17)				

* Duplicate analyses for whole elutriate PCBs, triplicate for all others.
** Dissolved elutriate and site water were filtered for all analyses.

Table 12

Fractionation of Water Column PCB Concentrations

Fraction	PCB Concentration mg/P	Percent of PCB in Fraction*
Original sample**	3.2	--
>2.7 mm	2.8	98.9
0.7-2.7 mm	0.010	0.4
<0.7 mm	0.020	0.7
Sum of fractions	2.83	100.0

* Percentages based on the sum of the three fractions.
** Average of two analyses. Standard error = 0.39 mg/ℓ.

Table 13

PCB Analysis of Estuary Composite Sediment Grain Size Fractions

Fraction	Sediment PCB Concentration mg/kg (dry weight)
>No. 16 sieve	1,300
<No. 16 sieve, >No. 200 sieve	700
<No. 200 sieve, >2.7 μm	1,200
<2.7 μm, >0.7 μm	600

Table 14

Summary of Elutriate Test Results for PCBs

Contaminant	Sample	Type Elutriate Test	TSS mg/ℓ	Contaminant Concentration Total mg/ℓ	Dis-solved mg/ℓ	Cont./TSS* mg/kg
PCB (A1242 + A1254)	Estuary composite	Modified	320	0.208	0.104	325
		Standard	120	0.182	0.111	592
	Hot spot	Modified	132	1.20	0.455	5,640
		Standard	437	3.04	0.581	5,630
Cadmium	Hot spot	Modified	132	0.0059	0.0025	26
Copper	Estuary composite	Modified	320	0.079	0.057	69
	Hot spot	Modified	132	0.180	0.017	1,230
		Standard	437	0.116	0.0067	250
Lead	Estuary composite	Modified	320	0.026	0.011	47

* Cont./TSS calculated by (Total concentration - Dissolved concentration)/TSS.