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FIELD EVALUATIONS OF THE QUALITY OF EFFLUENT FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS

by

Michael R. Palermo

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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The effluent discharged from confined dredged material disposal areas during filling operations is considered a dredged material discharge under Section 404 of the Clean Water Act. The Corps of Engineers has recently developed modified elutriate testing procedures for predicting the quality of effluent, to include both dissolved and particle-associated contaminant concentrations. As a part of this effort, field evaluations were conducted at five confined disposal areas to assess the effluent quality and compare field data with laboratory predictions. The comparisons serve to verify the accuracy and precision of the predictive techniques.

For all five sites evaluated, the laboratory test adequately predicted the dissolved and particle-associated concentrations of contaminants in the effluent. The predictions were also generally conservative, i.e., higher than the measured field data. The field data

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showed that all five disposal areas were very efficient in retaining suspended solids. The relative retention of contaminants within the sites also was very high, since most contaminants were directly associated with particles and were removed with them. Additional comparisons of predictions with field data under a wider variety of operating conditions were recommended.

PREFACE

This work was conducted as part of the Long-Term Effects of Dredging Operations (LEDO) Program at the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The LEDO Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is assigned to WES under the purview of the EL's Environmental Effects of Dredging Programs (EEDP). This report was written as part of LEDO Work Unit 31775, Techniques for Predicting Effluent Quality of Diked Containment Areas. The Technical Monitors were Drs. John Hall, William L. Klesch, and Robert Pierce, OCE, and Mr. Charles W. Hummer, Water Resources Support Center, Fort Belvoir, Va. One of the several field evaluations described in this report was conducted as a part of the EEDP Field Verification Program and has been documented and acknowledged in other reports. It is included here for purposes of completeness and comparison.

The principal investigator for this work and author of this report was Dr. Michael R. Palermo, Research Civil Engineer, Environmental Engineering Division (EED), EL. Dr. Edward L. Thackston of Vanderbilt University; Dr. Robert M. Engler, EEDP Program Manager, EL; and Dr. James M. Brannon, Ecosystem Research and Simulation Division, EL, were technical reviewers for this report. Additional guidance and technical review for portions of the report were provided by the author's dissertation research committee: Drs. Frank L. Parker, Peter G. Hoadley, Antonis D. Kousis, and Horace E. Williams, all of Vanderbilt University, and Drs. Thackston and Engler.

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This work was performed under the general supervison of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Chief, EL. Managers of the LEDO Program were Mr. Charles C. Calhoun and Dr. Engler. The LEDO Program Coordinator was Mr. Robert Lazor.

Commander and Director of WES was COL Dwayne G. Lee, CE. 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:

Multiply	By	To Obtain
acres	4,046.873	square metres
acre-feet	1,233.489	cubic metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
inches	2.54	centimetres
pounds (mass)	0.4535924	kilograms

FIELD EVALUATIONS OF THE QUALITY OF EFFLUENT FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS

PART I: INTRODUCTION

Background

General

1. Confined dredged material disposal has increased in recent years, primarily because of environmental constraints on open-water disposal of sediments classified as polluted and unacceptable for unrestricted disposal. Release of contaminants from the materials in the effluent from confined disposal areas* is dependent upon a number of factors relating to the physical, geochemical, and physicochemical characteristics of the dredged material in relation to the confined disposal process. The term effluent is defined for purposes of this report as water that is discharged on a continuous or intermittent basis from confined disposal areas as they are being hydraulically filled during active disposal operations.

2. The effluent from confined disposal areas is considered a dredged material discharge under Section 404 of the Clean Water Act. Regulatory guidance and evaluation procedures have recently been developed to predict contaminant release in effluents from confined disposal operations (Palermo 1986a, 1986b). These guidelines were also published as Environmental Effects of Dredging Programs Technical Notes (Palermo 1985) (Appendix A). The field evaluations described in this report were conducted as a part of the overall study to develop further guidance for prediction, with associated field verification of the procedure. Summary data plots are presented in Appendix B. Individual data plots for measured field influent and effluent water quality data are presented in Appendix C, which is reproduced on microfiche and enclosed in an envelope attached to the inside back cover.

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* The terms confined disposal area, confined disposal site, diked disposal area, containment area, and confined disposal facility are used interchangeably in the literature.

Description of processes influencing effluent quality

3. Figure 1 shows the supernatant water interactions in an active confined disposal area. Dredged material placed in a confined disposal area undergoes sedimentation, resulting in a "thickened" deposit of settled material overlain by the clarified supernatant. The supernatant waters are normally discharged from the site as effluent during active dredging operations. The effluent may contain both dissolved and particle-associated (adsorbed, coprecipitated, ion exchanged, etc.) contaminants. A majority of the total concentration of contaminants is, however, particle associated.

4. Release of supernatant waters from confined disposal areas occurs after a retention time ranging from hours to weeks. Furthermore, actual withdrawal of the supernatant is governed by the design and operation of the disposal area and location and operation of the discharge weir or structure.

5. Several factors influence the concentration of suspended particles and contaminants present in supernatant waters, as shown in Figure 1. A dredged material slurry enters the ponded water as a density flow. Fine particles remain suspended in the disposal area water column at the point of entry due to turbulence and mixing. The suspended particles are partially removed from the water column by gravity settling. However, some of the settled particles may reenter the water column because of the upward flow of

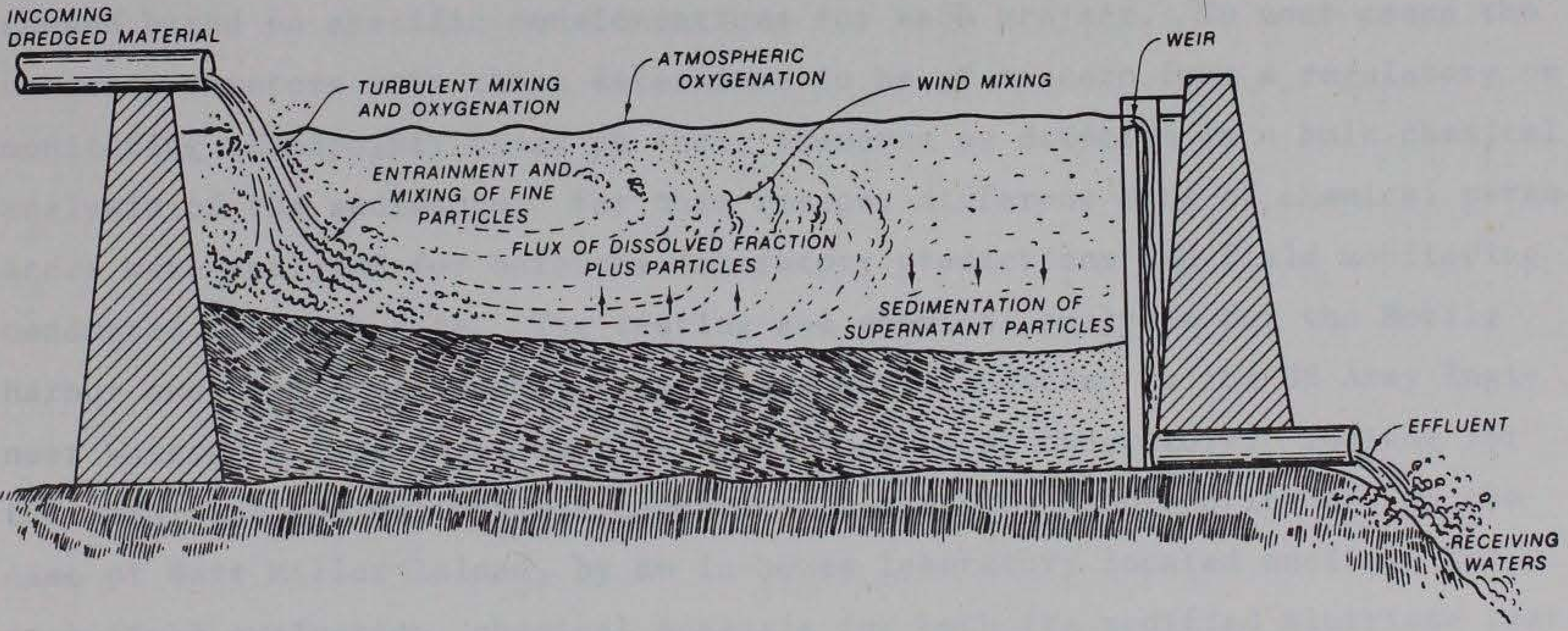

Figure 1. Schematic of ponded water interaction in an active confined disposal site

water through the slurry mass during compaction (or thickening). Wind and/or surface wave action will also resuspend settled particles. If carrier water is released during active phases of disposal, all solids cannot be retained, and adsorbed and associated contaminants are transported with the particles in the effluent to the receiving water outside the containment area.

Purpose and Scope

6. The purpose of this report is to describe the results of field evaluations of effluent quality for five confined dredged material disposal areas. The results of laboratory tests for prediction of effluent quality are presented and compared to measured field verification data collected at the sites. These comparisons serve as a verification of the accuracy and precision of the predictive techniques. The field data include both dissolved and total concentrations of contaminants as well as a discussion of the efficiency of the confined disposal areas in retaining contaminants during active filling and effluent discharge operations.

PART II: LABORATORY TESTING FOR PREDICTION OF EFFLUENT QUALITY

General

7. This part of the report describes sampling and laboratory testing conducted to predict effluent quality at the confined disposal sites used for the field evaluations in this study. Samples of sediment and water were collected and used to conduct modified elutriate and column settling tests. Results were used to predict both dissolved and total concentrations of contaminants in the effluent. The laboratory predictions are compared with field data in Part IV.

Selection of Parameters for Analysis

8. Due to funding considerations, the field evaluations described in this study were conducted during regular maintenance dredging operations at the selected sites. Some portion of the laboratory testing and/or the field sampling was conducted as a part of and was funded by the respective projects. In some cases, the sites used for the evaluations in this study were selected based on the availability of such field sampling assistance and funding. This was especially true regarding the extensive chemical analyses that were required. The parameters for analysis in the laboratory tests were therefore chosen based on specific considerations for each project. In most cases the chosen parameters were those determined to be of concern from a regulatory or monitoring standpoint, based on their presence as detected in a bulk chemical analysis of the sediments. For this reason, different sets of chemical parameters were analyzed for both the laboratory predictions and field monitoring conducted for each site. The testing and chemical analysis for the Mobile Harbor and Black Rock Harbor evaluations were conducted by the US Army Engineer Waterways Experiment Station (WES) Analytical Laboratory. Testing for the remaining evaluations was conducted by contract laboratories or, in the case of Hart Miller Island, by an in-house laboratory located onsite. For each field evaluation, chemical analysis for both the modified elutriate tests and field samples was conducted by the same laboratory using standard quality control procedures.

Sediment and Water Sampling

9. The purpose of sediment and water sampling was to obtain adequate quantities of material for sediment characterization and for conducting the laboratory tests required for prediction of effluent quality. In some cases these sampling operations involved collection of unusually large volumes of dredging site sediment (approximately 50 gal*) and water (approximately 100 gal), because of the large variety and replication of laboratory tests.

Equipment and procedures

10. Sediment samples for use in the laboratory tests were sampled using grab-type samplers. These samplers have proven adequate for obtaining samples from homogenous layers of bottom sediments associated with maintenance dredging activities, reflecting their in situ density and water content (Palermo, Montgomery, and Poindexter 1978). The samples for the Mobile and Norfolk Harbor evaluations were generally taken by repetitive grabs at the desired location in the channel until sufficient volume was obtained. For the Black Rock Harbor and Hart Miller Island evaluations, the samples were taken directly from barges previously loaded with dredged material by clamshell dredge. The Savannah Harbor sediments were sampled directly at the sediment-water interface by a diving team.

11. Water samples for use in the laboratory tests were obtained using a positive displacement pump, operating the intake within 1 m of the sediment-water interface. Care was taken to run the pumping apparatus for a sufficient length of time to allow approximately three times the combined tube volume to pass through the system before the sample was collected (Plumb 1981). These water samples were taken so as to be representative of the water entrained during the dredging process or hydraulic barge offloading process. Descriptions of the sampling locations and operations for each field evaluation are given in Part III.

Sampling rationale

12. The procedures that were used for sediment sample collection, handling, and preservation minimized sample contamination and preserved the physical and chemical integrity of the samples prior to testing (Plumb 1981).

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

13. Random locations within the desired channel areas or barges were sampled and composited so that the sample used for testing was representative of the material dredged during the field evaluations. The channel areas selected for sampling corresponded to positions of the operating dredge during field effluent sampling at the confined disposal sites. Similarly, barges selected for sampling were those off-loaded during field effluent sampling at the confined disposal sites. In this way, sediment samples taken from the channel or barges were generally representative of material dredged during the field evaluation studies. The locations for sediment sampling are given with the detailed project descriptions in Part III.

Sample handling and preservation

14. Samples of dredging site sediment and water were placed in prepared 5-gal airtight plastic containers. The containers were filled to the top to prevent any entrapment of air upon sealing. The samples were immediately transported to a cold room and were maintained at 4° C until tested.

Sediment and Water Characterization

15. Physical and engineering classification tests and bulk sediment chemistry are presented here solely for purposes of characterizing the sediments dredged in the various field evaluations. The characterization tests were conducted prior to the respective field evaluations.

Physical

16. Physical characterization data available for sediments consisted of Atterberg limits and grain size determinations. All physical characterization tests were performed in accordance with standard soil testing procedures (Office, Chief of Engineers 1970). Samples were then classified according to the Unified Soil Classification System (USCS) (WES 1953). The physical characterization data are summarized in Table 1.

Chemical

17. Previous chemical data for the dredging site sediments were available from baseline studies made in conjunction with environmental impact statements, routine sediment studies, or similar studies. The bulk chemical composition of the sediments was available in all cases. The bulk sediment concentrations were not used in making the predictions of effluent quality described in this Part. Rather, the particle-associated concentration in the

effluent was predicted using the results of the modified elutriate tests described below. Samples of dredging site water were also analyzed for dissolved contaminant concentrations as a part of this study. All chemical analyses for characterization of sediment and water were performed according to accepted procedures (US Environmental Protection Agency (EPA) 1974a, 1974b; American Public Health Association (APHA) 1981; Plumb 1981). Results of the chemical characterization tests are presented in Table 2.

Predictive Technique

18. The prediction of the quality of effluent from confined dredged material disposal areas must account for both the dissolved concentration of contaminants and the fraction associated with the total suspended solids that are released. A modified elutriate procedure recently developed for this purpose was used in making the laboratory predictions of effluent quality for this study (Palermo 1985, 1986b). This test determines dissolved concentrations of contaminants in milligrams per litre and particle-associated contaminant concentrations or fractions in the suspended solids (SS) in milligrams per kilogram SS under quiescent settling conditions, and considers the geochemical changes occurring in the disposal area during active disposal operations.

19. Refinements and extensions of column settling test procedures (Montgomery 1978; Palermo, Montgomery, and Poindexter 1978) were also used to predict the concentration of SS in the effluent for the given operational conditions at each field site (i.e., ponded area and depth, inflow rate, and hydraulic efficiency). Using results from both of these analyses, a prediction of the total concentration of contaminants in the effluent was made. Detailed procedures used for the predictions as given by Palermo (1985) are included in Appendix A.

Modified Elutriate Tests

Procedures

20. Modified elutriate tests were conducted on the sediment samples using procedures described by Palermo (1985). These tests consist of the following steps:

a. Mixing dredging site sediment and water to a concentration to be expected in the influent.

b. Aerating to simulate the oxidizing conditions present at the disposal site.

c. Settling for a time equivalent to the mean retention time at the disposal site.

d. Extracting a sample of the supernatant water for analysis of dissolved and total contaminant concentrations. Detailed procedures for the modified elutriate test and a schematic of the test are presented in Appendix A.

Selection of test factors

21. The modified elutriate test should be performed using a slurry concentration equal to that expected in the influent to the confined disposal site to be evaluated. The settling time used for the test should be equal to the mean field retention time in the confined disposal site, up to a maximum of 24 hr. These test factors must be known or assumed prior to conducting the tests. For the evaluations conducted for this study, the modified elutriate tests were performed after the field monitoring and sample collection at each site. In this way, field data on influent solids concentration and mean retention time were available prior to the tests and were used as described in Appendix A in setting the test factors. Therefore, the comparisons of laboratory predictions and measured field data described in Part IV were not biased due to a poor selection of test factors.

22. The field influent solids concentrations were determined from influent samples taken as described in Part III. The average influent concentration for each respective evaluation was used as a target concentration in making up the slurries for conducting the modified elutriate tests. Slurry concentrations in the laboratory can fluctuate with small variations in sediment sample water content. For this reason, the slurry concentrations for the tests vary somewhat from the target concentrations. Both the field influent concentrations and laboratory slurry concentrations are summarized in Table 3.

23. The field mean retention times were determined by dye tracer tests or estimates of theoretical retention time adjusted for the hydraulic efficiency normally associated with confined disposal sites. Procedures for determining the retention times are described in Part III and Appendix A. The field mean retention times and settling times used for the tests are summarized in Table 3.

24. Replicates of the modified elutriate test were conducted for each site evaluated. As many replicates as possible were conducted for each evaluation, but the number was limited by funding and scheduling constraints. The numbers of replicates are summarized in Table 3.

Measurement of physicochemical parameters

25. Conductivity, dissolved oxygen concentration, and pH were measured in the laboratory using instruments. All instrument readings were taken immediately upon sample extraction and processing.

Chemical analyses

26. All chemical analyses for this study were conducted according to standard procedures (EPA 1974a, 1974b; APHA 1981). Metals analyses were performed using atomic absorption spectrophotometers with heated graphite furnace. Nutrient analyses were performed using Technicon Auto Analyzers. Organic analyses were performed using high-resolution gas chromatograph/mass spectrometers. The WES Analytical Laboratory performed analyses for the Mobile Harbor and Black Rock Harbor samples. Analyses for the Savannah Harbor and Norfolk Harbor evaluations were performed by contract (Savannah Laboratories and Environmental Services 1982b, James R. Reed and Associates 1983). Analyses for the Hart Miller Island evaluations were performed by Maryland Environmental Service.

Results

27. The chemical analysis of the modified elutriate samples provided dissolved and total concentrations of parameters in milligrams per litre; the total suspended solids concentration was also determined. To predict the total concentration in the effluent, it was necessary to first calculate the fraction of the contaminants associated with the total suspended solids in the elutriate samples. These fractions were calculated as follows:

$$F_{SS} = (1 \times 10^6) \frac{C_{total} - C_{diss}}{SS} \qquad (1)$$

where

F_{SS} = fraction of analyte in the total suspended solids, mg analyte/kg of suspended solids

(1×10^6) = conversion factor, mg/mg to mg/kg

C_{total} = total concentration, mg analyte/ℓ of sample

C_{diss} = dissolved concentration, mg analyte/ℓ of sample

SS = total suspended solids concentration, mg solids/ℓ of sample

Results for the modified elutriate dissolved concentrations and calculated fractions in the total suspended solids are summarized for each site in Table 4.

Column Settling Tests

Procedures

28. Column settling tests were conducted on the composite sediment samples to predict the concentration of suspended solids in the effluent. The tests generally consist of the following steps:

- a. Mixing the dredging site sediment and water to a slurry concentration to be expected in the influent.
- b. Placing the slurry into an 8-in.-diam settling column and allowing it to settle.
- c. Taking samples of the supernatant water above the sediment-water interface which forms as settling progresses, and repeating the process at various time intervals.
- d. Analyzing the samples for suspended solids concentration.

29. As with the modified elutriate tests, the measured field influent concentrations were known prior to the tests. These values were used as target concentrations for mixing the slurries for the settling tests. Actual values for the test slurry concentrations are shown in Table 5. Detailed test procedures are given in Appendix A.

Prediction of effluent suspended solids

30. Using the column settling test results, predictions of the effluent suspended solids were made. The predictions were made using the following steps:

- a. Developing a relationship of column supernatant suspended solids versus settling time.
- b. Selecting a column supernatant suspended solids concentration corresponding to the expected mean field retention time.
- c. Determining a predicted effluent suspended solids value by adjusting the column value for wind and turbulence under field settling conditions using a resuspension factor.

The measured field mean retention times for each site were used in selecting the corresponding value of column supernatant suspended solids. Resuspension factors for adjusting the column values for wind and turbulence are a function of ponded surface area and ponded depth. The ponding conditions for each site, column suspended solids values, resuspension factors, and predicted effluent suspended solids values determined for each site are summarized in Table 5.

Laboratory Predictions of Effluent Quality

31. Predictions of the total contaminant concentrations in the effluent were made using the results of both the modified elutriate tests and column settling tests. The total concentrations are the sum of the dissolved concentrations and the particle-associated concentrations. Dissolved concentrations were determined directly by the modified elutriate tests. Particle-associated concentrations were calculated using the contaminant fractions of the total suspended solids determined by the modified elutriate tests and the predicted effluent suspended solids concentrations determined by the column settling tests. Using these test results, the predicted total contaminant concentration in milligrams per litre in the effluent was estimated as

$$C_{total} = C_{diss} + \frac{F_{ss} SS_{eff}}{(1 \times 10^6)} \qquad (2)$$

where

C_{total} = estimated total concentration in effluent, mg analyte/ℓ of water

C_{diss} = dissolved concentration determined by modified elutriate test, mg analyte/ℓ of sample

F_{SS} = fraction of analyte in the total suspended solids calculated from modified elutriate results, mg analyte/kg of suspended solids

SS_{eff} = predicted suspended solids concentration of effluent estimated from evaluation of sedimentation performance, mg suspended solids/ℓ of water

(1×10^6) = conversion factor, mg/mg to mg/kg

The results are summarized in Table 6.

PART III: FIELD EVALUATIONS

General

32. Field evaluations conducted at the five sites are described in this part of the report. The projects were located along the Gulf and Atlantic coasts. The field evaluations consisted of sampling dredging site sediments and water prior to dredging, definition of operational conditions at the field sites, and sampling and subsequent analysis of influent and effluent samples at the sites. This section describes rationales and procedures that were common to all the field evaluations.

Influent/effluent sampling

33. Many investigators have noted that high variability exists in the influent into disposal areas (Krizek, Gallagher, and Karadi 1976; Hoeppel, Myers, and Engler 1978; Montgomery 1978) because of the heterogeneous nature of sediment and the operating characteristics of suction dredges. These sources of variability result in wide variations among influent suspended solids and contaminant concentrations. The influent pipe may discharge clear water at one instant and high solids the next, or sandy material one instant and fine silts or clays the next.

34. Contaminant and suspended solids concentrations in effluents discharged from confined disposal sites are less variable than influents because of the relatively long retention times and the mixing and dispersion occurring within the disposal site.

35. When confronted with a highly variable sediment sampling situation, the more samples that can be obtained, the better the probability of determining the true mean of a population. Based on a general examination of results of other studies of influent and effluent contaminant concentrations (Hoeppel, Myers, and Engler 1978), 50 samples was selected as the preferred sample size for both influent and effluent sampling. However, it was generally impossible to obtain the preferred number of samples, especially for influent sampling, due to economic considerations, dredge breakdowns, weather, etc. The actual numbers of influent and effluent samples collected are given below for each field evaluation. Samples were generally taken on an hourly basis directly from the dredge pipe for the influent sample and from the weir overflow for effluent samples.

Determination of retention time

36. The field mean retention or residence time for the containment areas was determined by conducting a dye tracer study. Dye was injected at the point of inflow, and dye concentrations of the effluent were determined. The field mean retention time was calculated as the centroid of the plot of the dye concentration versus time. These data were calculated prior to conducting the modified elutriate tests described in Part II so that the estimated retention times could be used in setting the laboratory retention times for the tests. Also, the field mean retention times were used along with the column settling test results in estimating the effluent suspended solids concentrations. Dye tracer studies were conducted for all the field evaluations with the exception of the Hart Miller Island evaluation. The extremely long retention time at this site made a dye study impractical, so the retention time was estimated from the ponded volume and flow rates. Additional discussion of methods for determining retention times is found in Appendix A.

37. When operating conditions allowed, the field mean retention times were considered in determining a lag time for initiating the effluent sampling with respect to the influent sampling for the field evaluations. By lagging the initiation of effluent sampling by a time period approximating the mean retention time, the same "slug" of water was sampled for both influent and effluent, to the extent possible.

38. Total concentrations of contaminants were determined for both influent and effluent at each site. This made possible the calculation of retention percentage of contaminants. Retention of contaminants within the disposal area was determined from the influent and effluent concentrations as follows:

$$R = \frac{[C_{in}] - [C_{eff}]}{[C_{in}]} (100) \qquad (3)$$

where

R = retention in percent

$[C_{in}]$ = total concentration in influent, mg/ℓ

$[C_{eff}]$ = total concentration in effluent, mg/ℓ

Mobile Harbor Field Evaluation

Project description

39. The Mobile Harbor, Alabama, project consists of approach channels through Mobile Bay and a 40-ft-deep channel extending up the Mobile River. A project map for the Mobile River section of the project, including channels and other features, is shown in Figure 2.

40. The Mobile River sections of the project are maintained by hydraulic pipeline dredges. In past years, disposal of dredged material from maintenance dredging in the upper river was not confined. However, due to environmental constraints, dredged material is now placed in several confined disposal areas along the channel (US Army Engineer District (USAED), Mobile 1975).

41. The North Blakely, or Upper Polecat Bay, disposal site was used as a field evaluation site for this study. This 85-acre site was constructed in 1971 and is conveniently located adjacent to the main river channel (Figure 2).

Dredging and disposal operations

42. Dredging was conducted in the Upper Mobile River during July and August 1982. Approximately 500,000 cu yd of material was placed in the North Blakely disposal area during this contract. A 27-in. dredge was used for the project. Field sampling for this study was conducted on 7-16 July 1982. During this period, the dredge was operating in the vicinity of Station MB28 (see Figure 2). Field estimates of pipeline velocity were approximately 17 fps, yielding a flow rate of approximately 36 cfs, accounting for downtime. A plan view of the disposal facility during the sampling period is shown in Figure 3.

Dye tracer study

43. A dye tracer test was used to establish the retention time of the pond prior to influent and effluent sampling. The dye tracer data were also considered in selecting a lag time between initiation of influent and effluent sampling to ensure the best possible comparison of influent and effluent data.

44. Measurements of the ponded depth were taken from a small boat to establish the total volume of the pond prior to injecting the dye tracer. Total volume of the pond was estimated to be 38 acre-feet, which is a relatively shallow pond of 1 ft or less over a ponded area of about 40 acres.

45. Rodamine WT dye, commonly used in dispersion studies, was used for

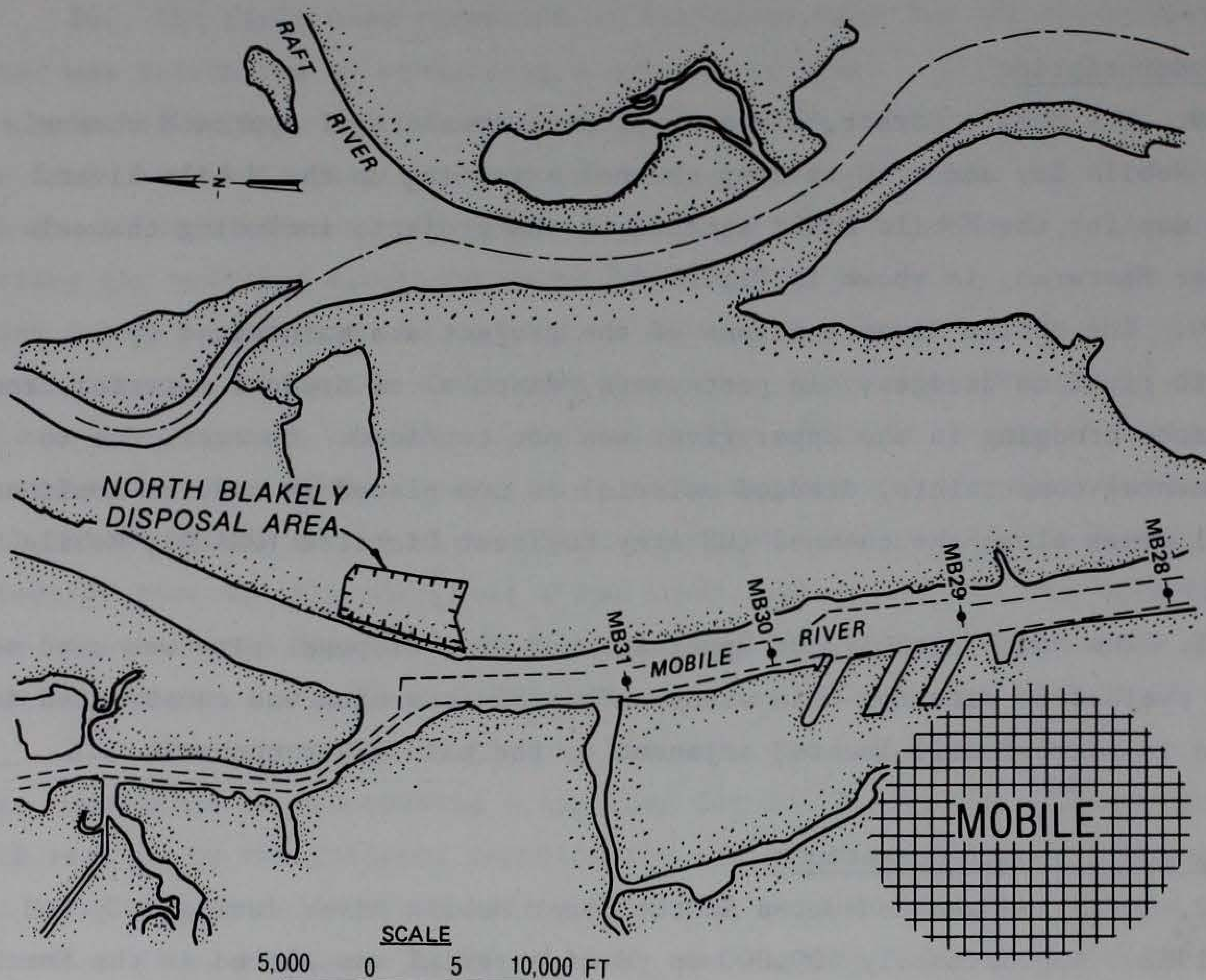


Figure 2. Mobile Harbor, Alabama, showing location of channels and North Blakely disposal area

the tracer. A total of 51 lb of 20-percent solution was poured into the influent pipe indicated in Figure 3. The flow was well channelized at this point, and good mixing due to turbulence could be obtained.

46. The dye concentration was measured at the weir using a Turner Model 10 fluorometer/nephelometer. Field readings were taken by pumping samples through the instrument at time intervals designed to establish the shape of the dispersion curve. Samples were also taken for later checks of dye concentrations in the laboratory. The dispersion curve or retention time distribution curve is shown in Figure 4. The field mean retention time was calculated to be approximately 12 hr.

Sediment sampling and testing

47. Station MB28 (see Figure 2) was selected for sediment and water

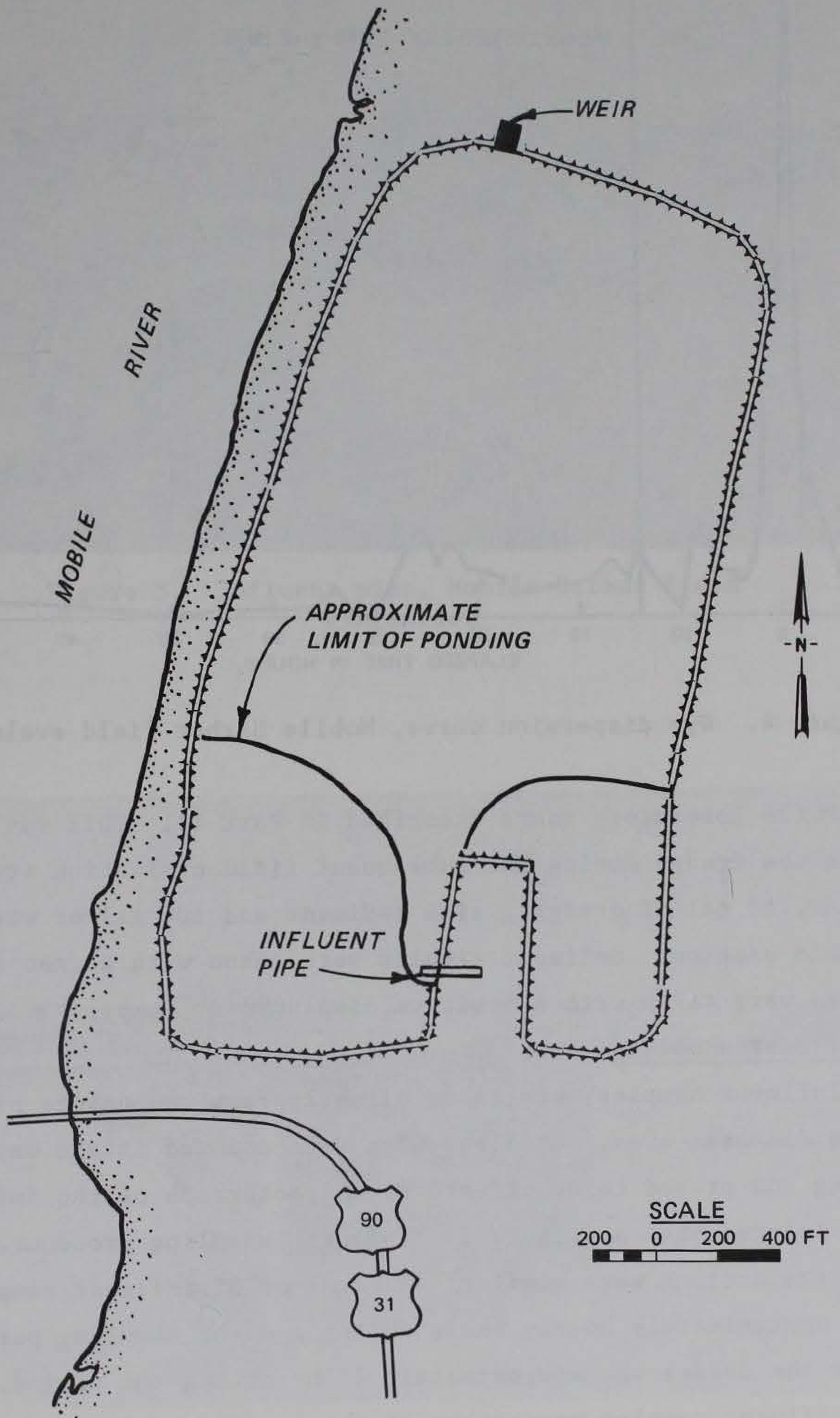


Figure 3. Plan of North Blakely disposal area,
Mobile Harbor field evaluation

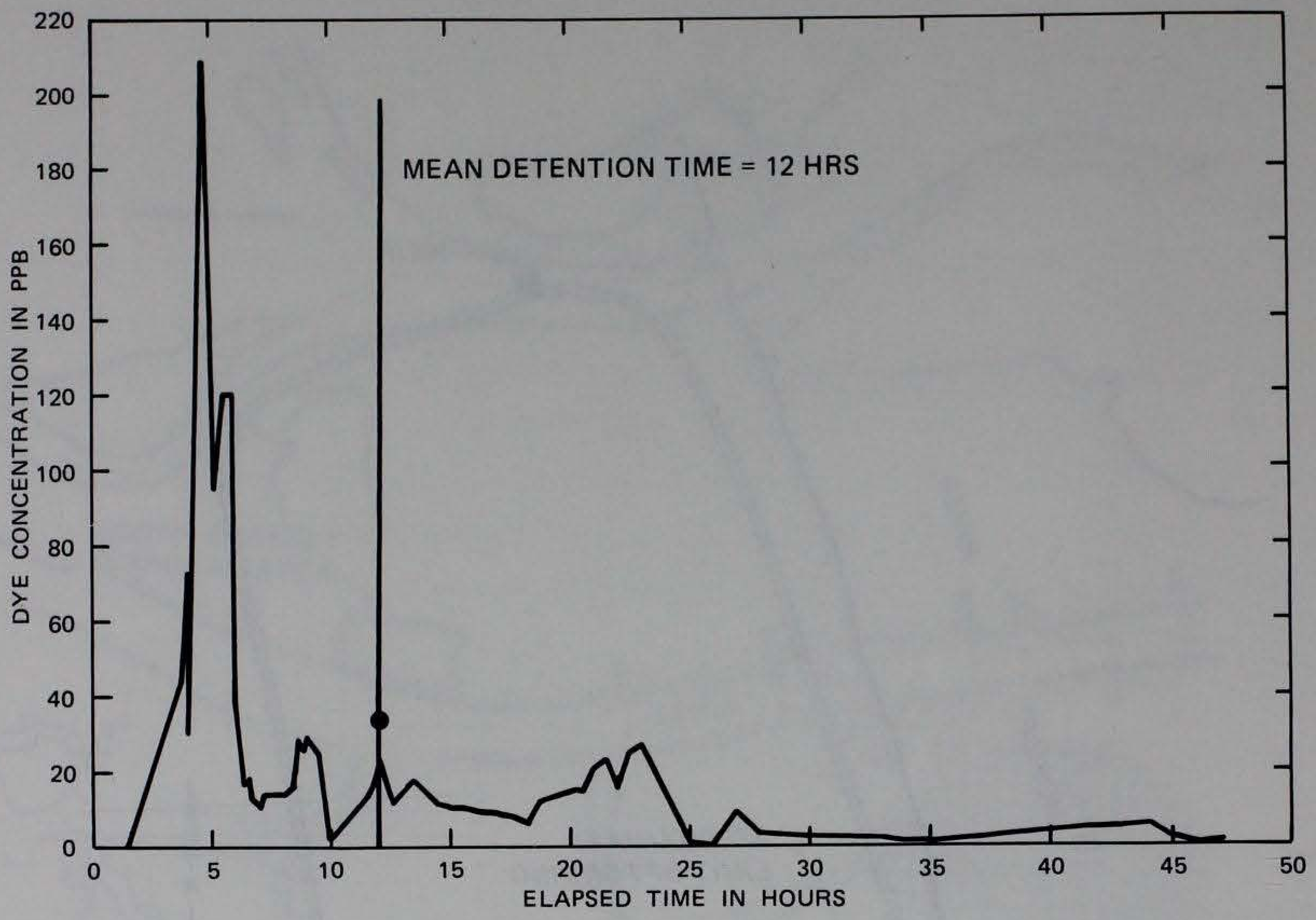


Figure 4. Dye dispersion curve, Mobile Harbor field evaluation

sampling for the laboratory tests described in Part II. This was the planned location for the dredge during the subsequent field evaluation studies. During July 1982, 50 gal of dredging site sediment and 100 gal of water were collected at this station. Sediment samples were taken with a grab sampler. Water samples were taken with a positive displacement pump.

Influent/effluent sampling

48. Influent samples were taken directly from the dredge pipe discharging into the disposal area. An elbow pipe with pointed intake was used for this sampling and proved to be effective. A photograph of the influent sampling point is presented as Figure 5. Influent sampling procedures for the other field evaluations were similar. A total of 31 influent samples were taken on an approximately hourly basis during a 48-hr sampling period. Total downtime for the dredge was approximately 17 hr during the period.

49. Effluent samples were taken at the overflow weir. A rectangular weir with a crest length of approximately 60 ft was used at the site, as shown in Figure 6. This weir proved very effective in releasing effluent without

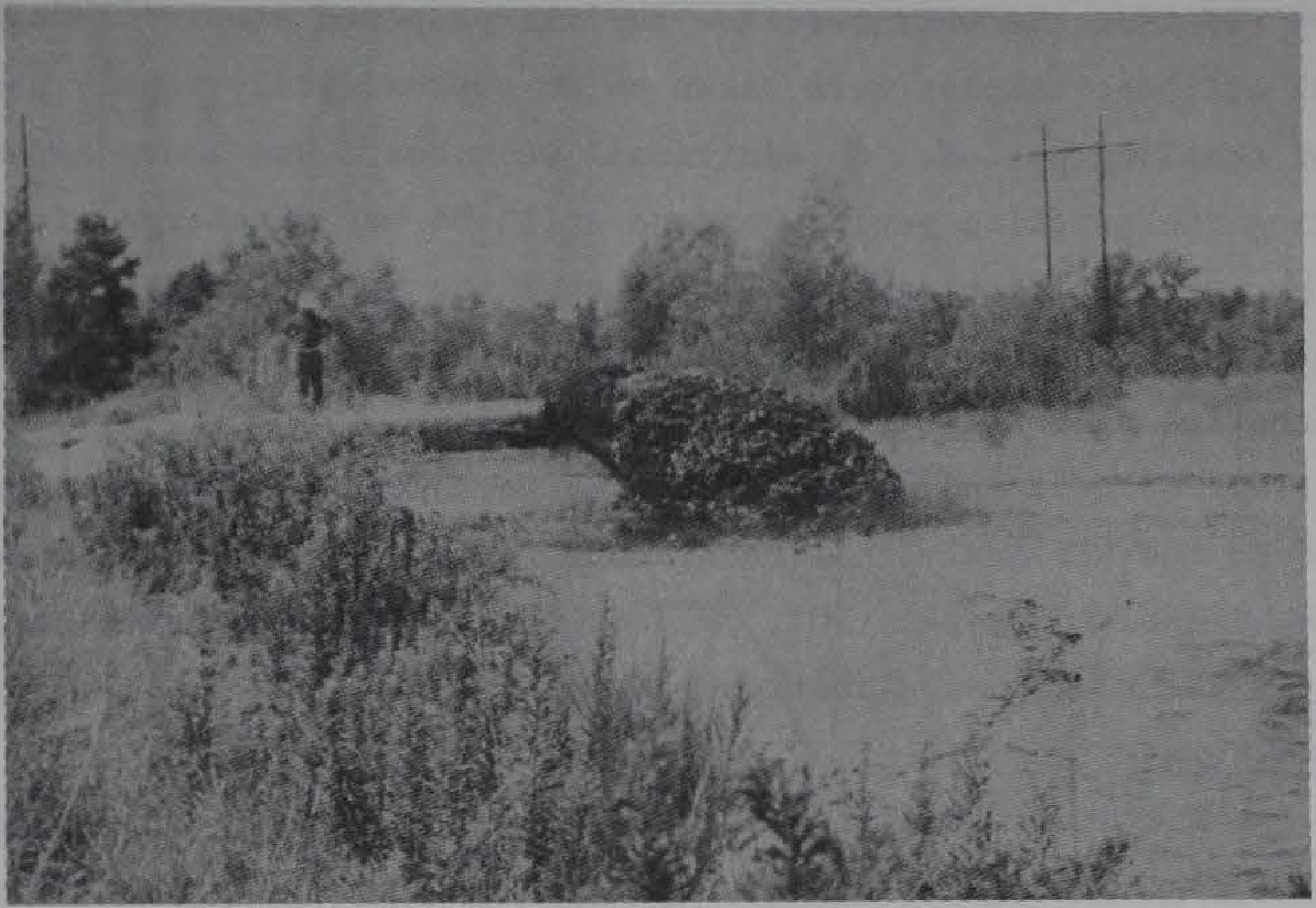


Figure 5. Influent pipe, Mobile Harbor field evaluation

Figure 6. Box weir structure, Mobile Harbor field evaluation

resuspending the settled dredged material. The effluent samples were taken directly by allowing the weir overflow to fill prepared sample containers. A total of 37 effluent samples were taken on an approximately hourly basis during a 48-hr sampling period. An additional weir board was added approximately midway during the sampling period, and no effluent was discharged for approximately 9 hr. The initiation of effluent sampling was lagged by 24 hr with respect to the initiation of the influent sampling, based on field estimates of mean retention time from the dye tracer results.

50. The influent and effluent samples were immediately refrigerated and transported to the WES Analytical Laboratory for processing and analysis. The temperature, dissolved oxygen (DO), pH, and conductivity for each sample were determined in the field using instruments.

Chemical analysis

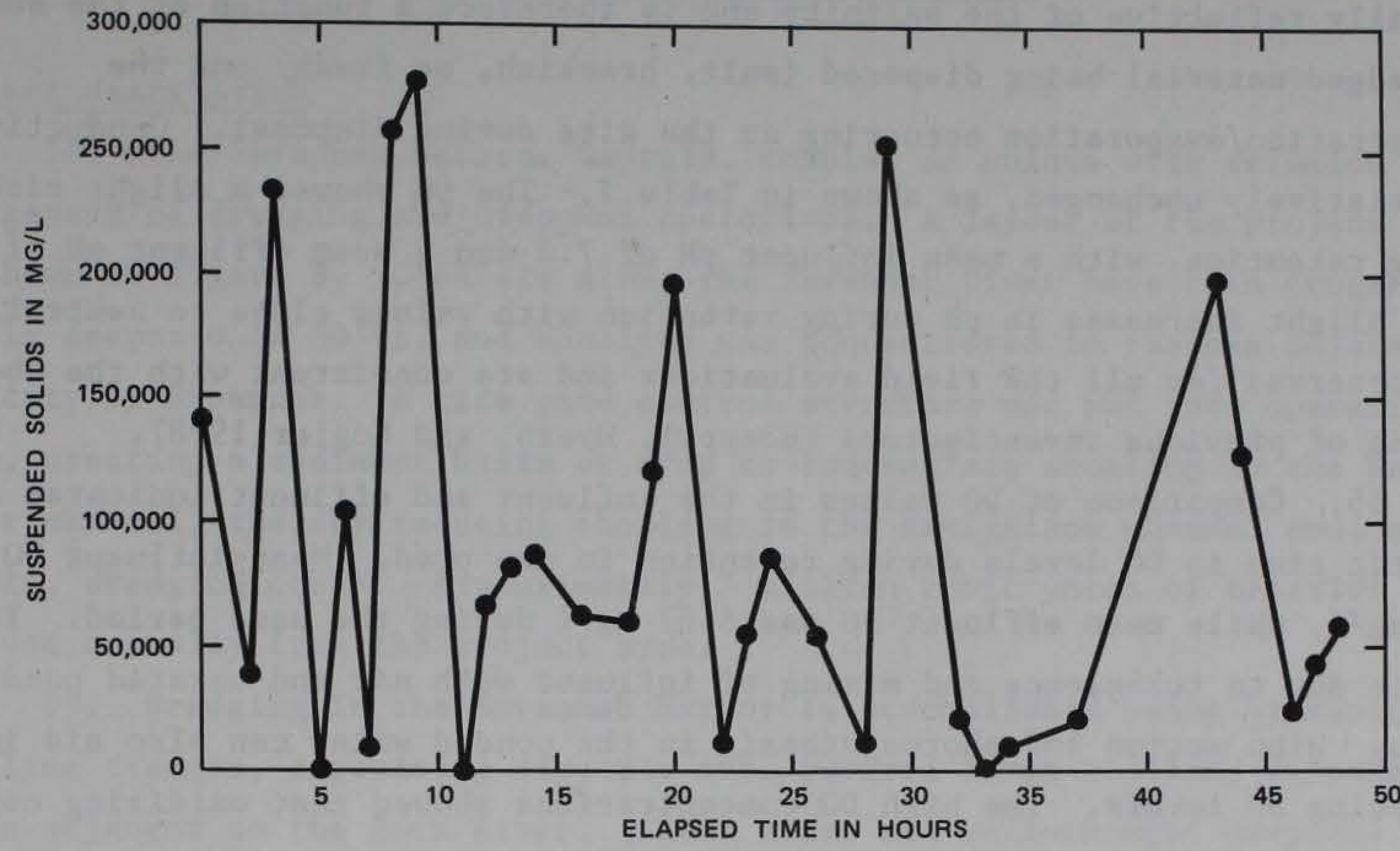
51. The influent and effluent samples were analyzed for suspended solids, total organic carbon, ammonia nitrogen, nitrate plus nitrite nitrogen, total phosphorus, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Both dissolved and total concentrations of nutrients and metals were determined, using a 0.45-μ filter to obtain a dissolved subsample. The chemical analyses for the Mobile Harbor field evaluation were conducted by the WES Analytical Laboratory.

Results

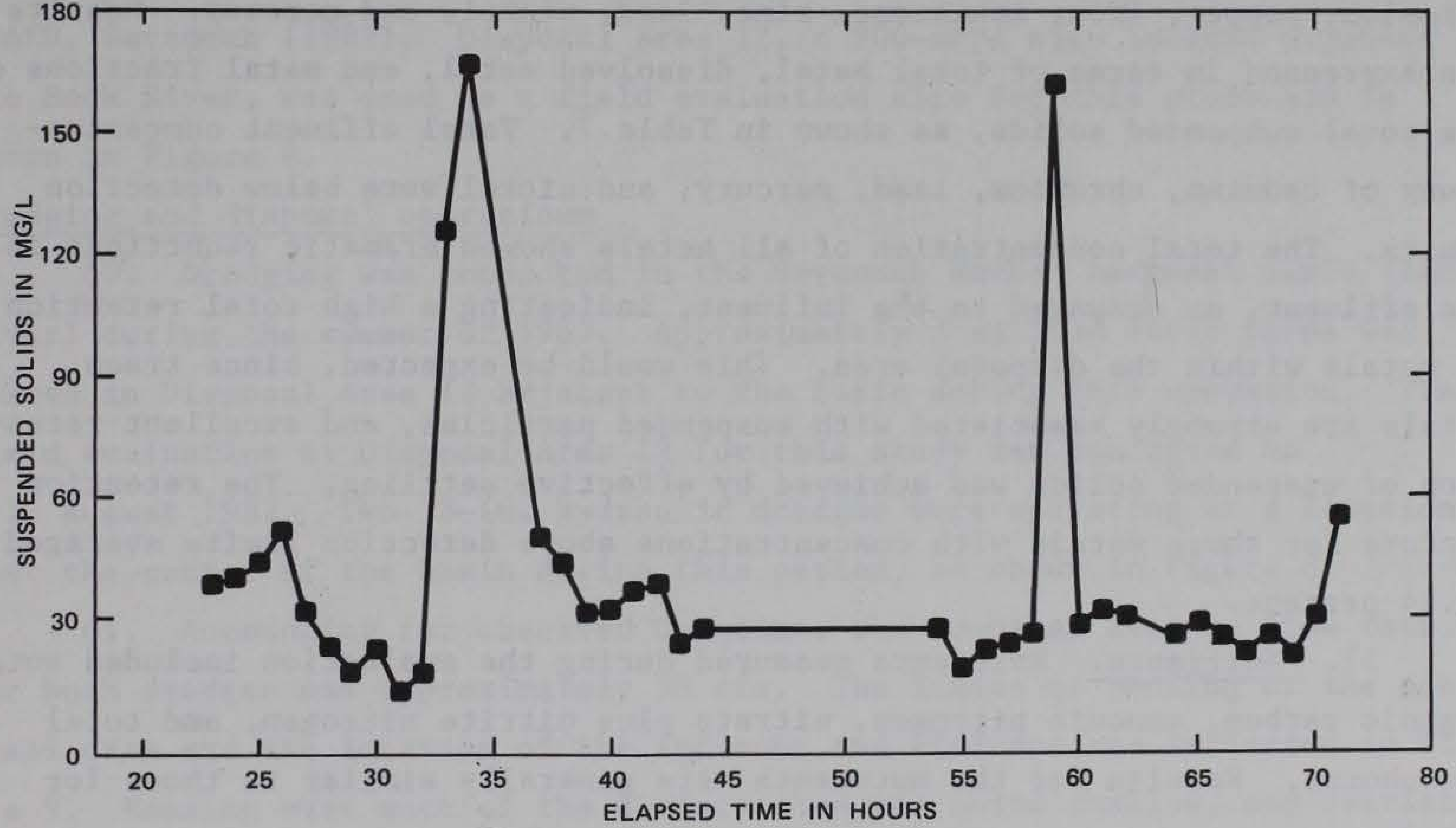
52. The chemical analyses determined both dissolved and total concentrations of parameters and the concentration of suspended solids in the samples. This allowed calculation of the contaminant fractions of the total suspended solids. The means and standard deviations for all measured parameters are summarized in Table 7. Summary data plots are presented in Appendix B.

53. Suspended solids. Plots of the influent and effluent suspended solids concentrations are shown in Figure 7. The trends shown are typical of all the field evaluations. The mean concentration of solids in the influent was 87 g/ℓ, while the mean concentration of suspended solids in the effluent was 40 mg/ℓ, as indicated in Table 7. The site therefore had a solids retention efficiency of approximately 99.96 percent. This high solids retention efficiency shows that the site was well operated and acted as an effective settling basin.

54. Physicochemical parameters. Physicochemical parameters measured



a. Influent



b. Effluent

Figure 7. Total suspended solids concentrations, Mobile Harbor field evaluation

included conductivity, pH, and DO. Conductivity within a disposal site is generally reflective of the salinity and is therefore a function of the source of dredged material being disposed (salt, brackish, or fresh) and the precipitation/evaporation occurring at the site during disposal. Conductivity was relatively unchanged, as shown in Table 7. The pH showed a slight rise during retention, with a mean influent pH of 7.2 and a mean effluent pH of 7.5. Slight increases in pH during retention with values close to neutrality were observed for all the field evaluations and are consistent with the observations of previous investigators (Hoeppel, Myers, and Engler 1978).

55. Comparison of DO values in the influent and effluent indicates a dramatic rise in DO levels during retention in the pond. Mean influent DO was 1.05 mg/ℓ, while mean effluent DO was 6.57 mg/ℓ during the same period. This rise is due to turbulence and mixing of influent with air and aerated ponded waters. Wind action and photosynthesis in the ponded water can also aid in increasing DO levels. The high DO concentrations showed that oxidizing conditions were present in the ponded water.

56. Metals. Metals measured during the evaluation included cadmium, chromium, copper, iron, manganese, zinc, lead, nickel, and mercury. Results are expressed in terms of total metal, dissolved metal, and metal fractions of the total suspended solids, as shown in Table 7. Total effluent concentrations of cadmium, chromium, lead, mercury, and nickel were below detection limits. The total concentration of all metals showed dramatic reductions in the effluent, as compared to the influent, indicating a high total retention of metals within the disposal area. This would be expected, since trace metals are strongly associated with suspended particles, and excellent retention of suspended solids was achieved by effective settling. The retention factors for those metals with concentrations above detection limits averaged 98.14 percent.

57. Nutrients. Nutrients measured during the evaluation included total organic carbon, ammonia nitrogen, nitrate plus nitrite nitrogen, and total phosphorus. Results for the nutrients were generally similar to those for metals.

Savannah Harbor Field Evaluation

Project description

58. The Savannah Harbor, Georgia, complex is unique with relation to management of dredging and disposal operations. A layout of the project area is shown in Figure 8. Channels along the Savannah River have been progressively deepened to 38 ft, and shoaling was concentrated to reaches adjacent to the city of Savannah. A tide gate control structure was put into operation in 1977, creating a sediment basin or trap to concentrate shoaling in the Back River channel, thereby reducing shoaling in the navigation channel and, as a result, dredging costs. Approximately 7 million cubic yards of material is removed annually from the project area.

59. Dredging in the Savannah Harbor is accomplished using hydraulic pipeline dredges, depositing directly into several large confined disposal sites adjacent to the Back River. These sites are well-managed disposal areas that provide good sedimentation. An intensive postdisposal management program to extend the site life through dewatering has also been implemented by the USAED, Savannah (1982). Disposal Area 12, a 900-acre site located adjacent to the Back River, was used as a field evaluation site for this study and is shown in Figure 8.

Dredging and disposal operations

60. Dredging was conducted in the Savannah Harbor sediment basin (Back River) during the summer of 1982. Approximately 2 million cubic yards was placed in Disposal Area 12 adjacent to the basin during this operation. The field evaluation at Disposal Area 12 for this study was conducted on 9-12 August 1982. Two 18-in. hydraulic dredges were operating at a location near the center of the basin during this period, as shown in Figure 8.

61. Accounting for observed downtime, the combined average flow rate for both dredges was approximately 58 cfs. The limits of ponding of the disposal site and the location of the influent and effluent are indicated in Figure 9. Ponding over much of the surface area was quite shallow, and overland flow conditions were prevalent in most of the area. Although the total area ponded was in excess of 400 acres, the area ponded to a depth of 1 ft or greater was limited to a portion of the pond near the outlet weir. This ponded area was approximately 50 acres, with ponding depth varying from 1 to 2 ft at the weir structure.

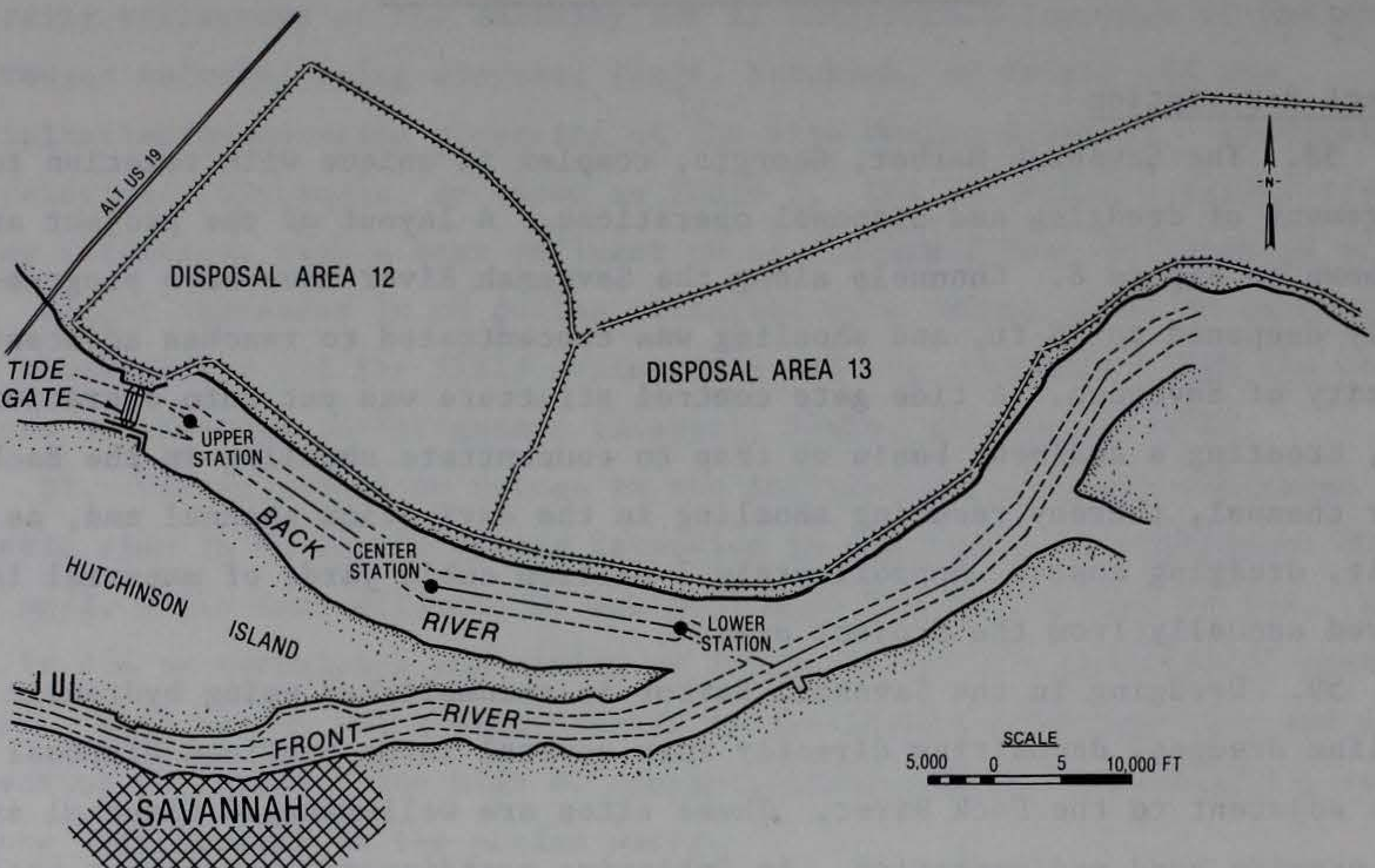


Figure 8. Savannah Harbor, Georgia, showing channels, sediment basin, and Disposal Area 12

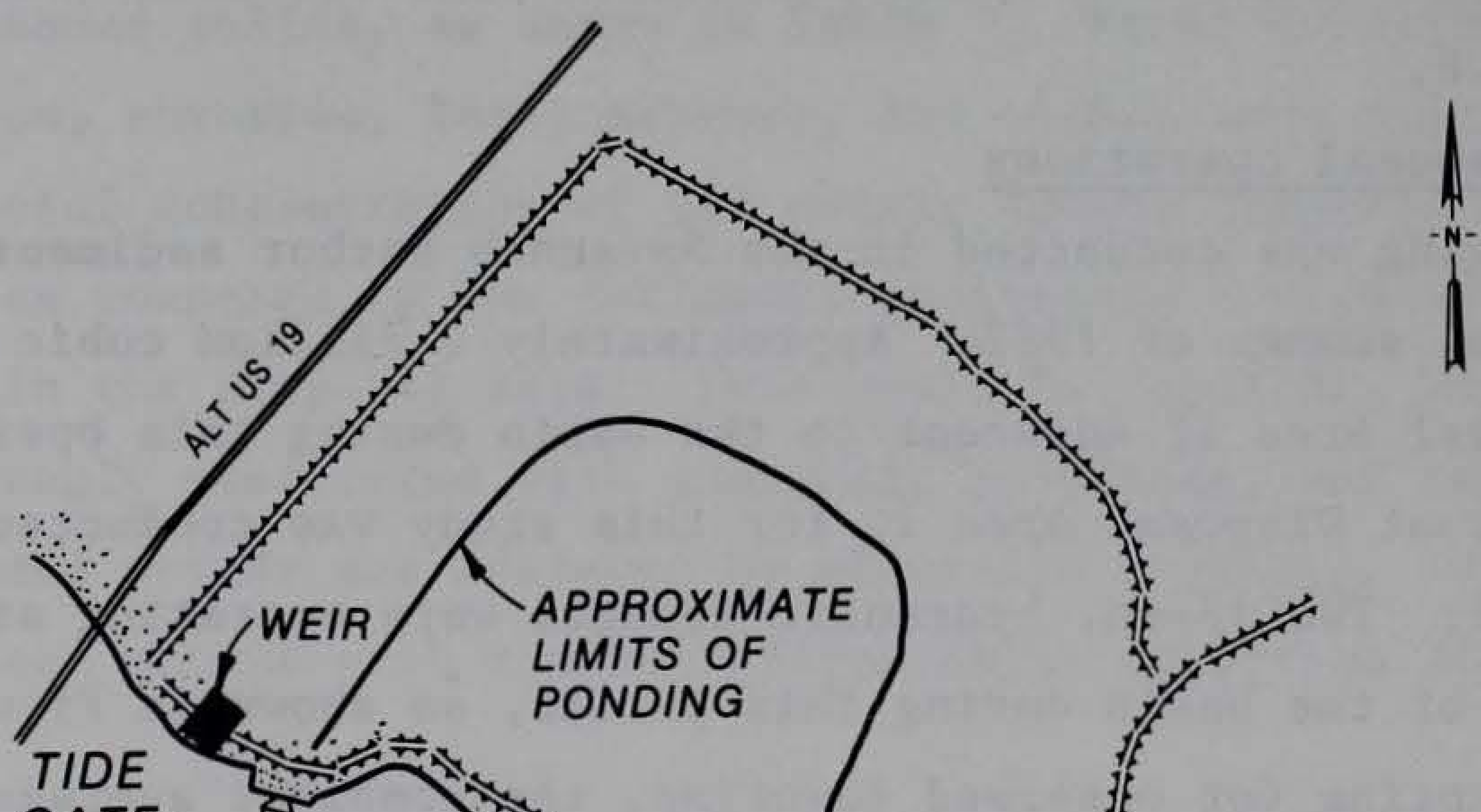


Figure 9. Plan of Disposal Area 12, Savannah Harbor

Dye tracer study

62. A dye tracer study was conducted prior to influent and effluent sampling. Approximately 75 lb of 20-percent rodamine WT dye was injected at the influent point. The dye concentration was measured at the effluent point using a Turner Model 10 fluorometer as previously described. The dye dispersion curve is shown in Figure 10. The mean field retention time as determined by the dye tracer test was 53 hr. A lag time of 48 hr between influent and effluent sampling was selected, based on the dye tracer results.

Sediment sampling and testing

63. Samples of dredging site sediment and water for use in the laboratory tests described in Part II were taken at the Savannah Harbor site during August 1982. Samples were taken from the Back River opposite Disposal Area 12 at the center station shown in Figure 8. The sediment samples were taken directly at the sediment-water interface by a diving team using a grab sampler a short distance ahead of the operating dredge. This ensured that the sediment sample would be as representative as possible of material sampled during the field evaluation study. Water samples were taken at the sediment-water interface using a positive displacement pump.

Influent/effluent sampling

64. Samples of influent and effluent were taken in a manner similar to the Mobile Harbor field evaluation. Influent samples were taken in prepared containers directly from the dredge discharges pipes, one of which is shown in Figure 11. Sampling of the influent was alternated between the two dredge pipes when both dredges were operating. A total of 48 influent samples were taken on an approximately hourly basis. Effluent samples were taken at the weir structure by directly filling prepared containers from the weir overflow. The weir structure was a standard corrugated metal drop inlet with a crest width of 6 ft. A photograph of the weir structure is shown as Figure 12. A total of 48 effluent samples were taken on an hourly basis.

65. The samples were immediately transported to the laboratory for processing and analysis. The DO, pH, and conductivity for each sample were determined in the field using instruments.

Chemical analysis

66. The influent and effluent samples were analyzed for suspended solids, total organic carbon, ammonia nitrogen, total phosphorus, chromium, copper, iron, lead, nickel, silver, and zinc. Both the dissolved and total

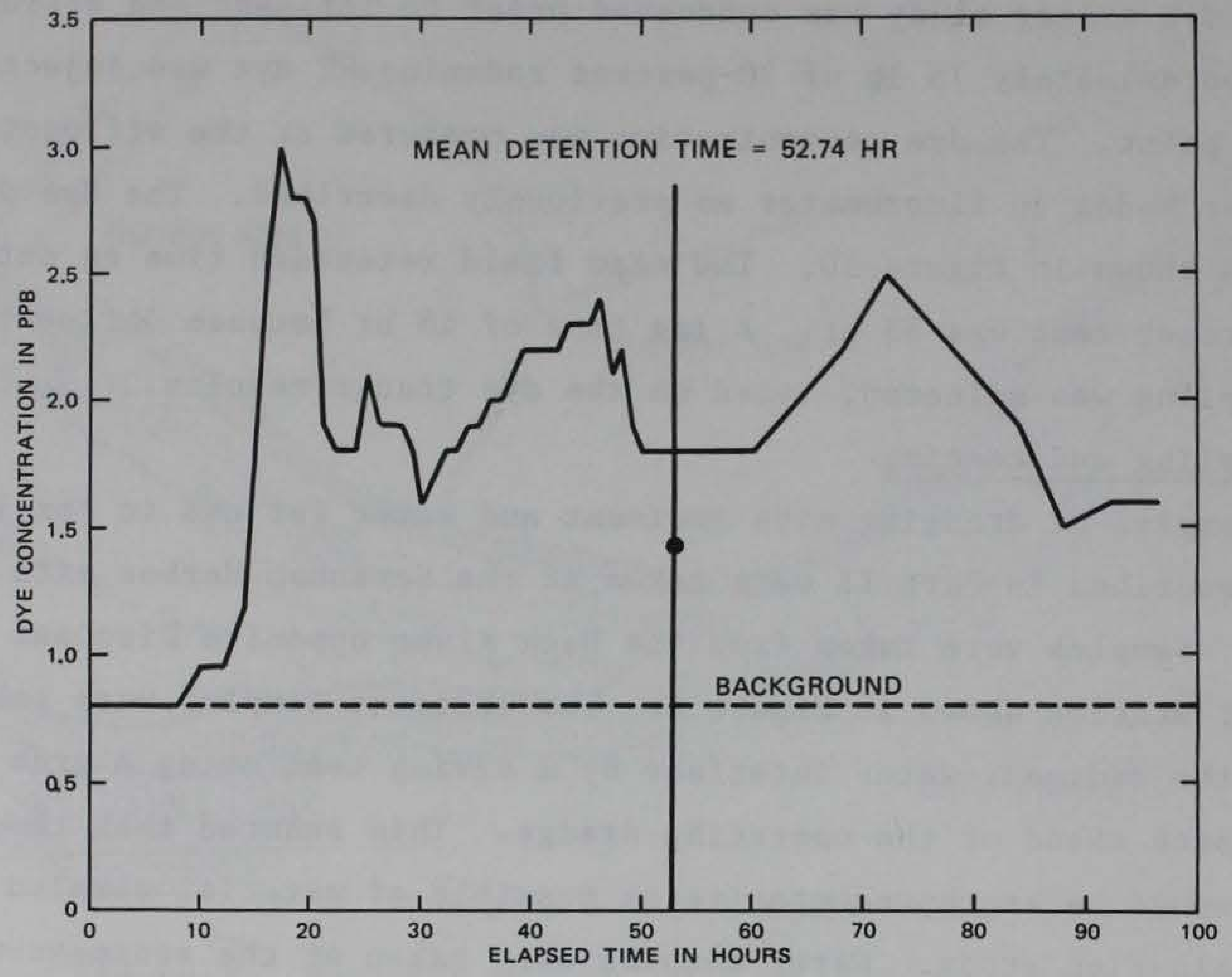


Figure 10. Dye dispersion curve, Savannah Harbor field evaluation

Figure 11. Dredge influent pipe, Savannah Harbor field evaluation

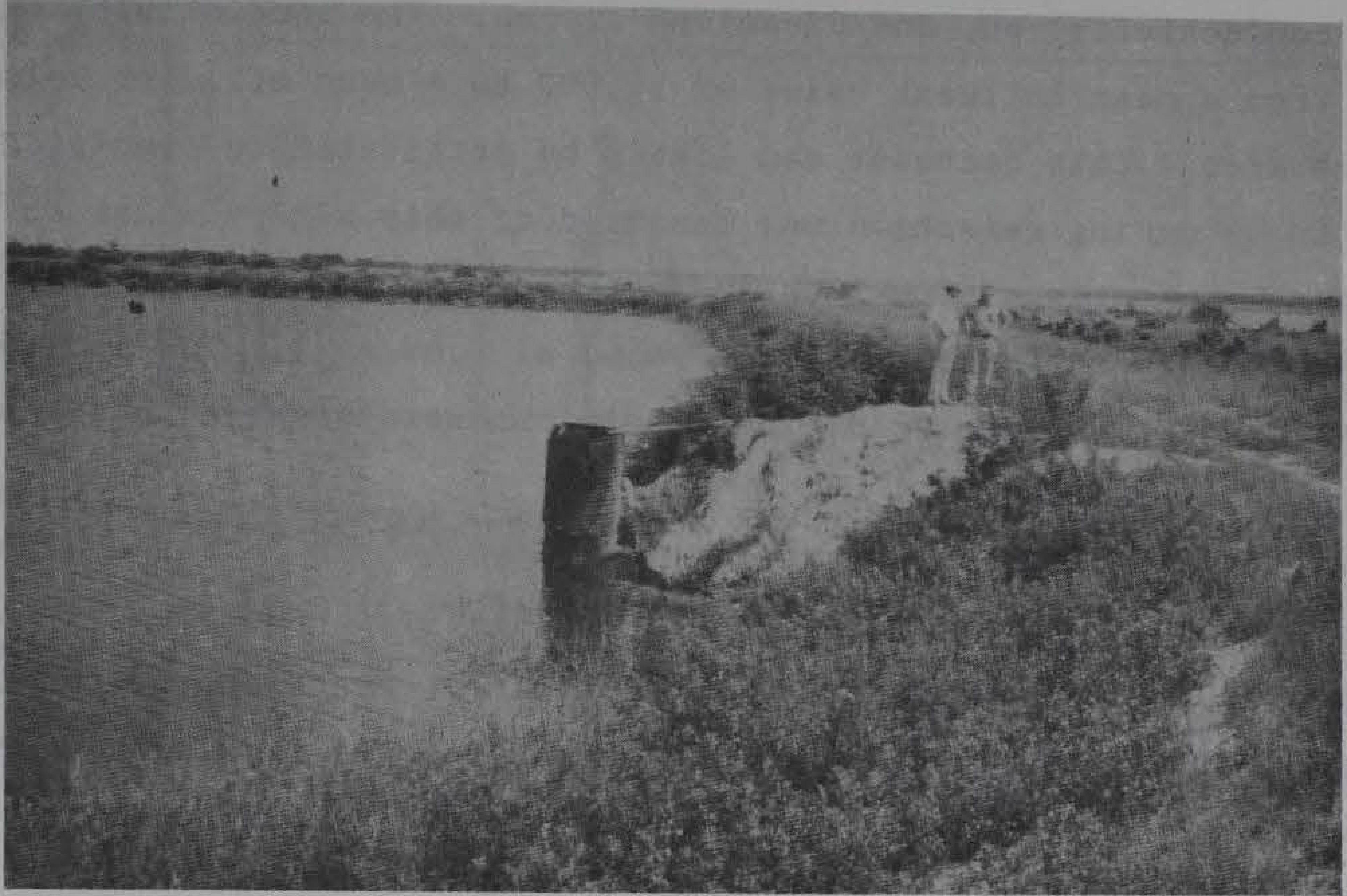


Figure 12. Drop inlet weir, Savannah Harbor field evaluation

concentrations of nutrients and metals were determined, using a 0.45-μ filter for obtaining a dissolved subsample. Sampling and chemical analyses were conducted by Savannah Laboratories and Environmental Services, Inc. (1982b) under contract to the USAED, Savannah.

Results

67. Analyses included both the dissolved and total concentrations of contaminants. The contaminant fractions of the total suspended solids were determined as described previously. The means, standard deviations, and calculated retention efficiencies are summarized in Table 8. Data plots are presented in Appendix B.

68. Suspended solids. The mean concentration of solids in the influent was 107 g/ℓ, while the mean concentration of suspended solids in the effluent was 75 mg/ℓ, as indicated in Table 8. The Disposal Area 12 site therefore had a solids retention efficiency of approximately 99.93 percent. This high solids retention efficiency shows that the site acted as an effective settling basin, and there was little resuspension despite the relatively small weir crest length. This was due primarily to the large surface area ponded and the relatively large ponded depths at the weir structure.

69. Physicochemical parameters. Physicochemical parameters measured

included conductivity, pH, and dissolved oxygen. The conductivity exhibited a decrease from a mean influent value of 34,000 to a mean effluent value of 20,100 μmhos/cm. This decrease can likely be attributed to precipitation. An increase in DO during retention was observed at this site similar to the other field sites. Comparison of values indicates an increase from a mean influent value of 1.25 mg/ℓ to a mean effluent value of 8.09 mg/ℓ. The increases in DO concentrations showed that oxidizing conditions were present in the ponded water at this site.

70. Metals. Metals analyzed during the Savannah Harbor evaluation included chromium, copper, iron, lead, nickel, silver, and zinc. Values of total and dissolved concentrations and contaminant fractions of the total suspended solids are shown in Table 8. The retentions of total concentrations of metals were similar to the other sites, with an average retention of 99.67 percent.

71. Nutrients. Nutrients measured during the evaluation included total organic carbon, ammonia nitrogen (see Figure 13), nitrate plus nitrite nitrogen and total phosphorus. Results for the nutrients were generally similar to those for metals.

Norfolk Harbor Field Evaluation

Project description

72. Norfolk Harbor, Virginia, is the location of one of the major coal exporting facilities in the United States. The Norfolk Harbor complex consists of 45-ft channels and anchorages that serve major commercial and naval facilities. A layout of the harbor area is shown in Figure 14.

73. The Craney Island disposal area, located as shown in Figure 14, was used for the field evaluation portion of this study. The site has a surface area of 2,500 acres, making it one of the largest such sites in the Nation. Plans for the site were developed in the early 1940s to provide a long-term disposal area for material dredged from channels and ports in the Hampton Roads area. Construction of dikes at Craney Island was completed in 1957, and material has since been placed within the disposal area almost continuously, using both direct pipeline discharge and hopper dredge pumpout. Over 142 million cubic yards of dredged material has been placed within the area so far, and maintenance requirements now average 5 million cubic yards per year.

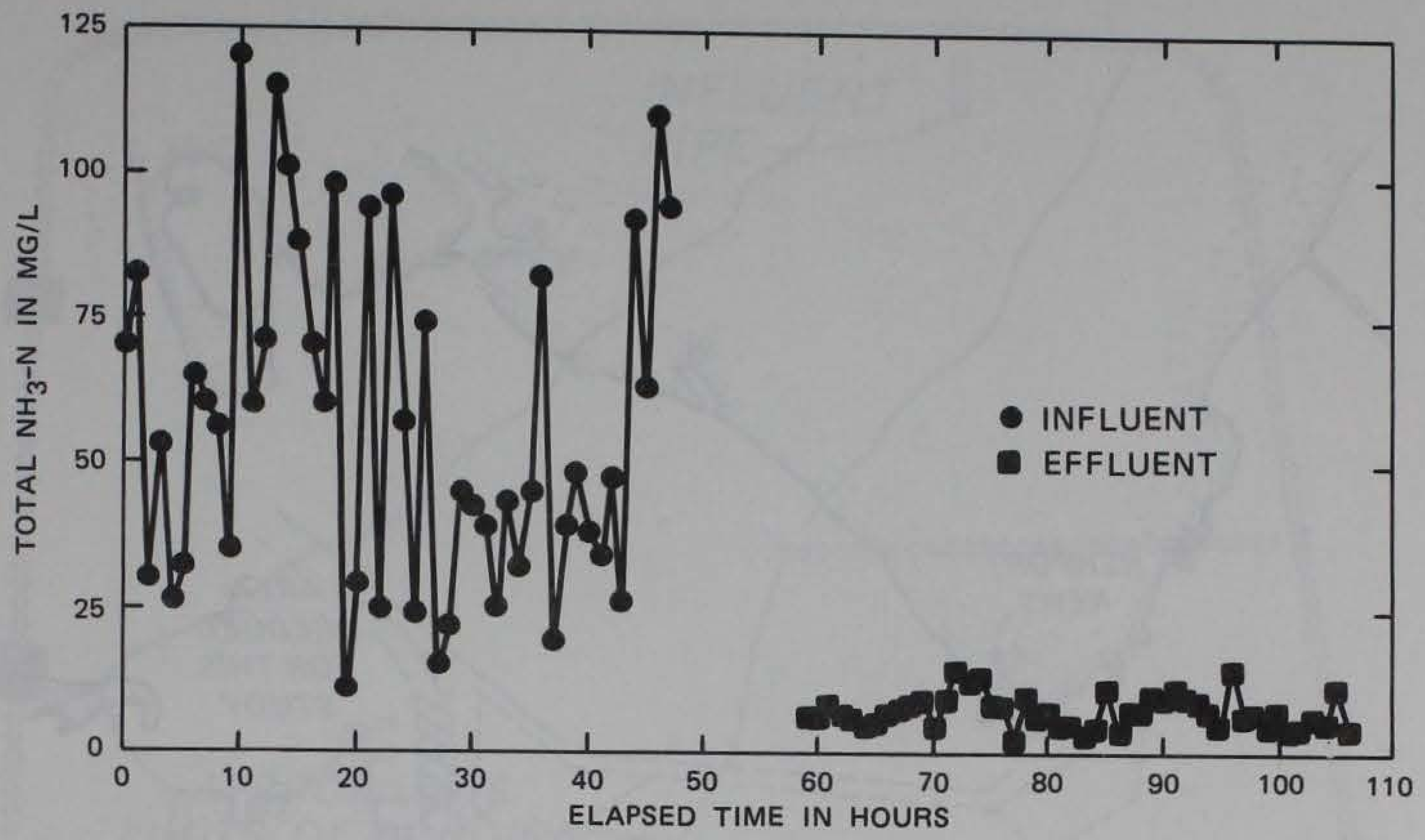


Figure 13. Influent and effluent total ammonia nitrogen concentrations, Savannah Harbor field evaluation

Dredging and disposal operations

74. Dredging was conducted in the Norfolk Harbor channel during the period November 1982 to May 1983. Over 2 million cubic yards was placed in the Craney Island disposal area during this disposal operation, using a 16-in. hydraulic pipeline dredge. The field evaluation at Craney Island for this study was conducted on 13-16 February 1983. Field estimates of the influent rate were approximately 16 cfs, determined by observation of the pipe influent to the disposal area. The approximate ponding limits within the disposal area during the sampling period are shown in Figure 15. An estimated 600 acres was ponded. Depth of ponding at the weirs along the west dike was estimated to be approximately 2 to 3 ft; average ponding depth was estimated to be approximately 1 to 2 ft.

75. During influent sampling and the initial effluent sampling, a storm occurred at the site. Gale force winds were recorded, and significant wave action was observed within the disposal area pond. This resulted in significant resuspension of settled material. The storm also caused sample scheduling problems and dredging problems, resulting in a lower number of influent and effluent samples being taken than was anticipated.

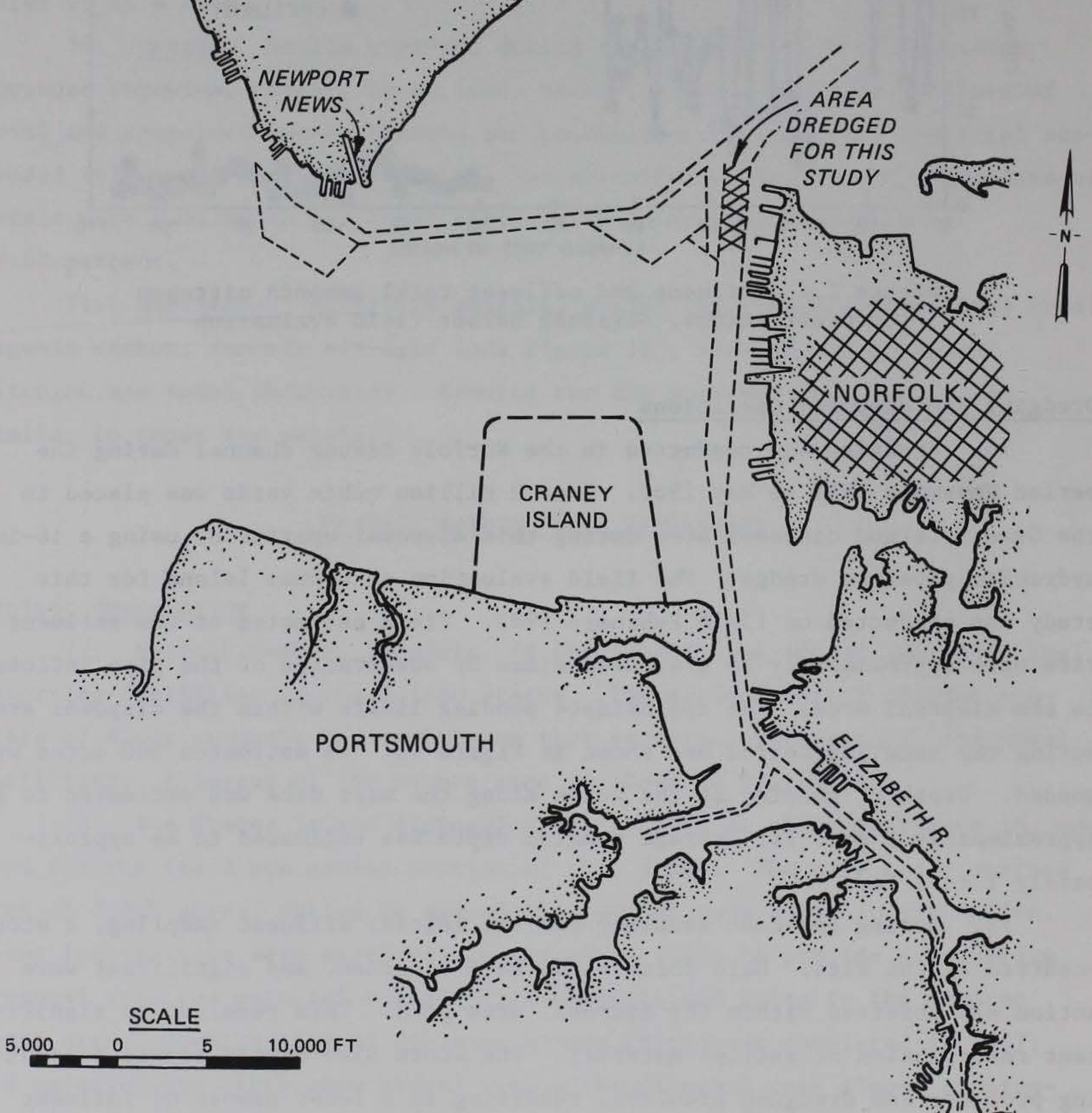


Figure 14. Norfolk Harbor, Virginia, showing location of channels, areas dredged, and Craney Island disposal area

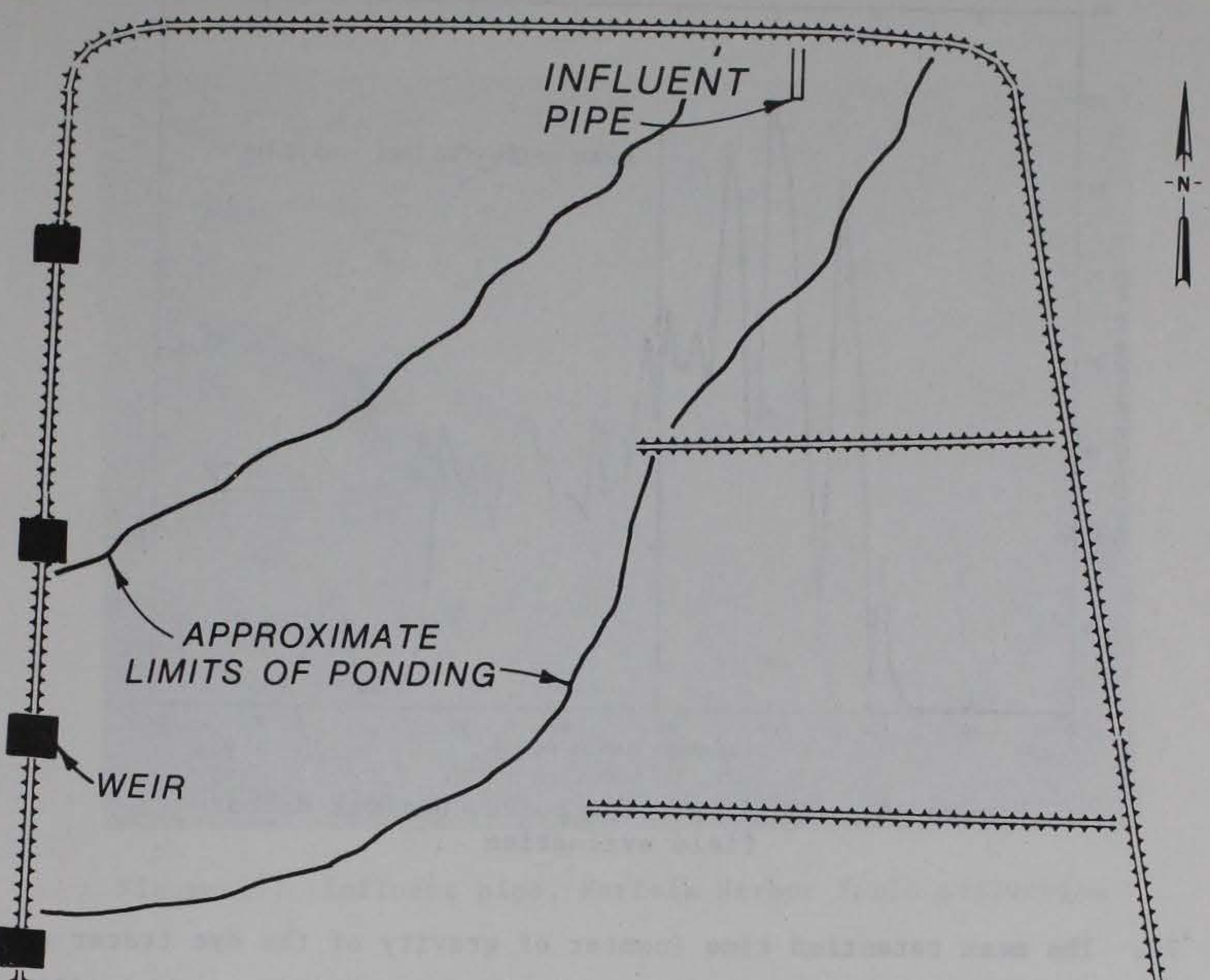


Figure 15. Plan of Craney Island disposal area, Norfolk Harbor field evaluation

Dye tracer study

76. A dye tracer study was conducted at the Craney Island site prior to initiating the influent and effluent sampling. Approximately 75 lb of 20-percent rodamine WT dye was injected at the dredge pipe influent. Concentration of dye in the effluent was monitored using a Turner Model 10 fluorometer. The resulting dye tracer curve is shown in Figure 16.

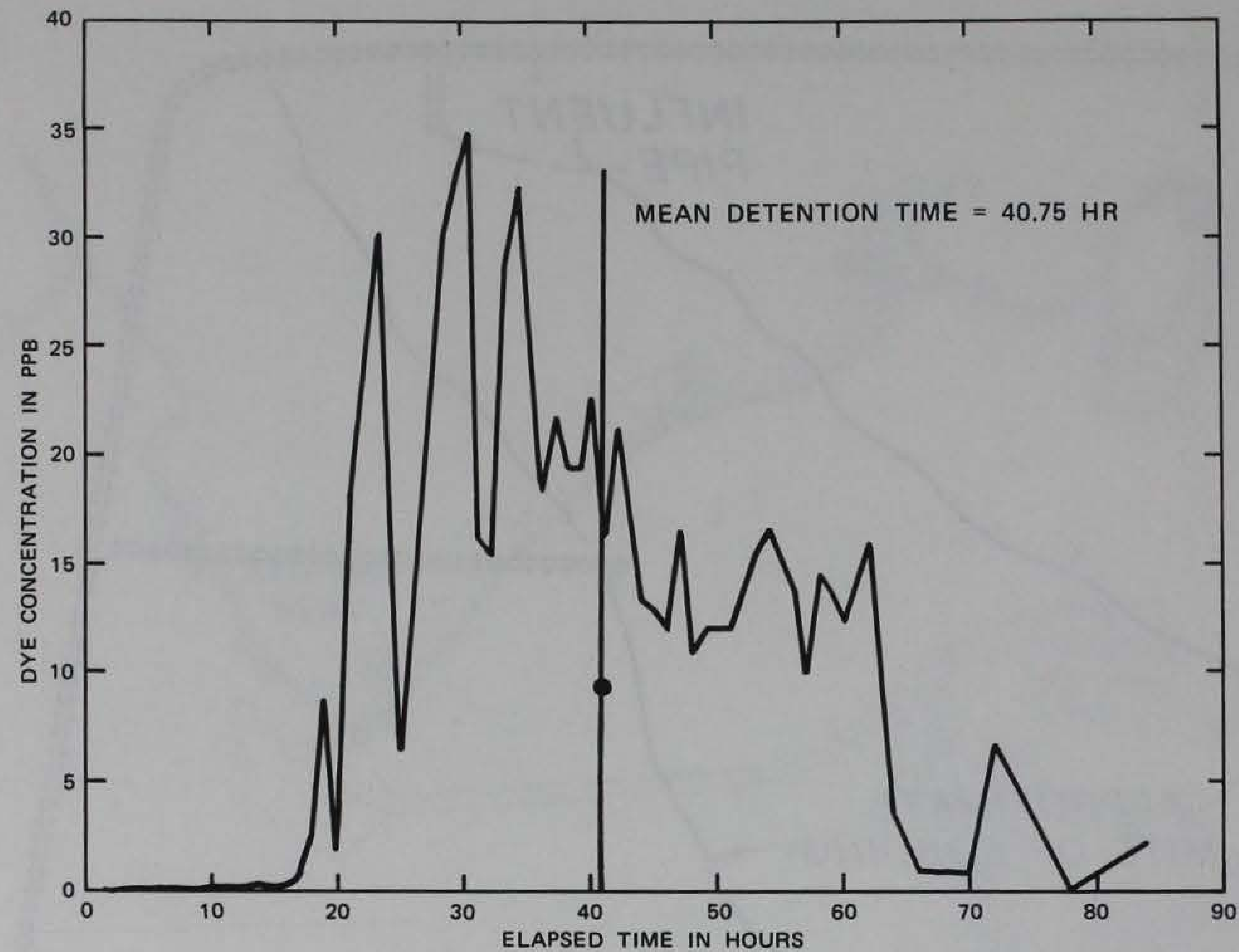


Figure 16. Dye dispersion curve, Norfolk Harbor field evaluation

77. The mean retention time (center of gravity of the dye tracer curve) was 41 hr. However, the lag time between initiation of influent and effluent sampling was limited to 24 hr, mainly because of weather conditions and a shortage of material remaining to be dredged.

Sediment sampling and testing

78. Samples of dredging site sediment and water for use in the laboratory tests described in Part II were collected from the Norfolk Harbor 45-ft channel during February 1983 at the location shown in Figure 14. Sediment samples were taken with a grab sampler immediately in front of the operating dredge at the time of the field evaluation at the Craney Island disposal area. This ensured that the sample of sediment taken would be as representative as possible of material sampled at the disposal site. Water samples were taken at the sediment-water interface with a positive displacement pump.

Influent/effluent sampling

79. Influent samples were taken directly from the dredge pipe discharging into the containment area. The location of the influent pipe is shown in Figure 15, and a photograph is provided as Figure 17. Only six samples could

Figure 17. Influent pipe, Norfolk Harbor field evaluation

be taken within a 19-hr period, because of dredge breakdowns, bad weather conditions, and a shortage of material remaining in the shoal being dredged. An additional six influent samples were taken for determination of solids content only.

80. Effluent samples were taken at the weir overflow, located as shown in Figure 15. A photograph of the weir is given as Figure 18. A total of 18 effluent samples were taken within a 52-hr period.

81. Samples were taken directly in prepared containers and were immediately transported to the laboratory for processing and analysis. The DO, pH, and conductivity of each sample were determined in the field using instruments.

Chemical analysis

82. The influent and effluent samples were analyzed for suspended solids, total organic carbon, ammonia nitrogen, total phosphorus, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, zinc, and polynuclear aromatic hydrocarbons (PAHs). Both the dissolved and total

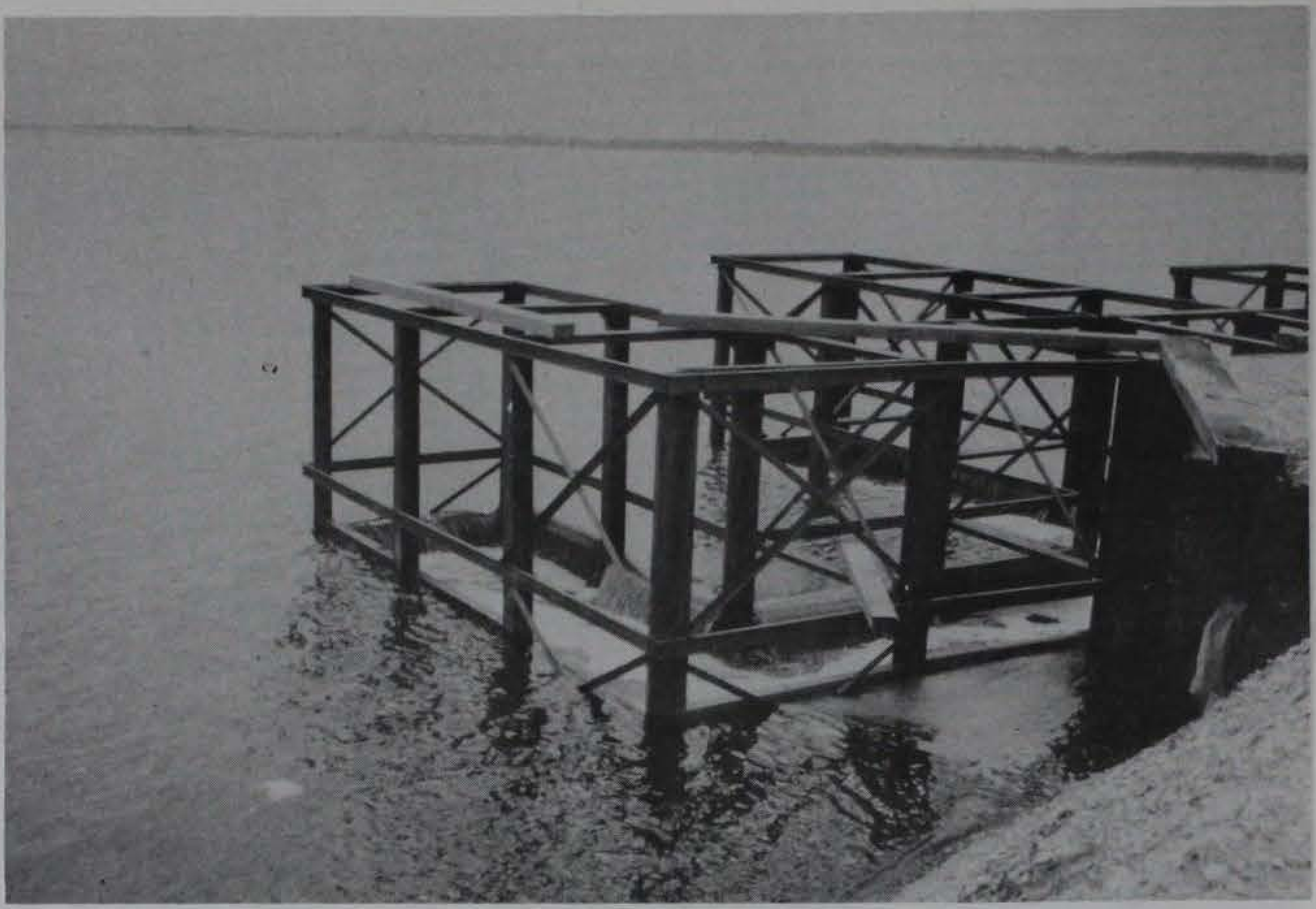


Figure 18. Polygonal weir, Norfolk Harbor field evaluation

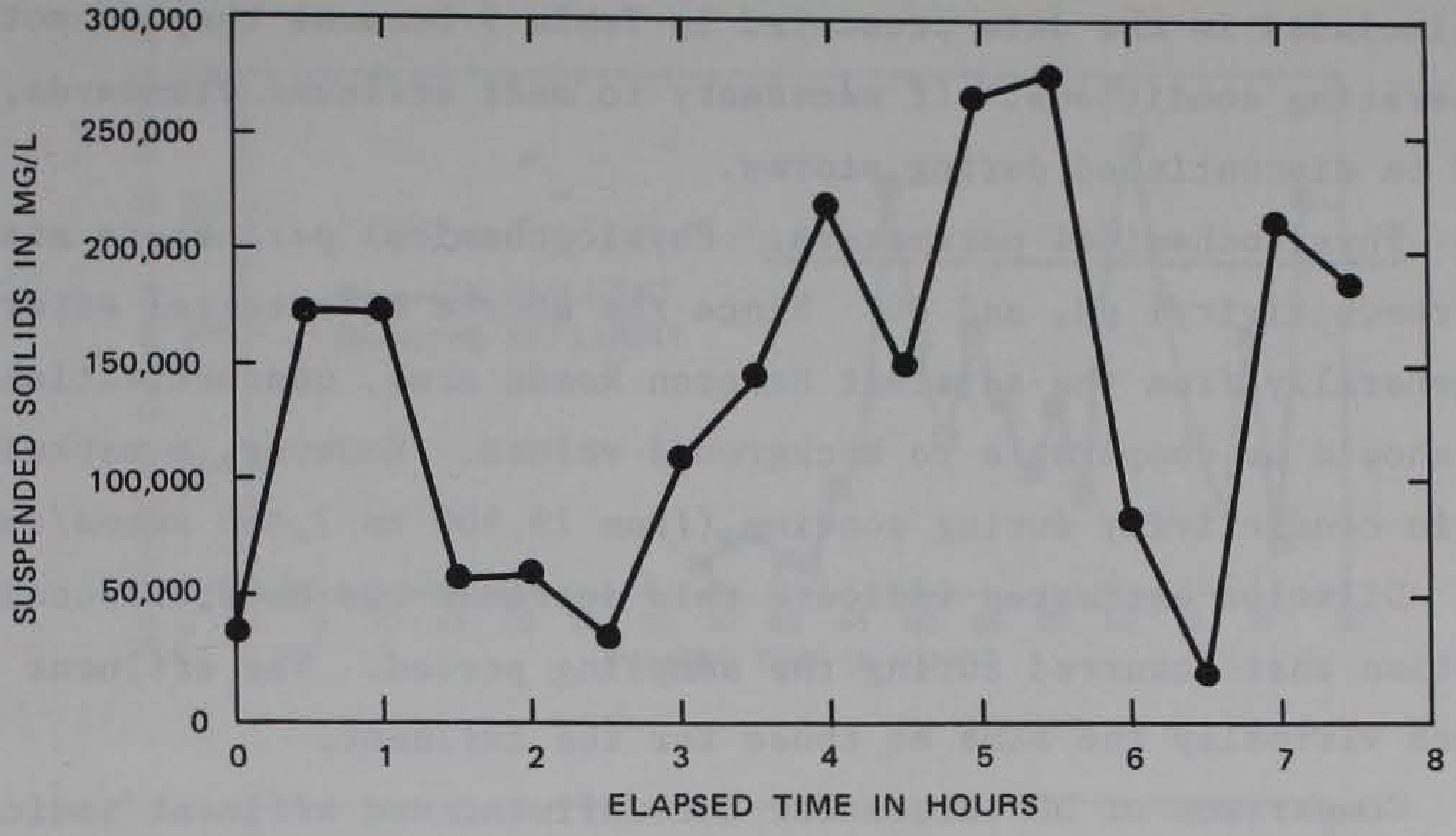
concentrations of nutrients and metals were determined, using a 0.45-μ filter for obtaining a dissolved subsample. Sampling and chemical analyses were conducted by James R. Reed and Associates (1983) under contract to the USAED, Norfolk.

Results

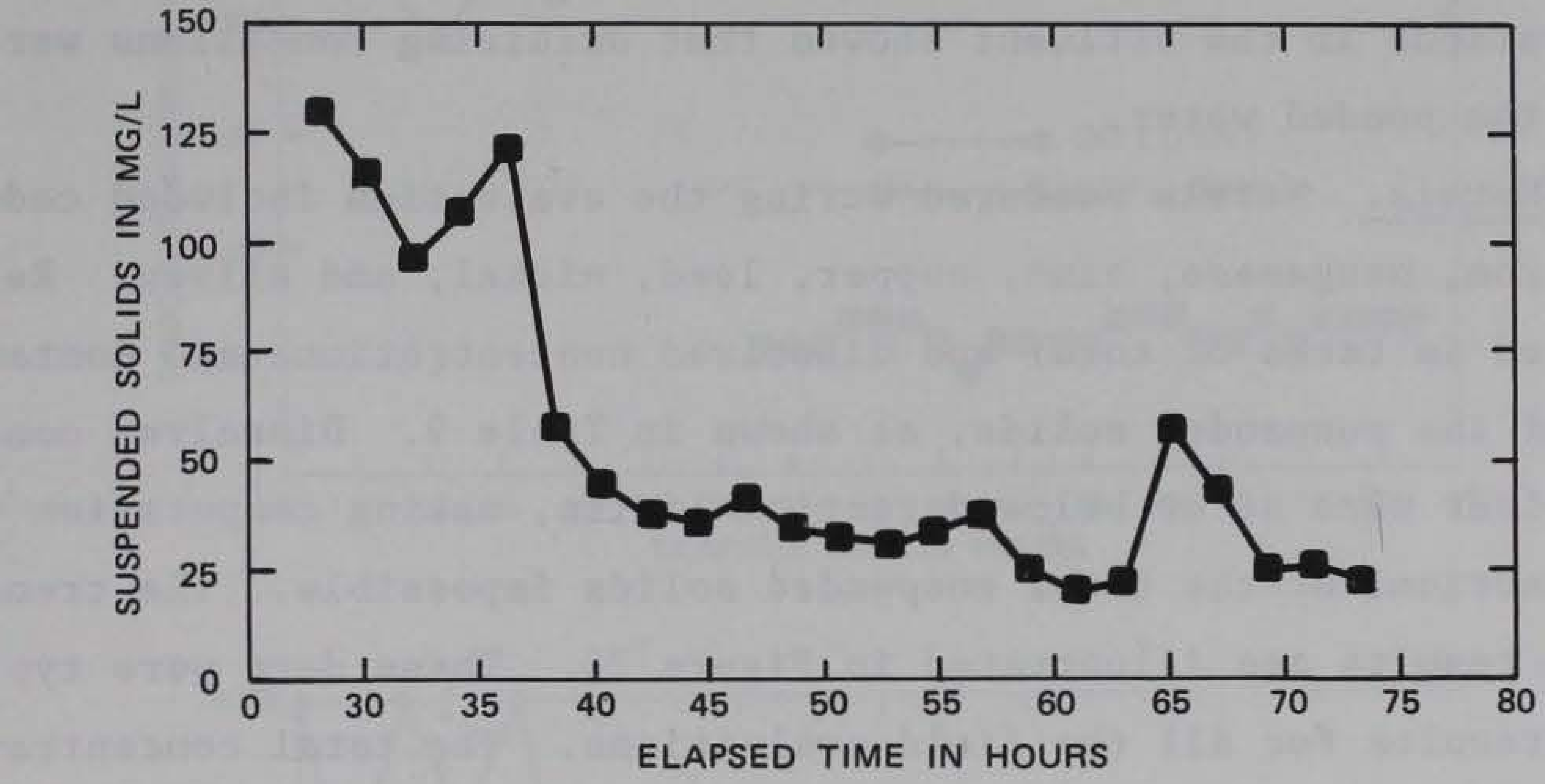
83. The means, standard deviations, and ranges for all parameters, including the dissolved and total (where appropriate) concentrations and the contaminant fractions of the total suspended solids, are summarized in Table 9. Data plots are shown in Appendix B.

84. Suspended solids. Plots of the influent and effluent suspended solids concentrations are shown in Figure 19. The mean concentration of solids in the influent was 122 g/ℓ, while the mean concentration of suspended solids in the effluent was 35 mg/ℓ (Table 9). The Craney Island site therefore had a solids retention efficiency of approximately 99.96 percent. This high solids retention efficiency shows that the site was well operated and managed and acts as a very effective settling basin. This is due primarily to the large surface area ponded during active disposal operations.

85. The relatively high values shown in Figure 19 for effluent suspended solids measured at elapsed times of approximately 30 to 41 hr reflect the resuspension in the pond due to the storm previously described. Following



a. Influent



b. Effluent

Figure 19. Suspended solids concentrations, Norfolk Harbor field evaluation

the storm, the resuspended material once again settled, and effluent suspended solids concentrations reflected a more normal condition, averaging 35 mg/ℓ. The concentrations of contaminants in these samples also reflected the increased suspended solids concentration and rainfall dilution effects during this period of sampling. Dissolved concentrations of contaminants were typically lower, as were contaminant fractions of the suspended solids (see plots for cadmium in Figure 20). The parameters measured in these initial samples were not included in the data presented in Table 9 because they do not reflect normal operating conditions. If necessary to meet effluent standards, dredging could be discontinued during storms.

86. Physicochemical parameters. Physicochemical parameters measured included conductivity, pH, and DO. Since the source of material entering the site is generally from the adjacent Hampton Roads area, conductivities of the influent should be comparable to background values. However, a marked decrease in conductivity during ponding (from 19,900 to 7,430 μmhos/cm) was observed. Dilution estimates indicate this decrease can be attributed to the precipitation that occurred during the sampling period. The effluent pH values were virtually the same as those for the influent.

87. Comparison of DO values for the influent and effluent indicates a dramatic rise in DO levels during retention in the pond. Mean influent DO was 2.98 mg/ℓ, while mean effluent DO was 11.42 mg/ℓ (near saturation). The high DO concentrations in the effluent showed that oxidizing conditions were present in the ponded water.

88. Metals. Metals measured during the evaluation included cadmium, chromium, iron, manganese, zinc, copper, lead, nickel, and silver. Results are expressed in terms of total and dissolved concentrations and contaminant fractions of the suspended solids, as shown in Table 9. Dissolved concentrations of silver were at or below detection limits, making computation of contaminant fractions of the total suspended solids impossible. The trends for the cadmium results are illustrated in Figure 20. These data were typical of the metals results for all the field evaluations. The total concentration of all metals showed dramatic reductions in effluent concentrations as compared to influent concentrations, indicating a high retention of metals within the disposal area. This would be expected, because trace metals are strongly associated with suspended particles, and excellent retention of particles was achieved by effective sedimentation performance in the Craney Island disposal area. The retention factors for total metals averaged 96.84 percent.

89. Nutrients. Nutrients measured during the evaluation included total organic carbon, ammonia nitrogen, and total phosphorus. Results for the nutrients were generally similar to those for metals. A high retention of total concentrations and a large increase in the nutrient fractions of suspended solids due to confinement were observed.

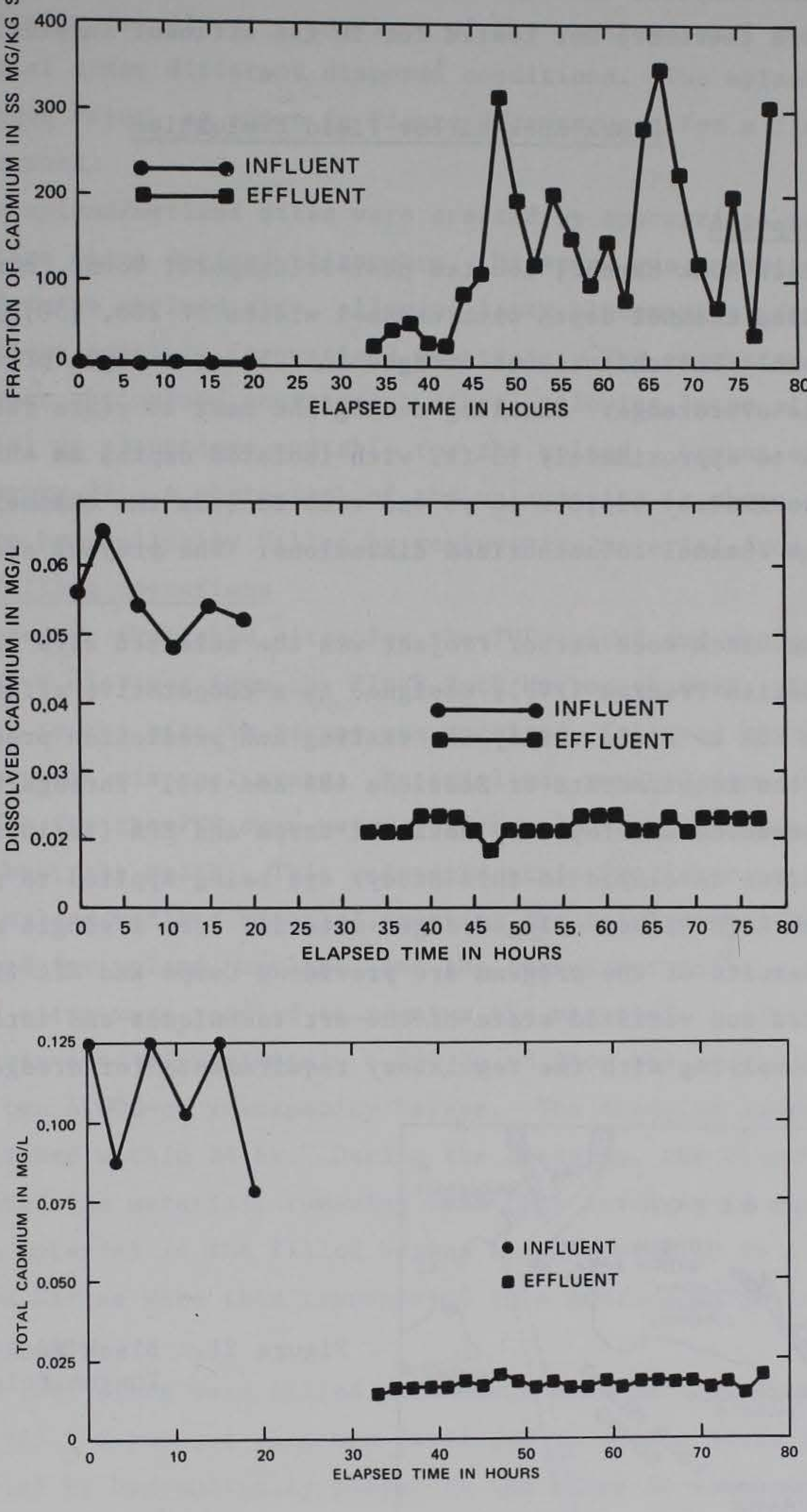


Figure 20. Influent and effluent cadmium concentrations, Norfolk Harbor field evaluation

90. Organics. Concentrations of several forms of PAHs were tested for in the influent samples, and all were found to be below detection limits. The parameters were therefore not tested for in the effluent samples.

Black Rock Harbor Field Evaluation

Project description

91. Black Rock Harbor, located near Bridgeport, Conn., consists of an 18-ft authorized channel depth with channel widths of 200, 150, and 100 ft, moving upstream. The channel was dredged in 1955 to a depth of 18.0 ft, with 1 ft allowable overdredge. Shoaling during the next 28 years reduced the channel depth to approximately 13 ft, with isolated depths as shallow as 9.0 ft. Approximately 425,000 cu yd was removed from the channel in late 1983 to restore the channel to authorized dimensions. The project area is shown in Figure 21.

92. The Black Rock Harbor Project was the selected site for the Corps Field Verification Program (FVP), designed as a cooperative effort between the Corps and the EPA to field verify the testing and prediction procedures for implementing the requirements of Sections 404 and 103. Through the FVP, promising procedures developed by both the Corps and EPA (including the predictive technique developed in this study) are being applied to project conditions at Black Rock Harbor using dredged material from a single maintenance operation. Results of the program are providing Corps and EPA field elements with documented and verified state-of-the-art techniques and interpretive procedures for complying with the regulatory requirements for dredged material

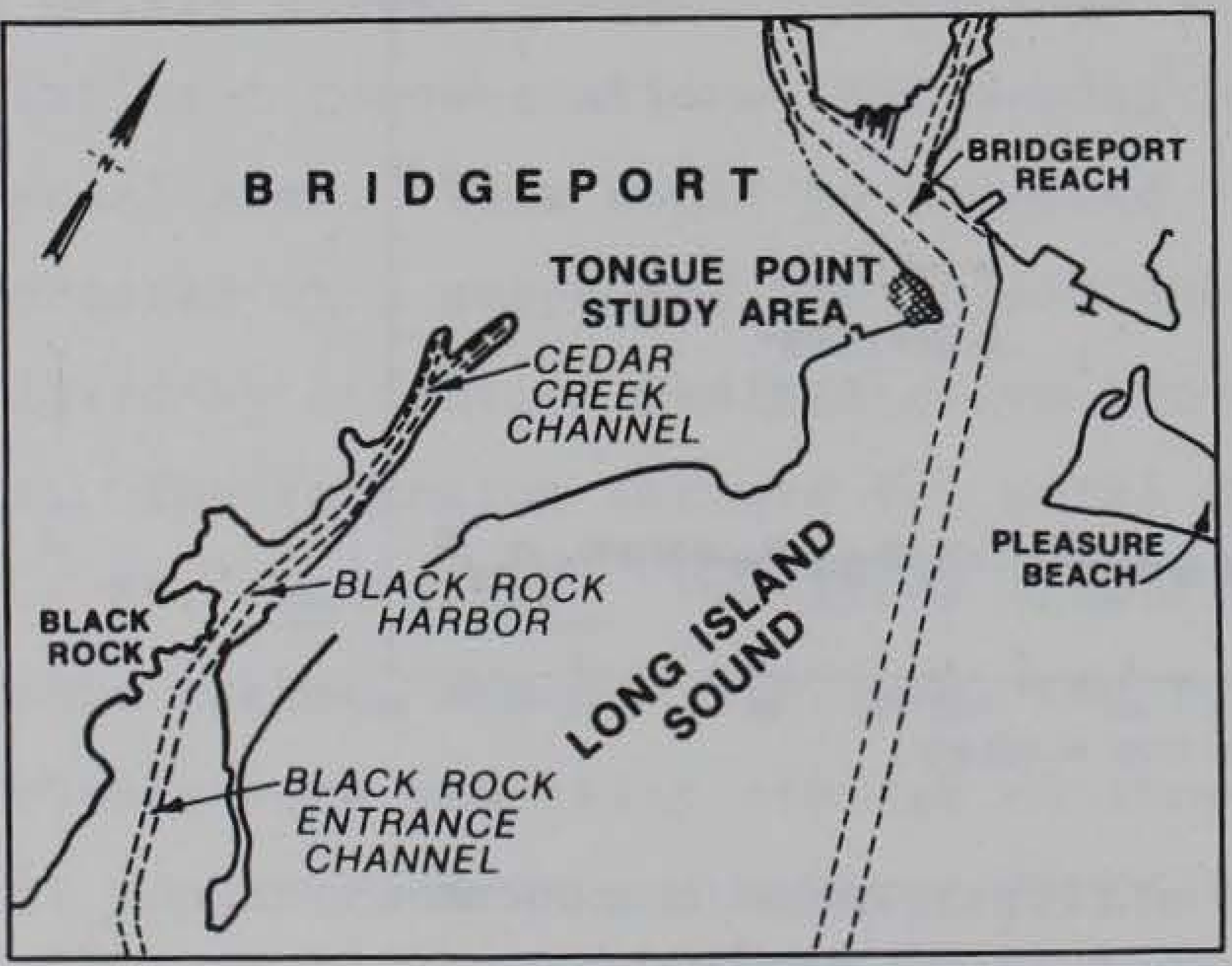


Figure 21. Black Rock Harbor and Tongue Point study area

evaluations. The dredged material was placed in both an aquatic site and a confined disposal site under wetland and upland conditions, thus providing an unusual opportunity for direct comparison of the environmental consequences of the same material under different disposal conditions. The upland site located at Tongue Point, as shown in Figure 21, was used for a field evaluation in this report.

93. The upland/wetland sites were created by appropriate grading and dike construction along desired alignments. Material was excavated from the area planned for the wetland site, allowing later placement of dredged material at elevations suitable for wetland substrate. The excavated material was used to construct the upland containment dikes, allowing later placement of dredged material at elevations suitable for the upland. Layout of the sites is shown in Figure 22. A photograph of the upland site is shown as Figure 23. Both sites were hydraulically filled by reslurrying material from scows.

Dredging and filling operations

94. Since the available sites for the FVP upland and wetland studies were located at a distance from the Black Rock Harbor channel, transportation of the material to the site in barges was required, followed by reslurrying and pumping into the disposal areas. Material was removed from the channel by clamshell dredge for the FVP open-water studies, leaving undredged a strip of channel throughout the reach. This undredged strip was later used for acquiring the upland/wetland material, meeting the requirement that the same sediment be used for upland, wetland, and the open-water sites. As the upland/wetland sites were readied to receive the material, a 13-cu yd clamshell dredge excavated approximately 6,000 cu yd from the reach and placed the material into two 4,000-cu yd-capacity barges. The dredging operation was easily accomplished within 24 hr. During the dredging, the clamshell bucket easily penetrated the material, removing full cuts at their in situ density. Therefore, the material in the filled barges was essentially in its in-channel condition. The barges were then transported to a mooring barge located adjacent to the site.

95. The test sites were filled with Black Rock Harbor sediments during late October 1983. A pumpout plan was developed to meet a study requirement that the material be hydraulically placed in the sites in a manner typical of confined dredged material disposal. During initial pumping, several intakes and equipment combinations were tried. A pump combination consisting of a

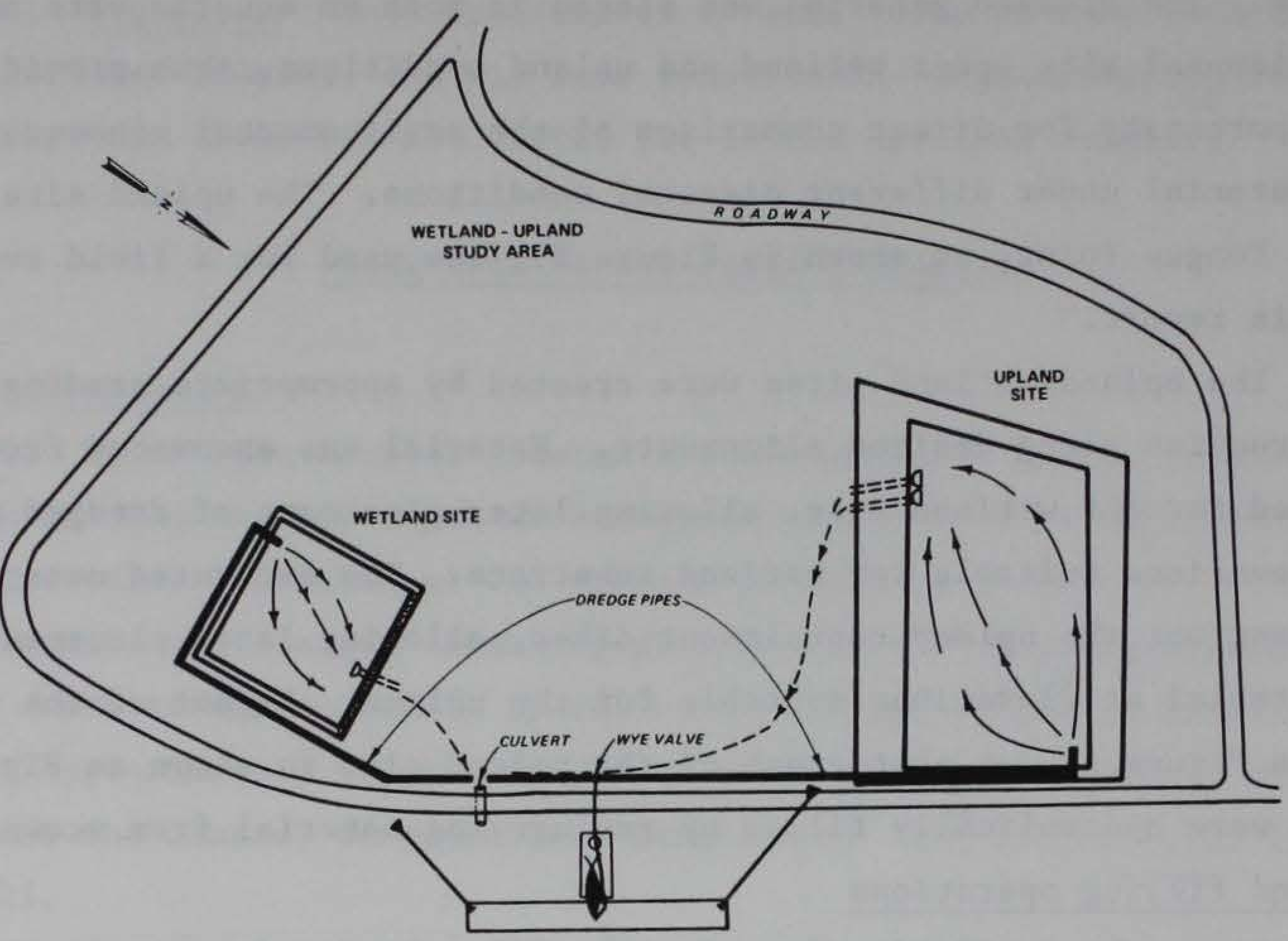


Figure 22. FVP upland/wetland containment areas located at Tongue Point

Figure 23. The FVP upland site, Black Rock Harbor

6-in. submersible pump, a 6-in. booster pump, and an attached 3-in. jet pump for adding slurry water was finally selected. Another 4-in. pump was used for additional slurry water as necessary. Slurry water was pumped from the Bridgeport Harbor channel directly adjacent to the moored barge. A crane was used to manipulate the intake within the barges. A 6-in. dredge pipe, equipped with a wye-valve, split the dredged material inflow between the upland and wetland site. During filling, the flow was proportioned between the sites according to their respective surface areas and depths of filling. This ensured that essentially the same dredged material was placed in both sites.

Dye tracer study

96. Dye tracer tests were used to establish the actual retention time of the pond. Measurements of the ponded depth were taken from a small boat to establish the total volume of the pond and the required dye volume prior to injecting the dye tracer. Rodamine WT dye was used for the tracer tests, in a manner similar to that previously described. The measured mean field retention time during the water quality sampling was approximately 8 hr, but the modal value was only about 15 min. The retention time distribution curve is shown in Figure 24.

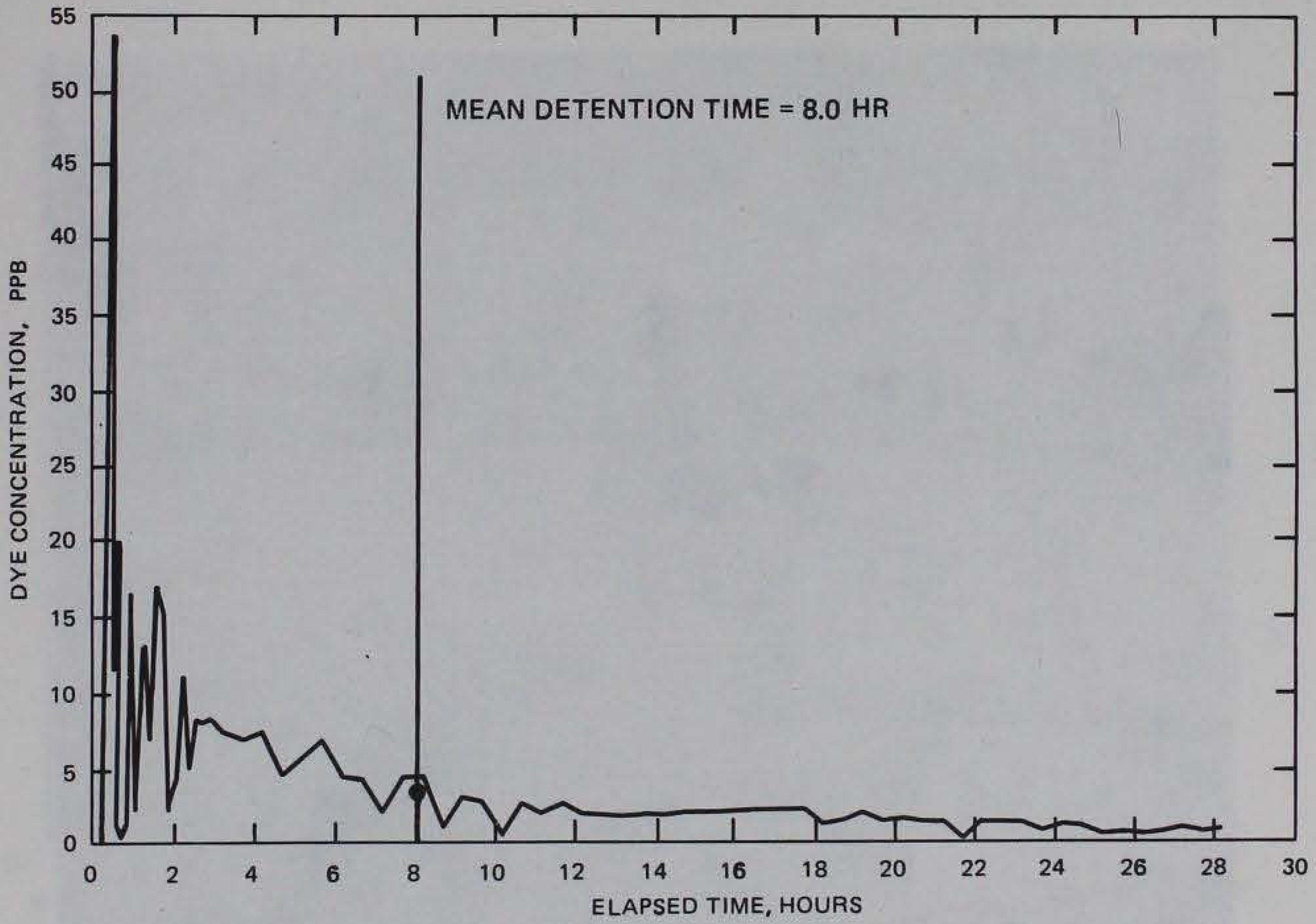


Figure 24. Dye tracer curve for FVP upland site, Black Rock Harbor

Sediment sampling and testing

97. Samples of the Black Rock Harbor sediments were taken from a single 4,000-cu yd bargeload of material used to fill the upland and wetland sites. This single barge had been filled by a clamshell dredge from a narrow strip along the entire length of the Black Rock Harbor channel used for the FVP study. The samples were taken with a grab sampler during November 1983. Water samples were taken from the Bridgeport Harbor channel adjacent to the barge mooring at the FVP site. The samples were taken at the sediment-water interface using a positive displacement pump. Water from this location was used for the slurrying and hydraulic off-loading of the dredged material from the barge.

Influent/effluent sampling

98. Influent/effluent sampling was conducted during a 24-hr period. Sampling intervals for influent and effluent were determined based on both operational and financial constraints. Influent samples were taken directly from the pipe discharging into the disposal area. The flow was allowed to directly fill prepared sample containers. A photograph of the influent sampling point is shown as Figure 25. A total of 23 influent samples were taken on an approximately hourly basis during the 24-hr water quality sampling period.

Figure 25. Influent pipe, Black Rock Harbor field evaluation

99. Effluent samples were taken at the overflow weir, which consisted of a 6-ft drop inlet, as shown in Figure 26. The effluent samples were taken directly by allowing the weir overflow to fill prepared sample containers. A total of 48 effluent samples were taken approximately every half-hour during the 24-hr water quality sampling period.

100. The influent and effluent samples were immediately transported to the laboratory for processing and analysis. The DO, pH, and conductivity for each sample were determined in the field using instruments.

Chemical analysis

101. The influent and effluent samples were analyzed for total organic carbon, ammonia and nitrate nitrogen, total phosphorus, arsenic, cadmium, chromium, copper, iron, lead, mercury, manganese, nickel, zinc, and total PCBs. Both the dissolved and total concentrations of contaminants were obtained, using a 0.45-μ filter or centrifugation for obtaining the dissolved subsample. Chemical analyses were conducted by the WES Analytical Laboratory.

Results

102. The means, standard deviations, and ranges for all parameters, including the dissolved and total (where appropriate) concentrations and the

Figure 26. Drop inlet weir structure, Black Rock Harbor field evaluation

calculated fraction of the total suspended solids, are summarized in Table 10. Data plots are shown in Appendix B.

103. Suspended solids. The mean concentration of solids in the influent was approximately 61 g/ℓ, while the mean concentration of suspended solids in the effluent was approximately 173 mg/ℓ, as shown in Table 10. The site therefore had a solids retention efficiency of approximately 99.7 percent. This high solids retention efficiency shows that the site, though small, was well operated and acted as an effective settling basin.

104. Physicochemical parameters. Physicochemical parameters measured included conductivity, pH, and DO. Conductivity and pH were relatively unchanged. Comparison of DO values in the influent and effluent indicates a dramatic rise in DO levels during retention in the pond, as shown in Figure 27. Mean influent DO was 0.63 mg/ℓ, while mean effluent DO was 5.57 mg/ℓ during the same period. This rise is due to turbulence and mixing of the influent with air and aerated ponded waters. Wind action can also aid in increasing DO levels in the ponded water. The high effluent DO concentrations showed that oxidizing conditions were present in the ponded water.

105. Metals. Metals measured in the field samples included arsenic, cadmium, chromium, copper, iron, lead, mercury, manganese, nickel, and zinc.

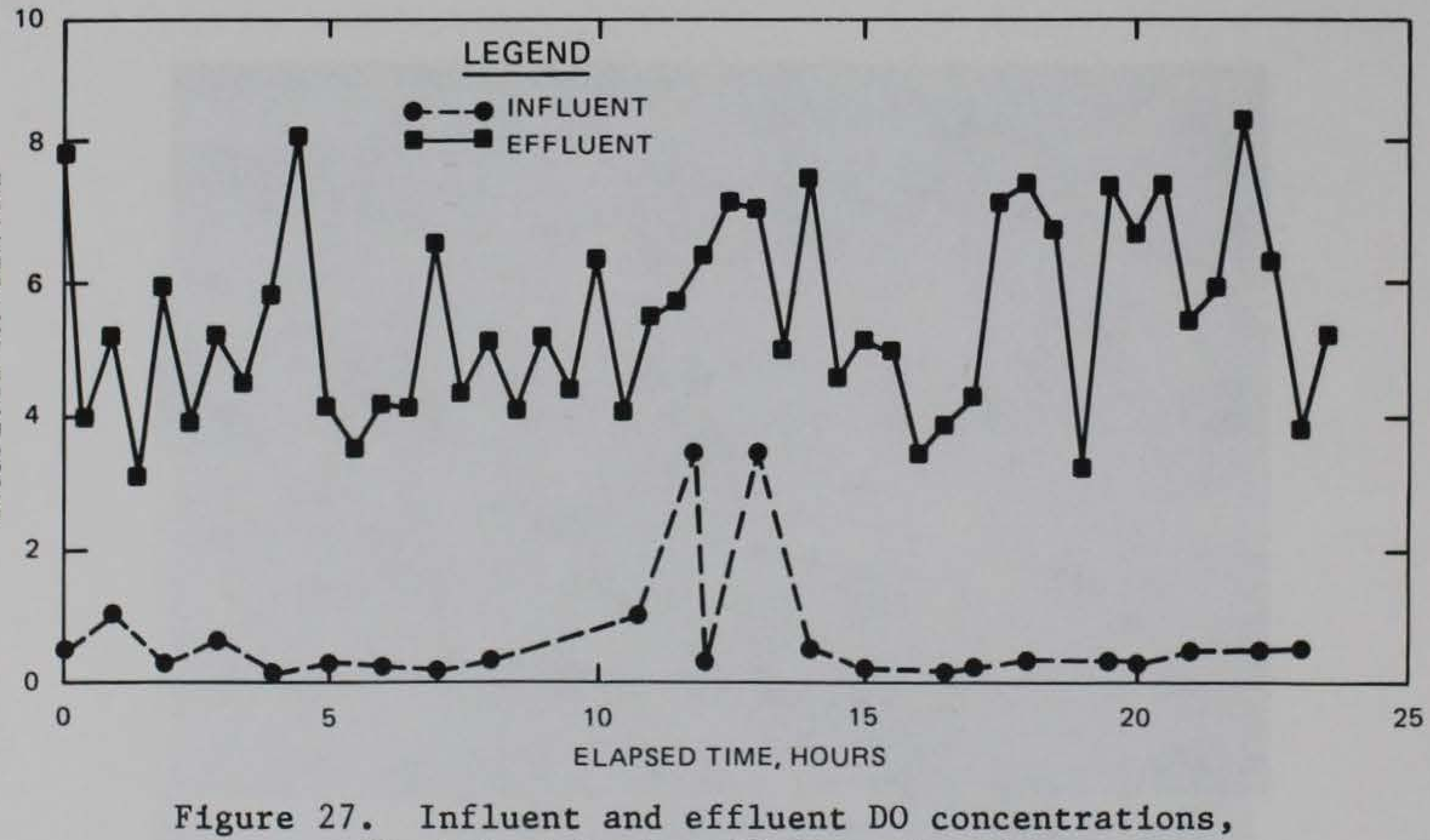


Figure 27. Influent and effluent DO concentrations, Black Rock Harbor field evaluation

Dissolved concentrations of mercury, arsenic, and zinc were at or below detection limits. The trends for the copper results are shown graphically in Figure 28. These data are typical of the metals results.

106. The total concentration of all metals showed dramatic reductions for effluent as compared to influent, indicating a high retention of metals within the disposal area. The average retention of total metals was 98.3 percent. This would be expected, since trace metals are strongly associated with suspended particles, and excellent retention of particles was achieved by effective sedimentation performance in the disposal area. This behavior is typical of most confined disposal sites.

107. Nutrients. Nutrients measured during the evaluation included total organic carbon, ammonia nitrogen, nitrate nitrogen, and total phosphorus. Results for total phosphorous and total organic carbon were generally similar to those for metals. Ammonia nitrogen and nitrate nitrogen reflected little retention due to ponding and sedimentation, since these parameters remained largely in the dissolved form.

108. PCBs. The results for PCBs (polychlorinated biphenyls) were similar to those for the metals. Total PCB concentrations showed a large net reduction in the effluent as compared to the influent, with a calculated retention in excess of 99 percent. This behavior was expected, since organic contaminants such as PCB normally have a high affinity for suspended particles.

Hart Miller Island Field Evaluation

Project description

109. Hart Miller Island is a 900-acre confined disposal facility located near Baltimore, Md. (Figure 29). The facility was constructed by the State of Maryland to contain dredged material from the inner portions of the Baltimore Harbor channels. Due to the distance from the dredging areas, the materials must be transported to the site by barge. Special hydraulic off-loading equipment was available to reslurry the material from the barges and pump the material into the facility.

110. The facility has been constructed in a two-cell configuration, with the cells separated by a cross dike, as shown in Figure 30. Two fixed-elevation weirs are located in the cross dike to pass flow from the smaller

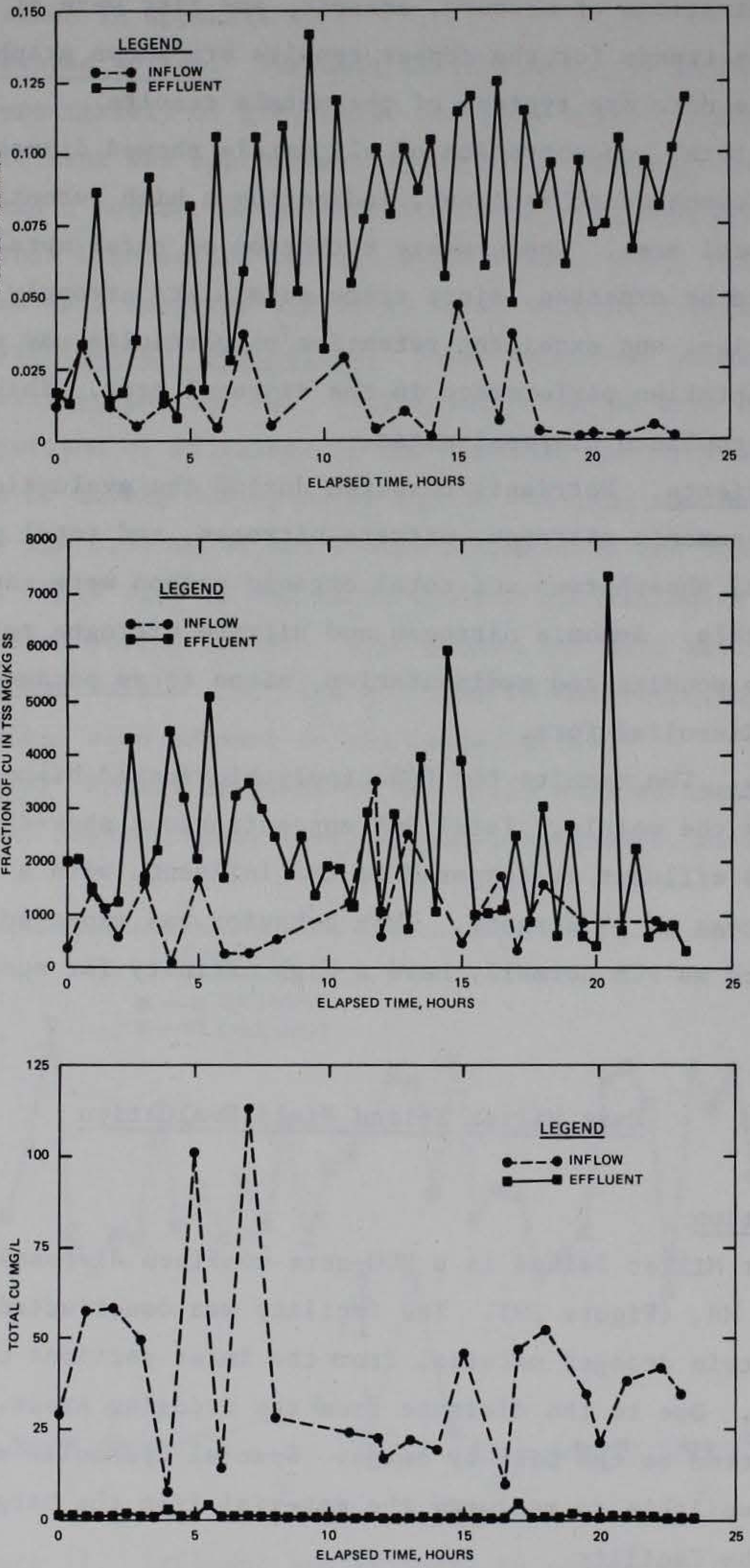


Figure 28. Influent and effluent copper concentrations, Black Rock Harbor field evaluation

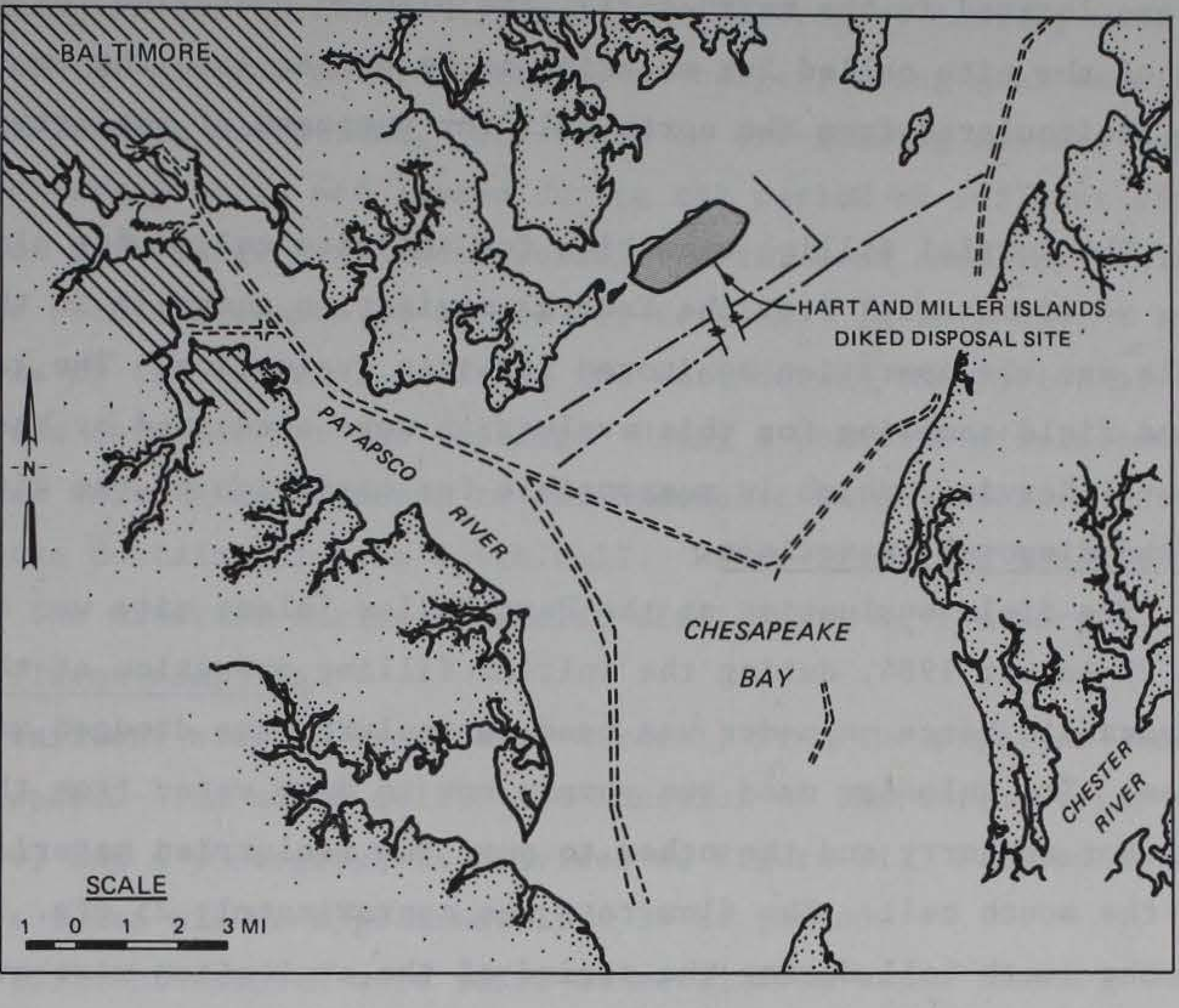


Figure 29. Hart Miller Island study area

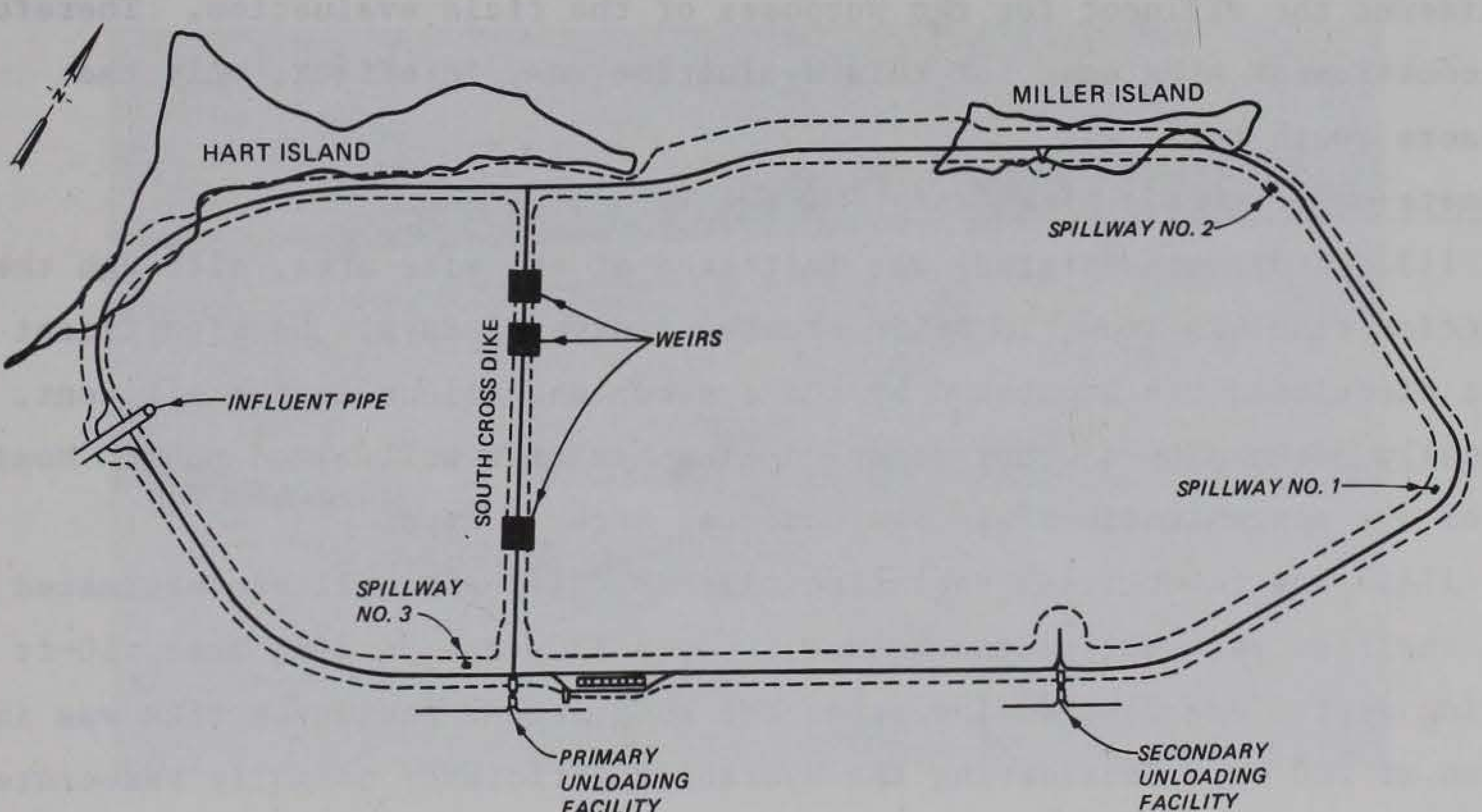


Figure 30. Hart Miller Island containment area

330-acre south cell to the larger north cell. Weirs to discharge water from the site are located in the north cell. The planned operation for the initial operation of the site called for material to be pumped into the south cell. Water was recirculated from the north cell for purposes of reslurrying the material.

111. The initial filling operation for the site called for placing 400,000 cu yd of material from the Federal navigation channels in the south cell. This was the operation monitored for this evaluation. The laboratory testing and field sampling for this evaluation were conducted by Maryland Environmental Service, which is responsible for operation of the site.

Dredging and disposal operations

112. The field evaluation at the Hart Miller Island site was conducted on 21 and 22 August 1984, during the initial filling operation at the site. A special hydraulic barge unloader was used to reslurry the dredged material from barges. The unloader used two pumps, one to draw water from the larger north cell for reslurry and the other to pump the reslurried material from the barges to the south cell. The flow rate was approximately 25 cfs. Ponding depths in the south cell during the period of the evaluation were over 10 ft, and the entire surface area of the site was ponded. Water flowed through the fixed weirs located in the cross dike and into the north cell, and no water was discharged from the north cell. Water flow through the fixed weirs was considered the effluent for the purposes of the field evaluation. Therefore, the containment area used for this evaluation was, in effect, only the 330-acre south cell.

Estimate of retention time

113. A dye tracer study was initiated at the site area, although the retention time was known to be in excess of several days. No significant short circuiting was indicated by the dye concentrations in the effluent, only gradually decreasing concentrations indicative of a well-mixed pond. Monitoring of dye concentrations was discontinued after 5 days.

114. The theoretical retention time in the south cell was estimated from the flow rate and ponded volume. For a 330-acre ponding area, 10-ft ponding depth, and 25-cfs flow rate, the theoretical residence time was in excess of 200 hr. Considering the hydraulic efficiency normally associated with confined disposal areas, the estimated field mean residence time was in excess of 80 hr.

Sediment sampling and testing

115. Samples for the Hart Miller Island laboratory testing were taken directly from the dredged material transport barges, using grab samplers, prior to off-loading operations. The rates of off-loading allowed for approximately five barges to be off-loaded during the period of influent sampling. Sampling from each barge off-loaded during the influent sampling period was conducted to obtain a composite sample for testing. In this way, a representative sample of the material entering the site during the period of the field evaluation was obtained for the testing. Using a positive displacement pump, water samples were taken adjacent to the hydraulic barge unloader intake located in the containment area south cell. Water from this location was used to reslurry the material during hydraulic off-loading of the barges.

Influent/effluent sampling

116. Influent samples were taken directly from the pipeline leading into the disposal area south cell. The location of the influent pipe is shown in Figure 30, and a photograph is provided as Figure 31. Fifteen influent samples were taken within approximately a 36-hr period.

117. Effluent samples were taken directly from water flowing through the southernmost fixed weir in the cross dikes, located as shown in Figure 30. A photograph of the weir is shown as Figure 32. Twenty-five effluent samples were taken on an hourly basis during the evaluation.

Figure 31. Influent pipe, Hart Miller Island field evaluation

Figure 32. Fixed-elevation weir in cross dike, Hart Miller Island field evaluation

118. Samples were taken directly in prepared containers and transported immediately to a laboratory facility located onsite. No physicochemical parameters were measured.

Chemical analysis

119. The influent and effluent samples were analyzed for suspended solids, silver, arsenic, barium, cadmium, chromium, copper, iron, mercury, lead, and selenium. Both dissolved and total concentrations of the metals were determined using a 0.45-μ filter for obtaining a dissolved subsample. The sampling and chemical analyses were conducted by Maryland Environmental Service using onsite personnel and laboratory facilities.

Results

120. Analyses included both the dissolved and total concentrations of contaminants. The contaminant fractions of the total suspended solids were determined as described previously. The means and standard deviations and calculated retention efficiencies are summarized in Table 11. Data plots are presented in Appendix B.

121. Suspended solids. The mean concentration of solids in the influent was 198 g/ℓ, while the mean concentration of suspended solids in the effluent was 25 mg/ℓ. The Hart Miller Island south cell therefore had a solids retention efficiency of approximately 99.99 percent, which was the

highest efficiency of any of the sites evaluated. This high efficiency was the result of the extremely long retention time for the cell.

122. Metals. The retentions of total concentrations of metals were similar to the other sites, with an average retention of 99.85 percent. This was due to the high retention of suspended solids. Both total and dissolved concentrations of silver and mercury and dissolved concentrations of arsenic were below detection in the effluent. The total and dissolved concentrations of cadmium were essentially equal. Therefore, fractions of cadmium in the total suspended solids were assumed to be equal to zero.

PART IV: COMPARISONS OF LABORATORY PREDICTIONS AND FIELD MEASUREMENTS

123. The effluent quality predictions based on laboratory tests were directly compared with the measured field data for purposes of verifying the accuracy of the overall predictive technique. Plots of the means and standard deviations of the modified elutriate laboratory test data for dissolved concentrations of contaminants and the contaminant fractions of the suspended solids are compared with the corresponding measured field values in Appendix B. Plots comparing the predicted total concentrations of contaminants (based on both the modified elutriate test and column settling laboratory test data) with the measured total concentrations are also shown in Appendix B. Ratios of predicted mean values to measured mean values are summarized in Tables 12 and 13.

Comparison of Modified Elutriate Predictions with Measured Field Data

124. The accuracy of the modified elutriate test as a predictor varies among the parameters analyzed. In most cases, the predicted values are within the standard deviations for measured field results. However, the data showed a high degree of variability. The predicted values are on the conservative side for most of the contaminant fractions of the suspended solids, i.e., the predicted fractions are higher than the measured field fractions. This can be explained by the fact that, under quiescent laboratory testing conditions, only the fine colloidal particles will remain in suspension. For the field results, turbulence and resuspension by wind currents can cause some coarser particles with relatively low levels of adsorbed contaminants to be discharged in the effluent. Since finer particles have a greater relative adsorption capacity for contaminants, it is reasonable to expect the modified elutriate test to predict a higher contaminant fraction of the total suspended solids than what will actually occur in many cases.

125. The predicted concentrations of most dissolved contaminants were lower than the measured field concentrations. This may be explained by the scavenging of dissolved contaminants in the laboratory test by the settling of particles which occurred more effectively under the quiescent laboratory condition.

126. The data summarized in Table 12 show that the modified elutriate laboratory test predictions were within a factor of 1.5 times the measured field value for 64 of 84 parameters measured for all sites. Accuracy within a factor of 1.5 compares favorably with similar comparisons of other predictive procedures, such as standard elutriate tests, with their associated field data.

Comparison of Laboratory-Predicted Total Concentrations with Measured Field Data

127. Ratios of mean laboratory-predicted values to mean measured field values for those parameters appropriately expressed in terms of total concentration are shown in Table 13. As with the modified elutriate test data comparisons, the predicted values of total contaminant concentrations are generally on the conservative side (i.e., higher predicted values than measured field values). This would be expected since both the predicted total suspended solids concentration, as estimated by column settling data, and the associated contaminant fractions, as predicted by modified elutriate test data, were generally conservative.

128. The effluent suspended solids concentrations predicted by the column settling analysis were generally higher than the mean measured field effluent concentrations. This degree of conservatism was reflected in the subsequent prediction of total contaminant concentrations. These predictions were within a factor of 1.5 times the mean measured values for 21 of 36 parameters.

Accuracy of Predictions

129. The average ratios of predicted total concentrations to mean measured concentrations for all parameters for the five field sites were 3.1, 1.7, 1.7, 1.4, and 1.6. This overall level of accuracy is acceptable when considering the complex nature of the behavior predicted. The predictive technique also represents an improved accuracy over previously available predictive methods, such as using the standard elutriate test. Evaluations of the standard elutriate tests for estimating quality of confined disposal effluents showed that only 7 of 14 dissolved concentration parameters were predicted within a factor of two of measured field results and only 9 of 14

were predicted within a factor of three (Blazevich et al. 1977). For the five evaluations, the modified elutriate test procedure predicted 41 of 50 dissolved concentration parameters within a factor of two and 45 of 50 dissolved parameters within a factor of three, as indicated in Table 12. For total contaminant concentrations, these techniques resulted in predictions within a factor of two of the measured mean field results for 24 of 34 parameters, as shown in Table 13. The only previously proposed technique that considers particle-associated contaminants was recommended by Eichenberger and Chen (1980). Their results were compared only with the range of observed field values, and no direct comparisons of means were made. Accuracy within a factor of 1.5 to 3.0 is comparable with similar predictive procedures for evaluation of the suitability of open-water disposal, such as standard elutriate tests. The predictive technique described herein is generally accurate for estimating effluent quality.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Predictive technique

130. The following conclusions are made regarding the technique for predicting the quality of effluent:

- a. For all five sites evaluated, the modified elutriate test adequately predicted the dissolved concentration of contaminants and the contaminant fractions of the total suspended solids in the effluent. The predictions were within a factor of 1.5 of the field data for a total of 64 of the 84 parameters measured. The modified elutriate test was also a generally conservative predictor, i.e., predictions of effluent contaminant concentrations were generally higher than the measured field results.
- b. Results from both the column settling tests and the modified elutriate tests were used to predict the total concentration of contaminants in the effluent. For the five sites evaluated, the predictions were within a factor of 1.5 of the measured field data for a total of 21 of the 36 parameters measured. The predictions of total concentrations were also generally conservative, i.e., higher than the measured field data.
- c. The five field evaluations described in this report serve as preliminary verification of the accuracy of the predictive technique for effluent quality.

Field evaluations

131. Based on the results of the field evaluations, the following conclusions are drawn regarding effluent water quality during typical active dredged material disposal operations:

- a. The quality of influent showed high variability typical of hydraulic dredging operations. Effluent water quality was less variable, indicative of the averaging effect of ponding and mixing occurring within the disposal areas.
- b. Effluent suspended solids data collected during disposal indicated that disposal sites are very efficient in retaining suspended solids if properly designed and operated. The relative retention of contaminants within the sites also was very high, since most contaminants were directly associated with particles and were removed with them.
- c. The effect of retention and ponding on physicochemical parameters is varied. Dissolved oxygen levels show marked increases due to turbulence, mixing, and atmospheric

reaeration, confirming that oxidizing conditions are present in ponded disposal area waters.

d. Total metal concentrations show a very high degree of retention in the disposal area. Dissolved metal concentrations were also reduced, indicating a scavenging effect from the formation and settling of ferric hydroxide precipitates which adsorb dissolved metals. Metal fractions of the suspended solids (milligrams per kilogram SS) were increased due to the high relative capacity of the smaller average effluent particles for adsorbed metals.

e. Results for nutrient and PCB removal were generally similar to those for metals removal.

Recommendations

132. Additional comparisons of predictions with field results using the proposed technique should be made under a wider variety of operating conditions. These additional comparisons should also include organic contaminants with varying tendencies for adsorption to particles. The testing procedures may then be modified if appropriate to improve accuracy and/or precision. This is currently an ongoing effort under the Corps of Engineers Long-Term Effects of Dredging Operations research program.

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Table 1

Physical Characterization of Sediments

Site	Sand percent	Liquid Limit percent	Plasticity Index percent	USCS Classification
Mobile Harbor	<5	119	84	Plastic clay, CH
Savannah Harbor	<5	169	117	Plastic clay, CH
Norfolk Harbor	<5	110	79	Plastic clay, CH
Black Rock Harbor	28	164	101	Organic clay, OH
Hart Miller Island	<3	75	17	Organic silt, MH

Table 2

Results of Bulk Sediment and Water Analyses

	Mobile Harbor *		Savannah Harbor **		Norfolk Harbor †		Black Rock Harbor		Hart Miller Island ††	
Parameter	Sediment Concentration mg/kg	Water Concentration mg/ℓ	Sediment Concentration mg/kg	Water Concentration mg/ℓ	Sediment Concentration mg/kg	Water Concentration mg/ℓ	Sediment Concentration mg/kg	Water Concentration mg/ℓ	Sediment Concentration mg/kg	Water Concentration mg/ℓ
Arsenic	--‡	--	--	--	--	--	--	--	126	<0.002
Cadmium	2	<0.002	1	<0.0001	25	0.032	20	0.01	4	0.001
Chromium	52	<0.01	72	<0.001	7	0.06	1,450	0.005	330	0.001
Copper	21	<0.01	19	0.001	7	0.04	2,812	0.06	153	0.03
Iron	27,000	<0.01	--	--	1,530	0.33	27,500	0.17	76,800	0.12
Lead	26	<0.01	21	0.00024	67	0.22	393	0.009	200	<0.001
Manganese	--	--	--	--	106	0.004	305	0.07	--	--
Nickel	26	<0.01	12	<0.001	--	--	198	0.07	--	--
Zinc	160	0.012	78	0.009	78	0.05	1,230	0.28	--	--
Total phosphorus	51	0.03	--	--	--	--	--	--	--	--
Ammonia nitrogen	184	0.36	--	--	--	--	--	--	--	--
Total organic carbon	10,460	4	--	--	38,000	7	53,300	3.7	--	--
Total PCB	--	--	--	--	--		14.3	--	--	--

* Environmental Protection Systems, Inc. (1982 letter report to US Army Engineer District, Mobile, Mobile, Ala.).

** Savannah Laboratories and Environmental Services (1982a).

† Thompson Engineering Testing (1982).

†† Maryland Environmental Service (unpublished data, 1984).

‡ No analysis performed.

Table 3

Modified Elutriate Test Factors

Site	n	Field Influent Concentration g/ℓ	Laboratory Test Slurry Concentration g/ℓ	Mean Field Retention Time, hr	Laboratory Test Retention Time, hr
Mobile	13	87	106	12	12
Savannah	11	107	99	51	24
Norfolk	24	88	89	41	24
Black Rock	10*	61	60	8	8
Hart Miller	3	198	132	>80	24

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* n = 3 for PCBs.

Table 4

Means and Standard Deviations for Replicate Modified Elutriate Tests

	Mobile		Savannah		Norfolk		Black Rock		Hart Miller	
Parameter*	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Dissolved oxygen, mg/ℓ	7.17	0.72	7.39	0.42	6.85	0.33	5.03	0.99		
pH	7.91	0.06	7.91	0.12	7.99	0.03	7.5	0.34		
Conductivity, mmhos/cm	24,800	4,770	18,700	289	25,300	286	28,800	185.00		
Dissolved metals, mg/ℓ										
Cd	<0.002	--**	--	--	0.036	0.0042	--	--	0.0013	0.00058
Cr	<0.02	--	--	--	0.063	0.0064	0.0027	0.0019	0.002	0.003
Ba	--	--	--	--	--	--	--	--	0.0113	0.0005
Cu	0.006	0.0035	0.0038	0.0023	0.042	0.0044	0.006	0.0040	0.025	0.002
Fe	0.026	0.023	0.040	0.017	0.153	0.0087	0.034	0.0083	1.55	0.80
Pb	<0.05	--	0.0017	0.0012	0.241	0.020	0.0026	0.0015	0.007	0.0003
Mn	2.22	0.59	--	--	0.82	0.070	0.25	0.017	--	--
Ni	<0.02	--	0.0059	0.0043	--	--	0.051	0.066	--	--
Se	--	--	--	--	--	--	--	--	0.0023	0.0058
Zn	<0.05	--	0.0069	0.0038	0.031	0.0045	--	--	--	--
Dissolved nutrients, mg/ℓ										
TOC	17.05	2.86	31.2	5.12	7.08	0.48	20.5	0.517	--	--
NH_3	12.7	1.13	11.3	1.40	--	--	31.6	0.538	--	--
NO_3	0.04	0.019	0.045	0.021	--	--	0.034	0.0055	--	--
Total P	<0.10	--	0.25	0.27	0.010	0.002	0.23	0.085	--	--
Dissolved total PCB, mg/ℓ	--	--	--	--	--	--	0.0013	0.0004	--	--

(Continued)

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* n = 13 for Mobile Harbor; n = 11 for Savannah Harbor; n = 24 for Norfolk Harbor.

** No analysis performed for this parameter.

Table 4 (Concluded)

	Mobile		Savannah		Norfolk		Black Rock		Hart Miller	
Parameter*	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Metal fraction of the total suspended solids, mg/kg SS										
Ba	--	--	--	--	--	--	--	--	323.7	147.2
Cd	BD*	--	--	--	332	303	--	--	BD	--
Cr	BD	--	--	--	618	745	1,770	327	44.8	38.8
Cu	993.0	739.6	124	32.4	405	606	2,830	605	92.9	12.09
Fe	84,800	25,100	13,200	4,590	11,344	4,570	66,000	9,820	5,480	695.5
Pb	BD	--	40	14.8	1,957	2,570	2,410	1,910	38	11.10
Mn	233,600	67,400	--	--	2,507	261	667	490	--	--
Ni	BD	--	147	74.7	--	--	441	699	--	--
Se	--	--	--	--	--	--	--	--	442.3	186.5
Zn	BD	--	156	79.9	110	376	--	--	--	--
Nutrient fraction of the total suspended solids, mg/kg SS										
TOC	152,000	83,600	--	--	87,900	93,100	218,000	8,480	--	--
NH_3	BD	--	--	--	--	--	8,740	11,600	--	--
Total P	BD	--	--	--	1,874	2,590	9,010	3,710	--	--
Total PCB fraction of the total suspended solids, mg/kg SS							56.1	49.2	--	--

---

* The notation BD indicates that dissolved or total concentrations were either below detection limits or were essentially equal in concentration, and fractions of the total suspended solids could not be calculated.

Table 5

Comparison of Suspended Solids Concentrations from Column Settling Tests with Mean Effluent Values

Site	Approximate[*] Ponded Area acres	Approximate[*] Ponded Depth ft	Mean[**] Field Retention Time hr	Test Slurry Concentration g/ℓ	Column Suspended Solids mg/ℓ	Resuspension Factor[†]	Predicted Effluent Suspended Solids mg/ℓ	Mean Field Suspended Solids mg/ℓ	Ratio Predicted to Field
Mobile	40	1	12	99	33	2.0	66	40	1.65
Savannah	53[††]	>2	53	142	85	1.5	128	75	1.70
Norfolk	600	>2	41	122	20	--	--	202 (high wind)	--
					20	2.0	40	35 (low wind)	1.14
Black Rock	<1	<1	8	57	84	2.0	168	173	0.97
Hart Miller	330	>10	>80	152	10	2.0	20	25	0.80

---

[*] Detailed descriptions of ponding conditions are given in Part III.

[**] Field mean retention was determined by dye tracer test with the exception of the Hart Miller site. For this site, the mean retention time was estimated by applying a hydraulic efficiency factor of 2.25 to the estimated theoretical retention time.

[†] Resuspension factor selected from Appendix A.

[††] Total surface area ponded for the Savannah site was approximately 400 acres. However, a majority of this area was involved in overland flow. A relatively sheltered area ponded to depths of 2 ft or greater was limited to approximately 50 acres immediately in front of the weir. The selected resuspension factor for this site corresponds to a ponded area less than 100 acres and ponded depth greater than 2 ft.

Table 6

Means and Standard Deviations for Predicted Total Concentrations of Contaminants

	Mobile		Savannah		Norfolk		Black Rock		Hart Miller	
Parameter*	Mean mg/ℓ	Std Dev mg/ℓ	Mean mg/ℓ	Std Dev mg/ℓ	Mean mg/ℓ	Std Dev mg/ℓ	Mean mg/ℓ	Std Dev mg/ℓ	Mean mg/ℓ	Std Dev mg/ℓ
Barium	--**	--	--	--	--	--	--	--	0.01967	0.0061
Cadmium	--	--	--	--	0.049	0.012	--	--	0.0013	0.0006
Chromium	--	--	--	--	0.088	0.025	0.386	0.072	0.009	0.0022
Copper	0.072	0.048	0.020	0.005	0.059	0.023	0.618	0.139	0.027	0.0018
Iron	5.62	1.65	1.73	0.595	0.61	0.017	14.3	2.12	1.648	0.792
Lead	--	--	0.0068	0.0019	0.32	0.093	0.524	0.414	0.00783	0.0028
Manganese	17.6	4.22	--	--	0.92	0.12	0.390	0.099	--	--
Nickel	--	--	0.025	0.010	--	--	0.146	0.149	--	--
Selenium	--	--	--	--	--	--	--	--	0.119	0.0033
Zinc	--	--	0.020	0.010	0.035	0.015	--	--	--	--
Total phosphorus	--	--	--	--	--	--	2.18	0.763	--	--
Ammonia nitrogen	12.8	1.11	--	--	--	--	33.5	2.07	--	--
Total organic carbon	27.1	4.56	--	--	10.6	3.63	67.7	18.3	--	--
Total PCB	--	--	--	--	--	--	--	--	--	--

* n = 13 for Mobile Harbor; n = 11 for Savannah Harbor; n = 24 for Norfolk Harbor.

** No analysis performed for this parameter.

Table 7

Means and Standard Deviations for Total and Dissolved Concentrations of Parameters and Fractions in the Total Suspended Solids, Mobile Harbor Field Evaluations

	Total Concentration, mg/ℓ				Retention	Dissolved Concentration, mg/ℓ		Fraction of Total Suspended Solids mg/kg SS	
	Influent*		Effluent**		Efficiency	Effluent		Effluent	
Parameter	Mean	Std Dev	Mean	Std Dev	percent	Mean	Std Dev	Mean	Std Dev
Total suspended solids	87,600	84,200	39.8	35.4	99.96				
Conductivity, µmhos/cm	36,300	3,780	38,300	2,950					
Dissolved oxygen	1.05	1.88	6.57	0.70					
pH	7.2	0.23	7.5	0.17					
Total organic carbon	4,111	5,365	11.00	2.54	99.80	8.85	0.94	71,600	99,800
Ammonia nitrogen	76.30	127.50	13.60	1.17	82.20	13.60	1.04	10,400	23,300
Nitrate + nitrite nitrogen	--†	--	--	--		0.018	0.012	--	--
Total phosphorus	34.10	30.60	0.20	0.09	99.4	BD††	--	--	--
Cadmium	0.16	0.16	BD	--	--	BD	--	--	--
Chromium	1.87	1.69	BD	--	--	BD	--	--	--
Copper	1.16	0.97	0.012	0.0039	98.0	0.0063	0.0079	275	279
Iron	1,700	1,720	3.18	1.66	100.0	0.051	0.061	99,100	57,100
Lead	3.30	3.04	BD	--	--	BD	--	--	--
Manganese	47.50	52.00	2.78	0.55	94.10	4.12	0.73	--	--
Mercury	BD	--	BD	--	--	BD	--	--	--
Nickel	0.87	0.81	BD	--	--	BD	--	--	--
Zinc	6.44	5.82	0.022	0.014	100.0	0.0054	0.0051	513	336

* n = 31.
** n = 37.
† No analysis performed.
†† BD = below detection limits.

Table 8

Means and Standard Deviations for Total and Dissolved Concentrations of Parameters and Fractions in the Total Suspended Solids, Savannah Harbor Field Evaluations

	Total Concentration, mg/ℓ				Retention Efficiency percent	Dissolved Concentration, mg/ℓ		Fraction of Total Suspended Solids mg/kg SS	
	Influent*		Effluent*			Effluent		Effluent	
Parameter	Mean	Std Dev	Mean	Std Dev		Mean	Std Dev	Mean	Std Dev
Total suspended solids	107,000,000	74.60	35.70	100	99.93				
Conductivity, μmhos/cm	34,000	4,810	20,100	4,100					
Dissolved oxygen	1.25	1.24	8.09	1.18					
pH		7.15	0.14	7.95					
Total organic carbon	2,420	970	28.10	4.78		26.30	5.14	24,900	13,600
Ammonia nitrogen	56.30	29.00	7.12	2.85		6.41	2.59	11,300	12,400
Nitrate + nitrite nitrogen						0.054	0.036		
Total phosphorus	109	55.20	0.64	0.25		0.61	0.25	541	653
Chromium	9.18	5.20	0.011	0.0028	99.9	0.0026	0.0015	123	36.20
Copper	5.77	3.80	0.030	0.14	99.50	0.0037	0.0018	78.90	34.40
Iron	3,670	1,910	1.14	0.49	100.0	0.088	0.102	15,100	4,800
Lead	2.38	1.61	0.0043	0.0019	99.82	0.0015	0.0006	39.30	15.20
Nickel	1.61	1.41	0.0065	0.0026	99.60	0.0026	0.0013	48.20	25.60
Silver	0.04	0.12	0.00036	0.00017	99.10	0.0004	0.0002	0.25	0.12
Zinc	11.90	6.49	0.018	0.0094	99.90	0.011	0.0096	102	39.00

---

* n = 48.

Table 9

Means and Standard Deviations for Total and Dissolved Concentrations of Parameters and Fractions in the Total Suspended Solids, Norfolk Harbor Field Evaluations

	Total Concentration, mg/ℓ				Retention Efficiency percent	Dissolved Concentration, mg/ℓ		Fraction of Total Suspended Solids mg/kg SS	
	Influent*		Effluent**			Effluent		Effluent	
Parameter	Mean	Std Dev	Mean	Std Dev		Mean	Std Dev	Mean	Std Dev
pH	6.25	0.29	6.48	0.39					
Conductivity μmhos/cm	19,900	1,940	7,430	688					
Dissolved oxygen	2.98	1.69	11.42	0.44					
Total suspended solids	122,000	68,300	35.10	11.10	99.96				
Cadmium	0.11	0.021	0.017	0.001	84.00	0.012	0.0014	164	96.40
Chromium	4.37	2.44	0.028	0.014	99.40	0.021	0.0024	299	557
Iron	4,130	2,400	1.01	0.35	100.0	0.19	0.12	25,000	1,900
Manganese	81.10	40.60	0.12	0.025	99.90	0.074	0.036	1,560	1,180
Zinc	21.50	10.80	0.026	0.0051	99.90	0.020	0.001	188	188
Copper	3.83	1.96	0.021	0.0047	99.00	0.011	0.0047	300	171
Lead	7.36	3.05	0.39	0.017	94.70	0.34	0.023	1,710	1,220
Nickel	2.22	1.71	0.067	0.0089	97.00	0.055	0.0092	372	371
Total organic carbon			7.11	1.19		2.96	0.96	122,000	46,700
Ammonia nitrogen	40.40	21.80	2.61	0.71		2.26	0.63	9,550	6,300
Total phosphorus	3.43	1.98	0.17	0.055		0.10	0.027	2,260	1,890

* n = 6.
** n = 18.

Table 10

Summary of Field Results, Black Rock Harbor

	Total Concentration, mg/ℓ				Retention Efficiency†	Dissolved Concentration, mg/ℓ		Fraction of Total Suspended Solids mg/kg SS	
	Influent*		Effluent**			Effluent		Effluent	
Parameter	Mean	Std Dev	Mean	Std Dev	percent	Mean	Std Dev	Mean	Std Dev
Total suspended solids	60,700	40,000	173	133	99.7	--	--	--	--
Conductivity, µmhos/cm	20,500	1,270	20,300	1,470	--††	--	--	--	--
Dissolved oxygen	0.63	0.91	5.57	1.43	--	--	--	--	--
pH	7.2	0.16	7.3	0.065	--	--	--	--	--
Total phosphorus	80.3	95.3	2.92	0.507	--	0.96	0.377	13,100	4,870
Ammonia nitrogen	73.7	39.4	63.6	3.62	--	60.4	4.55	23,600	24,500
Nitrate nitrogen	--	--	--	--	--	0.12	0.133	--	--
Total organic carbon	1310.	1,490	24.4	7.45	--	2.71	1.16	96,700	2,420
Arsenic	0.099	0.05	BD‡	--	--	BD	--	--	--
Cadmium	1.34	1.04	0.0102	0.0132	99.2	0.0046	0.0012	21.3	24.6
Chromium	58.4	48.9	0.400	0.393	99.3	0.0079	0.0047	2,060	703
Copper	38.5	26.2	0.82	0.826	97.9	0.074	0.0362	3,760	1,600
Iron	755	608	8.22	5.55	98.9	0.042	0.0315	48,700	14,700
Lead	14.0	11.3	0.31	0.959	97.8	0.0100	0.0127	914	1,880
Mercury	0.023	0.013	BD	--	--	BD	--	--	--
Manganese	7.25	5.88	0.36	0.088	95.0	0.28	0.0177	536	237
Nickel	5.01	3.74	0.07	0.063	98.6	0.0329	0.014	219	357
Zinc	52.2	42.4	0.39	0.358	99.3	BD	--	--	--
Total PCB	17.1‡	5.97	0.0099	0.0222	99.0	0.0017	0.00094	64.2	221

* n = 23 for physicochemical parameters, metals, and nutrients; n = 12 for PCB.

** n = 48 for physicochemical parameters, metals, and nutrients; n = 24 for PCB.

† R = retention efficiency defined as the ratio of total influent concentration minus total effluent concentration to the total influent concentration, expressed as a percentage.

†† No analysis performed.

‡ BD = below detection.

‡‡ Total concentration for influent PCB determined on milligram per kilogram basis.

Table 11

Means and Standard Deviations for Total and Dissolved Concentrations of Parameters and Functions in the Total Suspended Solids, Hart Miller Field Evaluations

	Total Concentration, mg/ℓ				Retention Efficiency percent	Dissolved Concentration, mg/ℓ		Fraction of Total Suspended Solids mg/kg SS	
	Influent*		Effluent**			Effluent		Effluent	
Parameter	Mean	Std Dev	Mean	Std Dev		Mean	Std Dev	Mean	Std Dev
Total suspended solids	198,000	63,000	25.0	18.6	99.99				
Barium	107	53	0.062	0.0096	99.94	0.0375	0.0080	1,150	729
Arsenic	45.5	21.8	0.030	0.0082	99.93	BD†	--††	--	--
Cadmium	2.55	0.65	0.0010	0.0002	99.96	0.0011	0.00034	BD	--
Chromium	298	56.1	0.0035	0.0017	99.99	0.0025	0.0019	72	159
Copper	141	54.4	0.033	0.0029	99.98	0.030	0.0011	148	205
Iron	38,600	30,406.6	0.487	0.0163	99.99	0.105	0.031	1,710	10,400
Lead	124.1	57.0	0.0055	0.0035	99.99	0.0013	0.0005	211	231
Mercury	0.35	0.49	BD	--	--	BD	--	BD	--
Selenium	4.3	1.5	0.040	0.021	99.06	0.0020	0.0021	1,711	1,020
Silver	0.5113	0.175	BD	--	--	BD	--	BD	--

---

* n = 15.

** n = 25.

† Below detection limits.

†† No analysis performed.

Table 12

Ratios of Mean Values from Modified Elutriate Laboratory Tests to Mean Measured Field Values

Parameter	Site				
	Mobile	Savannah	Norfolk	Black Rock	Hart Miller
Dissolved oxygen	1.1	0.9	0.6	0.9	--
pH	1.0	1.0	1.3	1.0	--
Conductivity	0.7	0.9	3.7	1.4	--
Dissolved metals					
Barium	--	--	--	--	0.3
Cadmium	BD	--	3.2	--	1.2
Chromium	BD	BD	2.7	0.3	3.2
Copper	1.0	1.0	3.4	0.1	0.8
Iron	0.5	0.5	0.6	0.8	--*
Lead	BD	1.1	0.7	0.3	5.6
Manganese	--**	--	--†	0.9	--
Nickel	BD	2.2	--	1.5	--
Selenium	--	--	--	--	1.1
Zinc	BD	0.6	1.2	--	--
Dissolved nutrients					
Total phosphorus	BD	0.4	BD	0.2	--

(Continued)

Note: "--" indicates no analysis performed; BD indicates value below detection limits.

* The measured concentrations of dissolved iron were much higher in the modified elutriate test as compared to the measured field values. Since this was not evident in any of the other field evaluations, the discrepancy was attributed to analytical error. This ratio was not included in computing the average of the ratios for this site.

** The measured concentrations of total manganese were below measured concentrations for dissolved manganese for the field effluent samples at the Mobile Harbor site (presumably due to analytical error). Therefore, values for the manganese fraction of the TSS could not be compared to the results from the modified elutriate tests.

† A high ratio of laboratory-to-field value for manganese at the Norfolk Harbor site was due to the abnormally high precipitation that which occurred during the field sampling period. This ratio was not included in computing the average of the ratios for this site.

Table 12 (Concluded)

	Site				
Parameter	Mobile	Savannah	Norfolk	Black Rock	Hart Miller
Dissolved nutrients (Cont.)					
Nitrate nitrogen	2.3	0.8	--	0.3	--
Ammonia nitrogen	0.9	1.8	--	0.5	--
Total organic carbon	1.9	1.2	2.2	2.3	--
Dissolved PCB	--	--	--	0.8	--
Metal fraction of the total suspended solids					
Barium	--	--	--	--	0.4
Cadmium	BD	--	2.4	--	1.0
Chromium	BD	0.7	2.5	0.9	0.7
Copper	3.5	1.6	1.5	0.7	0.7
Iron	0.8	0.9	0.5	1.3	0.3
Lead	BD	1.0	1.3	2.6	0.2
Manganese	--	--	--	1.2	--
Nickel	BD	3.0	--	2.0	--
Selenium	--	--	--	--	0.3
Zinc	BD	1.5	0.2	--	--
Nutrient fraction of the total suspended solids					
Total phosphorus	BD	--	0.9	0.7	--
Ammonia nitrogen	BD	--	--	0.4	--
Total organic carbon	2.1	--	1.0	--	--
PCB fraction of the total suspended solids	--	--	--	0.9	--
Average of all parameters	1.4	1.2	1.7	1.0	1.2

Table 13

Ratios of Predicted Total Contaminant Concentrations to Mean Field Values

Parameter	Mobile	Savannah	Norfolk	Black Rock	Hart Miller
Barium	--	--	--	--	0.3
Cadmium	--	--	2.7	--	1.3
Chromium	--	--	3.1	1.0	2.6
Copper	6.1	0.7	2.8	0.7	0.8
Iron	1.8	1.5	0.6	1.7	3.4
Lead	--	1.6	0.8	1.7	1.4
Manganese	--*	--	--**	1.1	--
Nickel	--	3.8	--	2.1	--
Zinc	--	1.1	1.4	--	--
Total phosphorus	1.3	--	0.5	0.7	--
Ammonia nitrogen	0.9	--	--	0.5	--
Total organic carbon	2.5	--	1.5	2.8	--
Total PCB	--	--	--	1.3	--
Average of all parameters	3.1	1.7	1.7	1.4	1.6

---

* The measured concentrations of total manganese were below measured concentrations for dissolved manganese for the field effluent samples at the Mobile Harbor site (presumably due to analytical error). The ratio of predicted to field values for this parameter was not included in computing the average of the ratios for this site.

** A high ratio of predicted field value for manganese at the Norfolk Harbor site was due to abnormally high precipitation which occurred during the field sampling period. This ratio was not included in computing the average of ratios for this site.

APPENDIX A: INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS

This appendix contains Environmental Effects of Dredging Technical Notes EEDP-04-1 through 4 (Palermo 1985). These technical notes present the detailed procedures used for predicting the effluent quality for the field evaluations in this study.

EEDP-04-1
June 1985

Environmental Effects of Dredging Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--GENERAL

<u>PURPOSE</u>: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during disposal operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operations (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluations of predictions and field measurement of effluent water quality.

<u>BACKGROUND</u>: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas (effluent) is a major environmental concern associated with such disposal.

A schematic of a typical active confined disposal area is illustrated in Figure 1. Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

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* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal site.

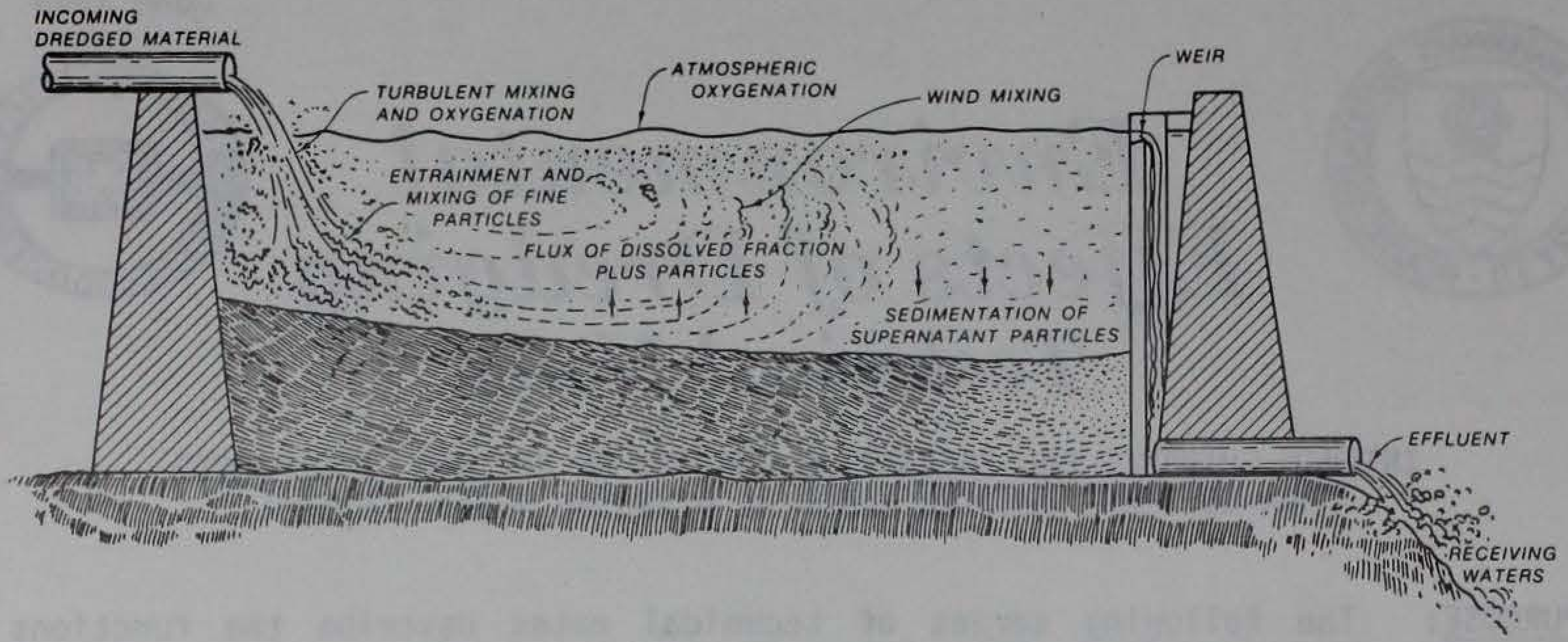

Figure 1. Schematic of factors affecting quality of effluent from confined disposal areas

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant level is particle associated. Results of the standard elutriate test do not reflect the conditions in confined disposal sites that influence contaminant release. A modified elutriate test procedure was therefore developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas. The modified test simulates contaminant release under confined disposal area conditions and reflects the sedimentation behavior of dredged material, retention time of the disposal area, and chemical environment in ponded water during disposal.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980a). Proposed testing requirements define dredged material according to the four categories shown in Figure 2 (EPA 1980b). Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of short-term water column impacts of disposal area effluents. Predicted contaminant levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

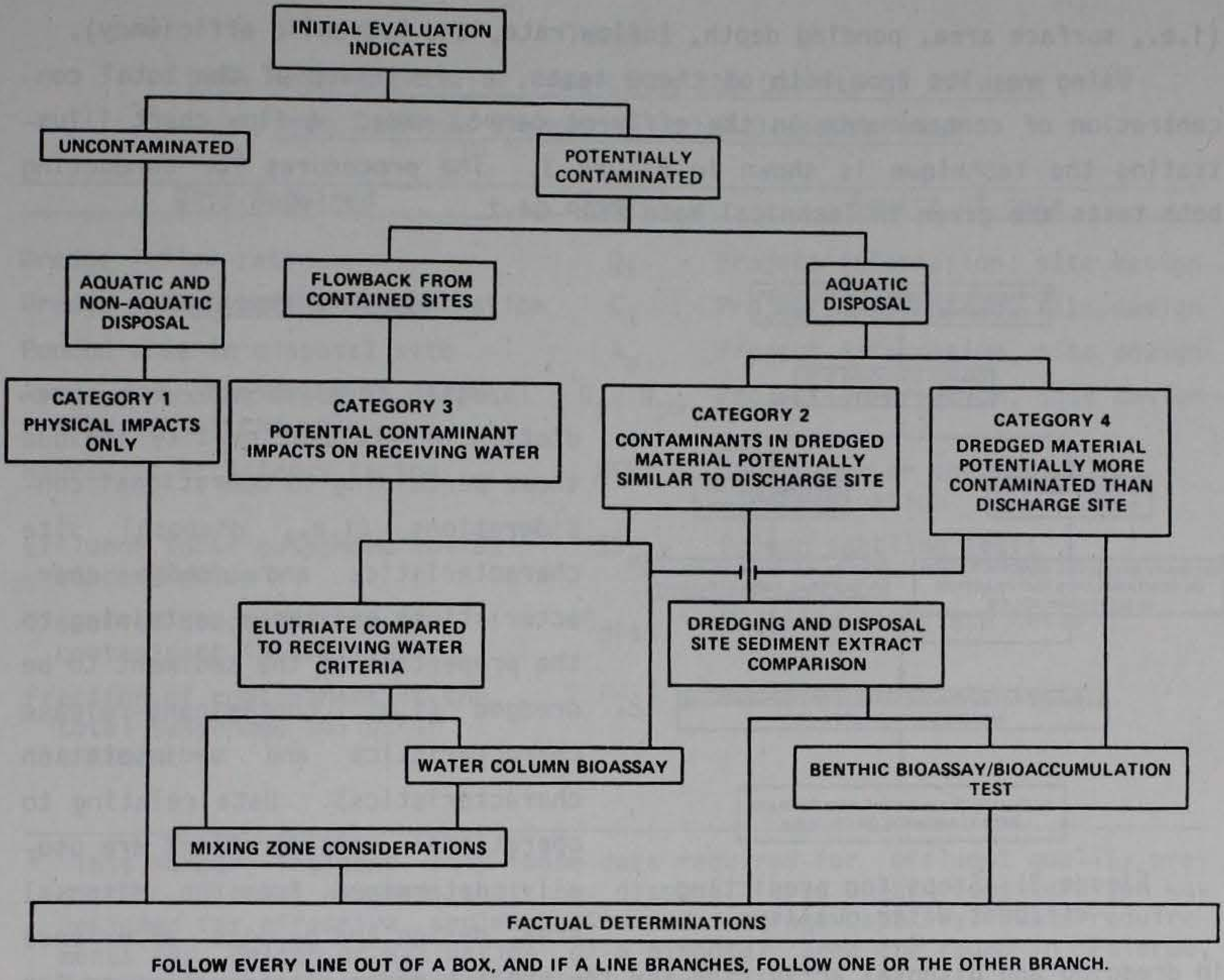

Figure 2. Proposed dredged material regulatory testing flow chart (EPA 1980b)

Predictive Technique

The prediction of the quality of effluent from confined dredged material disposal areas must account for both the dissolved concentrations of contaminants and that fraction in the total suspended solids. A modified elutriate test procedure, developed for this purpose, defines dissolved concentrations of contaminants and contaminant fractions in the total suspended solids under quiescent settling conditions and accounts for the geochemical changes occurring in the disposal area during active disposal operations. Column settling test procedures (Montgomery 1978; Palermo, Montgomery, Poindexter 1978) were refined and extended to define the concentration of suspended solids in the effluent for given operational conditions (i.e., surface area, ponding depth, inflow rate, and hydraulic efficiency).

Using results from both of these tests, a prediction of the total concentration of contaminants in the effluent can be made. A flow chart illustrating the technique is shown in Figure 3. The procedures for conducting both tests are given in Technical Note EEDP-04-2.

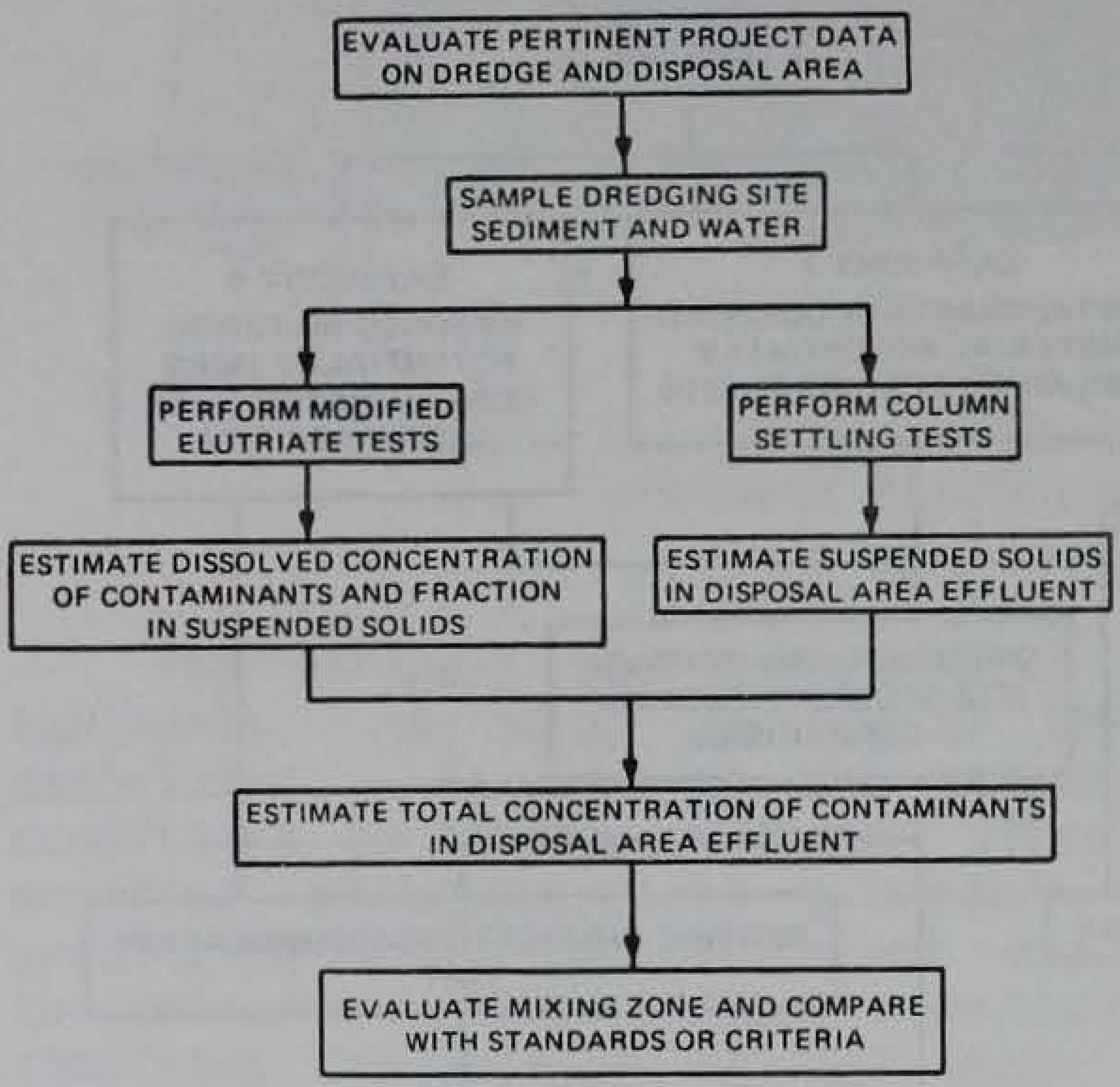

Figure 3. Steps for predicting effluent water quality

Data Requirements

Data requirements for prediction of effluent quality include those pertaining to operational considerations (i.e., disposal site characteristics and dredge characteristics) and those pertaining to the properties of the sediment to be dredged (i.e., contaminant-release characteristics and sedimentation characteristics). Data relating to operational considerations are usually determined from the disposal area design and by past experience in dredging and disposal activities for the project under consideration or for similar projects. Data relating to the characteristics of the sediment must be determined from samples of the sediment to be dredged and the dredging site water column.

A summary of the data requirements for effluent quality predictions is given in Table 1. Some of the data can be determined from the design or from evaluation of the site using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978). The remaining data must be developed using the procedures described in Technical Note EEDP-04-2.

Sampling Requirements

Samples of sediment and water from a proposed dredging site are required for characterizing the sediment to be dredged and for conducting modified elutriate tests and column settling tests. The level of effort, including the

Table 1

Data Requirements for Predicting the Quality of Effluent from Confined Dredged Material Disposal Area*

Data Required	Symbol	Source of data
Dredge inflow rate	Q_i	Project information, site design
Dredge inflow solids concentration	C_i	Project information, site design
Ponded area in disposal site	A_p	Project information, site design
Average ponding depth in disposal site and at the weir	D_p, D_{pw}	Project information, site design
Hydraulic efficiency factor	HEF	Dye tracer or theoretical determination
Effluent total suspended solids concentration	SS_{eff}	Column settling tests
Dissolved concentration of contaminant in effluent	C_{diss}	Modified elutriate tests
Fraction of contaminant in the total suspended solids in effluent	F_{SS}	Modified elutriate tests

* This summary includes only those data required for effluent quality prediction. It was assumed that the disposal area under consideration was designed for effective sedimentation and storage capacity. Data requirements for design or evaluation of a disposal area are found in Palermo, Montgomery, and Poindexter (1978).

number of sampling stations, quantity of material, and any scheme used for compositing samples, is highly project specific. If at all possible, the sampling operations required for sediment characterization (both physical and chemical), for design or evaluation of the disposal site, and for modified elutriate and column settling tests should be conducted simultaneously to avoid duplication of effort and to ensure sample similarity.

Normally effluent quality will be of concern for maintenance dredged material. Representative samples of sediments proposed for maintenance dredging are satisfactory for obtaining the quantities needed for all testing requirements. General guidance on sampling for chemical characterization purposes is found in Plumb (1981). This reference should be used for guidance in obtaining samples for use in the modified elutriate testing.

Application

The technique for predicting the quality of effluent discharged from confined dredged material disposal areas is described in Technical Note EEDP-04-3. The technique can be applied to predict the performance of existing sites or to design new sites.

For existing sites, the technique can be used to predict effluent quality for a given set of anticipated operational conditions (known flow and ponding conditions). In a similar manner, the procedure can be used to determine the operational conditions (size, geometry, maximum allowable dredge size, etc.) for a proposed site to meet a given effluent quality requirement. Examples of both of these cases are presented in Technical Note EEDP-04-4.

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Notations

The notations used in Technical Notes EEDP-04-1 through 4 are defined as follows.

A_p	Area ponded, acres
C_{diss}	Dissolved concentration of constituent, milligrams per liter
C_i	Inflow solids concentration, grams per liter
C_{slurry}	Solids concentration of slurry, grams per liter (dry weight basis)
$C_{sediment}$	Solids concentration of sediment, grams per liter (dry weight basis)
C_{total}	Total concentration of constituent, milligrams per liter
F_{SS}	Fraction of constituent in total suspended solids, milligrams per kilogram
D_p	Depth of ponding in disposal site, ft
D_{pw}	Desired ponding depth or ponding depth at weir, ft
HEF	Hydraulic efficiency factor
Q_i	Inflow rate, cubic feet per second
P	Percent of suspended solids remaining at test interval
R	Percent of solids removed from suspension at test interval
RF	Resuspension factor
SS	Total suspended solids concentration, milligrams per liter
SS_{col}	Suspended solids concentration determined by column test, milligrams per liter
SS_{eff}	Suspended solids concentration of effluent considering anticipated resuspension, milligrams per liter of water
T	Theoretical detention time, hours
T_d	Field mean detention time, hours
t	Sampling time, hr
$V_{sediment}$	Volume of sediment, liters
V_p	Volume ponded, acre-feet
V_{water}	Volume of water, liters
z	Sample depth, feet
ϕ	Percent of initial suspended solids concentration (beginning of column settling test used as 100 percent)

EEDP-04-2
June 1985

Environmental Effects of Dredging Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--TEST PROCEDURES

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during dredging operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operations (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluations of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

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* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal site.

US Army Engineer Waterways Experiment Station, Environmental Laboratory
PO Box 631, Vicksburg, Mississippi 39180-0631

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle associated. The modified elutriate test was developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980b). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water-column impacts of disposal area effluents. Predicted contaminants levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Initial Screening

An initial screening for contamination must be performed as outlined in the testing requirements for Section 404 of the Clean Water Act (EPA 1980b). The evaluation is designed to determine if there is reason to believe that the sediment contains any contaminant at a significant concentration (above background levels) and to identify the contaminants of concern that should be considered for analysis in the modified elutriate test. Considerations include but are not limited to:

a. Potential routes by which contaminants could reasonably have been introduced to the sediment.

b. Data from previous tests of the sediment or other similar sediment in the vicinity, provided comparison would still be appropriate.

c. Probability of contamination from surface runoff.

d. Spills of contaminants in the area to be dredged.

e. Industrial and municipal waste discharges.

Modified Elutriate Test

The modified elutriate test should be conducted and appropriate chemical analyses should be performed as soon as possible after sample collection. The volume of elutriate sample needed for chemical analyses will depend on the number and types of analyses to be conducted (Plumb 1981). Both dissolved and total concentrations of contaminants must be determined. The volume required for each analysis, the number of parameters measured, and the desired analytical replication will influence the total elutriate sample volume required. A 4-ℓ cylinder is normally used for the test, and the supernatant volume available for sample extraction will vary from approximately 500 to 1,000 ml, depending on the sediment properties, settling times, and initial concentration of the slurry. It may be necessary to composite several extracted samples or use large-diameter cylinders to obtain the total required volume.

Apparatus

The following items are required:

a. Laboratory mixer, preferably with Teflon shaft and blades.

b. Several 4-ℓ graduated cylinders. Larger cylinders may be used if large sample volumes are required. Nalgene cylinders are acceptable for testing involving analysis of metals and nutrients. Glass cylinders are required for testing involving analysis of organics.

c. Assorted glassware for sample extraction and handling.

d. Compressed air source with deionized water trap and tubing for bubble aeration of slurry.

e. Vacuum or pressure filtration equipment, including vacum pump or compressed air source and appropriate filter holder capable of accommodating 47-, 105-, or 155-mm-diam filters.

f. Presoaked filters with 0.45-μm pore-size diameter.

g. Plastic sample bottles, 500-ml capacity for storage of water and liquid phase samples for metal and nutrient analyses.

h. Wide-mouth 1-gal-capacity glass jars with Teflon-lined screw-type lids for sample mixing. These jars should also be used as sample containers when samples are to be analyzed for pesticide materials.

Prior to use, all glassware, filtration equipment, and filters should be thoroughly cleaned. Wash all glassware with detergent; rinse five times with tap water; place in a clean 10-percent (or stronger) HCl acid bath for a minimum of 4 hr; rinse five times with tap water; and then rinse five times with distilled or deionized water. Soak filters for a minimum of 2 hr in a 5-M HCl bath and then rinse 10 times with distilled water. It is also a good practice to discard the first 50 ml of water or liquid phase filtered. Wash all glassware to be used in preparation and analysis of pesticide residues using the eight-step procedure given EPA (1980a).

Test procedure

The step-by-step procedure for conducting a modified elutriate test, as shown in Figure 1, is given in the following paragraphs.

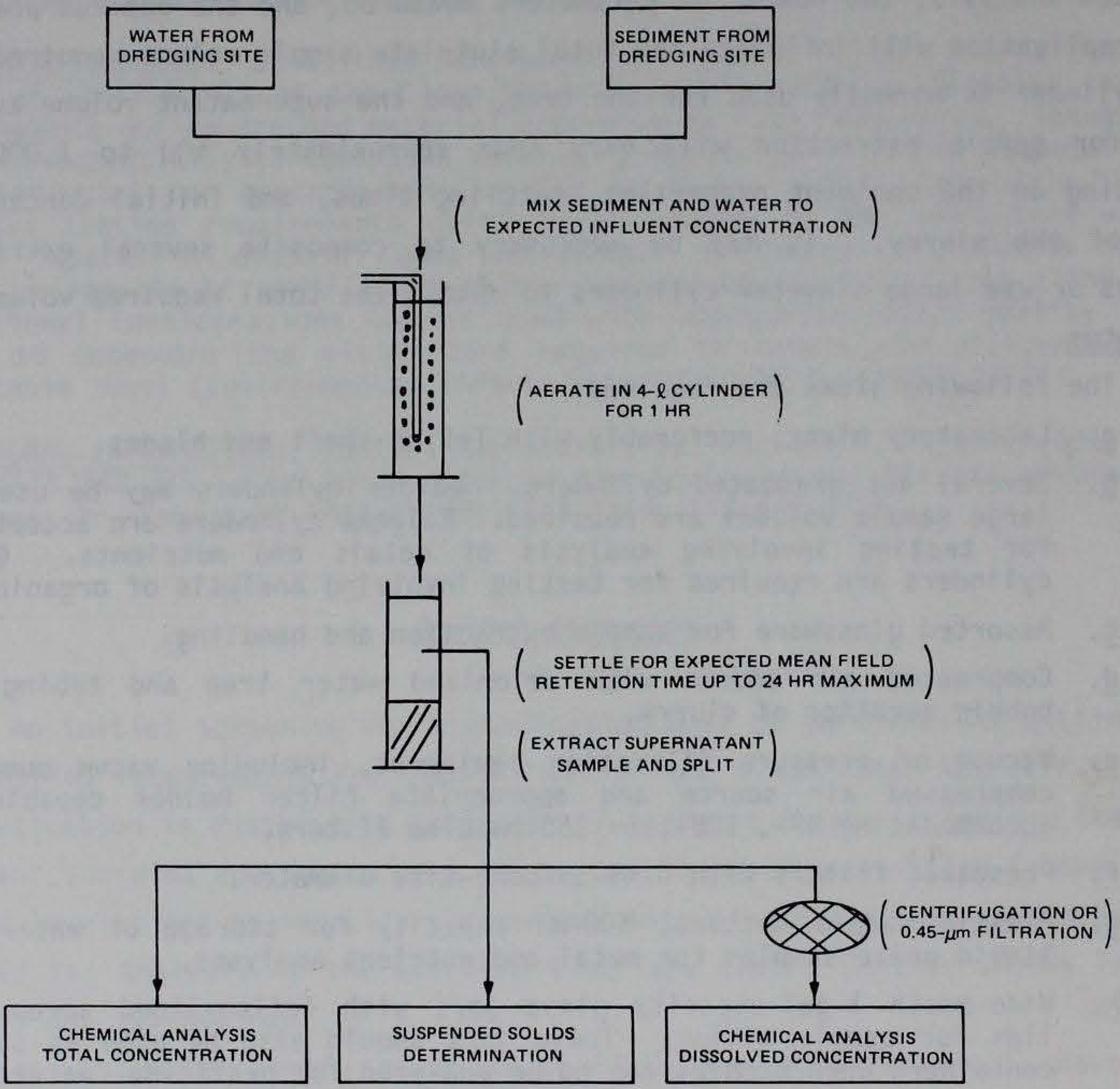

Figure 1. Modified elutriate test procedure

Step 1 - Slurry preparation. The sediment and dredging site water should be mixed to approximately equal the expected average field inflow concentration. If estimates of the average field inflow concentration cannot be made based on past data, a slurry concentration of 150 g/ℓ (dry-weight basis) should be used. Predetermine the concentration of the well-mixed sediment in grams per liter (dry-weight basis) by oven drying a small subsample of known volume. Each 4-ℓ cylinder to be filled will require a mixed slurry volume of 3-3/4 ℓ. The volumes of sediment and dredging site water to be mixed for a 3-3/4-ℓ slurry volume can be calculated using the following expressions:

and

$$V_{sediment} = 3.75 \frac{C_{slurry}}{C_{sediment}} \quad (1)$$

$$V_{water} = 3.75 - V_{sediment} \quad (2)$$

where

$V_{sediment}$ = volume of sediment, liters
3.75 = volume of slurry for 4-ℓ cylinder, liters
C_{slurry} = desired concentration of slurry, grams per liter (dry-weight basis)
$C_{sediment}$ = predetermined concentration of sediment, grams per liter (dry-weight basis)
V_{water} = volume of dredging site water, liters

<u>Step 2 - Mixing</u>. Mix the 3-3/4 ℓ of slurry by placing appropriate volumes of sediment and dredging site water in 1-gal glass jars and mixing for 5 min with a laboratory mixer. The slurry should be mixed to a uniform consistency with no unmixed agglomerations of sediment.

<u>Step 3 - Aeration</u>. Bubble aeration is used to ensure oxidizing conditions in the supernatant water during the subsequent settling phase. Pour the mixed slurry into a 4-ℓ graduated cylinder. Attach glass tubing to the aeration source and insert tubing to the bottom of the cylinder. The tubing can be held in place by insertion through a predrilled No. 4 stopper placed in the top of the cylinder. Compressed air should be passed through a deionized water trap, through the tubing, and bubbled through the slurry. The flow rate should be adjusted to agitate the mixture vigorously, and bubbling should be continued for 1 hr.

<u>Step 4 - Settling</u>. Remove the tubing and allow the aerated slurry to undergo quiescent settling for a time period equal to the anticipated field mean retention time up to a maximum of 24 hr. If the field mean retention time is not known, allow settling for 24 hr. Guidance for estimating the field mean retention is given in Technical Note EEDP-04-3.

<u>Step 5 - Sample extraction</u>. After the settling period, an interface will usually be evident between the supernatant water with low concentration of suspended solids and the more concentrated settled material. Samples of the supernatant water should be extracted from the cylinder at a point midway between the water surface and the interface using syringe and tubing. Care should be taken not to resuspend settled material.

Step 6 - Sample preservation and analysis. The sample should be analyzed as soon as possible after extraction to determine the total suspended solids and the dissolved and total concentrations of selected constitutents. The fraction of a constitutent in the total suspended solids can then be calculated. Filtration using 0.45-μm filters should be used to obtain subsamples for analysis of dissolved concentrations. Samples to be analyzed for dissolved pesticides or PCB must be free of particles but should not be filtered, due to the tendency for these materials to adsorb on the filter. However, particulate matter can be removed before analysis by high-speed centrifugation at 10,000 times gravity using Teflon, glass, or aluminum centrifuge tubes (Fulk et al. 1975). The total suspended solids concentration can also be determined by filtration (0.45 μm). The fraction of a constituent in the total suspended solids is calculated as follows:

$$F_{SS} = (1 \times 10^6) \frac{C_{total} - C_{diss.}}{SS} \qquad (3)$$

where

F_{SS} = fraction of constituent in the total suspended solids, milligrams per kilogram of suspended solids

C_{total} = total concentration of constitutent, milligram per liter of sample

$C_{diss.}$ = dissolved concentration of constituent, milligrams per liter of sample

SS = total suspended solids concentration, milligrams per liter of sample

Subsamples for analyses of total concentrations should undergo appropriate digestion prior to analysis. All digestion and chemical analyses should be performed using accepted procedures (American Public Health Association 1985; EPA 1980a; and EPA 1979).

Samples to be analyzed for pesticides or PCB should immediately undergo solvent extraction. The extract may then be held in clean uncontaminating containers for periods up to three or four weeks at -15 to -20° C before further analyses are performed.

Samples for metals analysis should be preserved immediately by lowering the pH to <2 with 3 to 5 ml of concentrated nitric acid per liter (EPA 1979). High purity acid, either purchased commercially or prepared in a subboiling unit, must be used.

Nutrient analyses should be conducted as soon as possible. Acidification with H_2SO_4 to pH <2 and storage at 4° C will allow the sample to be held for maximum of 24 hr for ammonia nitrogen, Kjeldahl nitrogen, and nitrate nitrogen analyses (EPA 1979). Storage at 4° C will allow holding of samples to be analyzed for dissolved orthophosphate and total dissolved phosphorus for up to 24 hr. Subsamples to be analyzed for cyanide should be preserved with 2 ml of 10 N sodium hydroxide per liter of sample (pH >12) (EPA 1979).

Column Settling Test

Sedimentation tests, performed in 8-in.-diam ported columns as shown in Figure 2, are necessary to provide data for design or evaluation of disposal areas for retention of suspended solids. These tests were originally designed to define the settling behavior of a particular sediment and to provide information concerning the volumes occupied by newly placed layers of dredged material. The test procedures were modified to obtain data for use in predicting the concentration of suspended solids in the effluent.

Sedimentation of freshwater slurries of solids concentration less than 100 g/ℓ can generally be characterized by flocculent settling properties. As solids concentrations exceed 100 g/ℓ, the sedimentation process may be characterized by zone settling properties in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling properties also govern when the sediment/water salinity is greater than 3 ppt. Recent studies have shown that flocculent settling governs behavior of suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface.

Apparatus

A settling column such as shown in Figure 2 is used. The test column depth should approximate the effective settling depth of the proposed disposal area. A practical limit on the depth of test is 6 ft. The column should be at least 8 in. in diameter with interchangeable sections and with sample port at 1-ft or closer intervals in the lower 3 ft and at 1/2-ft intervals in the upper 3 ft. The column should have provisions to bubble air from the bottom to keep the slurry mixed during the column filling period. Shop drawings for construction of the test columns are available from the Waterways Experiment Station.*

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* Address request for the shop drawings to the attention of WESEP-E.

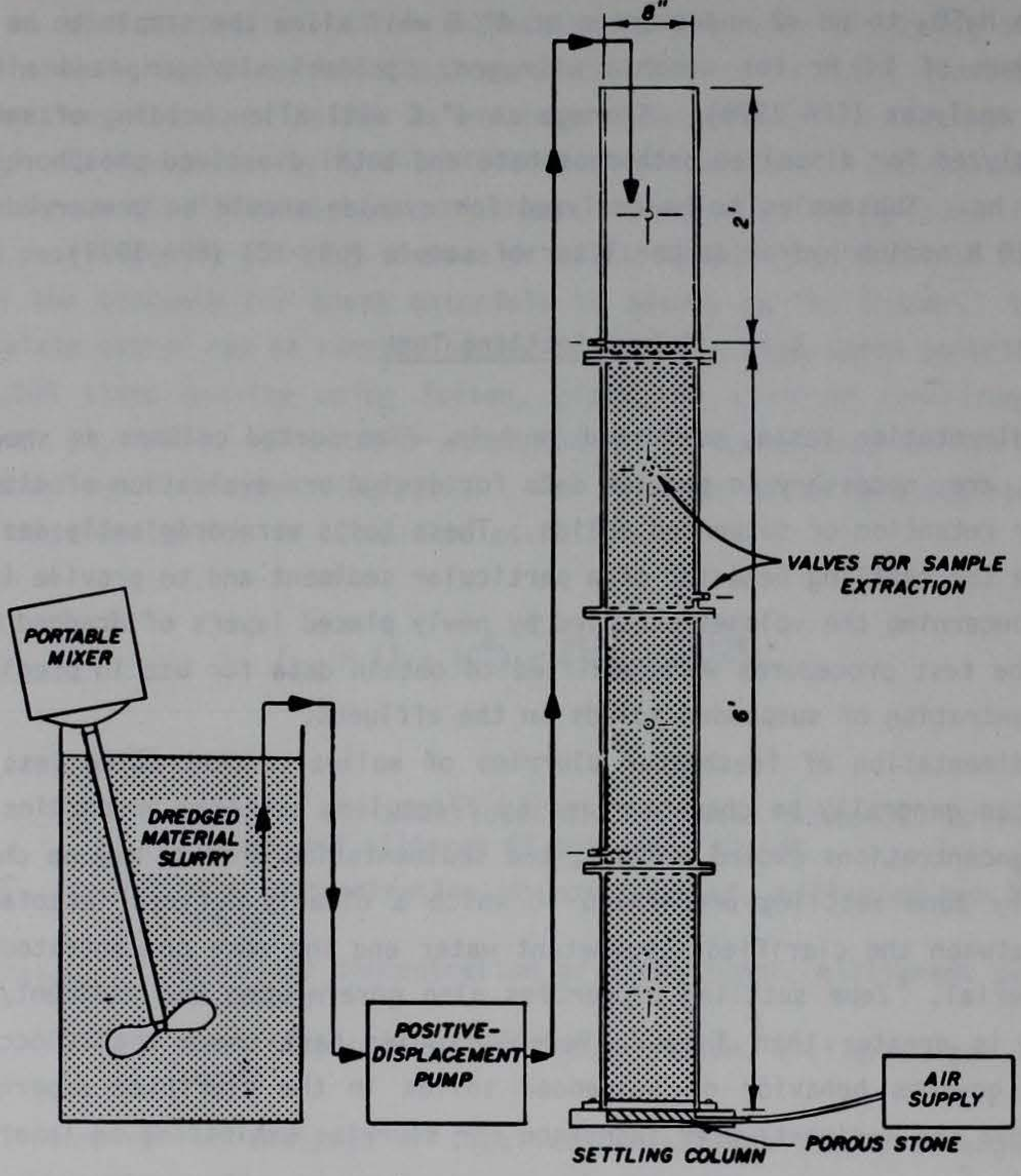

Figure 2. Schematic of apparatus for column settling tests (Montgomery 1978)

Flocculent settling test

Test data required to design or evaluate a disposal area in which flocculent settling governs and to predict the concentration of suspended solids in the effluent can be obtained using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978). The flocculent settling test consists of withdrawing samples from each sample port at regular time intervals to determine the concentration of suspended solids at various depths.

Zone settling test

Information required to design or evaluate a disposal area in which zone settling governs can be obtained by conducting a series of zone settling tests (Montgomery 1978 and Palermo, Montgomery, and Poindexter 1978). One of the tests should be performed on sediment slurries at a concentration equal to the expected mean field inflow concentration. This test should be continued for a period of at least 15 days to provide data for estimating volume requirements and to obtain data for prediction of effluent suspended solids concentrations.

The procedures described below include those modifications of the procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) required to define the flocculent process governing the sedimentation of suspended solids above the interface. The flocculent settling test as modified consists of measuring the concentration of suspended solids at various depths and time intervals by withdrawing samples from the settling column and timing the fall of liquid/solids interface.

Step 1 - Slurry preparation and loading. Mix the sediment slurry to the desired suspended solids concentration in a container with sufficient volume to fill the test column. The test should be performed at the concentration C_i selected to represent the anticipated concentration of the dredged material influent. Field studies indicate that for maintenance dredging in fine-grained material, the disposal concentration will average about 150 g/ℓ. This value may be used for C_i if no better data are available.

Step 2 - Settling and sampling. For sediments exhibiting zone settling behavior, an interface will form between the more concentrated settled material and the clarified supernatant water. The first sample should be extracted immediately after the interface has fallen sufficiently below the uppermost port to allow extraction. This sample can usually be extracted within a few hours after initiation of the test, depending on the initial slurry concentration and the spacing of ports.

As the interface continues to fall, extract samples from all ports above the interface at regular time intervals. Substantial reductions of suspended solids will occur during the early part of the test, but reductions will lessen at longer retention times. Therefore, the intervals can be extended as the test progresses. A suggested sequence of intervals would be 2, 4, 8, 12, 24, 48, 96 hr, etc. Continue to take samples throughout the 15-day test or until the suspended solids concentration of the extracted samples shows no decrease. Record the time of extraction and the port height for each port sample taken (Figure 3).

COLUMN SETTLING DATA

(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/ℓ	(4) PERCENT OF INITIAL CONCENTRATION φ	
3	0.2	93		
	1.0	169		
7	1.0	100		
	2.0	105		
14	1.0 2.0	45 43		
	3.0	50		
24	1.0	19		
	2.0	18		
	3.0	20		
48	1.0	15		
	2.0	7		
	3.0	4		

NOTES: COLUMNS 1 AND 2 - RECORD FOR EACH PORT SAMPLE.
COLUMN 3 - COMPLETE FROM TEST RESULTS.
COLUMN 4 - COMPUTE USING THE HIGHEST SUSPENDED SOLIDS CONCENTRATION OF THE FIRST PORT SAMPLE AS THE INITIAL CONCENTRATION SS_0.

Figure 3

References

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EEDP-04-3
JUNE 1985

Environmental Effects of Dredging
Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--DATA ANALYSIS

PURPOSE: The following series of technical notes described the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during dredging operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle associated. The modified elutriate tests was developed for use in predicting

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* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

US Army Engineer Waterways Experiment Station, Environmental Laboratory
PO Box 631, Vicksburg, Mississippi 39180-0631

both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Data Analysis

The results of the column settling tests are used to determine the concentrations of suspended solids in the effluent from a confined disposal site.

Sedimentation of freshwater slurries with solids concentrations of less than 100 g/ℓ are generally characterized by flocculent settling properties. When solids concentrations exceed 100 g/ℓ, the sedimentation process may be characterized by zone settling properties in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling properties also govern when the sediment/water salinity is greater then 3 ppt. Recent studies have shown that flocculent settling governs behavior of the suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface.

For the flocculent case, the procedures for data analysis given in Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) may be used. For the zone settling case, flocculent settling behavior governs in the supernatant water above the interface. Therefore, a modified flocculent data analysis procedure as outlined in the following paragraphs is required. Example calculations are given in Technical Note EEDP-04-4.

Step 1. Compute values of z, the depth of sampling below the fluid surface as shown in Figure 1. In computing ϕ, the fraction remaining, the highest concentration of the first port samples is considered the initial concentration SS_0.

COLUMN SETTLING DATA				
(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/ℓ	(4) PERCENT OF INITIAL CONCENTRATION ϕ	
3	0.2	93		
	1.0	169	100	
7	1.0	100	59	
	2.0	105	62	
14	1.0	45	27	
	2.0	43	25	
	3.0	50	30	
24	1.0	19	11	
	2.0	18	11	
	3.0	20	12	
48	1.0	15	9	
	2.0	7	4	
	3.0	14	8	

NOTES: COLUMNS 1 AND 2 - RECORD FOR EACH PORT SAMPLE.
COLUMN 3 - COMPLETE FROM TEST RESULTS.
COLUMN 4 - COMPUTE USING THE HIGHEST SUSPENDED SOLIDS CONCENTRATION OF THE FIRST PORT SAMPLE AS THE INITIAL CONCENTRATION SS_0.

Figure 1

Step 2. Plot the values of fractions remaining ϕ and z using column settling data to form a concentration profile diagram (Figure 2). Concentration profiles should be plotted for each time of sample extraction.

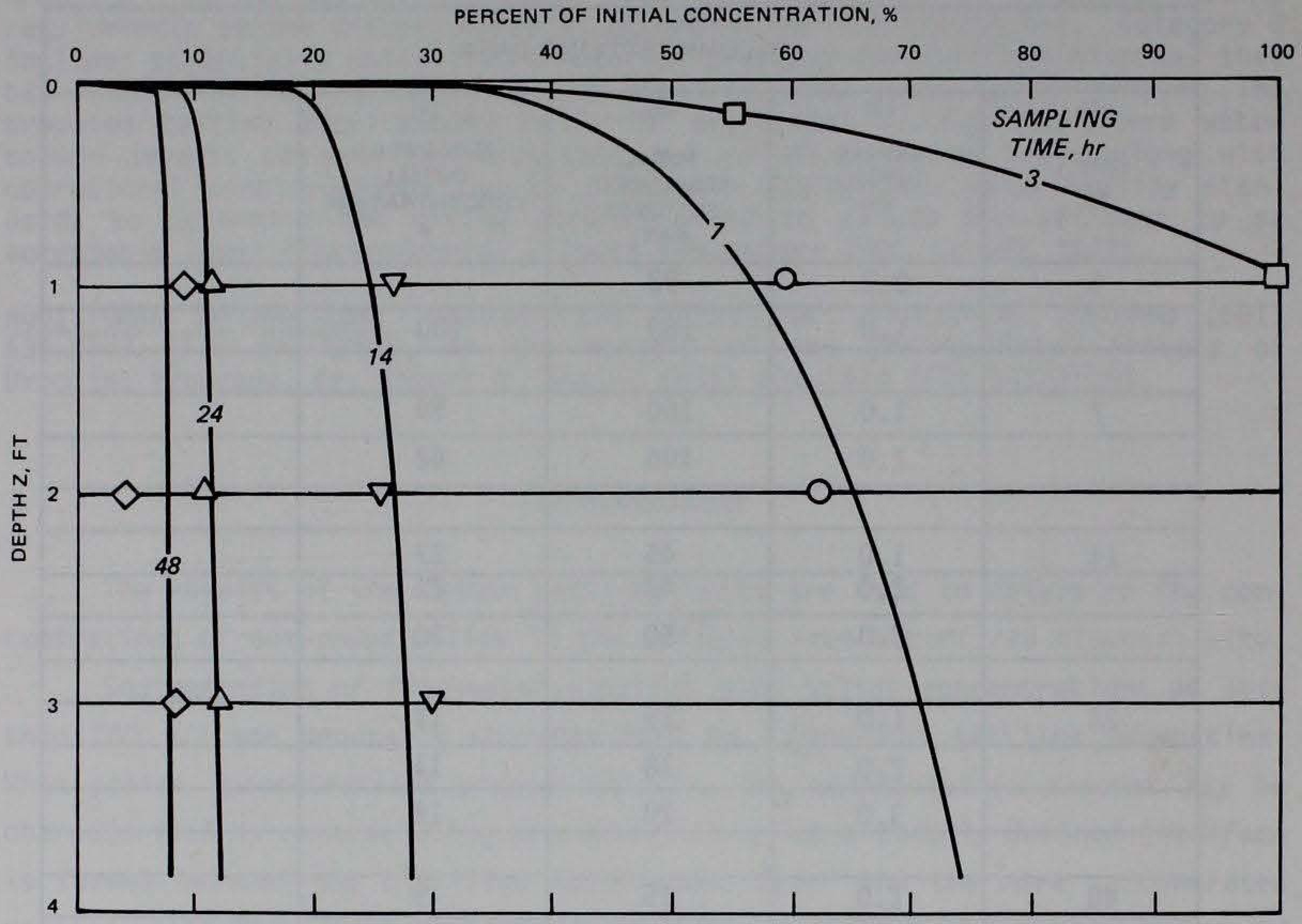

Figure 2. Concentration profile diagram

Step 3. Use the concentration profile diagram to graphically determine R, the percentages of solids removed for the various time intervals for any desired ponding depth D_{pw}. This is done by determining the area to the right of each concentration profile and its ratio to the total area above the depth D_{pw}. The removal percentage R is calculated as follows:

$$R = \frac{\text{Area Right of Profile}}{\text{Total Area}} 100 \tag{1}$$

Step 4. Compute P, the percentage of suspended solids remaining in suspension, as simply 100 minus the percentage removed as follows:

$$P = 100 - R \tag{2}$$

Step 5. Compute values for suspended solids for each time of extraction as follows:

$$SS = P \times SS_0 \tag{3}$$

Tabulate R , and P , and SS for each sampling time.

Step 6. Plot a relationship for suspended solids concentration versus time using the value for each sampling time (Figure 3). An exponential or power curve fitted through the data points is recommended.

By repeating steps 4 through 6 for each of several values of D_{pw} , a family of curves showing suspended solids versus retention time for each of several ponding depths can be developed as shown in Figure 3. These curves can be used for prediction of effluent suspended solids concentrations under quiescent settling conditions for any estimated ponding depth and field mean retention time. Simply enter a curve with the estimated field mean retention time T_d and select the value of suspended solids as estimated from the column test SS_{col} . Guidance for adjusting the value derived from the column test for anticipated resuspension and for estimated field mean retention time is given in the following paragraphs.

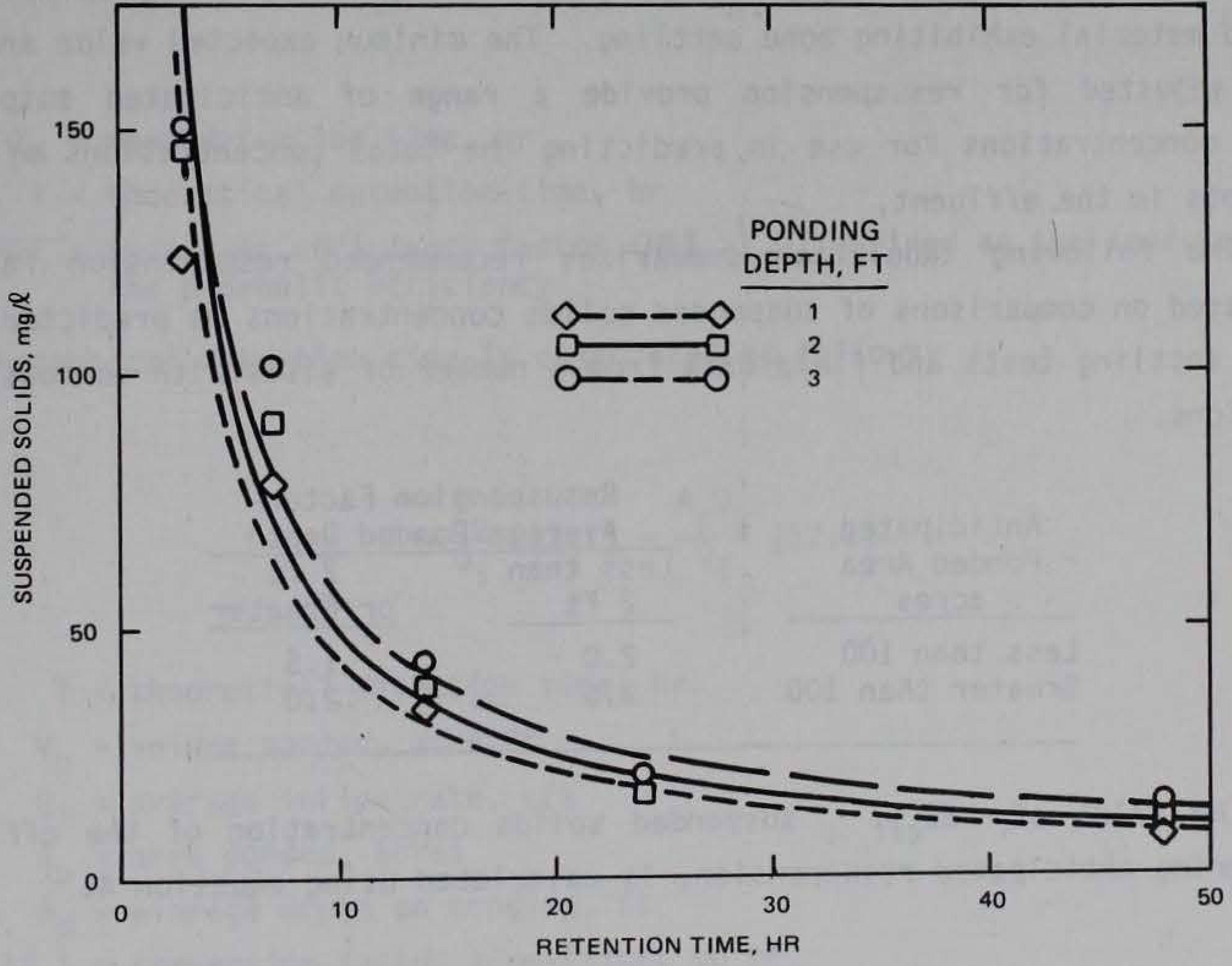

Figure 3. Supernatant suspended solids concentration versus time from column settling test

Effluent Suspended Solids Concentration

A prediction of the concentration of total suspended solids in the effluent must consider the anticipated retention time in the disposal area and must account for the possible resuspension of settled material because of wind effects. The relationship of supernatant suspended solids versus time developed from the column settling test is based on quiescent settling conditions found in the laboratory. The anticipated retention time in the disposal area under consideration can be used to determine a predicted suspended solids concentration from the relationship. This predicted value can be considered a minimum value that could be achieved in the field assuming little or no resuspension of settled material.

For dredged material exhibiting flocculent settling behavior, the concentration of particles in the ponded water is on the order of 1 g/ℓ or higher. The resuspension resulting from normal wind conditions will not significantly increase this concentration; therefore, an adjustment for resuspension is not required for the flocculent settling case.

However, an adjustment for anticipated resuspension is appropriate for dredged material exhibiting zone settling. The minimum expected value and the value adjusted for resuspension provide a range of anticipated suspended solids concentrations for use in predicting the total concentrations of contaminants in the effluent.

The following tabulation summarizes recommended resuspension factors (RF) based on comparisons of suspended solids concentrations as predicted from column settling tests and field data from a number of sites with various site conditions.

Anticipated Ponded Area acres	Resuspension Factor-Average Ponded Depth: Less than 2 ft	Resuspension Factor-Average Ponded Depth: 2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

The value of SS_{eff}, suspended solids concentration of the effluent considering anticipated resuspension, is calculated using equation 4.

$$SS_{eff} = SS_{col} \times RF \tag{4}$$

where

SS_{eff} = suspended solids concentration of effluent considering anticipated resuspension, milligrams per liter of water

SS_{col} = suspended solids concentration of effluent estimated from column settling tests, milligrams per liter of water

RF = resuspension factor

Field Mean Retention Time

Estimates of the field mean retention time for expected operational conditions are required for selecting appropriate settling times in the modified elutriate test and for determination of suspended solids concentrations in the effluent. Estimates of the retention time must consider the hydraulic efficiency of the disposal area, defined as the ratio of mean retention time to theoretical retention time. Field mean retention time T_d can be estimated for given flowrate and ponding conditions by applying a hydraulic efficiency factor to the theoretical detention time T as follows:

$$T_d = \frac{T}{HEF} \tag{5}$$

where

T_d = mean detention time, hr

T = theoretical detention time, hr

HEF = hydraulic efficiency factor (HEF >1.0) defined as the inverse of the hydraulic efficiency

The theoretical detention time is calculated as follows:

$$T = \frac{V_p}{Q_i}\,(12.1) = \frac{A_pD_p}{Q_i}\,(12.1) \tag{6}$$

where

T = theoretical detention time, hr

V_p = volume ponded, acre-ft

Q_i = average inflow rate, cfs

A_p = area ponded, acres

D_p = average depth on ponding, ft

12.1 = conversion factor acre-ft/cfs to hr

The hydraulic efficiency factor HEF can be estimated by several methods. The most accurate estimate for existing sites is made from field dye-tracer data previously obtained at the site under operational conditions similar to those for the operation under consideration. Guidance for conducting such field tests is presented by Schroeder et al. (in preparation).

Hydraulic flow models can also be used to evaluate the effiency factor. Koussis, Saenz, and Thackston* recommended steady-state two-dimensional models for such evaluations. Development of such techniques is still under study (Schroeder et al. in preparation).

In absence of dye-tracer data or values obtained from other theoretical approaches, the HEF can be assumed based on values obtained by dye-tracer studies at similar sites and under similar conditions. Montgomery (1978) recommended at a value for HEF of 2.25 based on field studies conducted at several sites.

Total Concentrations of Contaminants

For each contaminant of interest, the modified elutriate test procedure defines the dissolved concentration and the fraction of the particle-associated contaminant in the total suspended solids under quiescent settling conditions and accounts for geochemical changes occurring in the disposal area during active disposal operations. Using these test results in conjunction with those from column settling tests, the total concentration of the contaminant in the effluent can be determined based on the estimated sedimentation condition as follows:

$$C_{total} = C_{diss.} + \frac{F_{SS} \times SS_{eff.}}{1 \times 10^6} \qquad (7)$$

where

C_{total} = estimated total concentration in effluent, milligrams per liter of water

$C_{diss.}$ = dissolved concentration as determined by modified elutriate tests, milligrams per liter of water

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* A. D. Koussis, M. A. Saenze, and E. L. Thackston. 1982. "Evaluation of Hydraulic Models for Dredged Material Containment Areas," report prepared under contract for the US Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

F_{SS} = fraction of contaminant in the total suspended solids as calculated from modified elutriate results, milligrams per kilogram of suspended solids

$SS_{eff.}$ = suspended solids concentration of effluent as estimated from evaluation of sedimentation performance, milligrams per liter of water

1×10^6 = conversion of milligrams per milligram to milligrams per kilogram

The acceptability of the proposed confined disposal operation can then be evaluated by comparing the predicted total contaminant concentrations with applicable water quality standards, considering an appropriate mixing zone. (Environmental Effects Laboratory 1976, EPA/CE 1977).

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Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharge of Dredged Material into Navigable Waters," Miscellaneous Paper D-76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

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EEDP-04-4
June 1985

Environmental Effects of Dredging Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--APPLICATION

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during disposal operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle

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* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

US Army Engineer Waterways Experiment Station, Environmental Laboratory
PO Box 631, Vicksburg, Mississippi 39180-0631

associated. The modified elutriate test was developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of disposal area effluents. Predicted contaminant levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Example 1: Evaluation of Effluent Water Quality for an Existing Disposal Area

Project information

Dredged material from a maintenance project will be placed in an existing disposal site. The site will be ponded over an area of approximately 35 acres. The design indicated that the surface area was adequate for effective sedimentation if a minimum ponding depth D_{pw} of 2 ft was maintained. The dredging equipment and anticipated pumping conditions will result in a flowrate of approximately 30 cfs. A field mean retention time of 20 hr was determined from a dye tracer test run during earlier disposal operations at this site under similar operational conditions. Previous sampling of inflow from the dredged pipe under similar conditions indicated an influent solids concentrations of approximately 150 g/ℓ.

The quality of effluent must be predicted and compared to applicable water quality standards so that the acceptability of the proposed discharge can be evaluated. A mixing evaluation was conducted, and a dilution factor of 38 was determined for the allowable mixing zone. The water quality standard for copper at the perimeter of the mixing zone was set at 0.004 mg/ℓ (whole water). The concentration of copper in the effluent at the point of discharge must, therefore, be less than 0.15 mg/ℓ.

Modified elutriate test

Modified elutriate tests were conducted on samples of sediment and water from three stations at the proposed dredging site. Modified elutriate tests were run at the anticipated influent solids concentration C_{slurry} of 150 g/ℓ. Sediment samples from each sampling station were homogenized.

For one of the homogenized samples, a sediment solids concentration $C_{sediment}$ of 450 g/ℓ was determined by oven drying a sample of known volume. The volumes of sediment and water to be mixed to obtain 3-3/4 ℓ of slurry with 150 g of solids per liter was determined as follows:

$$V_{sediment} = 3.75 \frac{C_{slurry}}{C_{sediment}} = 3.75 \frac{150}{450} = 1.25 \qquad (1)$$

$$V_{water} = 3.75 - V_{sediment} = 3.75 - 1.25 = 2.50 \qquad (2)$$

The modified elutriate tests were completed as described in Technical Note EEDP-04-2. A settling time of 20 hr was used since that was the estimated field retention for this case. Samples were extracted for the replicate tests and analyzed for total suspended solids and both dissolved and total concentration of contaminants of concern.

The total suspended solids concentration SS in one of the extracted samples was 40 mg/ℓ. The dissolved concentration C_{diss} of copper in this sample was 0.06 mg/ℓ, while the total concentration C_{total} of copper was 0.08 mg/ℓ. The fraction of copper in the total suspended solids F_{SS} for this sample was determined as follows:

$$F_{SS} = 1 \times 10^6 \left(\frac{C_{total} - C_{diss}}{SS} \right)$$

$$= 1 \times 10^6 \left(\frac{0.08 - 0.06}{40} \right) \text{or } 500 \text{ mg/kg SS} \qquad (3)$$

These calculations were repeated for other replicate tests, and the average dissolved and particulate copper concentrations were found to be 0.06 mg/ℓ and 510 mg/kg SS, respectively.

Column settling test

Samples from all stations were homogenized into a composite for column settling tests. The test used for prediction of effluent suspended solids was run at a slurry concentration of 150 g/ℓ, which was equal to the anticipated influent slurry concentration.

The interface was formed early in the test. Samples were extracted from all ports above the interface at 3, 7, 14, 24, and 48 hr. The recorded observation and the subsequent computations are shown in Figure 1.

Since an interface formed in the test, the slurry mass was undergoing zone settling. Therefore, the initial supernatant solids concentration SS_0 was assumed equal to the highest concentration of the first port samples taken, 169 mg/ℓ. In computing ϕ and constructing the concentration profile diagram (Figure 2), 169 mg/ℓ was used as $\phi = 100$ percent .

The concentration profile diagram (Figure 2) was used for graphical determination of R , the percentage of solids removed, for the various time intervals at $z = 1$, 2, and 3 ft, which was the range of anticipated depths of withdrawal influence at the weir. This was done by using a planimeter to measure the area to the right of each concentration profile (defined by circled numbers in the figure) and computing its ratio to the total area above 1, 2, and 3 ft.

An example calculation of removal percentage for the concentration profile at $T = 14$ hr and a depth of influence of 2 ft is as follows:

$$R_{14} = \frac{\text{Area Right of Profile}}{\text{Total Area}}\ 100 = \frac{\text{Area 1-2-3-0}}{\text{Area 1-2-4-0}}\ 100 \text{ or 78 percent} \qquad (4)$$

The percentage of solids remaining at $T = 14$ hr was found as follows:

$$P_{14} = 100 - R_{14} = 100 - 78 \text{ or 22 percent} \qquad (5)$$

The value for the suspended solids remaining at $T = 14$ hr was determined as follows:

$$SS_{14} = \frac{P_{14}}{100} \times SS_0 = 0.22 \times 169 \text{ or 37 mg/ℓ} \qquad (6)$$

Values at other times were determined in a similar manner. The data for the 2-ft depth of influence were compiled as shown in the following tabulation.

Sample Extraction Time t , hr	Removal Percentage R_t	Remaining Percentage P_t	Suspended Solids SS, mg/ℓ
3	14	86	145
7	47	53	90
14	78	22	37
24	90	10	17
48	94	6	10

COLUMN SETTLING DATA

(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/ℓ	(4) PERCENT OF INITIAL CONCENTRATION ϕ	
3	0.2	93		
	1.0	169	100	
7	1.0	100	59	
	2.0	105	62	
14	1.0	45	27	
	2.0	43	25	
	3.0	50	30	
24	1.0	19	11	
	2.0	18	11	
	3.0	20	12	
48	1.0	15	9	
	2.0	7	4	
	3.0	14	8	

NOTES: COLUMNS 1 AND 2 - RECORD FOR EACH PORT SAMPLE.
COLUMN 3 - COMPLETE FROM TEST RESULTS.
COLUMN 4 - COMPUTE USING THE HIGHEST SUSPENDED SOLIDS CONCENTRATION OF THE FIRST PORT SAMPLE AS THE INITIAL CONCENTRATION SS_0.

Figure 1

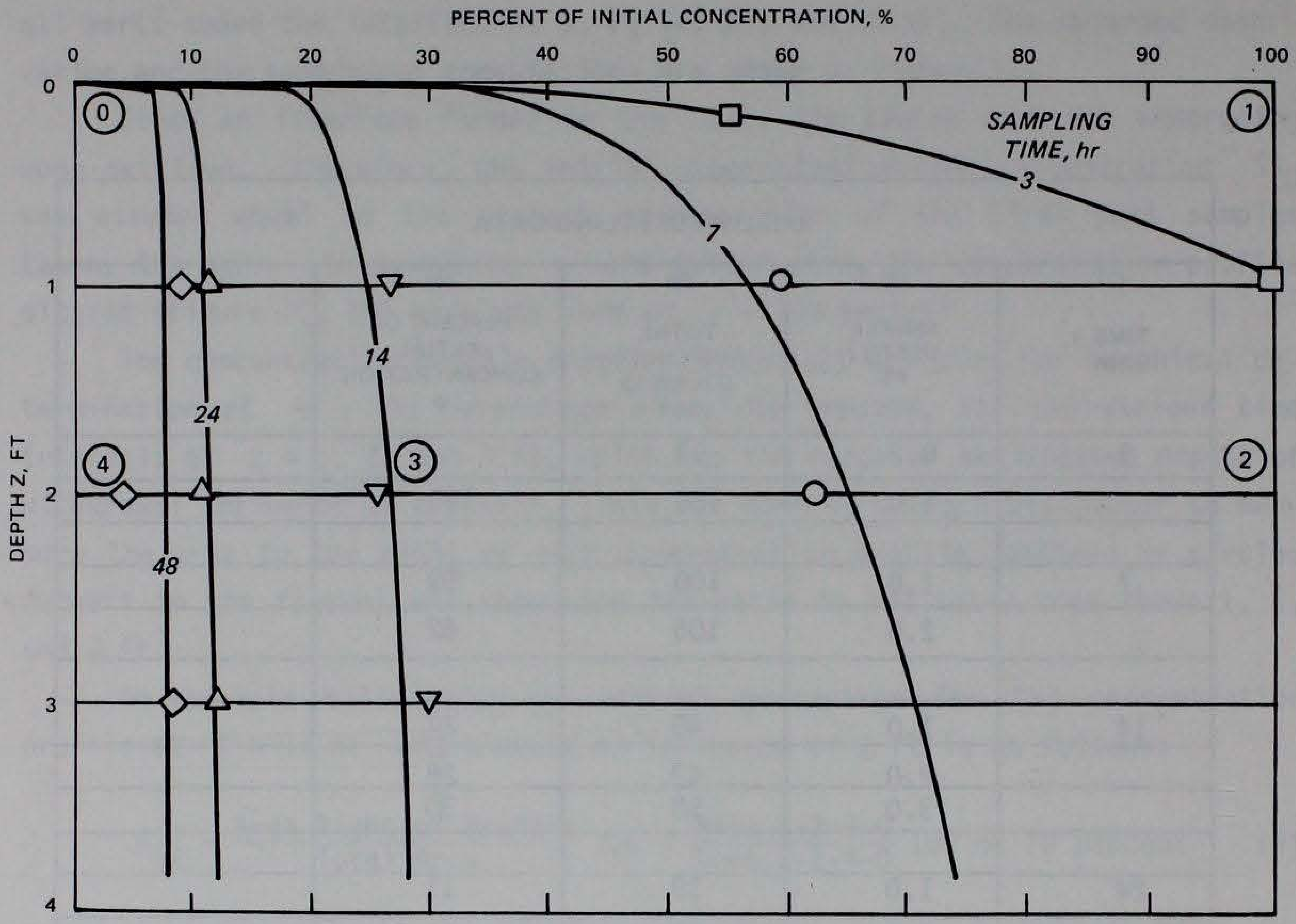

Figure 2. Concentration profile diagram

Similar calculations for other depths of influence were made. Curves were fitted to the total suspended solids versus retention time for depths of influence of 1, 2, and 3 ft, as shown in Figure 3.

Prediction of effluent suspended solids concentration

A value for effluent suspended solids can be determined for quiescent settling conditions using the column test relationships. In this case, the field mean retention time of 20 hr corresponds to a suspended solids concentration SS_{col} of 24 mg/ℓ, as shown in Figure 3. This value should be adjusted for anticipated resuspension using the resuspension factors as given in Technical Note EEDP-04-3:

Anticipated Ponded Area acres	Resuspension Factor-Average Ponded Depth	
	Less than 2 ft	2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

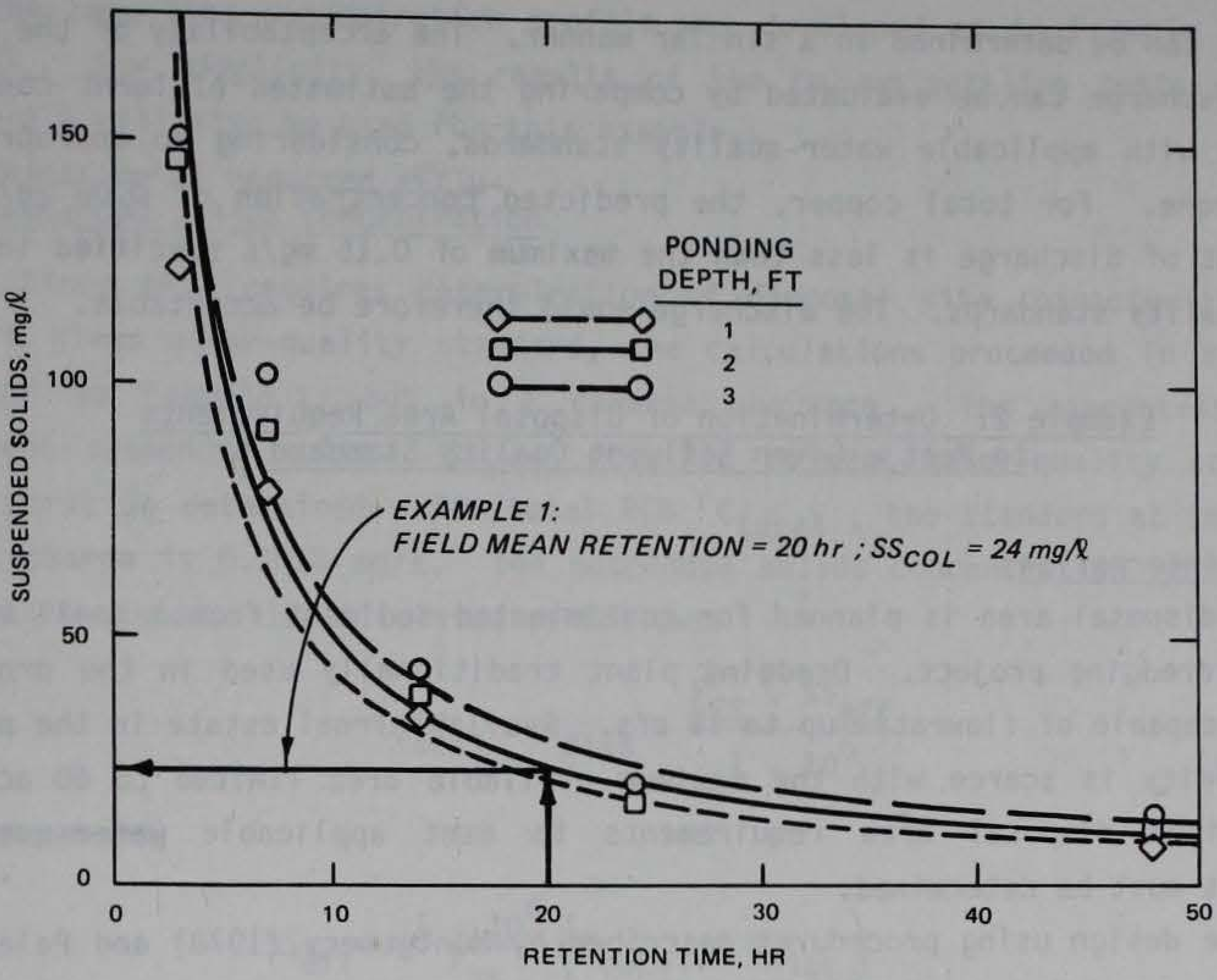

Figure 3. Suspended solids concentration estimated from column settling test

In this case, for a surface area less than 100 acres and average ponding depth of 2 ft, the resuspension factor RF is 1.5. The predicted total suspended solids concentration SS_{eff} in the effluent is calculated as follows:

$$SS_{eff} = SS_{col} \times RF = 24 \text{ mg}/\ell \times 1.5 \text{ or } 36 \text{ mg}/\ell \qquad (7)$$

Prediction of contaminant concentrations

The modified elutriate test results indicated that the concentration of dissolved copper C_{diss} would be 0.06 mg/ℓ and that the fraction of copper in the total suspended solids F_{SS} would be 510 mg/kg. The predicted total suspended solids concentration in the effluent SS_{eff} is 36 mg/ℓ . The predicted concentration of total copper in the effluent C_{total} is calculated as follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} = 0.06 + \frac{510 \times 36}{1 \times 10^6} = 0.078 \text{ or } 0.08 \text{ mg}/\ell \qquad (8)$$

The estimated concentrations of other contaminants in the disposal area effluent can be determined in a similar manner. The acceptability of the proposed discharge can be evaluated by comparing the estimated effluent concentrations with applicable water-quality standards, considering an appropriate mixing zone. For total copper, the predicted concentration of 0.08 mg/ℓ at the point of discharge is less than the maximum of 0.15 mg/ℓ specified in the water-quality standards. The discharge would therefore be acceptable.

Example 2: Determination of Disposal Area Requirements to Meet a Given Effluent Quality Standard

Project information

A disposal area is planned for contaminated sediment from a small maintenance dredging project. Dredging plant traditionally used in the project area is capable of flowrates up to 15 cfs. Available real estate in the project vicinity is scarce with the maximum available area limited to 60 acres. The minimum disposal area requirements to meet applicable water-quality standards must be determined.

The design using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) indicated that a minimum ponded surface of 20 acres was required for effective sedimentation, assuming a flow rate of 15 cfs and a minimum ponding depth of 2 ft. A mixing evaluation was conducted and a dilution factor of 60 was determined for the allowable mixing zone. The water-quality standard for PCB at the perimeter of the mixing zone was set at 0.00003 mg/ℓ . The concentrations of PCB in the effluent (at the point of discharge) must therefore be less than 0.0018 mg/ℓ to meet the standards, considering an appropriate mixing zone.

Modified elutriate test

Modified elutriate tests were conducted and calculations made as described for Example 1. For this example, the mean field retention time for the proposed disposal area was not known, so the maximum laboratory retention of 24 hr was used for the tests. Since the inflow concentration was not known, the tests were run at a slurry concentration of 150 g/ℓ . Results for replicate tests for this example were 0.001 mg/ℓ for the concentration of dissolved PCB C_{diss} and 44 mg/kg for the fraction of PCB in the total suspended solids F_{SS}.

Column settling test

Column settling tests were run at a slurry concentration of 150 g/ℓ , and the resulting concentration profile was developed as in Example 1 (Figure 2). For simplicity, the results of the column settling tests used in Example 1 will also be used for this example.

Determination of required effluent suspended solids concentration

Since this requires determination of disposal site characteristics to meet a given water-quality standard, the calculations proceeded in a manner similar to Example 1, but in a reverse sequence. The concentration of effluent suspended solids SS_{eff} required to meet water-quality standards must first be determined. For total PCB C_{total}, the standard at the point of discharge is 0.0018 mg/ℓ. The suspended solids concentration required to meet this standard is calculated as follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} \tag{9}$$

or transposed,

$$SS_{eff} = \frac{1 \times 10^6}{F_{SS}} \left(C_{total} - C_{diss} \right)$$

$$= \frac{1 \times 10^6}{44.0} (0.0018 - 0.001) \text{ or } 18 \text{ mg}/\ell$$

Based on this calculation, the effluent suspended solids concentration cannot exceed 18 mg/ℓ without exceeding the standard for PCB. Similar determinations should be made for other contaminants being considered in order to define the limiting value for the required effluent suspended solids concentration. For this example, 18 mg/ℓ was used as the limiting value.

Since the final site configuration is not known, a conservative resuspension factor RF should be selected from the tabulation given in Example 1. The minimum ponding depth of 2 ft required by the site design is used. A resuspension factor of 1.5 was selected corresponding to an area less than 100 acres and ponding depth of 2 ft.

The value of 18 mg/ℓ suspended solids (including resuspended particles) must be met at the point of discharge. The corresponding value for total suspended solids concentration under quiescent settling condition is determined by transposing Equation 7 ($SS_{eff} = SS_{col} \times RF$) as follows:

$$SS_{col} = \frac{SS_{eff}}{RF} = \frac{18 \text{ mg}/\ell}{1.5} \text{ or } 12 \text{ mg}/\ell$$

The required configuration of the disposal area must correspond to a retention time that will allow the necessary sedimentation. The required retention time to achieve 12 mg/ℓ under quiescent settling conditions can be determined from the laboratory column relationship for suspended solids versus retention time.

Using the concentration profile data and the assumed depth of ponding at the weir of 2 ft, the relationship for suspended solids versus field mean retention was developed as shown in Figure 4. Using Figure 4, 12 mg/ℓ corresponds to a field mean retention time T_d of 36 hr. To determine the required disposal site geometry, the theoretical retention time T should be used. Since no other data were available, the hydraulic efficiency factor HEF was assumed as 2.25. The theoretical retention time T was calculated as follows:

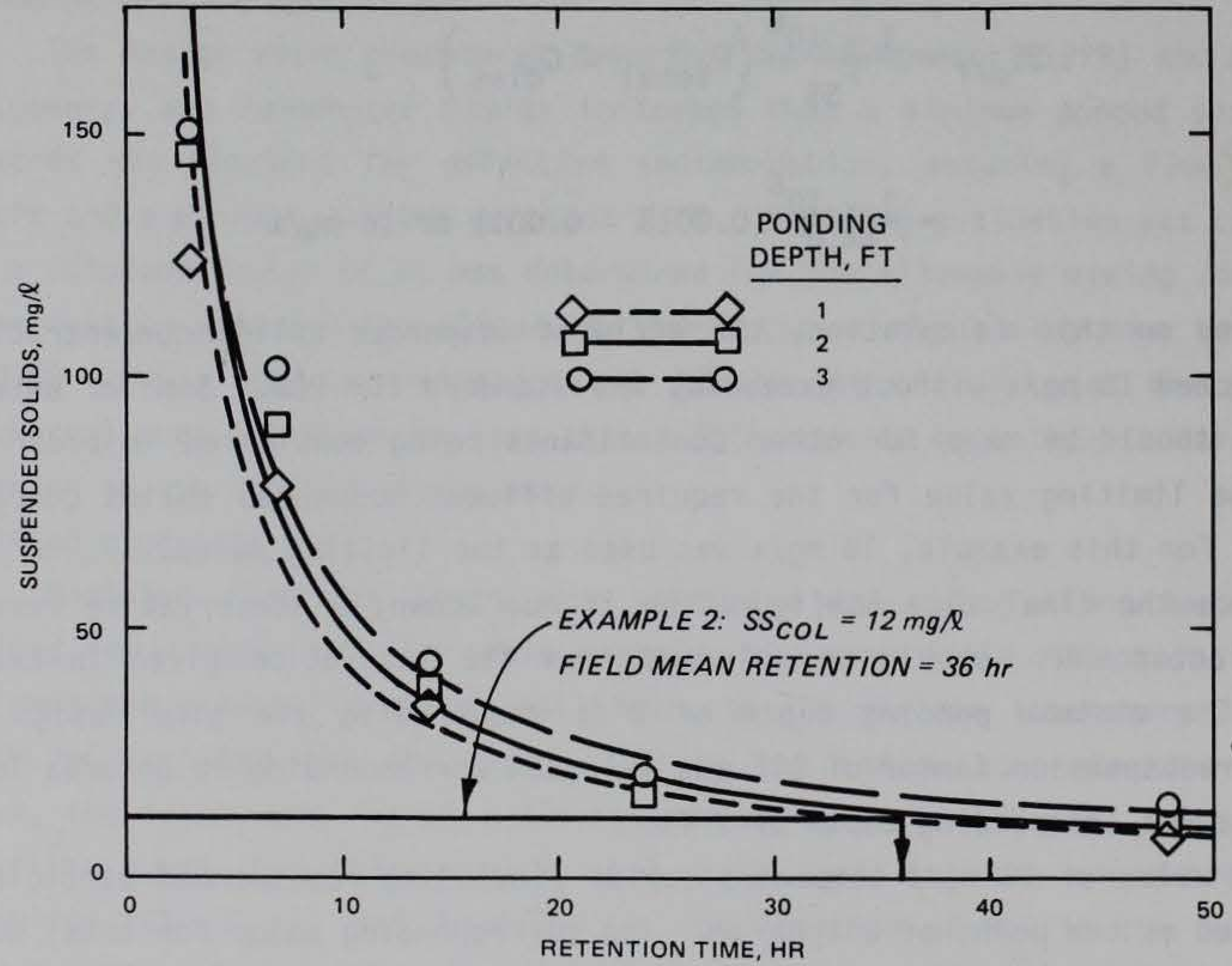

Figure 4. Field mean retention time estimated from column settling test

$$t_d = \frac{T}{(HEF)} \tag{10}$$

transposed to

$$T = T_d\ (HEF) = 36\ (2.25) \text{ or } 81 \text{ hr}$$

Determination of
<u>disposal area configuration</u>

The disposal area configuration can now be determined using data on anticipated flowrate and the required retention time. Since the dredging equipment available in the project area is capable of flowrates up to 15 cfs, the high value should be assumed.

The pond volume required is calculated as follows:

$$T = \frac{V_p}{Q_i}\ (12.1) \tag{11}$$

transposed to

$$V_p = \frac{T\ Q_i}{12.1} = \frac{81 \text{ hr} \times 15 \text{ cfs}}{12.1} \text{ or } 100 \text{ acre-ft}$$

A ponding depth of 2 ft is the minimum required. This same depth should be maintained over the entire ponded surface area and at the weir. The disposal site should, therefore, encompass approximately 50 acres of ponded surface area if the dredge selected for the project has an effective flowrate not greater than 15 cfs. The surface area of 50 acres required to meet the water-quality standard controls over the design surface area of 20 acres required for effective sedimentation.

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APPENDIX B: DATA PLOTS

This appendix presents plots of influent and effluent contaminant concentrations and other measured parameters for the five field evaluations described in this study. Figures B1 through B6 show the plotted means and standard deviations for both the field data and laboratory-based predicted values. The individual data points for measured field influent and effluent concentrations are reproduced on microfiche, enclosed in an envelope attached to the inside back cover.

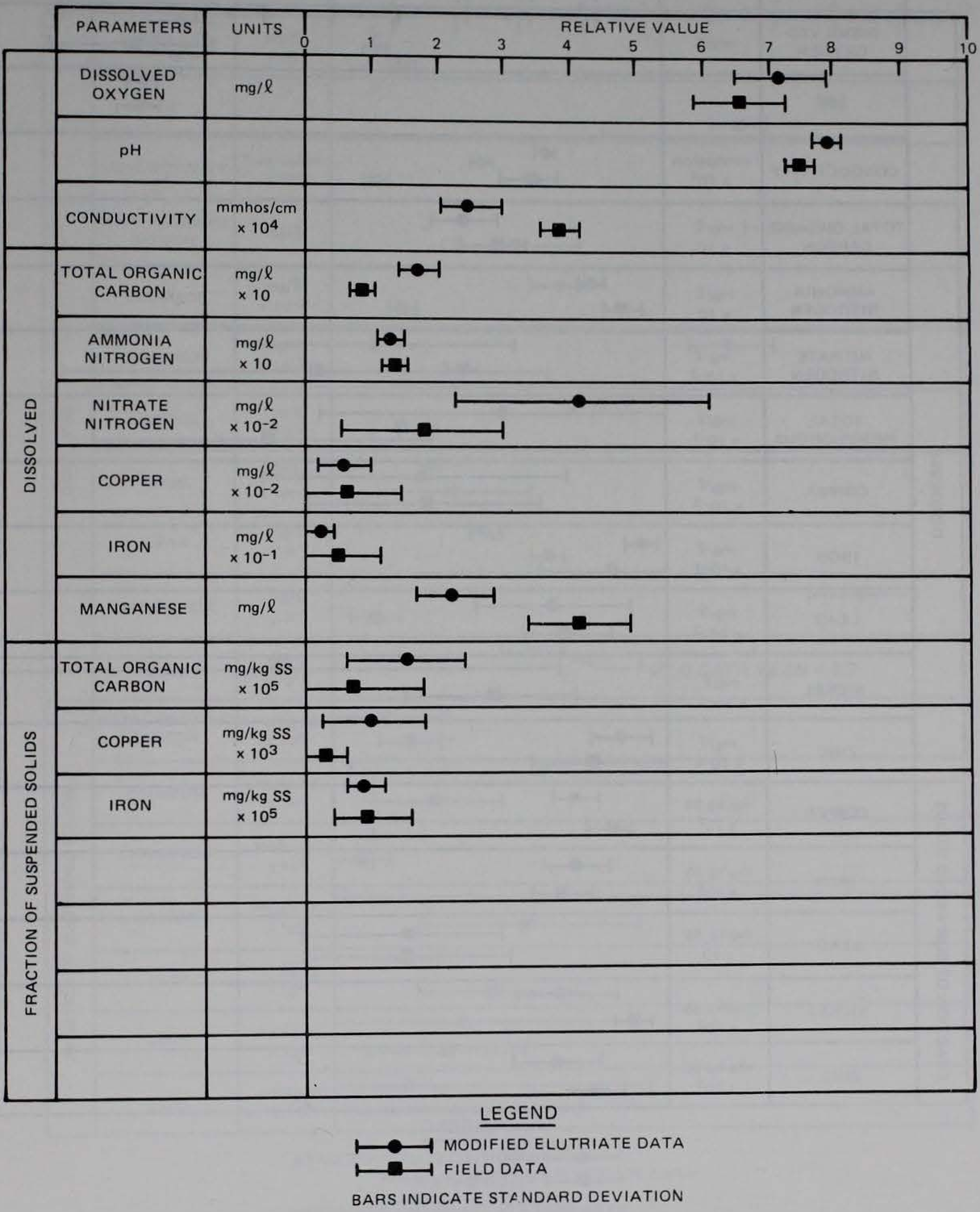

Figure B1. Plot of means and standard deviations for modified elutriate laboratory test and measured field data, Mobile Harbor

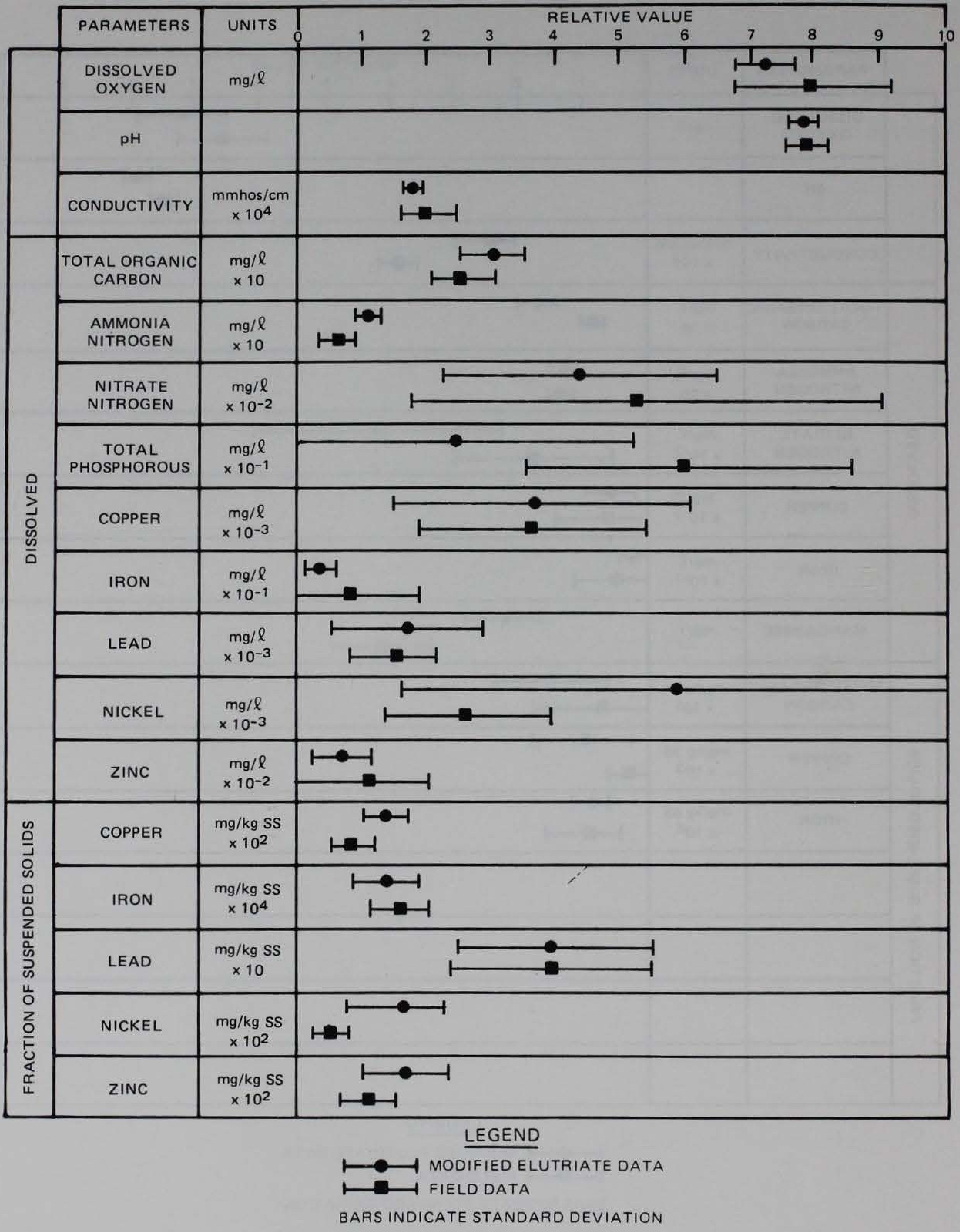

Figure B2. Plot of means and standard deviations for modified elutriate laboratory test and measured field data, Savannah Harbor

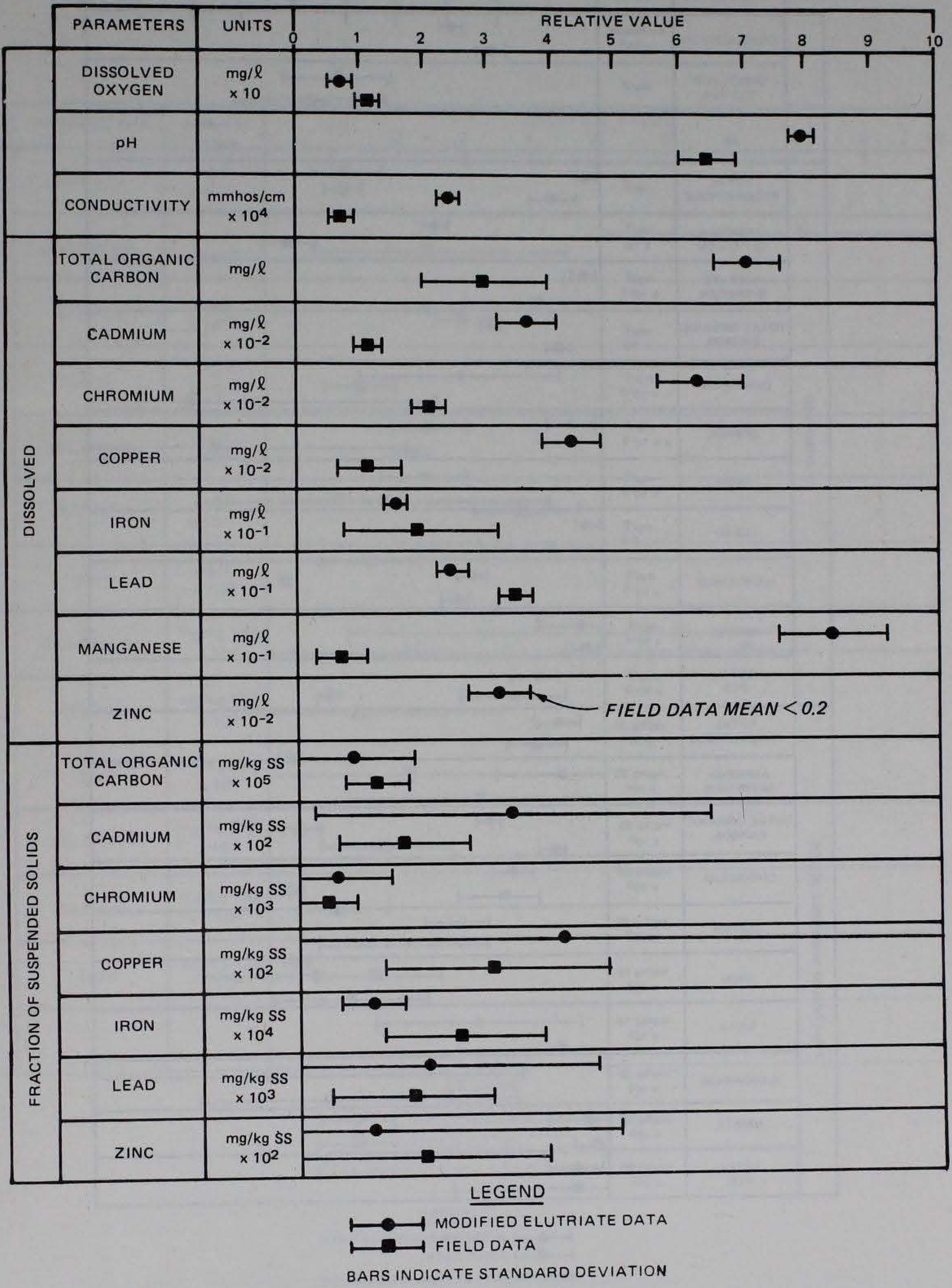

Figure B3. Plot of means and standard deviations for modified elutriate laboratory test and measured field data, Norfolk Harbor

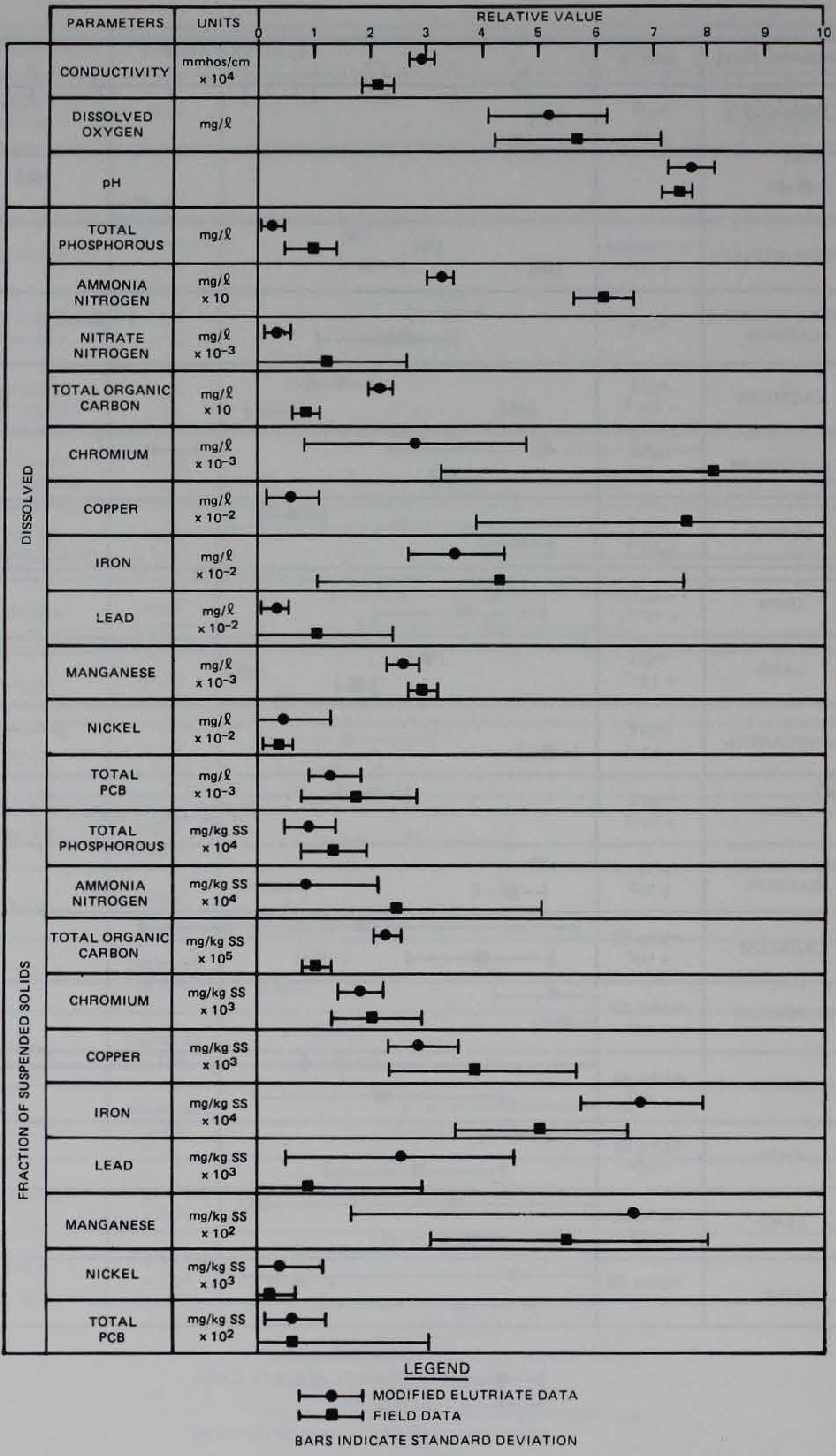

Figure B4. Plot of means and standard deviations of modified elutriate laboratory test and measured field data, Black Rock Harbor

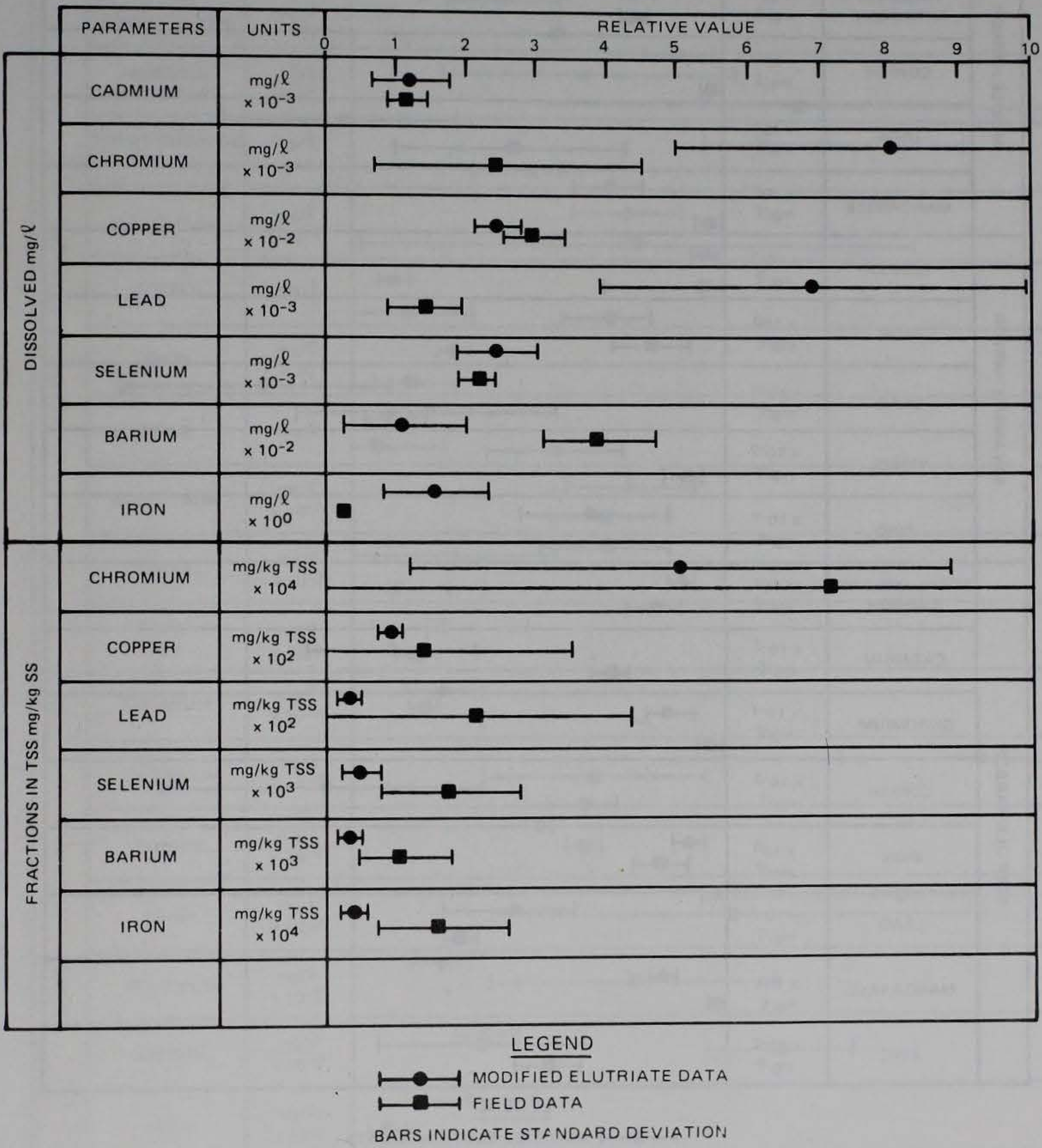

Figure B5. Plots of means and standard deviations of modified elutriate laboratory test and measured field data, Hart Miller Island

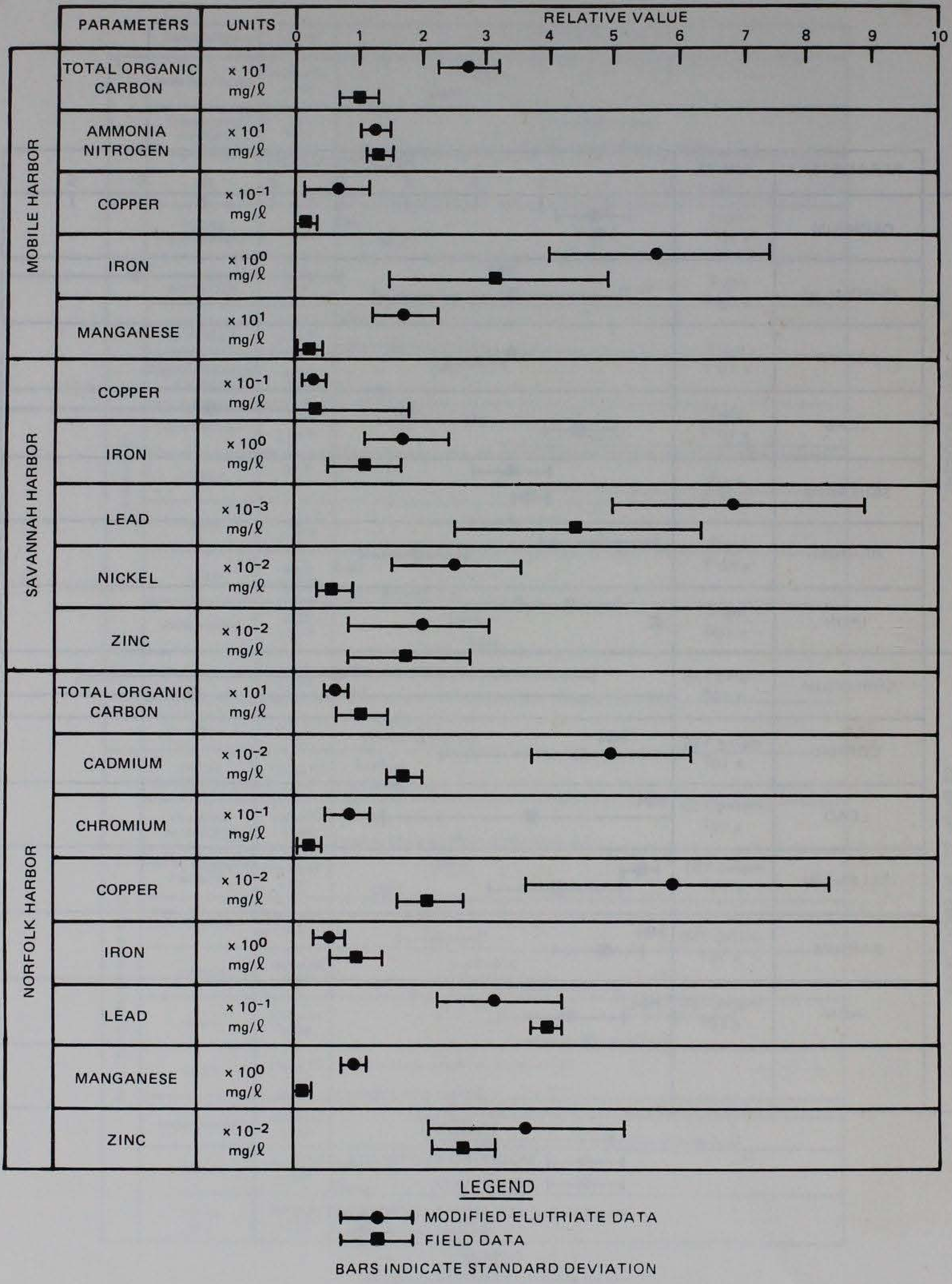

Figure B6. Plots of means and standard deviations for total elutriate concentrations of contaminants of laboratory predicted and measured field data (Continued)

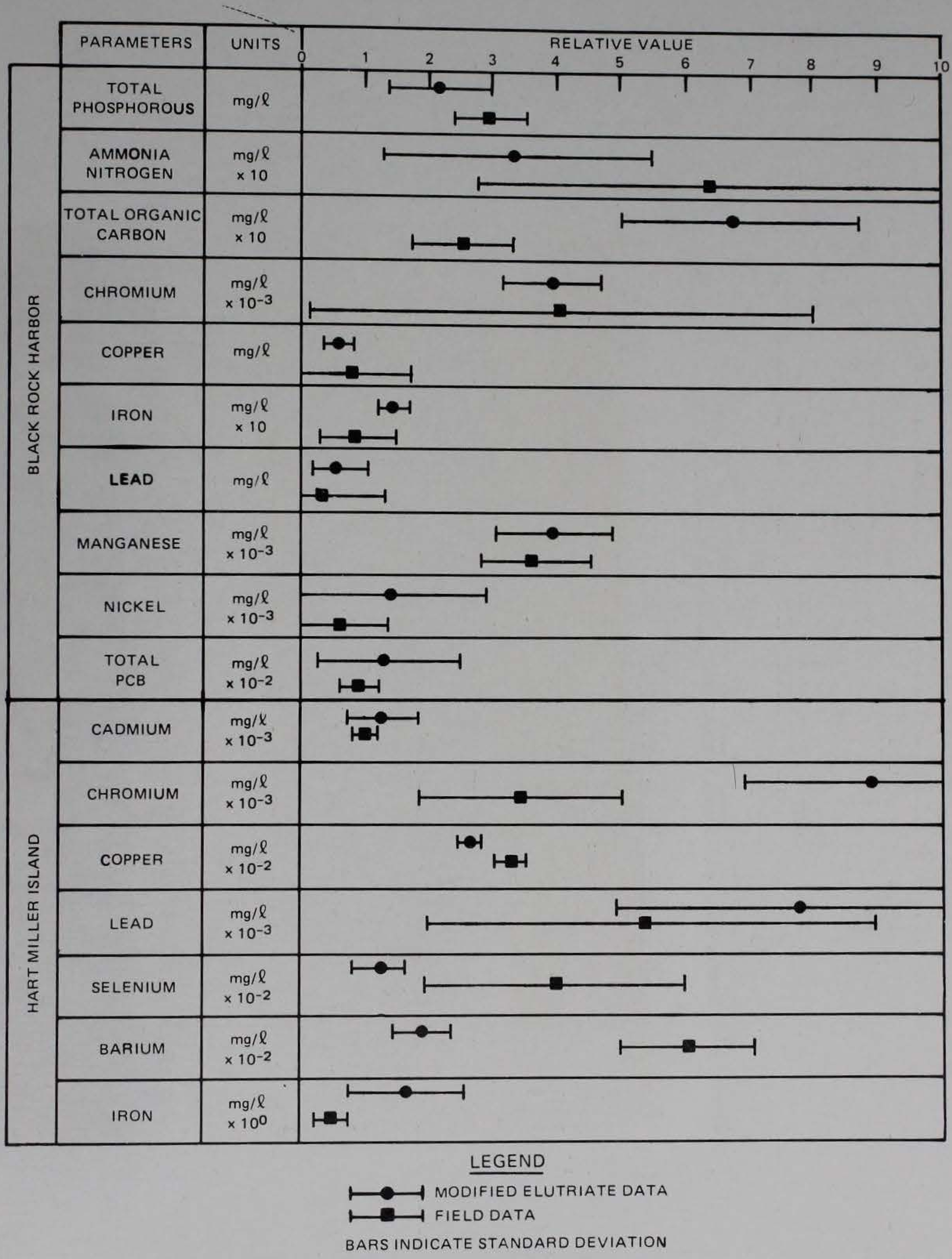

Figure B6. (Concluded)