CHARACTERIZATION OF CONFINED DISPOSAL AREA INFLUENT AND EFFLUENT PARTICULATE AND PETROLEUM FRACTIONS

by

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Final Report

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SUBJECT: Transmittal of Technical Report D-78-16

TO: All Report Recipients

1. The study reported on in the technical report transmitted herewith was undertaken as Work Unit 2D04 of Task 2D, Confined Disposal Area Effluent and Leachate Control, of the Corps of Engineers' Dredged Material Research Program. The major purpose of this task was to determine the potential pollution problems created by the land disposal of dredged material in containment areas, both from effluent and subsurface leachate discharges. Task 2D was a part of the Environmental Impacts and Criteria Development Project, which was concerned with the establishment of criteria for open-water and alternative disposal modes for dredged material.

2. Work Unit 2D04 was an extension of Work Unit 2D01, which evaluated the character of influents and effluents in land containment areas. Two island disposal areas were monitored, the brackish water Pinto Island site near Mobile, Alabama, and the freshwater Grassy Island site near Detroit, Michigan, to achieve the following objectives of Work Unit 2D04:

   a. Through influent-effluent monitoring, determine the physical and chemical changes that can occur in dredged material during land containment.

   b. Use results of effluent and background water monitoring to better characterize the potential impact that effluent discharges might have on receiving waters.

   c. Investigate the association of different contaminant species with different sized particles in effluents and determine the relationship between residence time and removal for some parameters such as oil and grease.

   d. Determine the association of trace metals and synthetic organo-chlorine compounds (e.g., PCBs and DDT) with the oil and grease fraction.
WESYV 15 June 1978
SUBJECT: Transmittal of Technical Report D-78-16

3. The results from this study showed that most trace metals, oil and grease, chlorinated pesticides, and PCBs were almost totally associated with settleable (>8μ) solids in influent, effluent, and background water samples; their removal efficiencies were usually very close to the total solids removal. However, significant quantities of the major ions (calcium, magnesium, sodium, and potassium), ammonium nitrogen, total carbon, and organic carbon were associated with the soluble phase (<0.05μ fraction). Removal efficiency of parameters mainly associated with the soluble phase was much lower than for the parameters mostly bound with settleable solids. The concentration of soluble trace metals measured in micrograms per liter were usually in the parts-per-billion or sub parts-per-billion range; thus the release of such low levels of most soluble trace metals from land disposal areas should create negligible impact on receiving waters.

4. The oil and grease fraction was not found to have an exceptional affinity for chlorinated hydrocarbons (e.g., DDT analogs and PCBs) or for trace metals. Although contaminants are not contained in the oil and grease fraction per se, high levels of effluent oil and grease may subsequently entrain contaminated settleable solids.

5. The findings of this report, in conjunction with the findings of other related studies, strongly indicate that land disposal of dredged material should not impact the environment if settleable solids are removed before effluent discharge. However, during this field study, low dissolved oxygen levels, as well as solid-phase concentrations of oil and grease, some chlorinated hydrocarbons, and total phosphorus, were occasionally observed in effluents (especially at Pinto Island, where effluent suspended solids were highest). Soluble phosphorus was usually at very low levels in effluent samples.

6. The data in this report are applicable for defining pollution problems associated with confined land disposal of dredged material. The specific physical, chemical, and geochemical tests performed and discussed herein should be used in conjunction with site-specific findings for developing mitigative measures should water-quality degradation be suspected at a particular site. The results should aid those persons concerned with the permit programs, writing of Environmental Impact Statements, or designing effluent monitoring programs or studies.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director
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### SUPPLEMENTARY NOTES

### KEY WORDS (Continue on reverse side if necessary and identify by block number)

- Containment areas
- Petroleum
- Dredged material
- Sampling
- Dredged material disposal
- Sedimentation
- Effluents
- Trace metals
- Influecnt
- Waste disposal sites
- Particulates
- Water quality

### ABSTRACT (Continue on reverse side if necessary and identify by block number)

A detailed analysis of contaminants in influents and effluents from two confined dredged material disposal areas is presented. The sites are located at Pinto Island, Mobile Bay, Alabama, and Grassy Island, Detroit, Michigan.

The samples were separated into 0.05-μ, 0.45-μ, and 8.0-μ fractions. The total sample and filtrate were analyzed for metals, nutrients, total carbon, organic carbon, chlorinated hydrocarbons, oil and grease, sulfide, and solids content. The total solids were subjected to a geochemical partitioning scheme to determine changes of metal solid phases during confined area disposal. The oil and grease fractions in the samples were analyzed for trace metals. A 48-hour settling test was performed to quantify the (Continued)
20. ABSTRACT (Continued).

migration of soil and grease and chlorinated hydrocarbons during resedimentation of dredged material within a confined area.

A statistical analysis of the data was performed to determine the significance of variance in terms of pollutant loading between influent and background water; influent and effluent in terms of removal efficiency; and effluent and background water in terms of potential water quality impact. Tests for significance at the 95 and 99 percent confidence levels are presented.

The results show that, in general, the removal efficiency of total trace metals was very similar to the total solids removal. These results are in agreement with the analytical data which show that approximately 99% of the total trace metals was associated with the solid settleable phase (>8-μ).

The results of the particle size study show that most of the other constituents in the influent and effluent samples were associated with settleable particulates. Only a very small portion was in the soluble (<0.65-μ) phase and in the medium-size (0.65-μ to 8-μ) fraction. A few species exhibited a different particle size fractionation. Significant quantities of sodium, calcium, magnesium, potassium, NH₃-N, total carbon, and organic carbon were in the soluble phase; hence, the removal efficiency of these constituents was low in comparison with the removal of total solids. Soluble phosphate and sulfide were below detection limits.

The results of the geochemical phase partitioning show that the concentration of most metals (As, Cr, Mn, Ni, Pb, and V) remained unchanged in both the exchangeable and carbonate phase extractions of influent and effluent samples. Zinc showed noticeable increases and iron showed decreases in both of the above phases during land containment; cadmium and copper also showed increases in the exchangeable phase extractions.

The nearly complete removal of chlorinated hydrocarbons during the settling tests indicates that the association of chlorinated hydrocarbons with the oil and grease fraction is not a significant factor. The data also show that the concentration of trace metals associated with the release of oil and grease is negligible in comparison with the total sample concentration.

The concentrations of soluble trace metals in the effluents at both sites were in the ppb or sub-ppb range. These values are well below marine water quality criteria; therefore, the water quality impact of the more readily available soluble trace metals discharged into the receiving waters is considered to be negligible.

Marine water quality criteria are based on total concentrations. The results of this study show that the total trace metal concentrations in the effluents at both disposal sites were significantly greater than the marine water quality requirements. Therefore, confined disposal operations will require either long detention times or treatment in order to meet applicable water quality standards. On the other hand, it may be necessary to amend appropriate water quality criteria to differentiate the ecological significance of soluble and particulate fractions so that meaningful water quality criteria can be established.
The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.
This report represents an extension of a study concerning the characterization of influents, effluents, and surface background waters in the disposal of dredged material in confined areas. It was conducted as part of the Corps of Engineers' Dredged Material Research Program (DMRP) under work unit 2D04 entitled, "Characterization of Confined Disposal Area Influent and Effluent Particulate and Petroleum Fractions," Environmental Impacts and Criteria Development Project (EICDP).

This study was conducted during the period of October 1976 - September 1977 by the Environmental Engineering Program at the University of Southern California, Los Angeles, CA. Sample collection and field data were performed by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The study was under supervision of Dr. Kenneth Y. Chen, Director, Environmental Engineering Program, at U.S.C. Dr. James C. S. Lu was responsible for the overall coordination and supervision of laboratory operation. M. Knezevic and B. Eichenberger assisted in the statistical analysis of data as well as preparation of the final report.

The collection of field samples, field measurements and site surveys were primarily conducted by Mr. Ronald E. Hoeppel, who was also the contract manager for this work unit.

The contract was monitored by Mr. Hoeppel under the direct supervision of Dr. Robert M. Engler, Project Manager of the EICDP, and the general supervision of Dr. John Harrison, Chief, Environmental Laboratory, WES.

Contracting Officer was Mr. A. J. Breithaupt. Directors of WES during the conduct of this study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.
U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

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<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
</tr>
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<td>millimeters</td>
</tr>
<tr>
<td>feet</td>
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<td>meters</td>
</tr>
<tr>
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</tr>
<tr>
<td>cubic yards</td>
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<td>cubic meters</td>
</tr>
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<td>3.785412</td>
<td>liters</td>
</tr>
<tr>
<td>gallons (U.S. liquid) per minute</td>
<td>3.785412</td>
<td>liters per minute</td>
</tr>
<tr>
<td>pounds (force) per square inch</td>
<td>6.894757</td>
<td>kilopascals</td>
</tr>
<tr>
<td>electron volts</td>
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<td>joules</td>
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1. Both particulate and petroleum fractions in dredged material suspensions from confined disposal areas have potential pollutional effects on the receiving waters. In the literature, there exists considerable data on sediment size fractions as well as the oil and grease content in sediments. However, information is lacking on the size fractionation of the contaminants in dredged material and the concentration of toxic materials associated with the oil and grease fraction after sediments are suspended.

2. Particle size distribution is important in evaluating the pollution potential of dredged sediment. A few factors to be considered are: (a) suspended solids or slow settling solids contribute to turbidity, (b) suspended solids reduce the penetration of light, hence affecting photosynthetic activity, (c) suspended solids may have a deleterious effect upon filter-feeding organisms, and (d) small particles usually contain larger specific surface areas and require longer retention times for removal. These slower settling particulates may cause degradation of receiving waters if not properly removed.

3. The petroleum fraction of the dredged material may be an important parameter because of its ability to easily separate from the particles and disperse into and float on the receiving waters. Also, the petroleum fraction can be associated with toxic pollutants such as trace metals.¹

4. In view of the potential problems as previously discussed, the characteristics of influent and effluent particulates and petroleum fractions become very significant.

¹
It is important not only to assess the particle size distribution and the oil and grease contents in the sediments and water columns, but also to evaluate the amount of pollutants associated with different particulates and oil and grease fractions. A detailed analysis was made on influents and effluents from two confined dredged material disposal areas: Pinto Island, Mobile Bay, Alabama, and Grassy Island, Detroit, Michigan.

5. The collected background water, influent, and effluent samples were separated into the following fractions: (a) total sample, (b) soluble fraction (0.05-μ filtrate), and (c) medium-size particulates (between 0.45- and 8-μ). Each fraction was analyzed for metals, nutrients, total carbon, total organic carbon, chlorinated hydrocarbons, oil and grease, sulfide, and solids content. In addition, the 0.45-μ filtrate was also analyzed for chloride, alkalinity, conductivity, and salinity. The total solids were also subjected to an elemental partitioning scheme for determining changes of metal solid phases during confined area disposal.

6. The oil and grease fractions for samples from these two sites were analyzed for metal content. A 48-hour settling study was also performed for quantifying the transport property of oil and grease and chlorinated hydrocarbons during resedimentation of dredged material.
7. Two active disposal sites were selected for in-depth characterization of influent, effluent and background water. The selection of these two sites was based on preliminary data obtained in a previous study carried out by U.S. Army Engineer Waterways Experiment Station (WES) on "Physical and Chemical Characterization of Contaminated Dredged Material Influents and Effluents in Confined Land Disposal Areas." 2

Site Description and Dredging Operations

Pinto Island Disposal Site, Mobile Bay, Alabama (Figure 1)

8. Size of diked area. 65 acres; 40 acres ponded.*
9. Dredging site. Marine Bulk Ore Handling Slip on the west side of the Mobile River Ship Channel. Dredged material was transported by direct pipeline to the disposal area.
10. Time period of dredging/disposal operations. 3 Sept. (10:20 PM) to 10 Sept. (9:00 PM) 1976.
11. Sample collection. 7, 8 Sept. 1976
14. Vegetation. About 15 to 20% of the northern section of the disposal area was covered with a moderate growth of vegetation identified as primarily Phragmites communis and other salt tolerant bushy plants (see Appendix A).

* A table of factors for converting U.S. customary units of measurement to metric (SI) units is presented on page iii.
15. Weather at disposal area. 7 Sept. 1976, about 3/4-inch rain, 4:00-5:00 PM; 8 Sept. 1976, about 3/4-inch rain, 6:30-8:30 AM.

Note: Effluent samples were collected on 8 Sept. 1976 after a total rainfall of approximately 1-1/2-inches; the dilution factor must be considered in the evaluation of parameter concentrations.

16. Surface background water samples were taken outside of the effluent mixing zone at the southern end of the disposal area at the confluence of the Mobile River and Mobile Bay.

17. The salinity of surface background water at the Pinto Island site was 3 o/oo. Dredged sediments from the dredging site were quite reducing, with substantial quantities of sulfides. Field studies of influent slurries from Pinto Island show a large immediate oxygen demand. The level of dissolved oxygen for this influent slurry was between 0.5 and 0.6 mg/l in the mixing pool beneath the influent discharge pipe.

Grassy Island Disposal Site, Detroit, Michigan (Figure 2)

18. The diked disposal facility on Grassy Island in the Detroit River was brought to its present dimensions in 1969 for the containment of polluted maintenance dredged material, primarily from the Rouge River in Detroit.

19. Subsequently, a cross dike was constructed dividing the disposal site into a north and south area. During the study only the north half of the disposal area was used with the influent pipe entering the southwest corner; effluent was discharged over a weir in the northeast corner.

20. EPA's 1973 sediment sampling indicated that the Rouge River was very heavily contaminated with many common industrial and municipal pollutants. Parameters to be tested for at the Grassy Island discharge were selected based on EPA's testing.
21. **Size of diked north area.** 30 acres; 10 acres ponded

22. **Dredging site.** Main channel of Rouge River.


24. **Sample collection.** 24, 25, 26, Aug. 1976

25. **Total in situ sediment volume dredged from channel (3 Aug. - 16 Sept. 1976).** 113,335 cu. yds. Dredging was performed with a hopper dredge; pump out time was approximately 45 minutes for each hopper load, with about a 2-1/2-hour dredging and hopper dredge transit time.

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<td>8</td>
<td>7</td>
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<tr>
<td>Total in situ sediment volume in hopper bin, cu. yds.</td>
<td>3464</td>
<td>3422</td>
<td>3254</td>
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<td>24-hour average influent volume, gpm</td>
<td>1950</td>
<td>1920</td>
<td>1825</td>
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No data are available for effluent volumes.

26. **Vegetation.** Dominant vegetation at Grassy Island was *Phragmites communis*.

27. Background water samples were taken from the Rouge River at about the same location as the dredging operations. The salinity of background water at the Grassy Island site was negligible (0.2 o/oo). Dredged sediments from the dredging site are quite reducing, with substantial quantities of sulfides. The level of dissolved oxygen in the influent slurry ranged from 7.1 to 7.6 mg/l.

**Analyses of Samples**

28. Samples from the dredged material disposal sites
were divided into three groups: (a) background water, (b) influent slurry, (c) effluent slurry.

29. All samples were collected by personnel of the Corps of Engineers at WES and preserved by packing them in ice upon collection and during transportation to the University of Southern California (USC) laboratory. Samples were then stored in an environmental chamber at 4°C until used. Chloroform was added in the field for the preservation of samples for nitrogen and phosphorus analyses. Samples for the analysis of chlorinated hydrocarbons were stored in Pyrex (glass) containers. Other samples were stored in polyethylene (plastic) containers. A detailed description of the collected samples is listed in Table 1.

30. All samples were separated into the following four fractions by successive filtrations:

   a. Total sample - this was prepared by homogeneously mixing the original sample followed by withdrawal of a desirable amount by plastic syringe or plastic automatic pipet.

   b. 8-μ filtrate - 8-μ filtrate sample was prepared by passing the homogenized sample through an 8-μ millipore membrane filter (SC nitrocellulose type) by pressurized filtration.

   c. 0.45-μ filtrate - 0.45-μ prepared by pressurized filtration through a 0.45-μ millipore membrane filter (HA nitrocellulose type).

   d. 0.05-μ filtrate - 0.05-μ was prepared the same way as the 8-μ and 0.45-μ filtrates. A 0.05-μ millipore membrane filter (VM nitrocellulose type) was used.

31. Settling tests were performed to determine the fates of oil and grease and chlorinated hydrocarbons and their interrelations in the water column after disposal. One liter of total sample was placed in a standard 1-liter cylinder and then shaken for 1 minute. The supernatants were withdrawn by a syringe at different time periods (2 hrs, 12 hrs, 24 hrs, and 48 hrs) from separate cylinders.
Analytical Parameters

32. Tests of physical and chemical properties were performed on all samples. The important environmental parameters analyzed are outlined as follows:

33. **Total Sample**
   a. nitrogen (total Kjeldahl, NH$_3$-N)
   b. Phosphorus (total)
   c. carbon (total, organic)
   d. dry weight
   e. oil and grease
   f. acid soluble sulfide
   g. cation exchange capacity
   h. chlorinated hydrocarbons
   i. metals (Ca, Mg, Na, K, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, Ti, V, and Zn) - on both acid soluble samples as well as metals in oil and grease.
   j. exchangeable metals
   k. metals associated with carbonate phase
   l. particle size distribution
   m. hydrocarbons

34. **8-μ filtrates**
   a. nitrogen (total Kjeldahl, NH$_3$-N)
   b. phosphorus (total, ortho-)
   c. sulfide (soluble)
   d. carbon (total, organic)

35. **0.45-μ filtrates**
   a. nitrogen (total Kjeldahl, NH$_3$-N, NO$_2$-N, NO$_3$-N)
   b. phosphorus (total, ortho-)
   c. sulfide (soluble)
   d. carbon (total, organic)
   e. salinity
   f. conductivity
g. pH
h. alkalinity
i. chloride
j. metals (Ca, Mg, Na, K, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, Ti, V, and Zn)

36. 0.05-\mu filtrates

a. nitrogen (total Kjeldahl, NH$_3$-N, NO$_2$-N, NO$_3$-N)
b. phosphorus (total, ortho-)
c. sulfide (soluble)
d. carbon (total, organic)
e. metals (Ca, Mg, Na, K, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, Ti, V, and Zn)

37. When sediments are resuspended in a confined disposal area, oil and grease may be released and later discharged into the receiving waters. During this process, trace metals and chlorinated hydrocarbons may also be mobilized in association with the oil and grease fraction. Therefore, the oil and grease extracts from total influent and effluent samples were also used for the determination of trace metals. Chlorinated hydrocarbons were analyzed in the surface layer (about 2-3 inches) below the surface of water samples after settling.

38. Oil and grease samples were also characterized with a gas chromatography-mass spectrometry (GC-MS) system for the identification and quantification of major hydrocarbons including aromatic, straight chain and branched aliphatics. These analyses were performed on some representative samples only.

Analytical Methods

39. The measurements of pH, nitrogenous compounds, total and organic carbon (TC and TOC), alkalinity, conduc-
tivity, sulfide, and chloride follow the methods described in Standard Methods. The procedures and instruments used in this study are listed as follows:

<table>
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<th>Parameter</th>
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<td>a. pH</td>
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<td>b. NH$_3$-N</td>
<td>Acidimetric method</td>
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<td>c. NO$_3$-N</td>
<td>Brucine method (Perkin-Elmer 124, light path 10 cm, 410 nm)</td>
</tr>
<tr>
<td>d. NO$_2$-N</td>
<td>Photometric method (Perkin-Elmer 124, light path 10 cm, 543 nm)</td>
</tr>
<tr>
<td>e. Organic-N</td>
<td>Kjeldahl method</td>
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<tr>
<td>f. TC and TOC</td>
<td>Combustion-infrared method (Beckman 915)</td>
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<td>g. Alkalinity</td>
<td>Potentiometric titration (Orion 601A and 801A)</td>
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<td>h. Conductivity</td>
<td>Conductivity meter (Barnstead PM-70CB)</td>
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<tr>
<td></td>
<td>YSI Model 33 salinity conductivity-temperature meter (used in field)</td>
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<tr>
<td>i. Chloride</td>
<td>Mercuric nitrate method</td>
</tr>
<tr>
<td>j. Sulfide (soluble)</td>
<td>Titrimetric (iodine) method</td>
</tr>
<tr>
<td>k. Cation exchange</td>
<td>Sodium saturation method</td>
</tr>
<tr>
<td>capacity</td>
<td></td>
</tr>
<tr>
<td>l. Exchangeable metals</td>
<td>Ammonium acetate extractable$^4$</td>
</tr>
<tr>
<td>m. Metals (carbonate phase)</td>
<td>Acetic acid extractable$^4$</td>
</tr>
</tbody>
</table>

4
| n. Salinity | Refractometer (American Optical Corp. Goldberg T/C, Model 10419) YSI Model 33 salinity, conductivity-temperature meter (used in the field) |
| o. Metals (total filtrates, hexane extracts) | Perkin-Elmer atomic absorption spectrophotometers. Models 305B and 460 (Appendix B) |
| p. Acid soluble sulfide | Titrmetric method (Appendix B) |
| q. Phosphorus (total, ortho-) | Modified ascorbic acid method (Appendix B) |
| r. Chlorinated hydrocarbons | Gas chromatography (Appendix B) |
| s. Petroleum hydrocarbons | GC-MS (Appendix B) |
| t. Dissolved oxygen | YSI Model 57 |
| | Dissolved oxygen meter |
PART III: RESULTS

40. The following results are, for the most part, based on the statistical analysis of the influent, effluent, and background water data. In some cases, when only one sample was analyzed, the determination of statistical significance (F-test) is not possible. In such circumstances, sound scientific judgement was applied in the interpretation of the analytical data. Time limitations did not permit the determination of statistical significance of variance between particulate fractions. The following F-tests for significance at the 95 and 99 percent confidence levels ($P \leq 0.05$, $P \leq 0.01$) are presented in Tables 2 and 3.

a. Influent vs. background water (pollutant loading)
b. Influent vs. effluent (removal efficiency)
c. Effluent vs. background water (potential water quality impact)

41. It should be noted that surface background water samples were collected at the Grassy Island dredging site and outside the mixing zone at the Pinto Island disposal area. Ideally, background water samples should have also been collected at the dredging and disposal sites for both Grassy Island and Pinto Island. This was not done because of time restrictions and collection problems.

Increase of Pollutant Loading During Dredging

General parameters (background water, influent)

42. Field data for the Pinto Island and Grassy Island disposal sites are given in Table 4. Average values for physical and chemical parameters of influent and background water samples are given in Table 5. From the results, it can be seen that the background water concentrations of most parameters were lower than those of the dredged material influent slurries at both disposal sites.
43. The average total solids in the Pinto Island influent samples were increased from the background level of 0.46% to about 7% (Table 3). This indicates that, during the dredging operation, the mixing weight ratio of dredge site water to bottom sediment ranged from 7 to 10 (based on a harbor bottom sediment moisture content of 30 to 50%).

44. For the Grassy Island samples, the total solids content increased from 0.01% to about 19%, indicated a 1.5 to 2.5 mixing weight ratio. These results indicate that there was better dredging efficiency at the Rouge River dredge site although the higher solids contents may have been obtained by allowing hopper overflow.

45. The change in salinity after mixing was negligible in the Grassy Island samples; however, salinity was about 8.5 times higher in the Pinto Island influent samples than in background water, with average influent and background water values of 25.5 o/oo and 3 o/oo, respectively. However, since surface water was obtained for a background water sample, much of the salinity increase may have been caused by higher salinity in bottom water at the dredging site; the Mobile River at the dredge site displays salinity stratification.

46. For Pinto Island samples, conductivity was about 5 times higher (from about 5 mMhos to 25 mMhos) in the influent samples. For Grassy Island samples, the conductivity was about 3 times greater (from about 0.04 mMhos to 0.11 mMhos). Again, it should be noted that surface background water samples were taken; the dredged bottom water at the Pinto Island site may have had a higher salinity than the surface water, which would contribute to the observed increases in influent conductivity.

47. The alkalinity measurements (as CaCO₃) after sediment-water mixing show an increasing trend at both sites. The alkalinity at Pinto Island was at about 50 mg/l in the surface background water and about 150 mg/l in an
Average effluent. Grassy Island alkalinity increased from 130 mg/l to about 500 mg/l.

48. The percent increase of chloride concentration was close to the increase of conductivity, indicating that soluble chloride salts probably account for most of the conductivity changes.

**Total carbon (TC) and total organic carbon (TOC)**

49. The TC and TOC measurements were obtained for different size fractions as well as total slurry samples (see Tables 5 and 6). The average TC and TOC concentrations in different filtrates (8-µ, 0.45-µ, and 0.05-µ) show similar concentrations in filtrates passing through all filter sizes. Thus, the data show that the TC and TOC are primarily in the 0.05-µ filterable phase for sample particles less than 8-µ.

50. The fraction of total carbon in the 0.05-µ filtrates was 64% and 61%, respectively, for Pinto Island and Grassy Island influent samples. Total organic carbon in the 0.05-µ influent filtrates was 53% for Pinto Island and 30% for Grassy Island.

51. The total filterable carbon concentration (0.05-µ filtrate) was lower in the background water by 3 and 4.5 times, respectively, for both the Pinto and Grassy Island sites. Similarly, the total filterable organic carbon (0.05-µ filtrate) increased about 3 and 6 times in Pinto and Grassy Island influents, respectively.

52. The total inorganic carbon (TIC=TC-TOC) data can be derived from Table 5. Figure 3 shows the relationship between alkalinity and TIC. The data fit quite well around a straight line with a slope of 5. This indicates that alkalinity is mostly comprised of bicarbonate ions:

\[
\frac{C_{\text{HCO}_3^-}}{C_{\text{TIC}}} = \frac{61}{12} \approx 5.
\]
Nutrients

53. The results of the nutrient analyses are given in Tables 5 and 6. The sum of the nitrogen compounds (NH$_3$-N + organic N + NO$_2$-N + NO$_3$-N) increased significantly in the influent slurries; the contribution of NO$_3$-N and NO$_2$-N was negligible for both sites. In the influent samples, the total nitrogen increase was about 40 times (from 1 mg/l as N to 40 mg/l as N) for Pinto Island samples and 145 times (from about 1 mg/l as N to 145 mg/l as N) for Grassy Island samples. For Pinto Island, the increase of total nitrogen contributed by NH$_3$-N and organic N was 25% and 75%, respectively. For Grassy Island, the increase due to NH$_3$-N was 58% and 42% for organic N. The use of the NH$_3$-N notation is one of convention. In this study, NH$_4^+$-N is the dominant species, i.e., pH <9.3.

54. The soluble (< 0.05-$\mu$) phosphorus concentrations in both the influent and background water samples were negligible at both sites. The increase in total phosphorus concentrations at Pinto Island and Grassy Island was due entirely to the solid phase (> 8-$\mu$) as shown in Tables 5 and 6.

Metals

55. Tables 5 and 6 present the data for metal release at both sites. These results show that the trace metal concentrations in both the solid and soluble phases were higher in the influent slurries than in the background water samples, with the exception of soluble zinc (0.05-$\mu$) at Pinto Island. The factors of increase for soluble metals (< 0.05-$\mu$) are as follows (minus sign indicates a scavenger effect):

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>Se</th>
<th>Ti</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>4</td>
<td>2</td>
<td>85</td>
<td>7</td>
<td>&gt;5</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>&gt;5</td>
<td>&gt;7</td>
<td>-3</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>40</td>
<td>4</td>
<td>20</td>
<td>3</td>
<td>38</td>
<td>6</td>
<td>5</td>
<td>&gt;1</td>
<td>&gt;2</td>
<td>&gt;3</td>
<td>50</td>
</tr>
</tbody>
</table>
56. Four metal species, Cd, Fe, Mn, and Zn, were found to be strongly released (with factors greater than 10) from Grassy Island dredged material while high concentrations of soluble Fe were released from Pinto Island sediments; comparisons were made with the background water values.

57. The increase of total metal concentrations in the influent samples was mainly associated with the total solid phase. The factors of increase based on total concentrations are listed as follows:

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>37</td>
<td>6</td>
<td>&gt;2300</td>
<td>&gt;34</td>
<td>20</td>
<td>460</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>340</td>
<td>83</td>
<td>190,000</td>
<td>85</td>
<td>&gt;26</td>
<td>2900</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Se</th>
<th>Ti</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>12</td>
<td>&gt;3</td>
<td>&gt;5</td>
<td>&gt;4</td>
<td>15</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>260</td>
<td>620</td>
<td>&gt;8</td>
<td>1800</td>
<td>105</td>
</tr>
</tbody>
</table>

58. Samples from Grassy Island show greater increases in total metal concentrations mainly due to the higher solids content of the influent samples.

Oil and grease

59. The total oil and grease concentrations in influent and background water samples are given in Table 5. The ratios of increase for total oil and grease was 130 for Pinto Island and 160 for Grassy Island, indicating that the in situ sediments were the major source for the oil and grease fractions.

Chlorinated hydrocarbons

60. Table 5 shows that the release of chlorinated hydrocarbons from the solid phase to the water column was negligible (for details, see the Settling Study section). The increase of chlorinated hydrocarbons in the influent samples was mainly associated with the solid phase. The ratios of increase for total DDT and total PCB are:
Total DDT | Total PCB
---|---
Pinto Island | 220 | > 1400
Grassy Island | 350 | 380

**Petroleum hydrocarbons**

61. Table 7 shows the total concentrations of selected petroleum hydrocarbons in influent and background water samples. The increase of petroleum hydrocarbons was negligible with the exception of total alkanes where the ratios of increase were > 6 for both Pinto Island and Grassy Island samples.

**Removal Efficiency of Disposal Sites**

62. The effectiveness of the disposal sites in removing the suspended and soluble constituents is affected by a combination of many factors, e.g., topography, geology, weather conditions, effective area, volume, depth of the disposal site, detention time, and flow rate, as well as the physical and chemical properties of dredged material and entrained waters (redox condition, particle size distribution, salinity, etc.). Due to the complexity of conditions at the disposal site and the variability of the influent samples, the removal mechanisms are usually difficult to predict and explain. The best way to judge the effectiveness of the disposal site is from the analytical results of both influent and effluent samples.

**General parameters**

63. The analytical results of some general water quality parameters of influent and effluent samples are listed in Table 5. Parameters such as pH, salinity, conductivity, and chloride show slight to moderate changes between influent and effluent samples. The average percent changes are as follows (minus sign indicates that the para-
meter was decreased in the influent); values within parentheses are not statistically significant (see Tables 2 and 3).

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Salinity</th>
<th>Conductivity</th>
<th>Chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>5.4</td>
<td>(-19.2)</td>
<td>-11.3</td>
<td>(-14.0)</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>0</td>
<td>*</td>
<td>-38.9</td>
<td>-5.9</td>
</tr>
</tbody>
</table>

* trace concentration

64. The Pinto Island disposal site showed approximately a 46% removal of the total solids. However, there was almost complete removal of the total solids for the Grassy Island disposal area, i.e., 99.7%. The high total solids removal at Grassy Island was due to long detention times obtained by total confinement procedures, i.e., negligible discharge of effluent to the receiving waters.

65. The decrease in alkalinity at Grassy Island was about 50%. This reduction could be the result of pH increase caused by the uptake of carbon dioxide during photosynthesis and the subsequent precipitation of calcium carbonate. Photosynthetic activity is indicated by the presence of planktonic algae in sufficient number to give the effluent a greenish color. The increase in alkalinity at Pinto Island was not significant. Significant, as used within the context of this study, refers to statistically significant differences.

66. The cation exchange capacity decreased 58% for the Pinto Island samples. Due to the very low solid content in the Grassy Island effluent, the cation exchange capacity could not be determined.

67. The soluble (< 0.05-μ) sulfide was determined for both sites; however, all of the samples showed only trace amounts of sulfide in the soluble phase. This may be due to the oxidation of sulfide species during sample transportation. Therefore, the results for soluble sulfide probably do not represent the actual field situation.
68. Results show that the total acid soluble sulfide was decreased at both sites during disposal activities. In the Pinto Island samples, the decrease was from about 20 mg/l to about 3 mg/l (Table 5). In the Grassy Island samples, the decrease was from about 38 mg/l to about 0.15 mg/l. It is believed that these decreases were due to both the removal of suspended solids and the oxidation of sulfide solids. In the Pinto Island samples, the 46% decrease in solids content can only account for approximately one-half of the decrease of total acid soluble sulfide, since the experimental results showed about an 83% decrease. This indicates that approximately 37% of the metals originally associated with the sulfide solids were changed to other species due to oxidation.

69. The percent removal of total acid soluble sulfide in the solid phase versus the quantity oxidized to other species is only an approximation. Since the particle size distribution of total acid soluble sulfide was not determined, its association or removal efficiency from different particle size fractions is not known. The 99.6% removal of total acid soluble sulfide at Grassy Island is in excellent agreement with the 99.7% removal of total solids.

Total carbon and total organic carbon

70. Data for total carbon and total organic carbon are listed in Tables 5 and 6. Total carbon in the Pinto Island effluent samples increased by 59%; the observed increases in the particulate size fractions were not significant. Total carbon in the Grassy Island effluent decreased by 55%. The following reductions were observed for the Grassy Island particulate fractions: 59% (8-μ); 58% (0.45-μ); 55% (0.05-μ).

71. The 111% increase of total organic carbon in the Pinto Island effluent samples was probably due to photosynthetic processes and subsequent vegetation decomposition.
Total organic carbon in the Grassy Island effluent decreased by 62%. This decrease was probably due to both the removal of suspended solids and the oxidation of soluble organic carbon. The percent oxidation of organic carbon cannot be determined because the results do not indicate a significant difference between influent and effluent samples.

**Nutrients**

72. Nutrient data are listed in Tables 5 and 6. No interpretation of the Pinto Island data is possible because the differences are either not significant or indeterminate. The average removal efficiencies of NH$_3$-N and organic N in the total slurry samples were 83% and 96%, respectively, at the Grassy Island site. The removal of (< 0.45-μ) NO$_3$-N was not significant; the removal of (< 0.45-μ) NO$_2$-N was indeterminate. The removal of soluble (< 0.05-μ) NH$_3$-N and organic N was also indeterminate.

73. Theoretically, in the oxidizing environment, the observed decrease in total NH$_3$-N and organic N at Grassy Island would indicate an increase in the nitrate level. The data do not show a significant increase of NO$_3$-N, probably as a result of denitrification in the anaerobic disposal area sediments or by biological uptake. Biological uptake is most plausible at Grassy Island, as the site contained abundant vegetation and algae in the water column.

74. Total phosphorus removal was 99.9% at Grassy Island; removal at Pinto Island was not significant. Phosphorus compounds in the soluble phase (< 0.05-μ) were below detection limits in influents and effluents from both sites. The absence of measurable influent soluble phase phosphorus indicates that the phosphorus compounds were strongly associated with the particulates and could not be released during dredging activities or rapid chemical scavenging occurred in the influent slurry. The low effluent values may result from the formation of FePO$_4$ precipitates; also,
biological uptake could maintain low soluble phosphorus (orthophosphate) concentrations in the disposal area.

**Metals**

75. Tables 5 and 6 give the results of metal concentrations in influents and effluents. The average percent removal efficiencies of major ions (Na, K, Ca, and Mg) in the total samples are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>--</td>
<td>54</td>
<td>(23)</td>
<td>--</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>--</td>
<td>61</td>
<td>(44)</td>
<td>10</td>
</tr>
</tbody>
</table>

76. The percent removal of major ions in the total samples was less than the percent removal of total solids, with the exception of potassium at Pinto Island. These results are reasonable when considering the particle size distribution of the ions, and the total solids removal, e.g., 89% of the potassium in the Pinto Island influent was in the settleable fraction (> 8-μ) compared with a total solids removal of 46%. Conversely, 41% of the magnesium in the Grassy Island influent was in the soluble (< 0.05-μ) phase compared with a total solids removal of 99.7%.

77. The percent removal of the soluble phase (< 0.05-μ) major ions (Na, K, Ca, Mg) was not significant at either site with the exception of 54% removal of magnesium at Grassy Island.

78. The average removal efficiencies of trace metals in the total samples are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>Se</th>
<th>Ti</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>18</td>
<td>52</td>
<td>46</td>
<td>35</td>
<td>54</td>
<td>67</td>
<td>35</td>
<td>39</td>
<td>48</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>~100</td>
<td>93</td>
<td>99</td>
<td>96</td>
<td>(98)</td>
<td>95</td>
<td>(99)</td>
<td>(99)</td>
<td>(97)</td>
<td>97</td>
<td>(96)</td>
</tr>
</tbody>
</table>

79. Comparing these results with those of total solids removal (46% for Pinto Island and 99.7% for Grassy Island), it appears that the removal efficiencies of metals in the total samples were very similar to the total solids removal
with the exception of cadmium and nickel at the Pinto Island site. This is quite reasonable since the majority of the trace metal concentrations are associated with the solid phase (see Tables 5 and 6). The weight percent of trace metals in the particulate phase (> 8-μm) was at least 99% for all of the influent samples with the exception of 97% for cadmium at Pinto Island.

80. Among the metals determined, the removal efficiency of cadmium in the Pinto Island site was far below the removal of total solids. On the other hand, the removal efficiency of nickel in the Pinto Island site was far above that of the total solids. This was probably caused by the separation of particles during resettling. In the former case, cadmium probably existed primarily in smaller particles, so that after resettling, more cadmium solids remained in suspension. However, the nickel in the Pinto Island samples might be associated more predominately with larger particles which could account for the increased percent removal.

81. The percent removal efficiencies of soluble trace metals (0.05-μm filtrate) are as follows (plus sign indicates that the concentration was increased in the effluent sample):

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Hg</th>
<th>Mn</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>26</td>
<td>(+45)</td>
<td>86</td>
<td>(23)</td>
<td>24</td>
<td>(13)</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>81</td>
<td>(54)</td>
<td>95</td>
<td>(0)</td>
<td>(36)</td>
<td>(12)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Se</th>
<th>Ti</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>(30)</td>
<td>(46)</td>
<td>(36)</td>
<td>(42)</td>
<td>(+250)</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>(+15)</td>
<td>(68)</td>
<td>(5)</td>
<td>(27)</td>
<td>98</td>
</tr>
</tbody>
</table>

The data show no significant differences for Cu, Hg, Ni, Pb, Se, Ti, and V at both sites; for Zn at Pinto Island; and for Mn at Grassy Island. The removal of iron at both sites, and cadmium and zinc at Grassy Island was quite effective. The soluble concentration levels of trace metals
in the effluents were less than 15 µg/l with the exception of manganese at Grassy Island which had a value of 49 µg/l.

**Oil and grease**

82. The oil and grease content in the total samples (solution plus solid phase) decreased after confinement (Table 5). The removal efficiencies were 90% and 99.7% for the Pinto Island and Grassy Island sites, respectively. The removal efficiency at the Grassy Island site was very close to that of the total solids removal. However, the removal efficiency at the Pinto Island site was much greater than the total solids removal, i.e., 90% vs. 46%.

**Chlorinated hydrocarbons**

83. The results for chlorinated hydrocarbons are given in Table 5. Among the chlorinated hydrocarbon species, only DDD, DDE, DDT, and PCB compounds were detected. The percent removal efficiencies of chlorinated hydrocarbons in the total samples are:

<table>
<thead>
<tr>
<th></th>
<th>op'DDD</th>
<th>pp'DDD</th>
<th>op'DDE</th>
<th>pp'DDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>(59)</td>
<td>70</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>99.0</td>
<td>99.6</td>
<td>96.7</td>
<td>99.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>op'DDT</th>
<th>pp'DDT</th>
<th>Total PB DDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>100</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>99.2</td>
<td>99.4</td>
<td>99.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Aroclor</th>
<th>Aroclor</th>
<th>Aroclor</th>
<th>Total PCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>1242</td>
<td>1254</td>
<td>1260</td>
<td>96.5</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>98.9</td>
<td>99.8</td>
<td>99.8</td>
<td>99.1</td>
</tr>
</tbody>
</table>

84. For the Grassy Island site, the removal of chlorinated hydrocarbons by confinement was very close to the total solids removal. For the Pinto Island site, the removal of chlorinated hydrocarbons was much higher than the total solids removal; this result could be due to the fact that
chlorinated hydrocarbons were associated with large particles. The 59% removal of op'DDD at Pinto Island was not significant.

Settling Study

85. The purposes of the settling tests were:
   a. To observe the general transport phenomena during resedimentation in confined disposal areas.
   b. To determine the relationships between particle size and the concentration of chemical constituents.
   c. To investigate the possibility of concentrating trace metals and chlorinated hydrocarbons in the oil and grease fraction.

86. Results of the settling tests are given in Table 5 and Figures 4 to 29.

Transport of oil and grease during resettling

87. The data for oil and grease release during resettlement are shown in Table 5, and Figures 4 to 7. The results show that during the resettlement of the influent dredged material, some oil and grease from the solid phase was being continuously released into the solution phase within the first 24 hours. The solution phase oil and grease concentration usually increased slowly after 24 hours if the value at 24 hours was low. The data also show a rapid removal after 24 hours if the value at 24 hours was high. After a careful check of the settling equipment, it appears that the subsequent removal was not due to readsorption by the sediment particles. It is speculated that for high oil and grease levels in the solution phase, the excess tends to flow to the surface and accumulates on the wall of the settling column, thus decreasing the oil and grease content within the water column. Similar removal could occur through contact of the slurry with vegetation or other solid surfaces within the disposal area.
Transport of chlorinated hydrocarbons during resettling

88. The results of the settling tests for chlorinated hydrocarbons are given in Table 5 and also Figures 8 to 29. The data show that the chlorinated hydrocarbons were removed rapidly during dredged material resettling. Most of the chlorinated hydrocarbons were resettled within the first 2 hours. Below is a list of the percent removal efficiencies of different chlorinated hydrocarbons in the influent samples within two hours of settling:

<table>
<thead>
<tr>
<th></th>
<th>op'DDD</th>
<th>pp'DDD</th>
<th>op'DDE</th>
<th>pp'DDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>80.9</td>
<td>77.9</td>
<td>74.1</td>
<td>55.2</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>77.2</td>
<td>77.3</td>
<td>77.3</td>
<td>56.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>op'DDT</th>
<th>pp'DDT</th>
<th>DDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>34.9</td>
<td>34.7</td>
<td>56.3</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>33.6</td>
<td>57.1</td>
<td>66.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Aroclor 1242</th>
<th>Aroclor 1254</th>
<th>Aroclor 1260</th>
<th>Total PCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>60.7</td>
<td>83.5</td>
<td>75.9</td>
<td>76.6</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>75.3</td>
<td>84.6</td>
<td>83.7</td>
<td>77.8</td>
</tr>
</tbody>
</table>

89. Among the chlorinated hydrocarbons, op'DDD, pp'DDD, op'DDE, and PCB's had the highest removal rates.

90. After 48 hours of resettling, all of the chlorinated hydrocarbons were removed to very low levels. This implies that the chlorinated hydrocarbons are strongly associated with large sediment particles and release into the solution phase should be negligible. The following table shows the percent removal efficiencies after 48 hours of resettling:

<table>
<thead>
<tr>
<th></th>
<th>op'DDD</th>
<th>pp'DDD</th>
<th>op'DDE</th>
<th>pp'DDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99.5</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>99.9</td>
<td>99.9</td>
<td>99.9</td>
<td>99.9</td>
</tr>
<tr>
<td></td>
<td>op'DDT</td>
<td>pp'DDT</td>
<td>Total DDT</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>--------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Pinto Island</td>
<td>97.8</td>
<td>99.5</td>
<td>99.7</td>
<td></td>
</tr>
<tr>
<td>Grassy Island</td>
<td>99.3</td>
<td>99.6</td>
<td>99.7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Aroclor 1242</th>
<th>Aroclor 1254</th>
<th>Aroclor 1260</th>
<th>Total PCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinto Island</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Grassy Island</td>
<td>99.0</td>
<td>99.7</td>
<td>99.7</td>
<td>99.2</td>
</tr>
</tbody>
</table>

Association of metals and chlorinated hydrocarbons with oil and grease

91. The association of metals with oil and grease in the total samples is given in Table 5. In general, the trace metal content of the oil and grease fraction in the effluent samples is less than 5 μg/l (in terms of the original sample volume), which is usually less than 1% of the trace metals in the total sample. The data show that the concentration of trace metals associated with the release of oil and grease is negligible in comparison with the total sample concentrations.

92. The association of chlorinated hydrocarbons with the oil and grease fraction is not significant. The results of the settling tests which show nearly complete removal of chlorinated hydrocarbons from influent during resettling indicate that the association of chlorinated hydrocarbons with the oil and grease fraction is not a significant factor.

Transformation of Metal Solids During Confined Area Disposal

93. The transformation of metal solids during the disposal of dredged material in diked containment areas was analyzed by determining the association of each metal with different geochemical phases of influent and effluent solids. This was accomplished by performing selective
chemical extractions on the solid phases of each sample. Since the exchangeable and acetic acid-extractable phases are most significant, these two were analyzed. Results are given in Table 5. Data for the effluent samples from Grassy Island are not available due to their very low solids content. Thus, the transformation of metal solids during confined area disposal can only be discussed for Pinto Island samples.

94. From the results, the following phenomena were observed for the exchangeable metals:
   a. Exchangeable amount increased after confined disposal - Cd, Cu, and Zn.
   b. Exchangeable amount decreased after confined disposal - Fe
   c. No significant changes - As, Cr, Mn, Ni, Pb, and V.

95. For the acetic acid-extractable phase, the following phenomena were observed:
   a. Amount increased after disposal - Zn.
   b. Amount decreased after disposal - Fe.
   c. No significant change - As, Cd, Cr, Cu, Mn, Ni, Pb, and V.

96. Among the trace metals studied, the increases in exchangeable metals are in the following order: Zn (+1790%) > Cd (+420%) > Cu (+115%). The exchangeable iron was reduced by 59% during disposal operations. The removal of exchangeable arsenic, chromium, lead, manganese, nickel, and vanadium was not significant, implying that the release of these species by ion exchange mechanisms was negligible.

97. The zinc carbonate phase (acetic acid extractable) was increased by 25% during confined area disposal. The iron carbonate phase decreased by 47%. The arsenic, cadmium, chromium, copper, manganese and nickel carbonates showed no significant changes.
The results of this study show an increase in total solids and pollutants in dredged material influent slurries compared to background water levels. In most cases, more than 99% of the trace metals loading is associated with the solid settleable phase (> 8-μm). Changes which affect the chemical form and concentration of soluble species are very complicated. Many mechanisms may be involved in governing these changes in the soluble phase, such as geochemical phase transformations, sorption, ion-exchange, dissolution, deposition, redox reactions, coprecipitation, complexation, and diffusion from interstitial water.

Regarding the higher levels of salinity, conductivity, and soluble chloride observed in the Pinto Island influent samples (compared to surface background water levels) it is believed that the major cause was salinity stratification within the Mobile River at the dredging site. However, dependent on the directions of tidal flow, volume of freshwater discharge, and rate of mixing, the dilution of higher concentrations of major ions in the sediment interstitial water during dredging could also be important. Chloride closely paralleled the changes in conductivity and salinity. It is quite probable that the surface background water samples, which were collected near the effluent discharge, are not representative of the salinity of dredged bottom water.

The increase of major ions in the Grassy Island influent samples over the background level was less than that of the Pinto Island site. However, the Grassy Island influents had a higher alkalinity (mainly bicarbonate) indicating increased oxidation of organic carbon to carbon dioxide, which in turn reacts with the solid carbonate species to form bicarbonate ions. The data show that Grassy Island
sediments released more soluble (< 0.05-μ) organic carbon during dredging operations. This was also true for the release of nutrients.

101. Field monitoring showed that the Pinto Island influent samples, collected in the mixing pool beneath the discharge pipe, contained between 0.5 to 0.6 mg/l of dissolved oxygen. However, measurements made directly at the end of the discharge pipe showed no measurable dissolved oxygen in the slurry. Thus, slightly oxidizing conditions were present in the mixing pool, but the slurry appeared to have a high immediate oxygen demand. In contrast, the D.O. levels of the Grassy Island samples ranged from 7.1 to 7.6 mg/l in the mixing pool indicating a strong oxidizing condition. Much of this oxygenation probably occurred during the two-hour period when the dredged material was in the hoppers of the dredge. Since both sites were subjected to oxidizing conditions, the precipitation of FePO₄ could be favored. This may explain why the phosphate release was negligible in the influent samples.

102. The release of trace metals into the dredging site water may be primarily due to the following:

a. Diffusion from the interstitial water.

b. Aerobic conditions change the reduced metallic sulfide solids, which are generally highly insoluble, to more soluble oxidized solids; this is also indicated by the geochemical fractionation data.

c. Formation of soluble metal complexes due to the increase of metal ligands in the soluble phase (such as the high levels of chloride, TOC, and nitrogen compounds in the influent samples).

d. Ion exchange.

e. Oxidation and decomposition of organic compounds.

f. Desorption from clay minerals or other solid species.
103. In comparing the two dredging sites, the relative release of metals from Grassy Island sediments was greater for Cd, Cu, Ni, Mn, and Zn, and less for Fe, Hg, Se, Ti, and V. As stated previously, Grassy Island sediments probably contained more carbonate species in the presence of high alkalinity and oxidizing conditions. Most carbonates are moderately soluble. On the other hand, in a strongly oxidizing environment, iron can be gradually transformed to oxyhydroxide or hydroxide solids, which have a much lower solubility.

104. The release of oil and grease into the dredging site water is probably derived mainly from the physical disturbances which tend to form oil in water emulsions as well as the specific gravity difference between water and the oil and grease emulsions.

Removal Efficiency of Disposal Sites

105. The effectiveness of a disposal site in removing suspended and soluble constituents is affected by many complicated factors. The removal of particulates is controlled mainly by the retention time of the containment area, and the particle size distribution of resuspended sediments. Generally, most of the trace metals were concentrated in the larger settleable solids of the dredged material, i.e., > 8-μ. Only a very small portion was found to exist in the solution phase (<0.05-μ). Therefore, if the metals were uniformly distributed within the solid phase, the removal efficiency of trace metals associated with the particulates should be close to the removal of the total solids. The removal efficiency of trace metals in the total samples was found to be very similar to the total solids removal with the exception of cadmium and nickel at Pinto Island.
106. The removal efficiency for other parameters was either higher or lower than the total solids removal. A compilation of the percent removal efficiencies of constituents in the total samples is presented in the following table (plus sign means concentration was increased).

<table>
<thead>
<tr>
<th></th>
<th>Total Solids</th>
<th>Cation Exchange Capacity</th>
<th>NH$_3$-N</th>
<th>Organic-N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pinto Island</strong></td>
<td>45.8</td>
<td>58.5</td>
<td>(+29.4)</td>
<td>(60.1)</td>
</tr>
<tr>
<td><strong>Grassy Island</strong></td>
<td>99.7</td>
<td>--</td>
<td>83.1</td>
<td>95.8</td>
</tr>
<tr>
<td><strong>Total-P</strong></td>
<td>(42.8)</td>
<td>59.3</td>
<td>+111</td>
<td>90.1</td>
</tr>
<tr>
<td><strong>Total Carbon</strong></td>
<td>99.8</td>
<td>55.1</td>
<td>61.9</td>
<td>99.7</td>
</tr>
<tr>
<td><strong>Ca</strong></td>
<td>(23)</td>
<td>54</td>
<td>--</td>
<td>18</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td></td>
<td>18</td>
<td>52</td>
<td>46</td>
</tr>
<tr>
<td><strong>Mg</strong></td>
<td></td>
<td>10</td>
<td>99.6</td>
<td>93</td>
</tr>
<tr>
<td><strong>Cd</strong></td>
<td></td>
<td>99.6</td>
<td>99</td>
<td>96</td>
</tr>
<tr>
<td><strong>Fe</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pinto Island</strong></td>
<td>54</td>
<td>67</td>
<td>35</td>
<td>39</td>
</tr>
<tr>
<td><strong>Grassy Island</strong></td>
<td>(98)</td>
<td>(95)</td>
<td>(99)</td>
<td>(97)</td>
</tr>
<tr>
<td><strong>Mn</strong></td>
<td></td>
<td>35</td>
<td>39</td>
<td>48</td>
</tr>
<tr>
<td><strong>Ni</strong></td>
<td></td>
<td>48</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td><strong>Pb</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Se</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ti</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Zn</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>op'DDD</strong></td>
<td>(59)</td>
<td>70</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td><strong>pp'DDD</strong></td>
<td>99.0</td>
<td>99.6</td>
<td>99.6</td>
<td>99.4</td>
</tr>
<tr>
<td><strong>op'DDE</strong></td>
<td>1242</td>
<td>1254</td>
<td>1260</td>
<td>Total PCB</td>
</tr>
<tr>
<td><strong>pp'DDE</strong></td>
<td></td>
<td></td>
<td></td>
<td>96.5</td>
</tr>
<tr>
<td><strong>Aroclor</strong></td>
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<td>97</td>
<td>99</td>
<td>96.5</td>
</tr>
<tr>
<td><strong>Aroclor</strong></td>
<td>98.9</td>
<td>99.8</td>
<td>99.8</td>
<td>99.1</td>
</tr>
</tbody>
</table>

107. Several reasons can be given for removal efficiencies higher than the total solids removal.

   a. Chemical constituents were associated more predominantly with larger particulates which are removed during the detention time.

   b. During resedimentation chemical reactions occurred which promoted precipitation of
soluble species.

c. The soluble species were adsorbed by clay minerals and/or hydrated oxides of iron and manganese.

108. For parameters that showed lower removal efficiencies than the total solids, the following reasons are suggested:

a. A significant amount of some parameters were associated with the soluble phase of the total sample, such as sodium, calcium, magnesium, NH₃-N, total carbon, and organic carbon. The settling process could not remove most of the soluble species; hence, the removal efficiency was lower than that of the total solids removal.

b. Some of these parameters were associated primarily with the solid phase of the total sample. However, they were more concentrated in the smaller particles and could not be effectively removed during the detention period.

c. During resedimentation, chemical or physical reactions may have altered the original constituents to more soluble species.

Transformation of Metal Solids During Confined Land Disposal

109. The importance of the transformation of geochemical phases in promoting the migration of metals has been discussed. The important relations can be summarized as follows:

a. Transformation of geochemical phases will change the controlling solids of metals, thus altering the solubility of the metals in solution.

b. Through the dynamic equilibrium the controlling solids of metals can also regulate the exchangeable amounts of metals in the sediments.

110. Since polluted sediments are usually in reduced states, the controlling solids of the in situ sediments are usually reduced solids such as metallic sulfides. Upon
resedimentation of the suspended solids in aerobic environments, other solids such as carbonates, hydroxides, oxyhydroxides, hydrated oxides, or even silicates can be formed. In general, the changes in the acetic acid-extractable phases and exchangeable phases can give information concerning major changes. Data from this study show that the acetic acid extractable phase of Zn increased after disposal of dredged material. It is likely that this increase mainly represents an increase in zinc carbonate solids. The amounts of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and V in the acetic acid-extractable phase either decreased or were unchanged, showing that carbonate solids of these metals are either unstable or rates of formation are slow. Therefore, other reducible solids such as hydroxides, oxides, or silicates could be predominant. The following solids are suggested as the most likely formation products for the studied metals by the ion-ratio method:

a. Cu: Cu$_2$CO$_3$(OH)$_2$
b. Cd: CdCO$_3$
c. Zn: ZnCO$_3$ or ZnSiO$_3$
d. Ni: NiCO$_3$
e. As: As$_2$O$_3$
f. Cr: Cr(OH)$_3$
g. Fe: Fe(OH)$_3$, FeOOH
h. Pb: Pb(OH)$_2$(CO$_3$)$_2$, or PbO or PbCO$_3$
i. V: V(OH)$_2$, V(OH)$_3$ or V$_2$O$_3$ or V$_2$O$_5$
j. Mn: Mn(OH)$_x$, MnOOH, or MnO$_x$

111. If the equilibria exist as predicted by thermodynamic considerations, the free metal ion concentrations, with the exception of Fe and Mn, will be increased under oxidizing conditions during confined area disposal.

112. As suggested by Jackson and Lu, from the dynamic equilibrium among controlling solids and the easily released fractions of metals, the following relation can be
113. Under oxidizing conditions, the newly formed controlling solids will generally have increased solubility; therefore, the exchangeable amounts of metals are likely to increase; however, the data show that cadmium, copper, and zinc were the only metals whose exchangeable phase concentrations increased during disposal in a containment area. The exchangeable phase concentrations of As, Cr, Fe, Mn, Ni, Pb, and V either decreased or were unchanged which may be the result of pH changes, competing mechanisms, and kinetic reaction rates, e.g., (a) incomplete oxidation of metallic sulfides to the more soluble controlling solids; (b) ion selectivity (preferential exchange) and exchange kinetics; (c) adsorption of free metal ions by clay minerals and hydrated oxides of iron and manganese.

114. Since there is likely to be a relationship between the potential pollutional effects and the particle size distribution, the collected influent and effluent samples were separated into three fractions:

a. 0.05-μm filtrate - defined as the soluble fraction.

b. 0.05-μm to 8-μm fraction - for determining the content of pollutants in medium-size suspended particulates.

c. Larger than 8-μm fraction - for identifying the association of pollutants with settleable particulates.

115. Results of the fractionation study show that most of the contaminants in the influent and effluent samples were associated with settleable particulates. With the exception of major ions, such as sodium, potassium, calcium, magnesium, and chloride, only a very small por-
tion of the chemical constituents was in the soluble frac-
tion. The concentrations in the medium-size particulates
were also at a very low level. Table 6 gives the compari-
son of the size fractionation of pollutants. Since large
particulates will generally settle within properly managed
containment areas, the impact caused by this fraction is re-
latively short-term. On the other hand, the soluble frac-
tion and medium-size suspended particulates may be the most
important fraction as a source for potential pollutional
effects. These substances can be transported in the efflu-
ents, and thus present a potential for the pollution of the
receiving waters.

Pollutional Potential of Soluble Fraction
of Pollutants

116. Information on soluble constituents in influ-
ents and effluents is very important due to the availability
of soluble contaminants for biological uptake. The follow-
ing sections discuss the fate of soluble constituents in
confined dredged material disposal areas.

Removal of major soluble ions

117. The removal of soluble calcium and magnesium was
insignificant with the exception of 54% removal of magnesium
at Grassy Island. This removal might have been caused by
pH changes due to photosynthetic reactions.

Removal of carbon, nitrogen, and phosphorus compounds

118. Carbon species in the influent samples may be
derived mainly from the interstitial water. Upon mixing of
background water with dredged sediments, additional inorganic
and organic carbon may be released from the dredged slurry
solids. Inorganic species either increased or decreased
after diked disposal, depending on the regulating mecha-
nisms, i.e., dissolution or precipitation of carbonate
solids. The bio-oxidation of organic carbon to carbon di-
oxide may contribute additional inorganic carbon during the detention period. Since the confined area is an open system, the loss or diffusion of carbon dioxide cannot be ruled out. Photosynthetic reactions can also reduce the concentration of inorganic carbon dioxide.

119. Total organic carbon was increased by 111% at Pinto Island probably as a result of the selective removal of the heavier mineral particles and the release of indigenous organic matter from the site. Total organic carbon at Grassy Island was reduced by 62%. This decrease was probably due to both the efficient removal of suspended solids and the biological oxidation of soluble organic carbon, with respiration exceeding photosynthesis.

120. The removal of NH$_3$-N, organic N, and NO$_3$-N at Pinto Island was not significant. At Grassy Island, 83% NH$_3$-N and 96% organic N in the total samples were removed. In an oxidizing environment, the bacterial decomposition of organic N to NH$_3$-N and subsequent nitrification should cause an increase in the nitrate concentration. However, nitrate levels in the effluent samples did not show a significant increase, suggesting possible removal by denitrification and biological uptake by vegetation and algae. Ion exchange and adsorption by clay minerals may also account for some of the nitrate removal. Nitrite species are generally unstable in both aerobic and anaerobic environments and were not detected in this study.

121. The release or precipitation of phosphate depends to a great extent on the form and concentration of soluble iron. Under aerobic conditions at neutral pH, the FePO$_4$ solid is very stable and can limit the soluble phosphate level to about 0.09 ppm. The soluble phosphate level may also be decreased by vegetation uptake and adsorption by clay minerals and ferric hydroxide precipitates.
Removal of Trace Metals

122. Under oxidizing conditions, newly formed metallic carbonate, hydroxide, and silicate solids could increase the solubility of most trace metals during detention. However, most soluble (< 0.05-μ) trace metal concentrations were reduced in the effluent samples. The following reasons are suggested:

a. The solubility-controlling solids might remain as metallic sulfides instead of being transformed to carbonates, hydroxides or silicates due to short detention times. Therefore, the concentrations of soluble metals could not be increased.

b. The decrease of metal ligands in the effluents as suggested by the decrease in TOC may account for the decrease in metal-organic complexes.

c. The soluble iron and manganese concentrations were quite high in the influents; these could be oxidized in the presence of oxygen to form hydrated oxides which could scavenge most of the other soluble metals from the solution.

Effluent Discharge From Confined Disposal Areas

vs. Pertinent Water Quality Criteria

123. A summary of the effluent data in Table 8 is compared with the California State Water Resources Control Board (CSWRCB) ocean water discharge standards of 1972 and the 1973 marine water quality criteria proposed by the National Academy of Science (NAS) and the EPA. The results are compared for general parameters, chlorinated hydrocarbons, soluble trace metal concentrations, and total trace metal concentrations. It should be noted that the CSWRCB, NAS, and EPA water quality criteria do not differentiate between soluble and particulate concentrations, i.e., the criteria in Table 8 are based on total concentrations.
General parameters

124. **Dissolved Oxygen.** Dissolved oxygen in the Grassy Island effluents was slightly higher than the background water (7 mg/l). The effluent D.O. at Pinto Island was 3 mg/l. This level is lower than the EPA marine water quality criteria. However, if the dilution ratio of the receiving waters is larger than 5, it will meet the CSWRCB and the EPA criteria; a dilution ratio of 5 should be obtainable in most situations of effluent discharges. Therefore, required D.O. levels would be achieved, e.g.,

\[
\frac{[3(1) + 7.5(5)]}{[1 + 5]} = 6.75
\]

125. **pH.** Effluent pH levels are acceptable.

126. **Oil and grease.** The California ocean discharge standards for oil and grease are 10 mg/l for less than 50% of the time and 15 mg/l for less than 10% of the time. Grassy Island effluent meets the 10% value but not the 50% value; however, the oil and grease levels in the Pinto Island effluent were three times the 10% required concentration value, and 4-1/2 times the 50% value.

127. **Suspended solids.** Suspended solids in the Grassy Island effluent satisfy the CSWRCB criteria; suspended solids in the Pinto Island effluent were somewhat higher than the acceptable level. Increased detention times or treatment may be necessary in some cases in order to meet applicable water quality criteria.

128. **NH₃-N.** Ammonium levels in both disposal area effluents were higher than both EPA and NAS marine water quality criteria.

129. **NO₃-N.** Nitrate levels in the effluents at both sites ranged from 0.1 - 0.25 mg/l. The listed criteria do not specify a required nitrate level. Since the background water contained about 0.1 mg/l nitrate, it is evident that the effluent levels were not significantly higher than the
background water. The nitrate criterion suggested by both the EPA and NAS for fresh water (public supply) is 10 mg/l. Therefore, the effluent concentrations at both sites are considered acceptable.

130. Phosphorus. Soluble orthophosphate in the effluents at both sites meets the NAS and EPA marine water quality criteria. The total phosphorus concentrations in the effluents at both sites were much higher than the NAS and EPA criteria.

Chlorinated hydrocarbons

131. The CSWRCB standards for total chlorinated hydrocarbons are 2 µg/l for less than 50% of the time and 4 µg/l for less than 10% of the time. Results show that the total chlorinated hydrocarbons in effluents at both sites were much higher than the standards. The settling tests indicate that most of the chlorinated hydrocarbons were associated with the particulate phase; therefore, increased detention times or treatment would be required in order to meet water quality criteria. This is particularly true at the Pinto Island site where only 46% of the total solids were removed. The Grassy Island site presents a different problem in that 99.7% of the total solids were removed; it is not known if the removal of additional suspended solids would lower the total chlorinated hydrocarbon concentrations to an acceptable level.

Soluble trace metal concentrations

132. The soluble (< 0.05-µ) trace metal concentrations in the effluents at both sites meet the CSWRCB, NAS, and EPA marine water quality criteria.

Total trace metal concentrations

133. In general, the total trace metal concentrations in the effluents at both sites were significantly higher than the NAS, EPA, and CSWRCB water quality re-
quirements, e.g., the total zinc concentration in the effluent at Pinto Island was over 100 times the allowable NAS level. The analytical results show that most of the trace metal concentrations are associated with the solid phase; therefore, increased detention times or treatment (coagulation) would be required to meet applicable water quality criteria.
PART V: CONCLUSIONS

134. The conclusions drawn from the analysis of data in this study are as follows:

a. The results show that the trace metal concentrations in both the solid and soluble phases of the influents were higher than the background water levels with the exception of soluble zinc at Pinto Island. The release of soluble trace metals was in the ppb and sub-ppb range. The initial release is most likely due to the mixing of interstitial waters, oxidation of metallic sulfides, dissolution, complex formation, and ion exchange.

b. The increase of total metal concentrations in the influent samples is primarily associated with the solid phase, i.e., 97 to 99%. Grassy Island showed higher levels of increase due to the greater solids content of the influent, i.e., 187 g/l vs. 71 g/l for Pinto Island.

c. Trace amounts of soluble sulfide were measured in the influents at both sites, indicating possible oxidation of sulfide species during dredging operations and transportation to the confined disposal areas. However, these values may be somewhat unreliable as they were not obtained directly in the field.

d. The results of the geochemical phase transformation study suggest that the concentrations of soluble trace metals under oxidizing conditions should increase during confined area disposal; however, most of these metal concentrations were decreased in the effluents. The observed reduction of soluble trace metals may be due to the following: (1) incomplete oxidation of metallic sulfides due to short detention times; (2) removal in the exchangeable phase; (3) decrease of metal ligands; and (4) coprecipitation or incorporation with the hydrated oxides of iron and manganese.

e. In general, the removal efficiency of trace metals in the total samples was very similar to the total solids removal. These results are in agreement with the analytical data.
which show that the major portion of the total trace metals was associated with the solid phase.

f. There was almost complete removal of total solids at the Grassy Island disposal area (99.7%) compared to the 46% removal at Pinto Island. The high solids removal at Grassy Island was due to long detention times obtained by total confinement procedures. The relatively poor removal of total solids at Pinto Island was due to the high concentration of dissolved solids (as indicated by high conductivity values) in conjunction with reduced detention times resulting from observed "short-circuiting" in the disposal area and subsequent discharge of the effluent over a weir at a 4-inch hydraulic head.

g. The observed decrease in total NH₃-N and organic N in an oxidizing environment should result in an increase in the nitrate concentration. However, at Grassy Island, nitrate levels did not show a significant increase in the effluent samples, suggesting that some denitrification, ion exchange of ammonium, biological uptake, and/or inhibition of nitrification occurred in the disposal area.

h. The decrease of total organic carbon at Grassy Island was probably due to both the removal of settleable solids and the biological oxidation of soluble organic carbon. The increase of total organic carbon at Pinto Island is probably the result of biological uptake and subsequent decomposition of organic matter at the site.

i. Phosphorus compounds in the soluble phase were below detection limits. The level of soluble phosphate may be limited by FePO₄ precipitates, biological uptake, or adsorption by clay minerals and ferric hydroxide precipitates.

j. The nearly complete removal of chlorinated hydrocarbons during the settling test indicates that the association of chlorinated hydrocarbons with the oil and grease fraction is not a significant factor. These results indicate that the chlorinated hydrocarbons were largely associated with large
sediment particles.

k. The decrease in alkalinity at Grassy Island may be the result of uptake of carbon dioxide during photosynthesis and the subsequent pH increase promoting the precipitation of calcium carbonate.

l. The increase in alkalinity at Pinto Island may be due to the oxidation of organic carbon to carbon dioxide followed by the dissolution of solid metal carbonate to yield predominately bicarbonate species.

m. The results show that the concentration of soluble trace metals in Grassy Island and Pinto Island effluents were in the ppb or sub-ppb range. These concentrations are well below the CSWRCB ocean water discharge standards and the NAS and EPA marine water quality criteria. Therefore, the water quality impact of soluble trace metals in effluents discharged into the receiving waters is considered to be negligible.

n. The results indicate that dissolved oxygen levels, and concentrations of oil and grease, chlorinated hydrocarbons, NH$_3$-N, solid phosphates, and suspended solids may pose a potential water quality problem. In general, these parameters could not meet the CSWRCB, NAS, and EPA water quality criteria.

o. The CSWRCB, NAS, and EPA marine water quality criteria are based on total concentrations. The results of this study show that the total trace metal concentrations in the effluents at both Grassy Island and Pinto Island disposal areas were significantly higher than the referenced water quality criteria. While the extent of redissolution is very small, contaminants attached to the particles can be transported by the effluent to the receiving waters. The ecological significance of these particles cannot be well-defined at present. Nevertheless, trace metals and chlorinated hydrocarbons associated with suspended particles, including macromolecular organic complexes, may pose some problems due to the possible biological uptake.

p. It is concluded that confined disposal operations will require either long detention
times or treatment in order to meet CSWRCB, NAS, and EPA effluent water quality requirements. One possible solution to minimize this problem is the direct treatment of dredged material or discharged effluents by the addition of coagulants to improve the settling characteristics of suspended particulates.
REFERENCES


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<th>F - Value</th>
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| Selenium | 0.429 0.561 | Selenium | 0.429 0.561 | 1.75 | NSD,
| Solids, mg/kg | 15.3 14.2 | 1.17 | NSD, |
| (<0.45), mg/l | 1.53 0.553 | 3.21 104 | NSD, |
| (<0.05), mg/l | 1.49 0.712 | 0.17 65 | NSD, |
| In Oil | 0.632 0.228 | 499 | NSD, |
| Grease, mg/l | 0.075 0.199 | 6.66 | NSD, |
| Vanadium | 0.436 0.800 | 3.39 | NSD, |
| Solids, mg/kg | 17.4 12.9 | 1.81 | NSD, |
| (<0.45), mg/l | 1.60 1.27 | 1.60 | NSD, |
| (<0.05), mg/l | 1.00 1.29 | 1.00 | NSD, |
| In Oil | 1.33 1.36 | 1.33 | NSD, |
| Grease, mg/l | 0.999 0.542 | 1.18 | NSD, |

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<td>50; 1; 5</td>
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<td>Arcochlor 1254</td>
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<td>0.006</td>
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<td>•</td>
<td>50; 1; 5</td>
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<td>0.001</td>
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### TABLE 3
Statistical Character Of Background Water, Influent and Effluent Samples
For Grassy Island, Detroit, Michigan - A Site Specific Analysis

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<tr>
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<td>Effluent</td>
<td>Background Water</td>
</tr>
<tr>
<td>pH</td>
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<td>3</td>
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<tr>
<td>Slurry (&lt;0.45 μm)</td>
<td>6</td>
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<td>1</td>
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<tr>
<td>Salinity, /o</td>
<td>9</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Slurry (&lt;0.45 μm)</td>
<td>6</td>
<td>6</td>
<td>1</td>
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<tr>
<td>Conductivity, in mhos</td>
<td>9</td>
<td>9</td>
<td>3</td>
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<tr>
<td>Slurry (&lt;0.45 μm)</td>
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<tr>
<td>Water Temp, °C</td>
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<tr>
<td>Dry Weight, %</td>
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<tr>
<td>D.O., mg/l</td>
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<td>Background W</td>
<td>Influent</td>
<td>Effluent</td>
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<tr>
<td>pH</td>
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<td>0.074</td>
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<tr>
<td>Slurry (&lt;0.45 μm)</td>
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<td>0.216</td>
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<td>1.95</td>
<td>*</td>
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<td>Salinity, /o</td>
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<td>0.132</td>
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<td>Slurry (&lt;0.45 μm)</td>
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<td>0.009</td>
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<td>0.017</td>
<td>0.01</td>
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<td>0.000</td>
<td>0.000</td>
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<td>Water Temp, °C</td>
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<td>0.866</td>
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<td>Dry Weight, %</td>
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(Continued)

IND. - Indeterminate.
(--) - Not Determined (Insufficient Sample or Sample Destroyed In Transit).
(0) - Not Enough Solids To Perform Analysis.
(*) - Cannot Ascertain Since Not Determined or Not Enough Solids to Perform Analysis.

SD1.5 - Significant Difference at P < 0.05 and P < 0.01.
NSD1.5 - No Significant Difference at Either P < 0.05 or P < 0.01.
SD1.5 - Significant Difference at P < 0.05 only.
ND - No Difference (Difficult to decide on significance of difference since values compared are at trace levels).
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<th>Range Effluent</th>
<th>Range Background Water</th>
<th>Mean Influent</th>
<th>Mean Effluent</th>
<th>Mean Background Water</th>
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<td>310-610</td>
<td>198-290</td>
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<td>505</td>
<td>244</td>
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<tr>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Chloride, mg/l</td>
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<td>40.7-67.8</td>
<td>44.9-53.9</td>
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<td>50.6</td>
<td>47.9</td>
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<tr>
<td>(0.45-μ)</td>
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<td>Cation Exchange Capacity, meq/l</td>
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<td>*</td>
<td>69.2</td>
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<tr>
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<td>85.0-101</td>
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<td>(60-μ)</td>
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<td>68.0</td>
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<td>64.0</td>
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<th>F-Value Effluent vs. Background Influent</th>
<th>F-Value Background W vs. Background Water</th>
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<th>Removal Influent vs. Background Influent</th>
<th>Impact Influent vs. Background Influent</th>
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<td>Cation Exchange Capacity, meq/l</td>
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Table 3 (Continued)

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<td>(&lt;0.45 μm)</td>
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<td>(&lt;0.05 μm)</td>
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<td>NH₃-N, mg/l</td>
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<td>(&lt;0.45 μm)</td>
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<td>(&lt;0.05 μm)</td>
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<td>Organic-N, mg/l</td>
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<td>(&lt;8 μm)</td>
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Table 3 (Continued)

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<td>1</td>
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<tr>
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<td>(&lt;0.45-μm)</td>
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<td>Influent</td>
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<td>Background Water</td>
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<td>%0</td>
<td>%0</td>
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### Table 3 (Continued)

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Table 3 (continued)

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<td>*</td>
<td>SD1,5</td>
</tr>
<tr>
<td>Slurry, mg/l</td>
<td>31.7 n n</td>
<td>*</td>
<td>n</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>Solids, mg/kg</td>
<td>52.1 1.05</td>
<td>*</td>
<td>2470</td>
<td>*</td>
<td>SD1,5</td>
</tr>
<tr>
<td>(&lt;6-μm), μg/l</td>
<td>39.0 1.11</td>
<td>**</td>
<td>1250</td>
<td>*</td>
<td>SD1,5</td>
</tr>
<tr>
<td>(&lt;0.05-μm), μg/l</td>
<td>22.2 0.902</td>
<td>*</td>
<td>608</td>
<td>*</td>
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<tr>
<td>In GIL</td>
<td>0.308 2.94</td>
<td>*</td>
<td>48.0</td>
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<tr>
<td>Grease, mg/l</td>
<td>52.2 n n</td>
<td>*</td>
<td>n</td>
<td>n</td>
<td>n</td>
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<tr>
<td>Carb. Phase, mg/kg</td>
<td>1.74 n n</td>
<td>*</td>
<td>n</td>
<td>n</td>
<td>n</td>
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<td>Exch. Phase, mg/kg</td>
<td></td>
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<tr>
<td>Chlorinated Hydrocarbons</td>
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<tr>
<td>OP’s DDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry, mg/l</td>
<td>7.22 0.057</td>
<td>*</td>
<td>17400</td>
<td>*</td>
<td>SD1,5</td>
</tr>
<tr>
<td>PP’s DDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Slurry, mg/l</td>
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<td>*</td>
<td>374000</td>
<td>*</td>
<td>SD1,5</td>
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<td>OP’s DDE</td>
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<tr>
<td>Slurry, mg/l</td>
<td>16.0 0.028</td>
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<td>320000</td>
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<tr>
<td>PP’s DDE</td>
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<tr>
<td>Slurry, mg/l</td>
<td>29.9 0.166</td>
<td>*</td>
<td>33100</td>
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<td>SD1,5</td>
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<tr>
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<td>Effluent</td>
<td>Background Water</td>
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<tr>
<td>DP DDT Slurry, mg/l</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<tr>
<td>PP DDT Slurry, mg/l</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total DDT Slurry, mg/l</td>
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<tr>
<td>Aroclor 1242 Slurry, mg/l</td>
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<table>
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<th>F - Value</th>
<th>Loading</th>
<th>Removal</th>
<th>Impact</th>
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<td>Effluent</td>
<td>Background Water</td>
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<td>Effluent</td>
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<tr>
<td>DP DDT Slurry, mg/l</td>
<td>4.85</td>
<td>0.036</td>
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<td>23500</td>
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<td>Total DDT Slurry, mg/l</td>
<td>95.8</td>
<td>0.365</td>
<td>*</td>
<td>70600</td>
<td>*</td>
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<tr>
<td>Aroclor 1242 Slurry, mg/l</td>
<td>43.7</td>
<td>0.527</td>
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<td>6820</td>
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Table 3 (Concluded)

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<td>Influent Effluent</td>
<td>Background Water</td>
<td>Influent Effluent Background Water</td>
</tr>
<tr>
<td>Acclor 1254 Slurry, mg/l</td>
<td>3     3          1</td>
<td>4.20-24.4  0.010-0.080</td>
<td>16.9  0.057</td>
</tr>
<tr>
<td>Acclor 1260 Slurry, mg/l</td>
<td>3     3          1</td>
<td>1.10-9.80  0.006-0.020</td>
<td>5.90  0.012</td>
</tr>
<tr>
<td>Total PCB Slurry, mg/l</td>
<td>3     3          1</td>
<td>16.9-133  0.166-1.28</td>
<td>80.1  0.715</td>
</tr>
</tbody>
</table>

<table>
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<th>Loading</th>
<th>Removal</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Influent Effluent</td>
<td>vs. Background W Effluent</td>
<td>vs. Background W</td>
<td>vs. Background W</td>
<td>vs. Background W</td>
</tr>
<tr>
<td>Acclor 1254 Slurry, mg/l</td>
<td>11.0  0.038</td>
<td>•</td>
<td>122000</td>
<td>•</td>
<td>501.4</td>
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<tr>
<td>Acclor 1260 Slurry, mg/l</td>
<td>4.42  0.007</td>
<td>•</td>
<td>351000</td>
<td>•</td>
<td>501.4</td>
</tr>
<tr>
<td>Total PCB Slurry, mg/l</td>
<td>58.7  0.557</td>
<td>•</td>
<td>111000</td>
<td>•</td>
<td>501.5</td>
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### TABLE 4
Average Values For Field Data Of Influent, Effluent, and Background Water From Pinto Island (Mobile Bay, Alabama) and Grassy Island (Detroit, Michigan) Dredged Material Disposal Areas

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pinto Island</th>
<th>Grassy Island</th>
<th>Number Of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Influent</td>
<td>Effluent</td>
<td>Background Water</td>
</tr>
<tr>
<td></td>
<td>Influent</td>
<td>Effluent</td>
<td>Background Water</td>
</tr>
<tr>
<td>Slurry PH</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Salinity, °/oo</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Conductivity, mMhos</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Dissolved O₂, mg/l</td>
<td>6</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Water Temp., °C</td>
<td>5</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

- Not Measured in Field.
### Table 5

Average Values for Physical and Chemical Parameters of Influent, Effluent and Background Water Samples from the Pinto Island (Mobile Bay, Alabama) and Grassy Island (Detroit, Michigan) Dredged Material Disposal Areas

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Number of Samples</th>
<th>Pinto Island</th>
<th>Grassy Island</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Influent</td>
<td>Effluent</td>
</tr>
<tr>
<td>PH ((&lt;0.45-\mu))</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Salinity ((&lt;0.45-\mu))</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Conductivity, mHos ((&lt;0.45-\mu))</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Dry Weight, %</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Total Alkalinity, mg/l ((&lt;0.45-\mu))</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Chloride, mg/l ((&lt;0.45-\mu))</td>
<td>6</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Cation Exchange Capacity, meq/l</td>
<td>6</td>
<td>12</td>
<td>–</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Average Values</th>
<th>Pinto Island</th>
<th>Grassy Island</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Influent</td>
<td>Effluent</td>
</tr>
<tr>
<td>PH ((&lt;0.45-\mu))</td>
<td>7.4</td>
<td>7.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Salinity ((&lt;0.45-\mu))</td>
<td>25.5</td>
<td>20.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Conductivity, mHos ((&lt;0.45-\mu))</td>
<td>24.8</td>
<td>22.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Dry Weight, %</td>
<td>7.06</td>
<td>3.83</td>
<td>0.16</td>
</tr>
<tr>
<td>Total Alkalinity, mg/l ((&lt;0.45-\mu))</td>
<td>151</td>
<td>213</td>
<td>50</td>
</tr>
<tr>
<td>Chloride, mg/l ((&lt;0.45-\mu))</td>
<td>13.5</td>
<td>11.6</td>
<td>1.90</td>
</tr>
<tr>
<td>Cation Exchange Capacity, meq/l</td>
<td>28.4</td>
<td>11.8</td>
<td>–</td>
</tr>
</tbody>
</table>

(Continued)

(—) Not Determined (Indicates Insufficient Sample or Sample Destroyed in Transit).

(*) Due to the Insufficient Amount of Solids, Values in ( ) are for Reference Only.

(•) Samples were shaken and then Allowed to Settle. The Supernatant was withdrawn with a Hamilton Syringe (406 – µ opening) and injected into the TOC Analyzer.
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pinto Island</th>
<th>Grassy Island</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number Of Samples</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Influent</td>
<td>Effluent</td>
</tr>
<tr>
<td><strong>Total Acid Soluble Sulfide, mg/l</strong></td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total Carbon Slurry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total * 4, mg/l</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>(&lt;8-μ), mg/l</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>(&lt;0.45-μ), mg/l</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>(&lt;0.05-μ), mg/l</td>
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<td>11</td>
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<tr>
<td><strong>Organic Carbon</strong> Slurry Total * 4, mg/l</td>
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<td>10</td>
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<tr>
<td>(&lt;8-μ), mg/l</td>
<td>6</td>
<td>11</td>
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<tr>
<td>(&lt;0.45-μ), mg/l</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>(&lt;0.05-μ), mg/l</td>
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<td>11</td>
</tr>
<tr>
<td><strong>Oil &amp; Grease</strong></td>
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<tr>
<td>Slurry Total, mg/l</td>
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<td>11</td>
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<tr>
<td>Supernatant After 2 hrs. settling, mg/l</td>
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<td>3</td>
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<tr>
<td>Supernatant After 12 hrs. settling, mg/l</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Supernatant After 24 hrs. settling, mg/l</td>
<td>3</td>
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<td>Supernatant After 48 hrs. settling, mg/l</td>
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<td>Influent</td>
<td>Effluent</td>
</tr>
<tr>
<td><strong>Total Acid Soluble Sulfide, mg/l</strong></td>
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<td><strong>Total Carbon Slurry</strong></td>
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<tr>
<td>Total * 4, mg/l</td>
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<td>93.8</td>
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<tr>
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<td><strong>Oil &amp; Grease</strong></td>
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Table 5 (Continued)

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<td>1</td>
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<tr>
<td>(&lt;0.05), mg/l</td>
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<td>2</td>
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<td>1</td>
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<td>3</td>
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Average Values

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<th>Influent</th>
<th>Effluent</th>
<th>Background Water</th>
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<td>TRACE</td>
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<td>60.5</td>
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<td>7.46</td>
<td>0.64</td>
<td>6.77</td>
<td>1.98</td>
<td>0.96</td>
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</tr>
<tr>
<td>Slurry Total, mg/l</td>
<td>0.28</td>
<td>0.23</td>
<td>0.09</td>
<td>0.20</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>(&lt;0.45), mg/l</td>
<td>0.28</td>
<td>0.23</td>
<td>0.09</td>
<td>0.20</td>
<td>0.11</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Total - P

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Mercury

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Average Values

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### Table 6

**Size Fractionation of Chemical Species in Influent, Effluent, and Background Water Samples from the Pinto Island, Mobile Bay, Alabama and Grassy Island, Detroit, Michigan Dredged Material Disposal Sites**

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**Grassy Island**

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*T = Total Slurry.
A = Soluble Fraction <0.05 μm.
B = Medium-Size Fraction, 0.05 to 0.5 μm.
C = Settleable Fraction, >0.5 μm.
- = Cannot Determine Since Dealing with Trace Values.
* = Not Determined (Indicates Insufficient Sample or Sample Destroyed in Transit).
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* = Total Slurry.
A = Soluble Fraction <0.05-μ.
B = Medium-Size Fraction, 0.05 to 8μ.
C = Settleable Fraction, >8μ.
- = Cannot Determine Since Dealing with Trace Values.
- = Not Determined (Indicates Insufficient Sample or Sample Destroyed in Transit).
Table 6 (Continued)

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GRASSY ISLAND

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### Table 6 (Concluded)

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* Analyzed on Total (Slurry) Sample.

- None Detected.
### Table 8

Comparison of Pinto Island and Grassy Island Effluents with Marine Water Criteria

| Parameters                        | Proposed EPA Marine Water Quality (1973) (9) | Proposed NAS Marine Water Quality (1973) (9) | Ocean Discharge Standards of California (1972) (8) | Effluents | Background Water (0.05-μm Filtrate) |  |
|-----------------------------------|---------------------------------------------|---------------------------------------------|------------------------------------------------|-----------|--------------------------------------|  |
|                                  | pH 6.5-8.5                                  | 6.5-8.5                                    | <0.2 changes                                    | 7.8       | 8.3                                  | 7.6 | 7.3                                  |
|                                  | D.O. (mg/l) 6                              | <0.2 changes                                | 7.8                                              | 8.3       | 7.6                                  | 7.3 |                                  |
|                                  | NH₃-N (mg/l) 0.4                           | 0.4                                        | <10% changes                                    | 2.4       | 7.3                                  | 7.6 | 7.0                                  |
|                                  | NO₃-N (mg/l)                                | <10% changes                                | 12.8                                             | 14.2      | 7.6                                  | 7.0 |                                  |
|                                  | P (mg/l) 0.07                               | 0.005                                      | 12.8                                             | 14.2      | 7.6                                  | 7.0 |                                  |
|                                  | Oil and Grease (mg/l)                       | not visible                                 | trace                                            | trace     | 0.147                                | 3.5 | 32                                  |
|                                  | Suspended Solids (mg/l)                     | 50                                          | 45                                               | 15        | 15                                   | 3.5 | 32                                  |
|                                  | As (ug/l) 200                               | 200                                        | 80                                               | 6         | 10                                   | trace |                                  |
|                                  | Cd (ug/l) 100                               | 10                                         | 20                                               | 2.0       | 2.0                                  | 2    | 0.9                                  |
|                                  | Cr (ug/l) 100                               | 50                                         | 10                                               | 5.06      | 0.67                                 | 0.9 |                                  |
|                                  | Cu (ug/l)                                  | 200                                        | 30                                               | 4.51      | 1310                                 | 4.43 | 1620                                |
|                                  | Fe (ug/l) 300                               | 300                                        | 200                                              | 3.85      | 3400                                 | 5.99 | 105                                 |
|                                  | Pb (ug/l)                                  | 100                                        | 100                                              | 3.58      | 21000                                | 49   | 600                                 | 2    |                                  |
|                                  | Mn (ug/l)                                  | 100                                        | 100                                              | 0.17      | 22                                   | 0.13 | 3.1                                 | 0.03 | 0.05                              |
|                                  | Hg (ug/l)                                  | 100                                        | 100                                              | 3.79      | 2020                                 | 1.89 | 210                                 |
|                                  | Ni (ug/l)                                  | 100                                        | 100                                              | 100       | 200                                  | 1.54 | 480                                 | 0.94 | 2.0                               |
|                                  | Zn (ug/l)                                  | 500                                        | 500                                              | 104       | 10,700                                | 1.54 | 480                                 |
|                                  | Total Chlorinated Hydrocarbons (μg/l)       | 2                                          | 4                                                | 448 settleable | 1320 settleable | 9 settleable | 540 settleable |

* Soluble (<0.05-μm).
** Total.
° 0.45-μm Filtrates.
Δ Field Data Averages.
El Vegetated Area (mostly Phragmites) 7'5" wide 4'10" I.D. Drain Effluent Pipe 1 7'5" weir with about 4-5" head of water

Figure 1. Pinto Island Disposal Site, Mobile, Alabama.
Figure 2. Grassy Island Disposal Site, Detroit, Michigan.
Figure 3. Relationships between Alkalinity and Total Soluble Inorganic Carbon.
Figure 4. Influent Oil and Grease Concentration vs. Settling Time.
Figure 5. Effluent Oil and Grease Concentration vs Settling Time.
Figure 6. Influent Oil and Grease Concentration vs. Settling Time.
Figure 7. Effluent Oil and Grease Concentration vs. Settling Time.
Figure 8. Supernatant Concentration of op'DDD vs. Settling Time.
Figure 9. Supernatant Concentration of pp'DDD vs. Settling Time.
Figure 10. Supernatant Concentration of op'DDE vs. Settling Time.
Figure 11: Supernatant Concentration of pp'DDE vs. Settling Time.
Figure 12. Supernatant Concentration of op'DDT vs. Settling Time.
Figure 13. Supernatant Concentration of pp'DDT vs. Settling Time.
Figure 14. Supernatant Concentration of Total DDT vs. Settling Time.
Figure 15. Supernatant Concentration of PCB 1242 vs. Settling Time.
Figure 16. Supernatant Concentration of PCB 1254 vs. Settling Time.
Figure 17. Supernatant Concentration of PCB 1260 vs. Settling Time.
Figure 18. Supernatant Concentration of Total PCB vs. Settling Time.
Figure 19. Supernatant Concentration of op'DDD vs. Settling Time.
Figure 20. Supernatant Concentration of pp'DDD vs. Settling Time.
Figure 21. Supernatant Concentration of op'DDE vs. Settling Time.
Figure 22. Supernatant Concentration of pp'DDE vs. Settling Time.
Figure 23. Supernatant Concentration of op'DDT vs. Settling Time.
Figure 24. Supernatant Concentration of pp'DDT vs. Settling Time.
Figure 25. Supernatant Concentration of Total DDT vs. Settling Time.
Figure 26. Supernatant Concentration of PCB 1242 vs. Settling Time.
Figure 27. Supernatant Concentration of PCB 1254 vs. Settling Time.
Figure 28. Supernatant Concentration of PCB 1260 vs. Settling Time.
Figure 29. Supernatant Concentration of Total PCB vs. Settling Time.
1. Echinochloa walteri (Pursh) Heller
2. Scirpus maritimums L.
3. Sesbania drummondii (Rydb.) Cory.
4. Panicum repens L.
5. Rumex chrysocarpus Moris.
6. Paspalum vaginatum Sw.
7. Distichlis spicata (L.) Greene
8. Cyperus strigosus L.
9. Sabatia Capestria Nutt.
10. Sebania vesicaria (Jacq.) Ell.
11. Myrica cerifera L.
12. Heliotropium curassavicum L.
13. Heterotheca subaxillairs (Lam.) Britt. & Rusby
15. Kosteletzkya virginica (L.) Gray
16. Hypericum gentianoides (L.) B.S.P.
17. Andropogon spp.
18. Diodia teres Walt.
19. Fimbristylis castanea (Michx.) Vahl.
21. Baccharis halimifolia L.
22. Verbena brasiliensis Vell.
23. Cyperus compressus L.
25. Xanthocephalium dracunculoides (DC.) Shinners
27. Sapium sebiferum (L.) Roxb.
28. Cinnamomum camphora (L.) Nees and Eberm.
30. Phytolacca americana L.
31. Solanum sisymbriifolium lam.
32. Aster subulatus Michx. (A. exilis of some suth.)
33. Typha angustifolia L.
34. Paspalum urvillei Steud.
35. Panicum dichotomiflorum Michx.
36. Eupatorium serotinum Michx.
37. Solidago sempervirens L.
38. Eupatorium capillifolium (Lam.) Small
39. Helianthus amarum (Raf.) Rock.
40. Salix nigra L.
41. Pluchea purpurascens (Sw.) DC.
42. Cynodon dactylon (L.) Pers.
43. Mollugo verticillata L.
44. Chenopodium ambrosioides L.
45. Leptochloa fascicularis (Lam.) A. Gray
46. Panicum spp.
47. Juncus spp.
48. Crotalaria spp.

General Notes

1. Barren areas appear to approach the 14' elevation where vegetation then begins. Annual herbs appear from approximately 15 to 19 feet elevation, shrubs and perennial herbs from 19 to 22 feet elevation.

2. Dominant herbs at lower elevations are Pluchea purpurascens, Aster subulatus and Panicum dichotomiflorum. At higher elevations Panicum rapens, Solidago sempervirens, Andropogon spp. and Strophostyles helvolia are very common. Shrubs (Baccharis halimifolia and Myrica certifera) and trees (Salix nigra) occur at the highest elevations along with Phragmites communis.

3. Pools of saline water occur at the lowest elevations. A gull rookery exists on barren dry land areas between dredging periods.
APPENDIX B: ANALYTICAL METHODS

Metals

**Total sample**

1. Total sample for the determination of metals (except Hg) was digested by concentrated HF, HNO₃ and HClO₃ at 175°F in a Teflon beaker (with Teflon cover) until the solution cleared. Atomic absorption spectrophotometers (Perkin-Elmer Models 305B and 460) were used for the analysis of metals. Both flame and heated graphite atomizers (HGA 2100) were used for total sample analysis. The choice of an atomizer is dependent on the suitable linear range of the element. The following table is a guide for choosing the atomizer:

<table>
<thead>
<tr>
<th>Element</th>
<th>Flame Atomizer (mg/l)</th>
<th>Heated Graphite Atomizer (pg)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0.03 - 1</td>
<td>20 - 2000</td>
</tr>
<tr>
<td>K</td>
<td>0.1 - 2</td>
<td>10 - 2500</td>
</tr>
<tr>
<td>Ca</td>
<td>0.2 - 20</td>
<td>20 - 1000</td>
</tr>
<tr>
<td>Mg</td>
<td>0.02 - 2</td>
<td>1 - 40</td>
</tr>
<tr>
<td>As</td>
<td>0.002 - 0.02</td>
<td>50 - 1000</td>
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<tr>
<td>Cd</td>
<td>0.05 - 2</td>
<td>3 - 100</td>
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<tr>
<td>Cu</td>
<td>0.2 - 10</td>
<td>50 - 2000</td>
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<tr>
<td>Fe</td>
<td>0.3 - 10</td>
<td>30 - 1000</td>
</tr>
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<td>Hg</td>
<td>10 - 300</td>
<td>500 - 7000</td>
</tr>
<tr>
<td>Mn</td>
<td>0.1 - 10</td>
<td>10 - 500</td>
</tr>
<tr>
<td>Ni</td>
<td>0.3 - 10</td>
<td>200 - 5000</td>
</tr>
<tr>
<td>Pb</td>
<td>1 - 20</td>
<td>50 - 1500</td>
</tr>
<tr>
<td>Se</td>
<td>0.002 - 0.02</td>
<td>50 - 1000</td>
</tr>
<tr>
<td>Ti</td>
<td>5 - 100</td>
<td>1000 - 80000</td>
</tr>
<tr>
<td>V</td>
<td>2 - 100</td>
<td>400 - 20000</td>
</tr>
<tr>
<td>Zn</td>
<td>0.05 - 2</td>
<td>1 - 70</td>
</tr>
</tbody>
</table>

* based on interrupt flow of argon gas

2. Samples for total mercury analysis were digested in Teflon bombs (Parr no. 4745). The procedures are as follows:

   a. Weigh in triplicate 0.1-1 g of sample and place in bottom of a Teflon acid digestion bomb.
b. Carefully add 10-ml conc. HNO₃, 3 ml 48% HF and close the digestion bomb tightly.

c. Place the digestion bomb into an oven (or hot plate) and adjust the temperature to 70°C.

d. Digest the sample until solution is clear.

**Filtrate sample**

3. Analyses of trace metal in filtrates (except Hg) were performed by flameless atomic absorption spectrophotometry. A Perkin-Elmer HGA 2100 was used. If the concentration of trace metals was below the detection limit of the graphite furnace atomizer, then the APDC-MIBK extraction method was used.

4. The cold vapor atomic absorption method was used for Hg determination. Major cations in the filtrate sample (Ca, Mg, K, and Na) were analyzed by flame atomic absorption spectrophotometry.

**Hexane extracts (oil and grease sample)**

5. The analysis of trace metals in hexane extracts was performed by direct injection of extracts in a heated graphite atomizer. Mercury analysis was not performed due to insufficient sample. Samples for major ions were prepared by drying the hexane extracts and redissolving into HNO₃ (pH ≤ 1).

**Phosphorus**

6. Total phosphorus was measured using the modified ascorbic acid method. The procedures are described as follows:

a. Measure 1 - 5 ml of slurry sample and put in Teflon beaker (if filtrate sample, use 50-100 ml).

b. Digest the sample at water boiling temperature using HF (1 ml) and HClO₄ (2 ml) with Teflon cover.

c. After solution is clear, remove the cover and
heat to dryness.

d. Cool, add 2 ml of H$_2$O$_2$ and heat to dryness again.

e. Add 20 ml of H$_2$O and 5 ml of 10N H$_2$SO$_4$.

f. Filter the sample through a glass fiber filter and dilute to 100 ml.

g. Take 40 ml of sample and add 3 ml of 1.6% ammonium molybdate and 4 ml of mixed reagent.
(Mixed reagent = 50 ml of tartrate + 50 ml of 10% ascorbic acid.) (If dilution is required, the reagents to sample ratio should be kept constant. An appropriate amount of 10N H$_2$SO$_4$ should be used to keep the final pH value constant.)

h. Measure the sample by spectrophotometer at 717 nm.

7. The measurement of orthophosphate infiltrates was performed as above without the digestion procedures.

**Acid Soluble Sulfide**

8. Total acid soluble sulfide was determined by stripping and titrimetric processes.

a. Measure 5 ml ZnAc and 95 ml distilled water into absorption flasks. Connect the two adsorption flasks with a 1-liter reaction flask and purge the system with N$_2$ gas for 5 minutes.

b. Transfer 10-to-50-ml slurry sample into the reaction flask and add distilled water to 500 ml, then mix completely.

c. Acidify the sample with 10 ml conc. H$_2$SO$_4$ and replace the prepared 2-hole stopper tightly. Pass N$_2$ through sample for approximately one hour.

d. Add 10 ml of iodine solution and 2.5 ml conc. HCl to each of the absorption flasks, shake and mix thoroughly.

e. Transfer contents of both flasks to a 500-ml flask and back-titrate with 0.025N sodium thiosulfate titrant, using starch solution as indicator.
Chlorinated Hydrocarbons

9. The extraction, separation, and identification of chlorinated hydrocarbons were performed in accordance with the published literature\textsuperscript{12-19}. The details of the operation are described as follows.

**Extraction**

10. 500-ml slurry sample (300-ml supernatant sample) was weighed into a 500-ml Erlenmeyer flask with ground glass stopper. To this flask was added 250 ml of acetonitrile (pesticide quality, Mallinkrodt). The flask was then shaken for 1 hr on a reciprocal shaker. The sample was kept in a constant temperature chamber (14 ± 2°C) overnight. Next, the sample was again shaken for 2 hrs and filtered through 5 g of Celite (Celite 545, Sargent Welch) media on Whatman No. 4 filter paper under mild vacuum. At this time another 100-ml of acetonitrile was added to avoid the possible loss of chlorinated hydrocarbons on the flask wall, Celite, or residue. The filtrate was transferred to a 500-ml Kuderna-Danish concentrator and concentrated to 5 ml in a water bath. The concentrated extract (filtrate) was then transferred to a 1000-ml separatory funnel containing 200 ml of double-distilled water and 10 ml of saturated aqueous NaCl. Eighty ml of petroleum ether (pesticide quality) was used to clean the concentrator, and was then added to the separatory funnel. The funnel was shaken by hand for 5 min and then kept still until clear separation of phases occurred. The aqueous phase (bottom layer) was drained into another separatory funnel containing 80 ml of petroleum ether for the second extraction. After the third extraction, the aqueous phase was discarded and all petroleum ether extracts were collected into a Kuderna-Danish concentrator. After the petroleum ether extract was concentrated to approximately 5 ml, it was then eluted on the prepared acti-
Florisil column elution

11. A chromatographic tube (450 x 28 mm) with a removable frittered glass and Teflon stopcock was packed with 15 g of activated florisil (60/100 mesh, G.C. grade) and topped with 15 g of anhydrous sodium sulfate (analytical grade, Mallinkrodt). The column was then washed with 70 ml of petroleum ether. The petroleum ether extract (concentrated) was added when the petroleum ether wash sank through the top surface of the anhydrous sodium sulfate. Elution was then carried out, first with 175 ml of petroleum ether (0% E.E. = 0%v ethyl ether + 100%v petroleum ether; 6% E.E. = 6%v ethyl ether + 94%v petroleum ether; and 15%v E.E. = 15%v ether + 85%v petroleum ether); next with 100 ml of 6% E.E.; and finally, with 150 ml of 15% E.E. During elution, flow rate was controlled by the stopcock at approximately 2 ml/min. With this florisil column elution, PCB's and most of the DDE were recovered in 0% E.E.; most organochlorine compounds in 6% E.E.; endrin and dieldrin in 15% E.E. The eluted sample was again concentrated and the exact volume was measured.

Identification and quantification

12. Standard solutions of chlorinated hydrocarbons used in this study are more than 99% pure. The DDT series were obtained from Supelco, PCB's from Monsanto, and dieldrin from Shell Chemical. A Hewlett-Packard Research Gas Chromatograph Model 5750 equipped with a Ni$^{63}$ electron capture detector was used throughout the study. The glass column (1220 x 4 mm) was packed with 5% QF-1 (Chromosorb W-HP, 80/100 mesh, Sargent-Welsh). The carrier gas was 95% argon and 5% methane.

13. The sample components were identified by comparison of retention times of unknown peaks to the known peaks of reference standard solutions, and were quantified by comparison of the peak height of the identified component to
the peaks of the component in the reference standard solution.

14. Preliminary sample injections were always performed to decide whether further concentration or dilution of the sample would be required, and to judge which series of reference standard solutions should be used.

15. Chlorinated hydrocarbons in the oil and grease fraction were analyzed by the same method as mentioned above. However, the acetronitrile extractant was omitted and the petroleum ether was directly used for the extraction.

**Hydrocarbons**

16. The following methods and comments pertain to GC-MS mass fragment graphic analysis of hydrocarbons in dredged material slurry and water samples. A high resolution glass capillary column was used to separate the sample components and mass fragment graphic analysis was also performed for hydrocarbon samples.

**Reagents**

- Silica gel 923 Davison
- Methylene Chloride distilled-in-glass
- Hexane distilled-in-glass
- Na₂SO₄ ACS, grade or better, with either Alundum boiling chips, broken in 1-mm fragments.

**Gas Chromatography**

17. All gas chromatography was performed in a Finnigan 9500 GC which is part of a Finnigan 1015D GC-MS system. The extracts were separated in a 30-meter x 0.25-mm glass capillary column coated with SE-30. The column was temperature-programmed from 100°C to 220°C at 2°C/min with no initial isothermal hold. The final hold was variable since no timer was available to control the parameter.
18. In some cases the temperatures were isothermal to permit rapid repetitive analysis of compound, e.g., naphthalene. The temperature for phenanthrene was $180^\circ C$ while the temperature for naphthalene was $100^\circ C$. The split ratio for the column was 10 to 1. The column inlet pressure was 21 pound/in$^2$. The dead volume of the column was 2 min for helium carrier gas.

**Mass spectrometer parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Emission current</td>
<td>450 pump µamp</td>
</tr>
<tr>
<td>Preamp range</td>
<td>$10^{-8}$ amp/volt</td>
</tr>
<tr>
<td>Mass coil</td>
<td>10-250 range</td>
</tr>
<tr>
<td>Electron multiplier voltage</td>
<td>1.9 kV</td>
</tr>
<tr>
<td>Electron energy</td>
<td>70 eV</td>
</tr>
</tbody>
</table>

**Programmable multiple-ion monitor settings**

- Alkanes: m/e 99 & m/e 85
- Naphthalene: m/e 128
- Phenanthrene: m/e 178
- Other aromatics: m/e 162, 156, 142

**Quantification with PROMIN**

19. The Finnigan PROMIN combined with the 1015D gives an inherently linear response in the concentration range under consideration. Quantification is therefore determined by the peak height ratio between standard and sample. For example, if a 4-µg naphthalene standard gives a peak height of 30 divisions and the sample has a peak of 25 divisions, then the sample has $\frac{25}{30} \times 4$-µg, or 3.33-µg of naphthalene.

20. Total alkane is calculated by summing all of the peak heights of the alkane peaks. A factor of 20-µg per 12 divisions was used to calculate the total amount of alkane. This factor is an average value. A more precise way to perform this calculation is to prepare a mixed standard containing all hydrocarbons observed in the sample and use a computer to integrate peak areas and calculate concentrations. It should be pointed out, however, that without
GC resolution of all hydrocarbons, the computer programs cannot accurately quantify fused peaks.

**Computer parameters**

21. A Systems Industries System 150 data system was used as adjunct to the PROMIN, particularly for the aromatics. The data system acquired the data in the scan mode. Ions specific for naphthalene, methylnaphthalenes, dimethylnaphthalenes, and phenanthrene were used to construct mass chromatograms. These mass chromatograms were examined with respect to ion current (GC peaks) at retention times appropriate for the specified organics. The GC peaks were integrated by the computer and the peak area compared to mass chromatograms generated from standards.

**Scan parameters**

- **Mass range:** 100 to 255
- **Integration time:** 20 milliseconds
- **Sample:** 1
- **Threshold:** 1
- **Total run time:** 50 min.

**Preparation of silica gel column**

- a. Heat Davison 923 silica gel for 2 hr at 180 °C. Deactivate by shaking 2 hr with 3 ml water per 100 g of silica gel. Allow to stand overnight in tightly sealed glass container.
- b. Prepare column as shown in diagram (Figure B1).

**Sample extraction**

22. **Sediment samples**

- a. Weight sediment sample into mortar and grind with 5x sample weight of 3% deactivated silica gel 923.
- b. Place mixture into Randall fat extractor thimble and lower thimble into boiling methanol.
- c. Reflux for two hours.
- d. Raise thimble out of methanol into the condensate stream to rinse and complete extrac-
Figure B1. Silica Gel Column.
tion for 2 additional hours.

e. Concentrate the methanol to about 20 ml then dilute to 250 ml with water (methylene chloride-washed) and extract 3 times with 25 ml of methylene chloride.

f. Add the methylene chloride to a Kuderna-Danish concentrator along with 30 ml hexane (redistilled in glass) and concentrate to 5 ml.

g. Transfer the hexane concentrate to the 4-cm x 1-cm silica 923 column. Wash the concentrator with 5 ml of hexane and add the hexane to the column. Wash the alkanes through the column with 25 ml hexane. Collect and concentrate the hexane fraction to 5 ml in a Kuderna-Danish concentrator. Transfer the concentrate to a rigorously-cleaned 5-ml screw-cap test tube. Allow the liquid to concentrate to 1 ml at ambient temperature. Loosely cover the test tubes with aluminum foil during this process. After the volume has reached 1 ml, tightly seal the test tubes with a clean, foil-lined screw cap. This test tube contains the alkanes. Wash the column with 25 ml of ethyl ether. Collect and concentrate to 5 ml in the K-D concentrator. Add 1 ml of hexane and transfer to a screw-cap test tube. Allow to concentrate as above. This fraction contains the aromatics.

23. Water slurry or samples
   a. Decant the water into a clean separatory funnel. Hold for later steps.
   b. Transfer the sediment portion into a Randall extraction thimble with methanol washes.
   c. Reflux the sediment as described previously and concentrate the methanol to ~20 ml.
   d. Add the methanol to the separatory funnel (step two) and concentrate as previously described.

Sensitivity

24. The absolute sensitivity of the capillary column GC-MS system for a particular compound depends upon split ratio, electron multiplier voltage, mass coil, MS resolution, and the structure of the individual compound. This
sensitivity will vary from day to day because of the ag-
grate small changes in several of the above parameters. The sensitivities for individual compounds given below are conservative and may not reflect the very best obtainable.

naphthalene: 0.5 μg
phenanthrene: 0.5 μg
an individual alkane: 1 μg

25. The detection limit for a specific alkane does not necessarily reflect the detection limit of total alkanes. In order to determine total alkanes, the chromatograph must be spread across 10 GC peaks, in which case, an alkane with as low a concentration as 0.1 μg/gm might be detected. The detection limit takes into account both sample size and sensitivity of instrumentation.
APPENDIX C: ANALYTICAL LABORATORY DATA
### TABLE CI

**PINTO ISLAND: GENERAL PARAMETERS OF INFLUENTS, EFFLUENTS, AND BACKGROUND WATER**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>pH</th>
<th>Salinity</th>
<th>Conductivity</th>
<th>Dry Weight</th>
<th>Total Alkalinity</th>
<th>Chloride</th>
<th>Cation Exchange Capacity</th>
<th>Total Acid Soluble Sulfide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RW-B</td>
<td>7.6</td>
<td>3</td>
<td>5.9</td>
<td>0.42</td>
<td>50</td>
<td>1.90</td>
<td>-</td>
<td>trace</td>
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* Analyses were performed on 0.45-μ filtrate.
- Not determined (indicates insufficient sample or sample destroyed in transit).
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* Analyses were performed on a 0.45-μm filtrate.
- Not determined (indicates insufficient sample or sample destroyed in transit).
\( /\) Due to the insufficient amount of the solids, values in ( ) are for reference only.
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*" Samples were shaken and then allowed to settle. The supernatant was withdrawn with a Hamilton Syringe (406-μl opening) and injected into the TOC Analyzer.

*Not determined (indicates insufficient sample or sample destroyed in transit).

*Composite sample.
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- Samples were shaken and then allowed to settle. The supernatant was immediately withdrawn with a Hamilton Syringe (406-μm opening) and injected into the TOC Analyzer.
- Not determined (indicates insufficient sample or sample destroyed in transit).
/ Composite sample.
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* Based on wet slurry sample.
+ Based on dry weight of sample.
* Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).
## Table C7 (Continued)

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* Based on wet slurry sample.
+ Based on dry weight of sample.
† Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).
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* Based on wet slurry sample.
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* Based on wet slurry sample.
+ Based on dry weight of sample.
\( \) Composite sample.
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* Based on wet slurry sample.
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* Based on wet slurry sample.
+ Based on dry weight of sample.
\(^\d\) Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).

Table C7 (Continued)
Table C7 (Concluded)

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\(\dagger\) Based on wet slurry sample.
\(f\) Composite sample.
\(-\) Not determined (indicates insufficient sample or sample destroyed in transit).
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* Based on wet slurry sample.
+ Based on dry weight of sample.
\* Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).

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Table C8 (Continued)

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* Based on wet slurry sample.
+ Based on dry weight of sample.
/ Composite sample.
- Not determined (indicates insufficient sample
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* Based on wet slurry sample.
+ Based on dry weight of sample.
§ Composite sample.
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* Based on wet slurry sample.
+ Based on dry weight of sample.
\* Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).

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* Based on wet slurry sample.
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/ Composite sample.
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* Based on wet slurry sample.
+ Based on dry weight of sample.
/ Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).
### Table C8 (Continued)

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* Based on wet slurry sample.
+ Based on dry weight of sample.
$\text{Composite sample.}$
- Not determined (indicates insufficient sample or sample destroyed in transit).
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* Based on wet slurry sample.
+ Based on dry weight of sample.
/ Composite sample.
- Not determined (indicates insufficient sample or sample destroyed in transit).
### TABLE C9

**PINTO ISLAND: CONCENTRATION OF DDE, DDD, DDT AND PCB SPECIES IN INFLUENT, EFFLUENT, AND BACKGROUND WATER SAMPLES**

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- Not determined (indicates insufficient sample).
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- Not determined (indicates insufficient sample).
## TABLE C10

**GRASSY ISLAND: CONCENTRATION OF DDE, DDD, DDT**

AND PCB SPECIES IN INFLUENT, EFFLUENT, AND BACKGROUND WATER SAMPLES

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- Not determined (indicates insufficient sample).
## TABLE C12

**GRASSY ISLAND: CONCENTRATION OF METALS IN OIL AND GREASE FRACTION IN INFLUENT, EFFLUENT, AND BACKGROUND WATER SAMPLES**

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<th>Oil &amp; Grease Fraction ug/l</th>
<th>% of Total</th>
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In accordance with letter from DAEN RDC, DAEN ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Lu, James C. S.
Characterization of confined disposal area influent and effluent particulate and petroleum fractions / by James C. S. Lu ... et al. ; Environmental Engineering Program, University of Southern California, Los Angeles, Calif. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
iv, 45, 2, 128 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-16)
References: p. 44-45.