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WATER QUALITY ASPECTS OF DREDGED MATERIAL DISPOSAL  
IN THE GULF OF MEXICO NEAR GALVESTON, TEXAS

by

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ABSTRACT

A study was conducted in the mid 1970s on the water quality impact of the disposal of sediments dredged from the Galveston Bay Entrance Channel, and Texas City Channel (Texas), in the open waters of the Gulf of Mexico near Galveston, Texas. The study focused on the heavy metals, chlorinated hydrocarbon pesticides and PCBs, nitrogen and phosphorus compounds, and other chemical constituents of the sediments, and their release from the sediments during laboratory elutriate tests and during dredged sediment disposal. These shipping channel sediments contained elevated concentrations of many contaminants, however, except for manganese and ammonia, little or no release to the watercolumn occurred upon open water disposal of the dredged sediments. The ammonia and manganese release was such that it would not

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adversely affect water quality because of the rapid dilution of the turbid plume arising from the disposal of the dredged sediment. It was found that the elutriate test developed by the Corps of Engineers and the US EPA for the purpose of predicting the release of contaminants upon open water disposal of hydraulically dredged sediment, reliably predicted the direction and approximate magnitude of contaminant release. It was concluded from these studies that the open water disposal of Galveston Bay Entrance Channel and Texas City Channel sediments would not cause a significant adverse impact on water quality upon open water dredged sediment disposal in the Gulf of Mexico.

#### INTRODUCTION

In the late 1960s and early 1970s considerable concern was voiced in various parts of the U.S. about the water quality significance of chemical contaminants in U.S. waterway sediments dredged for maintenance of navigation channel depth. In the early 1970s the U.S. Congress authorized the U.S. Army Corps of Engineers (CE) to conduct a \$30 million, five-year program designed to evaluate various aspects of the environmental impact of dredged sediment disposal. A significant part of the total study program conducted as part of the Dredged Material Research Program (DMRP), was devoted to evaluating the significance of contaminants in waterway sediments that might be released to the water-column at an open water dredged material disposal site.

Early attempts by the US EPA and its predecessor organization to regulate dredged sediment disposal had been based on bulk sediment criteria, in which the total concentrations of selected contaminants in the sediment were used to judge the potential for the sediments to cause adverse impacts on the beneficial uses of the waters at the dredged material disposal site. Because of the weakness of the technical basis for this evaluation approach, as part of the DMRP the authors conducted several studies around the U.S. in fresh, estuarine, and marine waters to evaluate the hazard that dredged sediment-associated contaminants represented to aquatic life and other beneficial uses of water. These studies also included evaluation of the suitability of the elutriate test as a basis for assessing potential water quality problems associated with dredged sediment disposal.

Several sites on the Texas Gulf Coast (Figure 1) were selected by the CE to be included in the DMRP studies; most of them were concentrated in the Houston-Galveston area (Figure 2), which is one of the most heavily industrialized regions of the U.S. The U.S. Army Corps of Engineers maintains a dredged channel that extends from approximately 8 km out in the Gulf of Mexico to the Houston Ship Channel Turning Basin located near the center of the city of Houston. In addition, the CE maintains a number of side channels, one of the most important of which is the Texas City Channel which leads to an industrial complex in the Texas City, TX area. As a result of dredging in this area, deep-draft

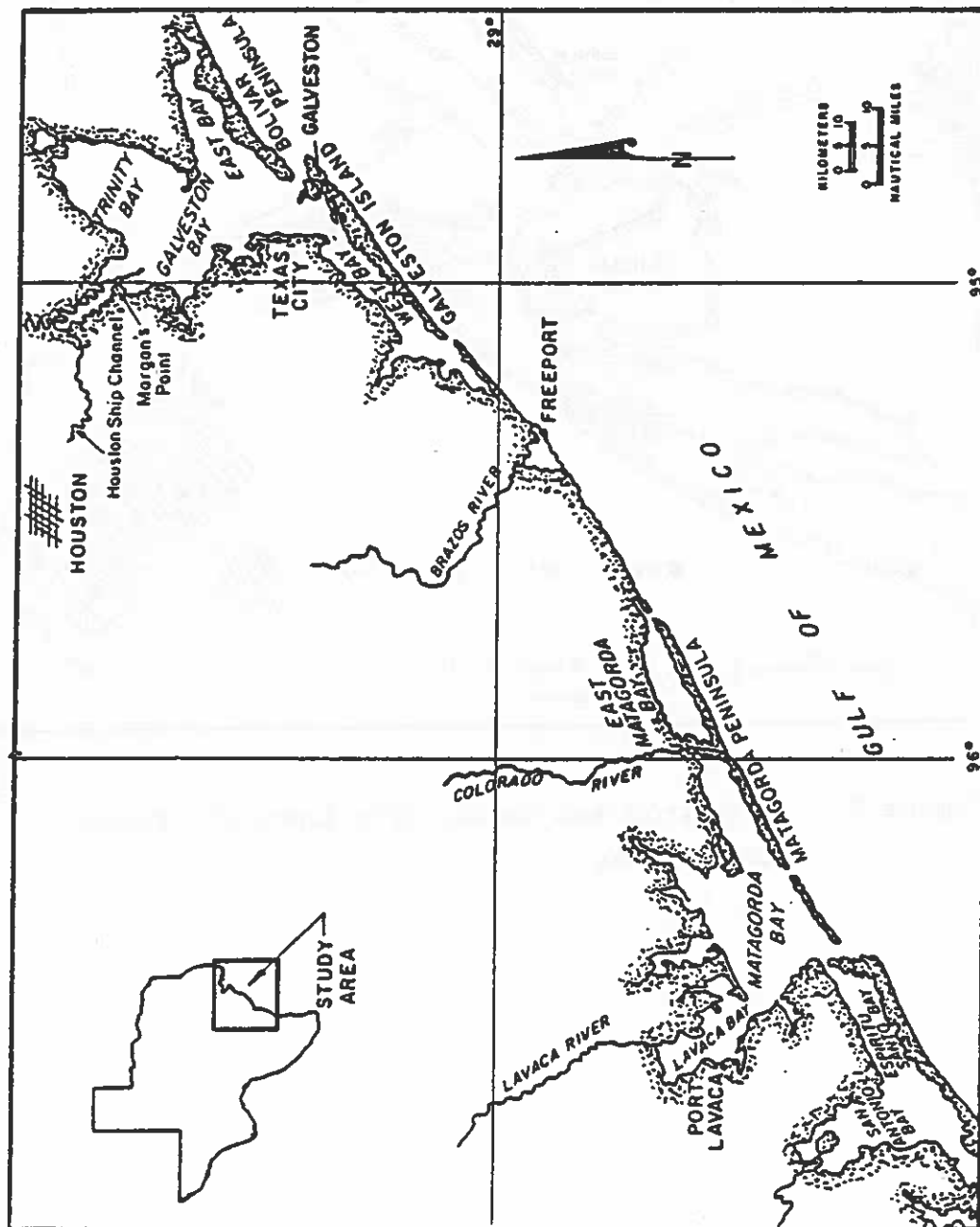


Figure 1. Texas Gulf Coast Study Areas

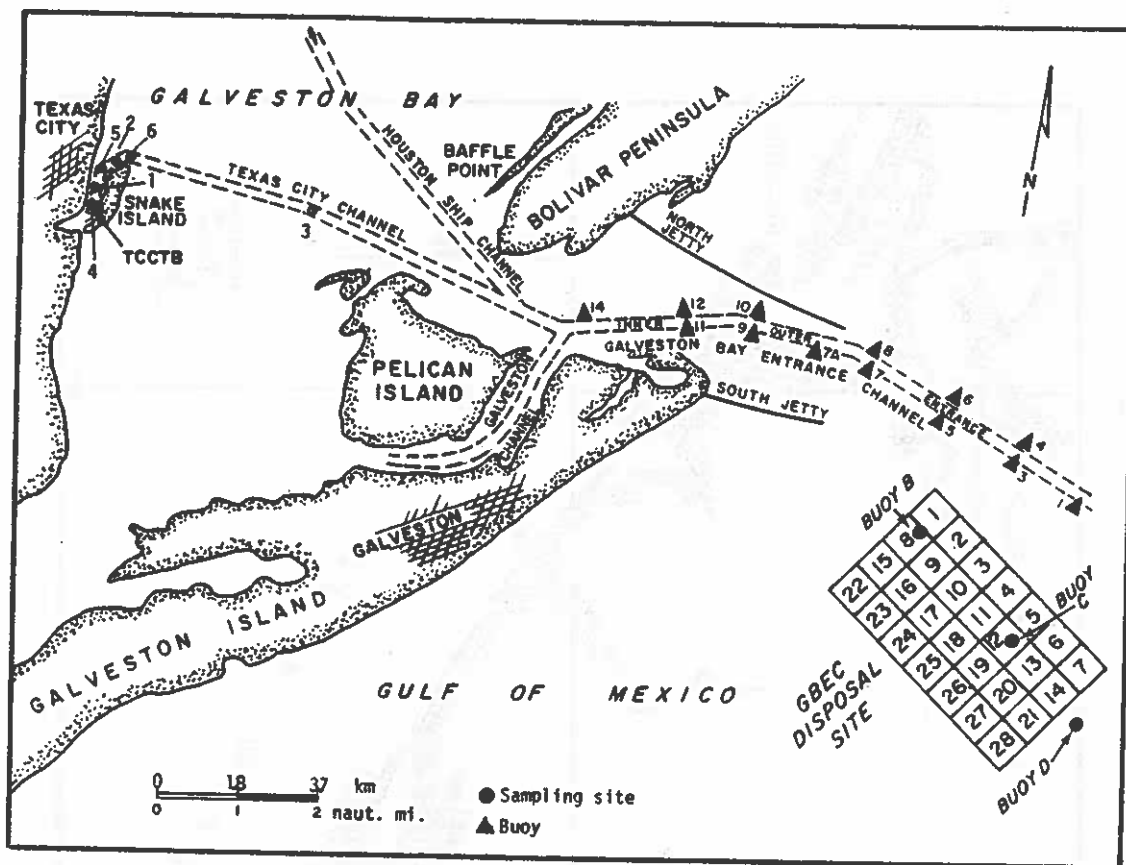


Figure 2. Galveston and Texas City Channel, Texas Study Areas

ships are able to load and unload cargo many kilometers inland.

Three major study areas in this region were included in the authors' investigation of the significance of dredged sediment-associated contaminants to disposal site water quality. One study area was the Houston Ship Channel (HSC), including several locations in the channel proper, near Morgan's Point which is where the HSC enters Galveston Bay, and within the HSC about 2 km into Galveston Bay beyond Morgan's Point. The second study area was the Texas City Channel (TCC) and the Texas City Channel Turning Basin (TCCTB) shown in Figure 2. The third and most intensive study was conducted in the Galveston Bay Entrance Channel (GBEC) and associated disposal area (GBEC Disposal Site). As shown in Figure 2, this channel leads all deep-draft ships through the nearshore waters of the Gulf of Mexico to the Houston-Galveston area ports.

Several other sites were also examined as part of the authors' Texas Gulf Coast DMRP studies. These included Cox Bay near Port Lavaca, TX (Figure 1), and Galveston Channel from which sediments were hydraulically dredged and disposed of on Pelican Island (Figure 2).

The results of the authors' Texas Gulf Coast DMRP studies as well as the details of the experimental and analytical procedures used, have been presented and discussed by Lee et al. (1977, 1978) and Jones and Lee (1978). The latter two reports also present the results of the authors'

entire DMRP investigation. This paper will present a summary of the studies conducted on the Texas City Channel and the Galveston Bay Entrance Channel sediments.

## METHODS

There were basically four phases of work associated with both of these two sites. The sediments and water being considered were evaluated for their bulk characteristics, including dry weight, oxygen demand, and content of selected contaminants. In the second phase, elutriate tests were run on the sediments. This test procedure was developed by the CE and US EPA as a tool to help estimate the release of chemical contaminants from hydraulically dredged sediment during open water disposal. The test is conducted by vigorously mixing one volume of sediment with four volumes of water (a 20% V/V test) for 30 min with compressed air (oxic test) or oxygen-free nitrogen gas (anoxic test). The mixture is allowed one hour of quiescent settling after which the supernatant is filtered through a 0.45  $\mu$ m pore-size membrane filter, or for organic compound evaluation, is centrifuged. Other sediment : water ratios were also used during this study, usually 5% sediment by volume. The testing conditions are identified for each test in the tables and text as, for example "20% oxic" meaning that 20% sediment by volume was mixed with the site water under oxic conditions. Total elutriate (sediment plus water) volume used was 2 liters.

The third phase of work was bioassay in which 96 hr static bioassays with Palemonetes pugio (grass shrimp) were performed on the settled sediment/water mixture.

The fourth phase of the study involved monitoring dredged sediment disposal operations. The sampling vessel was positioned and anchored generally 30 to 300 m downcurrent from the established point at which the dredged sediment was to be dumped, such that the turbid plume would pass directly beneath the sampling vessel. Water samples were collected from the surface (1 m depth), mid-depth, and about 1 m above the sediment-water interface periodically during the 30 min or so prior to disposal to characterize background characteristics. Samples were collected in rapid succession during the disposal event as the plume of turbidity created by the disposal (the turbid plume) passed beneath the sampling vessel. Sampling generally continued for an hour or so after the dump event or until characteristics returned to their background conditions. The presence of the turbid plume was indicated by a decrease in percent light transmission of the water. The close proximity of the sampling vessel to the dumping point enabled a comparison to be made between the increase in turbidity and the release of contaminants. Parameters such as percent light transmission, dissolved oxygen, pH, and salinity were measured with submersible transducers. Water samples were collected using submersible pumps; sediment samples were collected with a Ponar grab sampler. All samples were stored at 4°C in the dark until used in elutriate tests.



Included in this phase of the study was limited sampling of the dredged material in the hopper bins of the hopper dredge during its travel from the dredging site to the disposal site.

## GALVESTON BAY ENTRANCE CHANNEL STUDY

### GBEC Sediment Elutriate Tests

Sample Sites. Sediment and water samples for elutriate tests were collected from Buoy 1 in the GBEC on June 11, 1975, and from GBEC Buoys 9 and 11 on April 12, 1975 (Figure 2). Elutriate tests were performed using sediment and water from the same location. They were also run on Buoy 9 and 11 sediments with disposal site water collected from a 2 m depth at GBEC Disposal Site Grid Square (GS) 8 on April 17, 1975.

General Sediment Characteristics and Oxygen Demand. One of the GBEC sediment samples was analyzed for oxidation-reduction (redox) potential (Eh) sulfide; percent dry weight and oxygen uptake were measured on all three (Table 1). The redox potential of the GBEC Buoy 1 sediment indicated that it was not strongly reducing, although it had a fairly substantial amount of sulfide present. Percent dry weight values were about 41% at GBEC Buoys 1 and 9 and 60% at GBEC Buoy 11.

The oxygen demand of the sediments was determined by

TABLE 1. GENERAL SEDIMENT CHARACTERISTICS AND OXYGEN UPTAKE:

GALVESTON BAY ENTRANCE CHANNEL BUOYS 1, 9 AND 11

## SEDIMENT SAMPLES

Sample Designation	Eh (mv)	Sulfide (mg/kg)		Percent Dry Wt		Oxygen Uptake First Hour	
		$\bar{X}$	SD*	$\bar{X}$	SD*	Per Cubic Meter (g O <sub>2</sub> )	Per Gram Dry Wt (mg O <sub>2</sub> )
GBEC Buoy 1	+101	446	57	40.7	2.7	$3.6 \times 10^2$	0.67
GBEC Buoy 9	-	-	-	41.2	0.9	$1.5 \times 10^2$	0.16
GBEC Buoy 11	-	-	-	60.0	0.1	80	0.14

\* Mean and standard deviation calculated from triplicate analyses.  
Dash (-) indicates not applicable.

placing a known volume of the sediment in a BOD bottle which contained water from the area and stoppering the bottle with a BOD bottle dissolved oxygen membrane electrode probe. Dissolved oxygen (DO) concentrations were measured over time while the sample was continuously being stirred by a magnetic stirrer inside the bottle. Figure 3 shows the DO data plotted as a function of time for the GBEC Buoy 1 sediment and water. The standard deviations between duplicate runs ranged from 0 to  $0.2 \text{ g O}_2/\text{m}^3$  indicating good reproducibility. The fast component of the demand was found to be  $-0.023 \text{ mg O}_2/\text{l/min.}$ , while the slow component was  $-0.006 \text{ mg O}_2/\text{l/min.}$  The overall first hour oxygen demand (Table 1) for this sediment was  $3.6 \times 10^2 \text{ g O}_2/\text{m}^3$ , and  $0.67 \text{ mg O}_2/\text{g dry wt.}$

The oxygen demand test was also run on samples from GBEC Buoys 9 and 11. The overall first hour oxygen uptake rates for Buoy 9 and 11 sediments were  $1.5 \times 10^2 \text{ g O}_2/\text{m}^3$  and  $80 \text{ g O}_2/\text{m}^3$ , respectively. While there was more than an order of magnitude difference in the per volume uptake rate, the uptake rates per gram dry weight were similar, 0.16 and  $0.14 \text{ mg O}_2/\text{g dry wt}$  for Buoys 9 and 11, respectively.

Heavy Metals. Table 2 lists the concentrations of the selected heavy metals measured in the sediments collected from Buoys 1, 9, and 11 in the GBEC. Manganese concentrations in all three sediments were high, ranging from 1170 mg/kg at Buoy 9 to 1430 mg/kg at Buoy 1. The zinc concentration was 300 mg/kg in the Buoy 1 sediment but decreased with

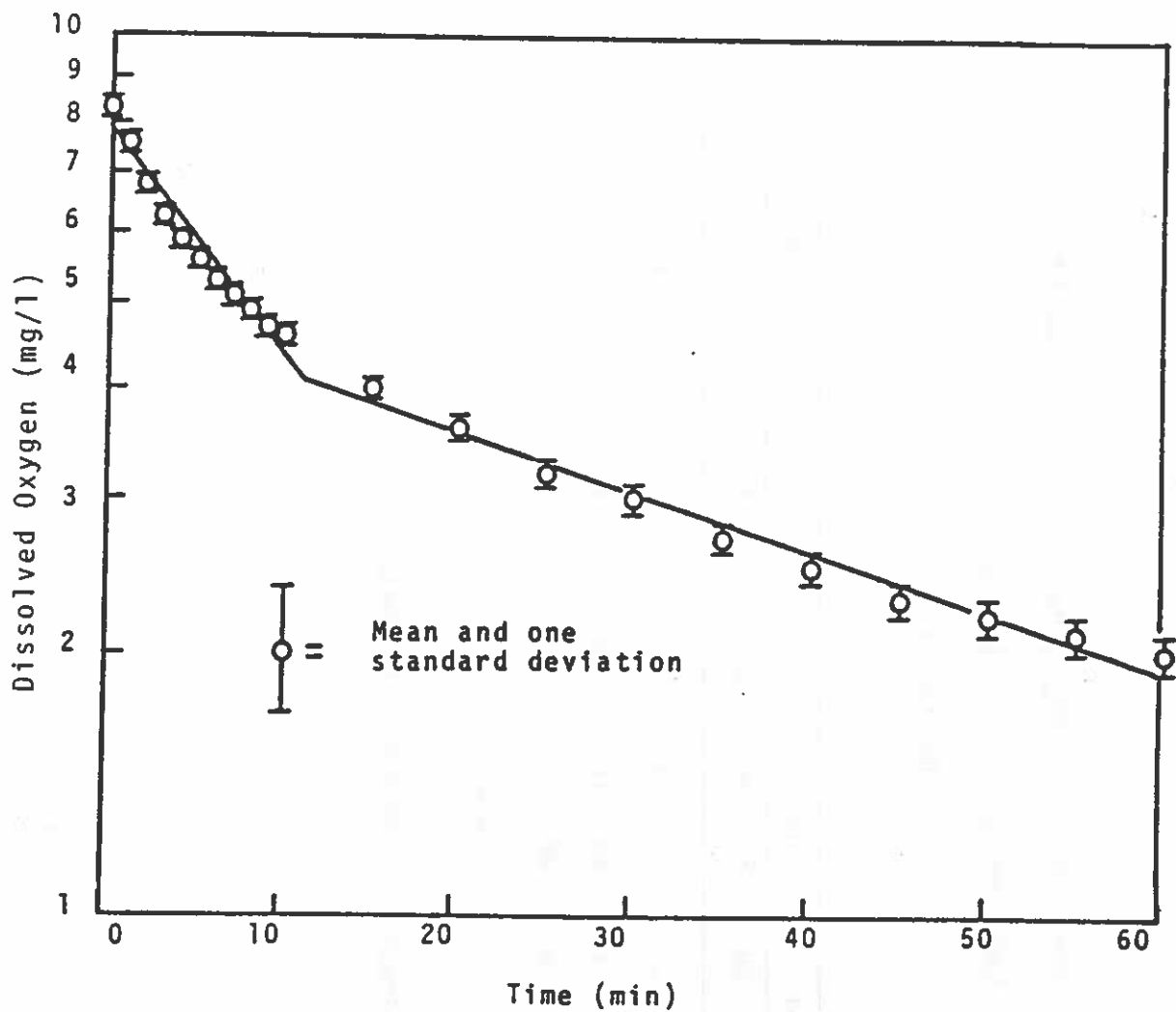


Figure 3. Oxygen Demand Test: Galveston Bay Entrance  
Channel Buoy 1 (Sample Size - 5 cc)

TABLE 2. TOTAL HEAVY METAL CONCENTRATIONS: GALVESTON  
BAY ENTRANCE CHANNEL SEDIMENT

(mg/kg dry wt)\*

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe*	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Buoy 1	1430	20	<5	=0	40	25	300	0	40	20	15	5	7.3	2.5	40	1.3
Buoy 9	1170	130	41	3	20	10	38	10	40	10	10	0	2.7	1.2	13	2.1
Buoy 11	1290	50	38	4	30	14	12	1	17	16	28	11	2.5	2.1	94	6.9

\*Iron content given in g/kg.

Mean and standard deviation calculated from duplicate analyses.

decreasing distance from the industrialized areas of the channel to 38 and 12 mg/kg at Buoys 9 and 11, respectively (Figure 2). Cadmium concentrations were below the detection limit (5 mg/kg) at Buoy 1, and 41 and 38 mg/kg at Buoys 9 and 11, respectively. These last two concentrations are among the highest cadmium concentrations found in the many sediments analyzed in the Lee et al. (1978) studies. Iron concentrations were also high, ranging from 13 to 94 g/kg. Concentrations of nickel, chromium, lead, and copper were below levels generally considered indicative of heavy metal contamination of sediments.

Tables 3 and 4 present the soluble heavy metal concentrations in the elutriates of GBEC Buoy 1, 9, and 11 sediments and in the site waters used. Table 3 shows that Buoy 1 sediment released manganese in large amounts, 1165 µg/l and 370 µg/l, in the 5 and 20% tests, respectively. What appeared to be small releases of chromium, zinc, nickel, copper, iron, and mercury were not statistically significant at the 95% confidence level. There were no detectable changes in the lead or cadmium concentrations as a result of elutriation.

Elutriation of Buoy 9 and 11 sediments resulted in the release of manganese generally to 1000 to 5000 µg/l. There were indications of slight releases of chromium with both of these sediments. Small and probably insignificant uptake of copper, zinc, and mercury was also noted to result from elutriation. No significant changes in concentrations of

TABLE 3. SOLUBLE HEAVY METAL CONCENTRATIONS: GALVESTON  
BAY ENTRANCE CHANNEL BUOY 1 ELUTRIATE TESTS

( $\mu\text{g/l}$ )

Sample Designation	Mn		Cd		Cr		Zn		Ni		Pb		Cu		Fe		Hg	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Site Water	2.6	0	1.2	0.1	1.6	0.0	3.5	1.1	2.9	0.4	<1.0	0	1.9	0.1	5	0.6	<0.006	0
5% Oxid	1165	11	1.2	0.2	2.3	0.3	9.2	4.4	4.6	1.1	<1.0	0	2.5	0.6	7	0.3	0.0018	0.06
20% Oxid	370	8	1.2	0.6	2.6	0.3	7.3	2.9	5.8	1.8	<1.0	0	2.9	0.4	103	4.6	0.026	0.02

Mean and standard deviation calculated from duplicate analyses.

TABLE 4. SOLUBLE HEAVY METAL CONCENTRATIONS: GALVESTON BAY  
ENTRANCE CHANNEL BUOYS 9 AND 11 ELUTRIATE TESTS  
(µg/l)

Sample Designation	Mn		Cd		Cr		Zn		Pb		Cu		Fe		Hg	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
GBEC Disposal																
Site Water	40.3	-	< 0.3	-	8.0	-	12.4	-	4.0	-	3.7	-	< 1	-	0.041	-
Buoy 9:																
Buoy Site																
Water	17.2	-	< 0.3	-	< 2.0	-	12.4	-	2.1	-	2.5	-	< 1	-	0.069	-
5% Oxid*	1010	8	< 0.3	-	10.0	-	5.0	5.0	2.0	0	< 1.0	-	< 1	-	0.034	-
5% Oxid**	467	39	< 0.3	-	5.1	0	13.7	0.2	3.1	1.4	< 1.0	-	< 1	-	0.034	-
20% Oxid**	1780	101	< 0.3	-	5.9	1.1	15.4	1.1	1.1	1.3	< 1.0	-	< 1	-	0.028	-
Buoy 11:																
Buoy Site																
Water	48	-	< 0.3	-	< 2.0	-	16.0	-	4.0	-	1.4	-	< 1	-	0.021	-
5% Oxid*	1730	3	< 0.3	-	6.0	3.0	8.3	1.0	5.0	1.4	< 1.0	-	< 1	-	0.020	-
5% Oxid**	1840	40	< 0.3	-	4.0	0	12.8	1.4	4.0	0	1.0	0.3	< 1	-	0.021	-
20% Oxid**	5050	58	< 0.3	-	4.5	0.7	13.7	1.2	5.0	1.4	< 1.0	-	< 1	-	0.014	-

Dash (-) indicates single analysis.  
Mean and standard deviation calculated from duplicate analyses.  
\* Elutriated with buoy site water.  
\*\* Elutriated with disposal site water.



cadmium, lead, or iron were observed. No consistent measurable difference in heavy metal release occurred as a result of using disposal site as opposed to Buoy site water or as a result of 5% versus 20% sediment in the elutriate tests.

Nitrogen Compounds. Table 5 presents the total kjeldahl nitrogen (TKN) concentrations in the GBEC sediments; the concentrations were 152 mg N/kg in GBEC Buoy 9 sediment, and 6 and 9 times higher in Buoy 11 and 1 sediments, respectively.

Tables 6 and 7 show that organic N, nitrate, and ammonium\* concentrations in GBEC Buoy 1 water were lower than concentrations in other GBEC or disposal site water samples. In general, elutriation resulted in no discernible change in the organic N or nitrate concentrations whereas ammonium was released in all tests. Ammonium concentrations in the elutriates, which ranged from 0.41 to 1.7 mg N/l, were 5 to 24 times the site water values; more ammonium was released in the 20% sediment tests than in the 5% tests. Percentage-wise, elutriations of Buoy 1 sediments resulted in the greatest increase in ammonium concentrations, while elutriates of Buoy 11 sediment contained the highest concentrations.

Phosphorus Compounds. Total phosphorus concentrations

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\*The word "ammonium" is used herein to mean the sum of the ionized and un-ionized ammonia concentrations.

TABLE 5. NITROGEN COMPOUND CONCENTRATIONS: GALVESTON  
BAY ENTRANCE CHANNEL SEDIMENTS

(mg N/kg dry wt)

Sample Designation	Total Kjeldahl Nitrogen	
	$\bar{X}$	SD
Buoy 1	1325	211
Buoy 9	152	1
Buoy 11	1013	92

Mean and standard deviation calculated from duplicate analyses.

TABLE 6. NITROGEN COMPOUND CONCENTRATIONS: GALVESTON BAY  
ENTRANCE CHANNEL BUOY 1 ELUTRIATE TESTS

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
Site Water	0.17	0.04	<0.05	~0	<0.04	~0
5% Oxid	<0.05	~0	0.41	0	<0.04	~0
20% Oxid	<0.05	~0	1.2	0.1	0.05	0

\*Mean and standard deviation calculated from duplicate analyses.

\*\*Mean and standard deviation calculated from triplicate analyses.

TABLE 7. NITROGEN COMPOUND CONCENTRATIONS: GALVESTON BAY  
ENTRANCE CHANNEL BUOYS 9 AND 11 ELUTRIATE TESTS

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Disposal Site Water	0.55	0.16	0.25	0	0.18	0.01
Buoy 9:						
Buoy Site Water	0.27	0.09	0.13	0.01	0.20	0.01
5% Oxidic*	0.07	0.09	0.69	0.01	0.22	0.01
5% Oxidic**	0.44	0.21	0.80	0.01	0.13	0.01
20% Oxidic**	0.58	0.26	1.6	0.02	0.14	0.01
Buoy 11:						
Buoy Site Water	0.38	0.08	0.10	0	0.24	0.01
5% Oxidic*	0.07	0.29	0.93	0.01	0.21	0.02
5% Oxidic**	0.24	0.28	0.92	0	0.13	0.01
20% Oxidic**	0.42	0.17	1.7	0.01	0.13	0.01

Organic N and ammonium mean and standard deviation calculated from duplicate analyses. Nitrate mean and standard deviation calculated from triplicate analyses. All samples were centrifuged.

\*Elutriated with buoy site water.

\*\*Elutriated with disposal site water.

of GBEC sediments are presented in Table 8. The greatest total phosphorus concentration found was at Buoy 11, the location farthest up the channel. Soluble orthophosphate concentrations found in elutriates from GBEC tests are presented in Table 9. The site waters from Buoys 1, 9, and 11 and the GBEC Disposal Site all appeared to have about the same concentration of soluble orthophosphate (generally between 0.005 and 0.013 mg P/l). Total phosphorus was greatest at Buoy 11, lowest at Buoy 1, and intermediate at Buoy 9 and the GBEC Disposal Site. The overall total phosphorus concentration range was small, however.

TABLE 8. TOTAL PHOSPHORUS CONCENTRATIONS: GALVESTON  
BAY ENTRANCE CHANNEL SEDIMENT  
(mg P/kg dry weight)

Sample Designation	Total Phosphorus	
	$\bar{X}$	SD
Buoy 1	136	4
Buoy 9	111	2
Buoy 11	247	4

Mean and standard deviation calculated from triplicate analyses of one digested sample.

TABLE 9. SOLUBLE ORTHOPHOSPHATE AND TOTAL PHOSPHORUS  
CONCENTRATIONS: GALVESTON BAY ENTRANCE  
CHANNEL BUOYS 1, 9, AND 11 ELUTRIATE TESTS  
(mg P/l)

Sample* Designation	Soluble Ortho P		Total Phosphorus	
	$\bar{X}$	SD	$\bar{X}$	SD
Disposal Site Water	0.009	0.002	0.05	0.001
Buoy 1:				
Buoy Site Water	< 0.02	0.001	< 0.02	0
5% Oxic*	< 0.02	0	0.03	0.01
20% Oxic*	0.064	0.004	0.07	0.01
Buoy 9:				
Buoy Site Water	0.005	0.001	0.05	0
5% Oxic*	0.024	0.001	0.10	0.01
5% Oxic**	0.023	0.002	0.09	0.01
20% Oxic**	0.023	0.002	0.09	0.01
Buoy 11:				
Buoy Site Water	0.013	0.002	0.09	0
5% Oxic*	0.028	0.002	0.09	0.01
5% Oxic**	0.029	0.001	0.10	0.01
20% Oxic**	0.038	0.003	0.11	0.01

Mean and standard deviation calculated from duplicate or triplicate analyses of one sample.

\* Elutriated with buoy site water.

\*\* Elutriated with disposal site water.

The Buoy 9 and 11 elutriate phosphorus concentrations appeared to be independent of the site water source. Buoy 9 elutriate tests all showed increases in soluble orthophosphate and total phosphorus; all elutriates (both 5 and 20%) contained about the same total P concentrations and about the same soluble ortho P concentrations. The 5% and 20% elutriates from GBEC Buoy 11 sediments showed slightly greater release of soluble orthophosphate than those from Buoy 9 but total P concentrations were the same. The total phosphorus concentration in the GBEC Buoy 11 5% oxic elutriate run with buoy site water was the same as that in the site water. The Buoy 11 20% elutriate had a greater concentration of soluble orthophosphate than the 5% elutriates; the total phosphorus concentration was the same as it had been in the 5% elutriates, however.

The soluble orthophosphate and total phosphorus concentrations in the Buoy 1 5% oxic elutriate was not discernibly different from those in the site water. Of all the GBEC elutriates, the 20% oxic Buoy 1 elutriate showed the greatest soluble orthophosphate release. The Buoy 1 site water had a lower total phosphorus concentration than any of the other sampling locations. The total phosphorus concentrations in these Buoy 1 elutriates were also lower than the others.

Organic Compounds. A 5% oxic elutriate test was run for evaluation of the release of selected organic compounds, using sediment and water taken from the GBEC at Buoy 1.

Aldrin, pp'DDT, op'DDE, dieldrin, lindane, and PCBs were detected in the sediment. Sixteen peaks present in the sediment chromatogram were also present in the water chromatogram. Except for dieldrin which was not detected in the water, the same group of chlorinated compounds detected in the sediment was also detected in the water. The profile of organic residues in the elutriate chromatograms showed fifteen of the peaks detected in the site water. The magnitudes of the peaks were lower than those of the site water, however, indicating a tendency for sorption of organic residues during elutriation.

The analytical results for this sediment, water, and elutriate are presented in Table 10. The pesticide levels in the sediment were low, usually below detection; the elutriate showed no detectable change in the concentrations of most of the pesticides measured, although the concentration of aldrin was lower in the elutriate than in the site water. The PCB concentration showed a 19% decrease in concentration after elutriation. The oil and grease levels in this sediment were low compared to others evaluated in the overall study.

### Bioassays

Bioassays of the dredged sediment elutriates were conducted using P. pugio (grass shrimp). These tests involved placing the organisms in the elutriate waters after the one-hour settling time. The test systems thus still contained

TABLE 10. DATA FOR ORGANIC COMPOUNDS: GALVESTON  
BAY ENTRANCE CHANNEL BUOY 1, 5% OXIC  
ELUTRIATE TEST

Parameter	Sediment	Water	Elutriate
	( $\mu\text{g/kg}$ )	( $\text{ng/l}$ )	( $\text{ng/l}$ )
<u>Chlorinated Hydrocarbons:</u>			
Aldrin	2.5	4.1	2.8
op'DDT	< 1.6	< 3.0	< 3.0
pp'DDT	< 2.2*	< 3.0*	< 3.0*
op'DDD	< 2.0	< 2.0	< 2.0
pp'DDD	< 2.0	< 2.0	< 2.0
op'DDE	2.2	5.2	5.2
pp'DDE	< 1.4	< 2.0	< 2.0
Dieldrin	< 0.8*	< 1.2	< 1.2*
Endosulfan I	< 0.9	< 1.2	< 1.2
Endosulfan II	< 3.4	< 4.4	< 4.4
Endrin	< 1.2	< 1.6	< 1.6
Heptachlor	< 0.3	< 0.4	< 0.4
Lindane	0.8	2.5	2.5
PCBs	192	210	170

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Other Organic Compounds

Oil and Grease	23.5 mg/kg	-	-
Total Inorganic Carbon	1.12%	-	-

\*Compound indicated on two columns but below detection limit.  
Dash (-) indicates not measured.



the settled as well as suspended sediment; therefore the contaminant release that occurred over the four-day testing period was also included in the bioassay test results. Results of the bioassay tests using P. pugio and GBEC Buoy 1 elutriates (5%, 10%, and 20% sediment) are presented in Table 11. Only a slight toxicity to P. pugio was found. One and two deaths occurred after 36 hrs in the two 20% sediment test; one death occurred in each of the 5% tests after 70 to 80 hrs exposure; no deaths occurred in the 10% test or in the controls.

Toxicity results of the Buoy 11 elutriate bioassays for P. pugio are presented in Table 12. These tests showed no toxicity to P. pugio in the 5 or 10% elutriates. There was one organism death after 24 hrs in one of the two 20% tests and another after 48 hrs in the other replicate.

#### GBEC Disposal Operations - Dump No. 4

Background. Lee et al. (1977) monitored seven disposal operations involving sediment dredged from the GBEC. This section summarizes the results of these studies, with results from one representative operation, GBEC Dump No. 4, presented. A complete description of the experimental procedures, dump nomenclature, and results are presented in Lee et al. (1977, 1978).

GBEC Dump No. 4 took place on August 29, 1975 at Buoy D in the Gulf of Mexico (Figure 2). Approximately 850 m<sup>3</sup>

TABLE 11. RESPONSE OF P. PUGIO TO GALVESTON BAY  
ENTRANCE CHANNEL BUOY 1 BIOASSAY ELUTRIATES

Time (hr)	Number of <u>P. pugio</u> Living at Varying Sediment Percentages									
	Control		5%		10%		20%			
	A	B	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	10	10	10	10
36	10	10	10	10	10	10	9	9	8	8
48	10	10	10	10	10	10	9	9	8	8
60	10	10	10	10	10	10	9	9	8	8
72	10	10	9	10	10	10	9	9	8	8
84	10	10	9	9	10	10	9	9	8	8
96	10	10	9	9	10	10	9	9	8	8

A and B are replicates.

TABLE 12. RESPONSE OF P. PUGIO TO GALVESTON BAY  
ENTRANCE CHANNEL BUOY 11 BIOASSAY ELUTRIATES

Time (hr)	Control		Number of <u>P. pugio</u> Living at Varying Sediment Percentages					
			5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	9	10
36	10	10	10	10	10	10	9	10
48	10	10	10	10	10	10	9	9
60	10	10	10	10	10	10	9	9
72	10	10	10	10	10	10	9	9
84	10	10	10	10	10	10	9	9
96	10	10	10	10	10	10	9	9

A and B are replicates.

(1100 yd<sup>3</sup>) of sediment dredged between GBEC Buoys 1 and 3 was dumped during this hopper-dredge operation. The sampling vessel was positioned approximately 30 m down surface current from the established dumping point; surface water current was found to be about 0.5 knot (25 cm/sec). The dump event occurred at 1258 hrs.

Optical Properties. Figure 4 shows the passage of the turbid plume at the three depths monitored during Dump No. 4, as measured by percent light transmission. The turbid plume took 2.75, 3.25, and 2.25 min to reach the monitoring location at surface, mid-depth, and bottom, respectively. As in other dumps, turbidity was greatest near the bottom where the elevated turbidity conditions persisted for about 10 min. The Secchi depth was 2.5 m both prior to disposal and 37 min after Galveston Dump No. 4.

Dissolved Oxygen. Figure 5 shows that just after the turbid bottom plume arrived at the sampling vessel, there was a 1.7 mg/l decrease in the bottom water DO concentration to about 4.8 mg/l. Before the turbid bottom plume was past the vessel, DO concentrations were near pre-disposal levels; by the time it was past the sampling boat, the initial DO levels were re-established.

Heavy Metals. Table 13 presents the heavy metal concentrations at the disposal site during Dump No. 4. Although few pre-disposal samples were taken, concentrations of the heavy metals were in line with what had been found prior to

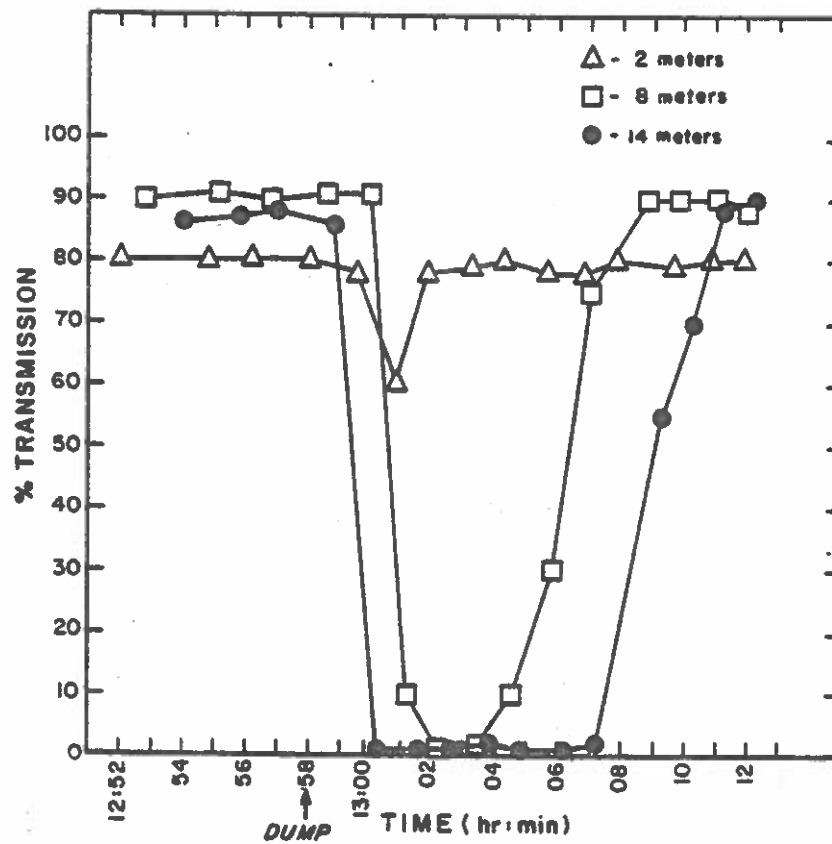


Figure 4. Percent Light Transmission: Galveston  
Dump No. 4

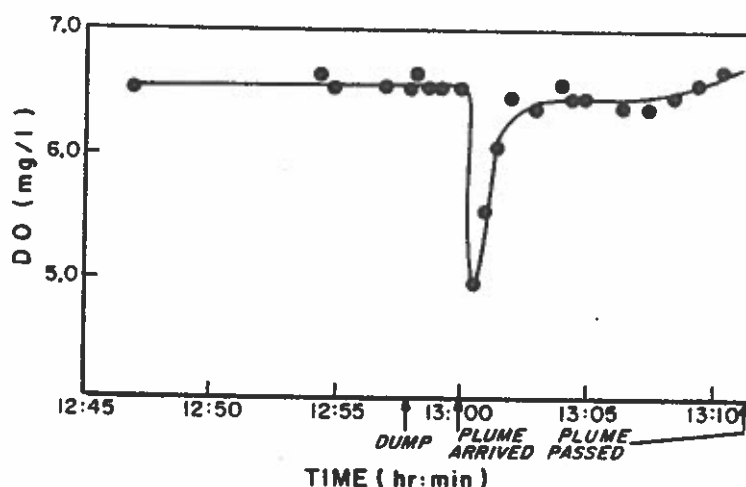


Figure 5. Dissolved Oxygen Concentrations:  
Galveston Dump No. 4 Near-Bottom  
Waters

disposal there the day before. No manganese release was observed in Galveston Dump No. 4; in fact, soluble manganese concentrations were about an order of magnitude lower with the passage of the turbid plume, possibly because of precipitation or sorption. Decreases in concentrations of soluble lead, zinc, cadmium, nickel, copper, and iron also apparently occurred with the passage of the turbid plume.

Four samples, two from 8 m and two from 14 m depths, showed increased mercury concentrations. These elevated concentrations, ranging from 0.010 to 0.048  $\mu\text{g/l}$  (0.003  $\mu\text{g/l}$  was observed prior to disposal), occurred while the turbid

TABLE 13. HEAVY METAL\* CONCENTRATIONS: GALVESTON DUMP NO. 4

(µg/l)

Time of Collection (hr:min:sec)	Depth (m)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
		SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT	SOL	TOT
12:54:00	14	186	-	<2	<2	1.7	-	11.3	-	9.3	-	17.8	-	7.2	-	58	431	0.003	0.003	<2	<2
12:58 - Dump occurred																					
12:59:30	14	201	-	<2	<2	1.5	-	12.5	-	14.7	-	13.8	-	5.6	-	35	344	<0.001	0.003	<2	<2
13:00 - Surface turbid plume arrived at sampling station																					
13:00:30	1	172	-	<2	<2	1.5	-	10.0	-	12.7	-	12.8	-	8.3	-	18	46	<0.001	<0.001	<2	<2
13:01:30	8	186	-	<2	<2	1.7	-	10.0	-	10.0	-	7.2	-	4.4	-	13	103	0.003	0.003	<2	<2
13:02 - Surface turbid plume passed sampling station																					
13:02:30	1	123	160	<2	<2	2.1	-	-	-	3.6	59.8	13.2	92.1	6.1	28.1	37	1100	0.003	0.039	<2	<2
13:03:00	8	105	-	<2	<2	<0.5	-	-	-	3.1	-	7.3	-	2.6	-	9	-	<0.001	0.023	<2	<2
13:03:30	8	-	-	-	<2	-	<0.5	-	2.4	-	-	-	-	-	7.2	-	480	<0.001	0.003	<2	<2
13:03:50	14	105	182	<2	<2	<0.5	<0.5	0.7	16.8	3.1	37.9	8.5	59.9	3.5	21.2	25	1700	0.003	0.016	<2	<2
13:04:15	8	88	111	<2	<2	<0.5	<0.5	6.6	-	2.0	88.0	9.6	30.9	3.5	12.7	13	900	0.016	-	<2	<2
13:04:30	14	-	147	<2	<2	<0.5	2.2	3.3	5.9	4.0	14.6	7.0	22.0	2.6	6.7	227	900	0.010	-	<2	<2
13:05:30	8	35	200	<2	<2	<0.5	<0.5	2.7	4.5	1.7	13.1	7.9	24.7	5.7	8.2	155	900	0.048	-	<2	<2
13:06:00	14	18	200	<2	<2	<0.5	<0.5	4.1	12.9	<1	26.3	2.5	44.2	2.8	15.2	<5	1100	0.023	0.023	<2	<2
13:06:30	1	14	126	<2	<2	0.7	-	3.6	-	<1	7.3	2.4	10.8	4.0	4.2	<5	-	0.006	0.010	<2	<2
13:07:15	14	25	200	<2	<2	0.6	-	2.8	14.0	<1	30.6	1.4	54.3	2.8	18.7	8	1100	0.006	0.016	<2	<2
13:09:45	14	56	165	<2	<2	0.7	-	3.6	7.7	<1	14.6	2.3	18.8	3.6	7.2	15	1000	0.006	0.006	<2	<2
13:11:30	8	29	108	<2	<2	<0.5	<0.5	2.8	-	<1	5.8	2.0	5.4	2.8	-	<5	22	0.006	0.026	<2	<2
13:12:15	1	40	133	<2	<2	<0.5	<0.5	4.1	-	<1	5.8	1.6	3.7	2.3	3.7	<5	55	0.003	0.023	<2	<2

\* SOL and TOT represent soluble and total concentrations, respectively.

Dash (-) indicates not measured.

plume was still present at these depths, and appeared to persist for 4 to 6 min. Samples taken when the turbid plume had passed showed that mercury levels at these depths had returned to pre-disposal concentrations. There appeared to be a slight elevation in mercury concentrations in the surface waters, but this was declining at the end of the monitoring period.

Nitrogen Compounds. The results of nitrogen compound analyses during GBEC Dump No. 4 are presented in Table 14. An increase in ammonium concentrations in the surface and mid-depth water samples was observed with the passage of the turbid plume. Before light transmission values returned to pre-disposal levels, ammonium concentrations were at ambient levels. Bottom water samples showed that ammonium concentrations did not change there during the disposal operation. A sharp increase in organic N concentration (to 7.2 mg N/l) was observed in the surface water at 13:02:30, however when the next sample was collected 4 min later, the concentration was about 0.4 mg N/l. Mid-depth organic N concentrations appeared to increase somewhat while the bottom water organic N concentrations rose to as high as 2 mg N/l and remained elevated for the duration of sampling. Sampling was terminated just as the turbid bottom plume was passing beyond the sampling vessel.

In the bottom water, organic N concentrations appeared to show two maxima. There was a sharp increase (to 1.3 mg N/l)



TABLE 14. NITROGEN COMPOUND DATA: GALVESTON DUMP NO. 4

Time of Collection (hr:min:sec)	Depth (m)	Organic N (mg N/l)	Ammonium (mg N/l)	Nitrate (mg N/l)
12:52:00	1	-	0.01	-
12:53:00	8	-	0.01	-
12:54:00	14	0.30	0.02	0.05
12:58 - Disposal occurred.				
12:58:30	1	-	0.01	-
12:58:45	8	-	0.02	-
12:59:30	14	0.35	0.01	0.10
13:00 - Surface turbid plume arrived at sampling location.				
13:00:30	1	0.87	0.01	0.06
13:01:30	8	0.30	0.06	0.05
13:02 - Surface turbid plume passed sampling location.				
13:02:30	1	7.2	0.36	0.09
13:03:00	8	-	0.15	0.06
13:03:30	8	0.27	0.01	0.05
13:03:45	1	-	0.01	-
13:03:50	14	1.3	0.01	0.05
13:04:00	1	-	0.01	-
13:04:15	8	0.66	0.02	0.07
13:04:30	14	0.65	0.03	0.08
13:05:30	8	0.63	0.01	0.08
13:06:00	14	2.0	0.01	0.05
13:06:30	1	0.39	0.01	0.13
13:06:45	8	-	0.01	-
13:07:15	14	2.1	0.01	0.10
13:08:30	1	-	0.02	-
13:09:00	8	-	0.01	-
13:09:45	14	1.0	0.02	0.07
13:11:00	14	-	0.01	-
13:11:30	8	0.26	0.02	0.07
13:12:15	1	0.43	<0.01	0.05

Dash (-) indicates no analysis made.

5 min after the disposal, followed by a decrease. About 8 min after the disposal, a second increase (to 2.1 mg N/l) was observed.

Nitrate concentrations started increasing in the surface water about 5 min after disposal but returned to ambient concentrations by 14 min after the dump. In the bottom and mid-depth water, nitrate concentrations did not show any clear pattern of variation, although concentrations fluctuated at both depths.

Phosphorus Compounds. Data in Table 15 show that the soluble ortho P concentrations during Dump No. 4 appeared to increase at all three depths during this disposal operation. Concentrations increased 25 to 55-fold but returned to ambient levels within a 6 to 8 min period. These increases occurred shortly after the rapid decrease in light transmission (Figure 4). It appears that the smallest reduction in percent light transmission and the greatest release of soluble ortho P occurred in the surface waters. The sample taken at 14 m at 12:54:00 prior to the dump also showed a higher concentration (0.45 mg P/l) of soluble ortho P. This value could be related to residual effects from previous dumps or pre-disposal leaking of the hopper-dredge.

Organic Compounds. Soluble total organic carbon concentrations in composite surface water samples collected before, during, and after the passage of the surface turbid plume from Galveston Dump No. 4 were 11.2, 23, and 9.8 mg/l,

TABLE 15. SOLUBLE ORTHOPHOSPHATE CONCENTRATIONS:  
GALVESTON DUMP NO. 4

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
12:54:00	14	0.45
12:58 - Dump occurred.		
12:59:30	14	<0.01
13:00 - Surface turbid plume arrived at sampling location.		
13:00:30	1	0.29
13:01:30	8	<0.01
13:02 - Surface turbid plume passed sampling location.		
13:02:30	1	0.55
13:03:00	8	0.018
13:03:30	8	<0.01
13:03:50	14	0.25
13:04:15	8	0.077
13:04:30	14	0.19
13:05:30	8	0.26
13:06:00	14	0.013
13:06:30	1	<0.01
13:07:15	14	0.012
13:09:45	14	<0.01
13:11:30	8	<0.01
13:12:15	1	<0.01

Concentration based on one analysis of one sample.

respectively. Total organic carbon in those composites were 25.8, 38.4, and 38.3 mg/l, respectively. The total oil and grease, and soluble oil and grease concentrations in those composites were all less than 0.5 mg/l.

#### TEXAS CITY CHANNEL STUDY

Since the sediments from Galveston Bay Entrance Channel would be considered relatively "clean" compared to sediments from industrialized areas, it was decided that a comparison study should be conducted on the nearby Texas City Channel sediments. Ordinarily the CE would not dispose of Texas City Channel sediments at the GBEC disposal site in the Gulf of Mexico because of the great distance (approximately 50 km) between the dredging and disposal sites. However, permission was granted for the Corps to dredge Texas City Channel sediments with the hopper-dredge McFarland and transport them to GBEC the disposal site so that a comparison could be made between the contaminant release from the relatively "clean" Galveston Bay Entrance Channel sediments and that found when the highly contaminated Texas City Channel sediments are disposed of at the same site by the same disposal method.

#### Texas City Channel Sediment Elutriate Tests

Sample Sites. Two sets of sediment and water samples were collected in the Texas City Channel for elutriate tests.

The first set of Texas City Channel samples was collected on March 28, 1975 at sites designated as TCC-1, TCC-2, and TCC-3. Their locations are shown in Figure 2. The second set of three sites (TCC-4, TCC-5, and TCC-6) was sampled September 20, 1975 (Figure 2).

#### General Sediment Characteristics and Oxygen Demand.

The results of oxidation reduction potential (Eh), sulfide concentration, and percent dry weight determinations on sediment samples from TCC-1, 2, 4, 5, and 6 are presented in Table 16. Sediments from TCC-1 and 2 had similar Eh values (-38 mv and -20 mv), sulfide concentrations (1205 mg/kg and 1251 mg/kg), and dry weight (53% and 51%). There was also a general similarity between the Eh and percent dry weight characteristics of the sediments from TCC-4, 5, and 6. The Eh readings were -100, -136, and -124 mv, respectively. The dry weights were 38, 44, and 40%, respectively. The sulfide concentrations did not show the same trend; in fact, the three values were quite dissimilar: 2519, 237, and 1557 mg/kg for TCC-4, 5, and 6, respectively. The pattern of similarities in sediment characteristics corresponded more to date of sampling than to the location of the sampling sites in the channel. However, in general, percent dry weight values were all about the same at the five locations; except for TCC-4 and 5 sediments, the sulfide values were also all about the same. As expected, the TCC sediments were far more reducing in nature as assessed by Eh than the GBEC Buoy 1 sediment evaluated, and were also considerably higher

TABLE 16. GENERAL SEDIMENT CHARACTERISTICS: TEXAS CITY CHANNEL SEDIMENTS

Sampling Location* (TCC Site)	Eh (mv)	Sulfide (mg/kg)		Percent Dry Weight		Oxygen Uptake Per Cubic Meter (g O <sub>2</sub> )		First Hour Per Gram Dry Wt. (mg O <sub>2</sub> )	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1	- 38	1205	108	53	0.7	5.0 x 10 <sup>2</sup>		0.66	
2	- 20	1251	95	51	2.1	4.8 x 10 <sup>2</sup>		0.64	
4	-100	2519	10	38	0.3	6.0 x 10 <sup>2</sup>		1.21	
5	-136	237	10	44	0.9	4.5 x 10 <sup>2</sup>		1.17	
6	-124	1557	140	40	0.1	6.1 x 10 <sup>2</sup>		0.76	

Mean and standard deviation calculated from triplicate analysis.

\*Site 3 sediment was not analyzed.

TABLE 17. TOTAL HEAVY METAL CONCENTRATIONS: TEXAS CITY CHANNEL SEDIMENTS  
(mg/kg dry wt)\*

Sampling Site and Date (1975)	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe <sup>*</sup>		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
March 28:																				
TCC-1	840	40	650	20	4.3	0.6	720	20	50	30	240	60	40	1	23	0.3	0.68	0.04	**	
TCC-2	400	20	340	180	4.5	1.3	10	1	60	20	80	10	30	10	17	4.7	0.68	0.04	**	
TCC-3	4680	150	170	90	3.3	0.3	20	1	90	20	50	10	10	1	33	2.3	0.40	0.07	**	
September 20:																				
TCC-4	556	8	77	5	<0.5	-	24	4	<1	-	160	3	83	1	26	0.3	0.041	0.002	12.8	0
TCC-5	557	21	58	4	<0.5	-	21	2	<1	-	114	6	43	1	26	0.3	0.031	0.002	11.8	0
TCC-6	671	13	90	3	<0.5	-	25	1	<1	-	141	2	60	1	26	0.5	0.032	0	13.0	0.2

Dash (-) indicates single analysis.

Mean and standard deviation calculated from triplicate analyses.

\* Iron concentrations in g/kg.

\*\* Analyses not performed.

in sulfide.

The data from the oxygen demand test of TCC-1 sediment are plotted in Figure 6. Table 16 presents the first hour oxygen uptake rates for the four sediments evaluated, on both volume and dry weight bases. First hour uptake rates on a sediment volume basis ranged from 480 to 610 g O<sub>2</sub>/m<sup>3</sup> and appeared to decrease with increasing distance from the Turning Basin. The demand was somewhat higher at TCC-6 than at TCC-2, however. This pattern was not found for the oxygen uptake computed on a per dry weight basis, which appeared to vary more with sampling date than location. The sediment oxygen uptake rates at TCC-4 and 5 were about twice those found for TCC-1 and 2 sediments. The per volume and in general the per dry weight uptake rates were considerably greater than those found for the GBEC sediments evaluated, although the per dry weight uptake rates for TCC-1 and GBEC Buoy 1 sediments were about the same.

Heavy Metals. Table 17 shows that there were some major differences in heavy metal concentrations between the two sets of Texas City Channel sediments. The TCC-1, 2, and 3 sediment samples contained 3.3 to 4.5 mg/kg Cd and 50 to 90 mg/kg Pb. In the samples collected in September, concentrations of these metals were below the respective detection limits of 0.5 and 1 mg/kg. Mercury concentrations, which ranged from 0.4 to 0.68 mg/kg in sediments from TCC-1, 2, and 3, were an order of magnitude lower in the TCC-4, 5, and 6 samples. Similarly, Cr concentrations were substantially

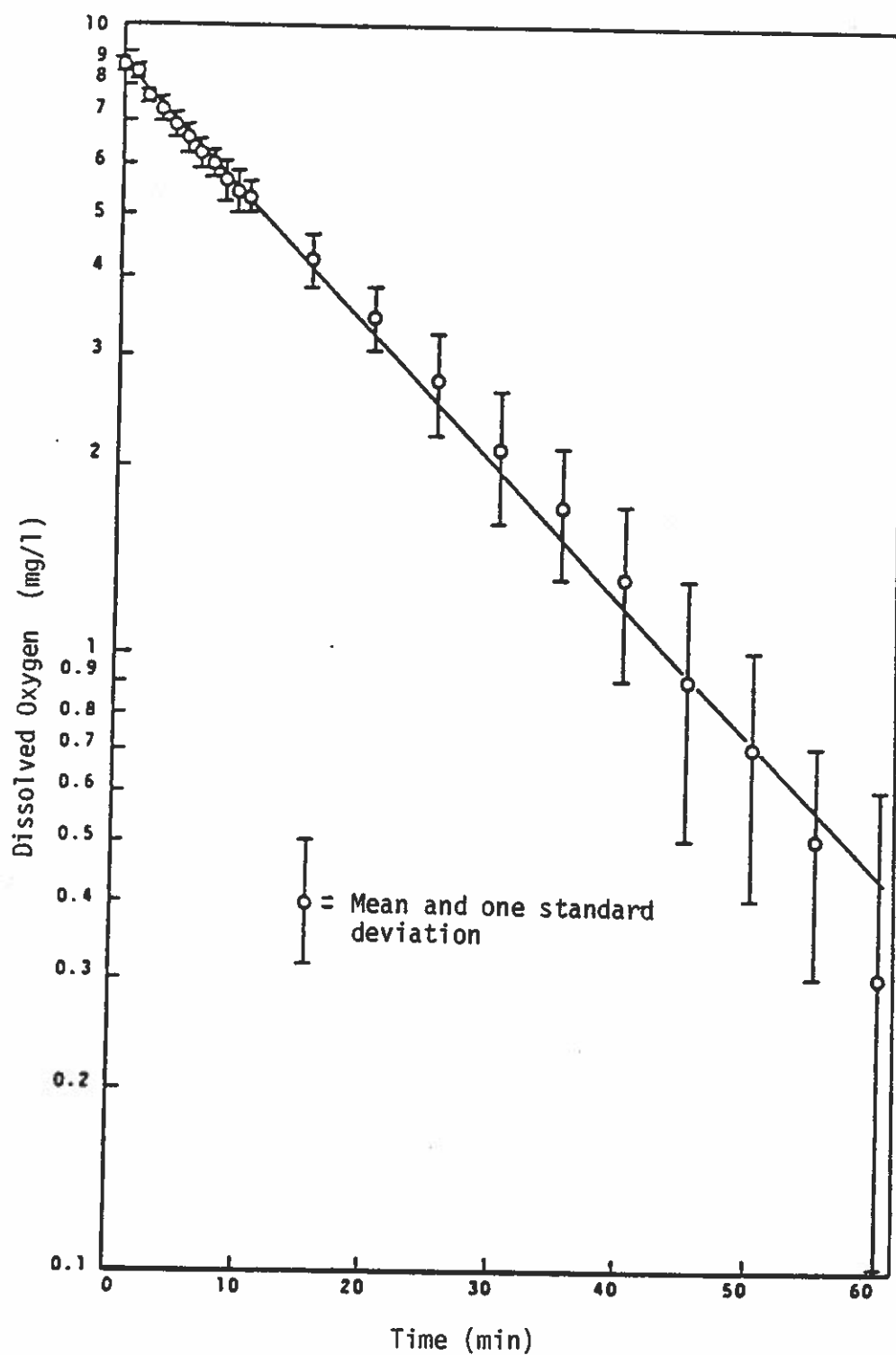


Figure 6. Oxygen Demand Test: Texas City Site 1 Sediment  
(Sample Size - 5 cc)



higher at TCC-1, 2, and 3 than they were at TCC-4, 5, and 6. However, the ranges of Ni, Cu, Mn, Zn, and Fe were similar for the two sampling periods. For most of the heavy metals measured on TCC-1, 2, and 3 sediment, the concentrations decreased with increasing distance from the Turning Basin area. This relationship was not generally found for the TCC-4, 5, and 6 sediments.

Table 18 presents the results of the soluble heavy metals analyses for the TCC-1 through 6 elutriate tests which were run using both 5% and 20% sediment and some of which were allowed to settle for both 1 hr and 24 hrs. Large amounts of Mn were released from all sediments during elutriation; the greatest release was found from TCC-3 sediments, resulting in elutriate concentrations of about 4000 and 6000  $\mu\text{g/l}$ . There was also measurable release of Cd, Cr, and Fe from TCC-1 sediments although no apparent Cd or Fe release occurred from TCC-2 or 3 sediments. It appeared that there was a decrease in the Zn and Hg concentrations as a result of elutriation of TCC-1 and 3 sediments; release or uptake from TCC-2 sediments was unclear. The statistical validity of the apparent changes in concentrations of other heavy metals was uncertain because of the standard deviations for the analyses. It appears that the only heavy metals that have a potential for release from Turning Basin area sediments (TCC-1, and 4) are Mn and Cr, and possibly Ni and Fe.

Concentrations of Mn were greater in the elutriates

TABLE 18. SOLUBLE HEAVY METAL CONCENTRATIONS: TEXAS CITY CHANNEL OXIC ELUTRIATE TESTS

Sample Designation	Mn		Cr		Cd		Ni		Pb		Zn		Cu		Fe		Hg		As	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
TCC-1:																				
Site Water	52	8	11.1	2.5	1.8	0.1	4.1	1.5	3.6	1.2	13.3	0.6	5.4	0	5	3	0.27	0.01	*	*
5% (1 hr)	262	52	108	8.1	5.5	1.9	11.4	3.1	3.9	2.4	4.8	3.9	4.6	4.0	18	1	0.08	0.01	*	*
(24 hr)	551	13	41.4	5.6	3.8	0.6	9.5	1.9	4.1	0.7	5.1	0.9	4.2	1.6	15	8	0.01	0.01	*	*
20% (1 hr)	626	48	159	10	5.9	1.1	14.7	0.6	4.5	1.9	4.7	2.6	2.2	0.2	20	5	0.22	0.01	*	*
(24 hr)	1063	35	135	14	3.9	1.2	9.5	1.9	5.2	2.9	3.2	1.0	1.8	0.4	27	5	0.10	0.01	*	*
TCC-2:																				
Site Water	5	-	<2.0	-	<0.3	-	7.8	-	<1.0	-	8.7	-	<1.0	-	<1	-	0.028	-	*	*
5%	296	11	10.3	7.0	<0.3	~0	12.9	0.3	2.0	0	14.3	0.6	<1.0	~0	2	1	0.048	-	*	*
10%	472	53	3.7	2.3	<0.3	~0	9.8	0	2.0	0	10.7	0.8	<1.0	~0	2	0	0.014	-	*	*
TCC-3:																				
Site Water	12	-	<2.0	-	<0.3	-	4.6	-	1.0	-	19.3	-	1.7	-	<1	-	0.099	-	*	*
5%	3970	17	<2.0	~0	<0.3	~0	6.9	1.1	3.2	2.3	15.7	0.4	<1.0	~0	<1	~0	0.034	-	*	*
20%	5760	170	4.0	0	<0.3	~0	8.1	0	1.6	0	17.0	2.7	1.2	0.8	<1	~0	0.034	-	*	*
TCC-4:																				
Site Water	74	7.8	<2	-	1.1	0	4.9	0.7	7.2	1.1	1.3	-	5.7	0.2	5	1.0	0.007	0	<2	-
5%	315	79	<2	-	1.5	0.1	6.8	0.9	8.6	1.0	1.4	-	4.2	0.1	12	0.9	0.009	0.002	<2	-
20%	1200	200	<2	-	1.5	0.1	5.4	0.4	8.6	1.0	<1	-	3.8	0.4	10	1.3	0.007	0	<2	-
TCC-5:																				
Site Water	68	0	<2	-	0.8	0.2	5.1	0.4	15.0	1.0	1.3	0.3	5.7	0.5	10	2.9	0.003	0	<2	-
5%	2750	495	<2	-	0.6	0.1	8.2	0.3	13.9	0.6	<1	-	3.6	0.3	10	0.2	0.003	0	<2	-
20%	1200	2828	<2	-	0.6	0.1	7.1	0.5	16.4	1.0	<1	-	6.4	2.3	16	1.3	0.009	0.002	<2	-
TCC-6:																				
Site Water	51	7.8	<2	-	1.4	0.1	4.8	0	9.7	0.5	3.0	0.6	5.4	0.3	5	1.0	0.007	-	<2	-
5%	905	134	<2	-	0.7	0.1	5.3	1.2	10.7	1.0	<1	-	4.1	0.5	8	1.6	0.007	-	<2	-
20%	1600	-	<2	-	0.5	-	5.7	-	12.1	-	<1	-	3.7	-	20	-	0.007	-	<2	-

Mean and standard deviation calculated from duplicate analyses.

Dash (-) indicates standard deviation could not be calculated.

\* Not determined.

that settled for 24 hrs than in those that settled for 1 hr. For all of the other heavy metals measured, the concentrations in the 24 hr test were below those in the 1 hr test (Cr, Hg) or were not detectably different. There was not a clear, consistent difference between contaminant behavior in the 5% elutriate tests and the 20% tests.

Nitrogen Compounds. Total kjeldahl nitrogen (TKN) concentrations were determined for each of the Texas City sediments; ammonium and organic N were only determined on TCC-4, 5, and 6 sediments. As shown in Table 19, total kjeldahl nitrogen concentrations ranged from 643 mg N/kg for TCC-2 sediment to 1820 mg N/kg for the TCC-3 sediment.

TABLE 19. NITROGEN COMPOUND CONCENTRATIONS: TEXAS CITY CHANNEL SEDIMENT SAMPLES  
(mg N/kg dry wt)

Sample Designation	Total Kjeldahl Nitrogen		Organic N		Ammonium	
	X	SD	X	SD	X	SD
TCC-1	1670	47	-	-	-	-
TCC-2	643	12	-	-	-	-
TCC-3	1820	432	-	-	-	-
TCC-4	1670	47	1376	159	294	112
TCC-5	654	35	618	35	36	0
TCC-6	1249	116	1027	143	222	27

Mean and standard deviation calculated from duplicate analyses. Dash (-) indicates not measured.

Except for the sediments from TCC-2, and 5, all Texas City Channel sediments had TKN concentrations above 1000 mg N/kg. The TKN concentrations of the sediments appeared to decrease between TCC-1, and 5, and then increase again beyond; there was no distinct concentration difference between the two sampling dates. The lowest ammonium and organic N concentrations were in the TCC-5 sediment sample; the TCC-4, and 6 sediments had about the same concentrations of ammonium and organic N. Table 20 shows that the TCCTB water had higher organic N concentrations than the other TCC site waters, but had about the same nitrate concentrations. TCC-1 site water had higher ammonium levels than the other site waters; nitrate levels in all samples were similar.

There were substantial amounts of ammonium released in all of the Texas City Channel sediment elutriate tests. Concentrations in the standard 5% elutriates ranged from 1.6 to 4.5 mg N/l, and in the standard 20% elutriates from 3 to 16 mg N/l. The highest concentrations were in TCC-1, 4, and 6 elutriates. With the longer settling, somewhat greater ammonium release occurred. Organic N concentrations appeared to generally decrease during elutriation. Since the TCC-2, and 3 elutriates were centrifuged prior to analysis, however, the organic N concentrations for these samples only reflect the dissolved fraction and any organic N associated with fine particulates. Nitrate concentrations did not change by measurable amounts during elutriation of TCC-1, 2, or 3 sediments, but tended to be released from

TABLE 20. NITROGEN COMPOUND CONCENTRATIONS: TEXAS CITY CHANNEL  
OXIC ELUTRIATE TESTS

(mg N/l)

Sample Designation	Organic N		Ammonium		Nitrate	
	$\bar{X}$	SD*	$\bar{X}$	SD*	$\bar{X}$	SD**
TCC-1:						
Site Water	5.0	1.0	0.59	0.04	0.08	0.01
5% ( 1 hr)	3.2	1.3	3.1	0.18	0.05	0.01
(24 hr)	2.2	0.7	3.8	0.2	0.06	0.02
20% ( 1 hr)	0.2	1.5	7.5	0.1	0.05	0
(24 hr)	0.6	0.6	10	-	0.07	0.02
TCC-2:						
Site Water	0.25	0.02	0.15	0.01	0.11	0.01
5%***	< 0.05	-	1.6	0	0.11	0.01
20%***	< 0.05	-	6.0	0.08	0.09	0.01
TCC-3:						
Site Water	0.30	0.21	0.22	0.01	0.11	0.01
5%***	< 0.05	-	3.0	0.01	0.09	0.01
20%***	< 0.05	-	4.7	0.23	0.11	0.01
TCC-4:						
Site Water	0.84	0.30	0.12	0	0.10	0.01
5%	< 0.05	~ 0	4.5	0.09	0.42	0.01
20%	< 0.05	~ 0	10	0.25	0.74	0.02
TCC-5:						
Site Water	0.79	0.22	0.12	0	0.11	0.01
5%	0.93	0.16	1.6	0.01	0.05	0.01
20%	< 0.05	~ 0	3	0.02	0.09	0.01
TCC-6:						
Site Water	0.15	0.09	0.12	0.01	0.04	0.01
5%	0.91	0.01	4.4	0.01	0.50	0.01
20%	2.6	2.3	16	0.42	0.31	0.02

\* Standard deviation calculated from duplicate analyses.

\*\* Standard deviation calculated from triplicate analyses.

\*\*\* Samples centrifuged prior to analysis.

Dash (-) indicates standard deviation could not be calculated.

TCC-4 and 6 sediments and taken from solution during elutriation of TCC-5 sediments.

Phosphorus Compounds. The total phosphorus concentrations in the Texas City Channel sediments are presented in Table 21. There does not appear to be an overall pattern (considering all six locations) of concentration with regard to sampling location. In the first sampling series (TCC-1, 2, and 3), the greatest concentration was found at TCC-1 (farthest up the turning basin), the lowest at TCC-2, and an intermediate value at TCC-3 (the most seaward site). Concentrations at TCC-4, 5, and 6 were all greater than those from the other TCC sites, but showed a similar pattern,

TABLE 21. TOTAL PHOSPHORUS CONCENTRATIONS:  
TEXAS CITY CHANNEL SEDIMENT  
(mg P/kg dry wt)

Sample Designation (TCC Site)	Total Phosphorus	
	$\bar{X}$	SD
1	750	70
2	473	59
3	644	23
4	1468	34
5	937	7
6	1232	14

Mean and standard deviation calculated from duplicate analyses of one sediment sample.

i.e., the greatest concentration was found farthest up the Turning Basin (TCC-4), the lowest was found at the mouth of the Turning Basin (between TCC-1 and 2), and the intermediate concentration at TCC-6, the most seaward site.

The mean soluble orthophosphate and total phosphate concentrations found in Texas City Channel elutriates are presented in Table 22. The site waters from all three locations had essentially the same concentrations of soluble ortho P and total P. The TCC-1 sediment released about the same amount of soluble ortho P in both the 5% and 20% standard elutriate tests; it released greater amounts after the 24 hr settling period than after the 1 hr period. The total P release was also about the same in the 5% and 20% elutriates settled for 1 hr. The settling time did not appear to affect the total P concentration in the 5% elutriate. However, the 20% elutriate settled for 24 hrs had a phosphorus concentration at least four times greater than that settled for 1 hr. The results of the rest of the elutriate tests were mixed, with TCC-4 sediments showing a release of soluble ortho P and the others either no change or an uptake.

Organic Compounds. A 5% oxic elutriate test was run on samples from Texas City Channel Site 1. Aldrin, pp'DDT, dieldrin, lindane, and PCBs were detected in the sediment. The PCB value of 7426  $\mu\text{g/kg}$  is one of the highest PCB concentrations found in sediment in the Lee et al. (1978) studies. This is likely due to a point source PCB discharge that has occurred in this area.

TABLE 22. SOLUBLE ORTHOPHOSPHATE AND TOTAL PHOSPHORUS CONCENTRATIONS: TEXAS CITY CHANNEL OXIC ELUTRIATE TESTS  
(mg P/l)

Sample Designation	Soluble Ortho P		Total P	
	$\bar{X}$	SD	$\bar{X}$	SD
TCC-1				
Site Water	0.095	0.021	0.10	0
5% ( 1 hr)	0.24	0.005	0.27	0.01
(24 hr)	0.30	0.008	0.30	0.01
20% ( 1 hr)	0.22	0.008	0.24	0.01
(24 hr)	1.3	0.03	> 1.0*	-
TCC-2				
Site Water	0.11	0.006	0.12	0.01
5% ( 1 hr)	0.048	0.002	0.09	0.01
20% ( 1 hr)	0.11	0	0.24	0.01
TCC-3				
Site Water	0.10	0.003	0.13	0.01
5% ( 1 hr)	0.054	0.005	0.13	0.01
20% ( 1 hr)	0.074	0.003	0.15	0.01
TCC-4:				
Site Water	0.17	0	-	-
5%	0.28	0.018	-	-
20%	0.26	0.001	-	-
TCC-5:				
Site Water	0.18	0.003	-	-
5%	0.13	0.003	-	-
20%	0.15	0.001	-	-
TCC-6:				
Site Water	0.20	0.002	-	-
5%	0.12	0.001	-	-
20%	0.22	0	-	-

Dash (-) indicates no analysis made.

Mean and standard deviation calculated from duplicate or triplicate analysis of one sample.

\*Sample absorbance exceeded that of highest standard; insufficient sample remained to rerun analysis.



Sixteen of the peaks present in the sediment were detected in the water sample. The same chlorinated hydrocarbons identified in the sediment were also identified in the water, but only the aldrin concentration was above the detection limit. The profile of organic residue in the elutriate showed the 16 peaks detected in the water plus five others. Generally, the magnitudes of these peaks were higher in the elutriate than in the water, indicating a tendency for release of those organic residues.

The concentrations of chlorinated hydrocarbon pesticides and PCBs are presented in Table 23. The oil and grease content of the sediment (304 mg/kg) was relatively low which would indicate a low tendency for sorption of PCBs and chlorinated hydrocarbon pesticides by the suspended sediments. The results of the elutriate test showed a possible release of lindane, aldrin, and PCBs.

A 20% elutriate test was run on samples from Texas City Channel Site 4. The profile of organic residues on the chromatograms of the sediment and water showed essentially the same fingerprints found for the TCC-1 sediment and water samples. The heights of the chromatogram peaks for the elutriate were substantially higher than most of the peaks detected in the site water.

Measurable amounts of aldrin, pp'DDT, pp'DDE, lindane, and PCBs were detected in the TCC-4 sediment. Only lindane, aldrin, and PCBs were detected in the site water. In the elutriate there was release of aldrin, pp'DDT, pp'DDE, lindane,

TABLE 23. DATA FOR ORGANIC COMPOUNDS AND RELATED PARAMETERS:  
TEXAS CITY CHANNEL SITE 1, 5% OXIC ELUTRIATE TEST

Parameter	Sediment	Water	Elutriate
	(µg/kg)	(ng/l)	(ng/l)
<u>Chlorinated Hydrocarbons:</u>			
Aldrin	3.4	1.4	3.6
op'DDT	<1.6	<3.0	<3.0
pp'DDT	8.4	<3.0*	<3.0*
op'DDD	<2.0	<2.0	<2.0
pp'DDD	<2.0	<2.0	<2.0
op'DDE	<1.4	<2.0	<2.0
pp'DDE	<1.4	<2.0	<2.0
Dieldrin	2.7	<1.2*	<1.2*
Endosulfan I	<0.9	<1.2	<1.2
Endosulfan II	<3.4	<4.4	<4.4
Endrin	<1.2	<1.6	<1.6
Heptachlor	<0.3	<0.4	<0.4
Lindane	1.0	<0.3*	1.5
PCBs	7426	130	150
<hr/>			
<u>Other Organic Compounds</u>			
Oil and Grease	304 mg/kg	-	-
Total Carbon	1.8%	-	-

\*Compound indicated on two columns, but below detection limit.  
Dash (-) indicates not determined.

and PCBs.

### Bioassays

Table 24 presents the results of the 96 hr bioassays of P. pugio in 5%, 10%, and 20% sediment elutriates of TCC-1 sediment. Examination of the data shows that no toxicity to P. pugio was found for the 5% and 10% sediment elutriates. One organism death was observed in the duplicate 20% sediment elutriates after 24 hrs and another in each after 36 hrs.

Table 25 presents the toxicity response of P. pugio to bioassay elutriates of TCC-4 sediment, the other sediment from the TCCTB area. Mortality in the 5% and 20% tests was similar to that in the respective TCC-1 tests. There was somewhat greater toxicity in the TCC-4 10% tests than in the TCC-1 10% test. The TCC-4 sediment showed sufficient toxicity to be of potential concern if disposal were to take place in an area in which there would be limited opportunity for mixing-dilution to take place. Mixing was found to be rapid at the GBEC Disposal Site, so this amount of toxicity in these laboratory bioassays would not be of great concern in this disposal operation.

### Texas City Channel Disposal Operations -

#### Texas City Channel Dump No. 2

Background. In October 1975, Lee et al. (1977) monitored two disposal operations in which sediments dredged

TABLE 24. RESPONSE OF P. PUGIO TO TEXAS CITY CHANNEL  
SITE 1 BIOASSAY ELUTRIATE

Time (hr)	Number of <u>P. pugio</u> Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10
24	10	10	10	10	10	10	9	9
36	10	10	10	10	10	10	8	8
48	10	10	10	10	10	10	8	8
60	10	10	10	10	10	10	8	8
72	10	10	10	10	10	10	8	8
84	10	10	10	10	10	10	8	8
96	10	10	10	10	10	10	8	8

A and B are replicates.

TABLE 25. RESPONSE OF P. PUGIO TO TEXAS CITY CHANNEL  
SITE 4 BIOASSAY ELUTRIATE

Time (hr)	Number of <u>P. pugio</u> Living at Varying Sediment Percentages							
	Control		5%		10%		20%	
	A	B	A	B	A	B	A	B
0	10	10	10	10	10	10	10	10
12	10	10	10	10	9	10	9	9
24	10	10	10	10	9	10	9	9
36	10	10	10	10	9	8	9	9
48	10	10	10	10	9	8	9	9
60	10	10	9	10	9	7	9	9
72	10	10	8	10	9	7	9	8
84	10	10	8	10	9	7	9	8
96	10	10	8	10	9	7	9	8

A and B are replicates.

from the TCCTB (in the vicinity of TCC-1, 4) were dumped near Buoy B<sub>1</sub> located about 500 m from Buoy B in the GBEC Disposal Site (Figure 2). Although two operations were studied, for only one (Dump No. 2) was there sufficient data collected for a comparison of elutriate test results with those of the disposal operation. Lee et al. (1977, 1978) provide additional data and discussion of the Texas City Channel sediment disposal operations.

Texas City Channel Dump No. 2 occurred at 1014 hrs on October 10, 1975. This disposal of approximately 585 m<sup>3</sup> of sediment occurred approximately 40 m off the bow of the sampling vessel. The current readings were 0.1 knots (5 cm/sec) and 0.2 knots (10 cm/sec) in surface and bottom waters, respectively.

Optical Properties. Figure 7 presents percent light transmission values for the surface, mid-depth, and bottom waters during the Texas City Channel Dump No. 2 and illustrates the passage of the turbid plume. The turbid plume took 4, 5, and 3 min to reach the sampling vessel in surface, mid-depth, and bottom waters, respectively. Turbidity at the 10 m depth (bottom) gradually began to decrease 16 min after disposal but remained above the general pre-disposal level for the duration of the 1.5 hr sampling period. Secchi depth prior to disposal (0922 hrs) was 3.0 m; at 1036 hrs (after the turbid surface plume had passed) Secchi depth was 2.5 m.

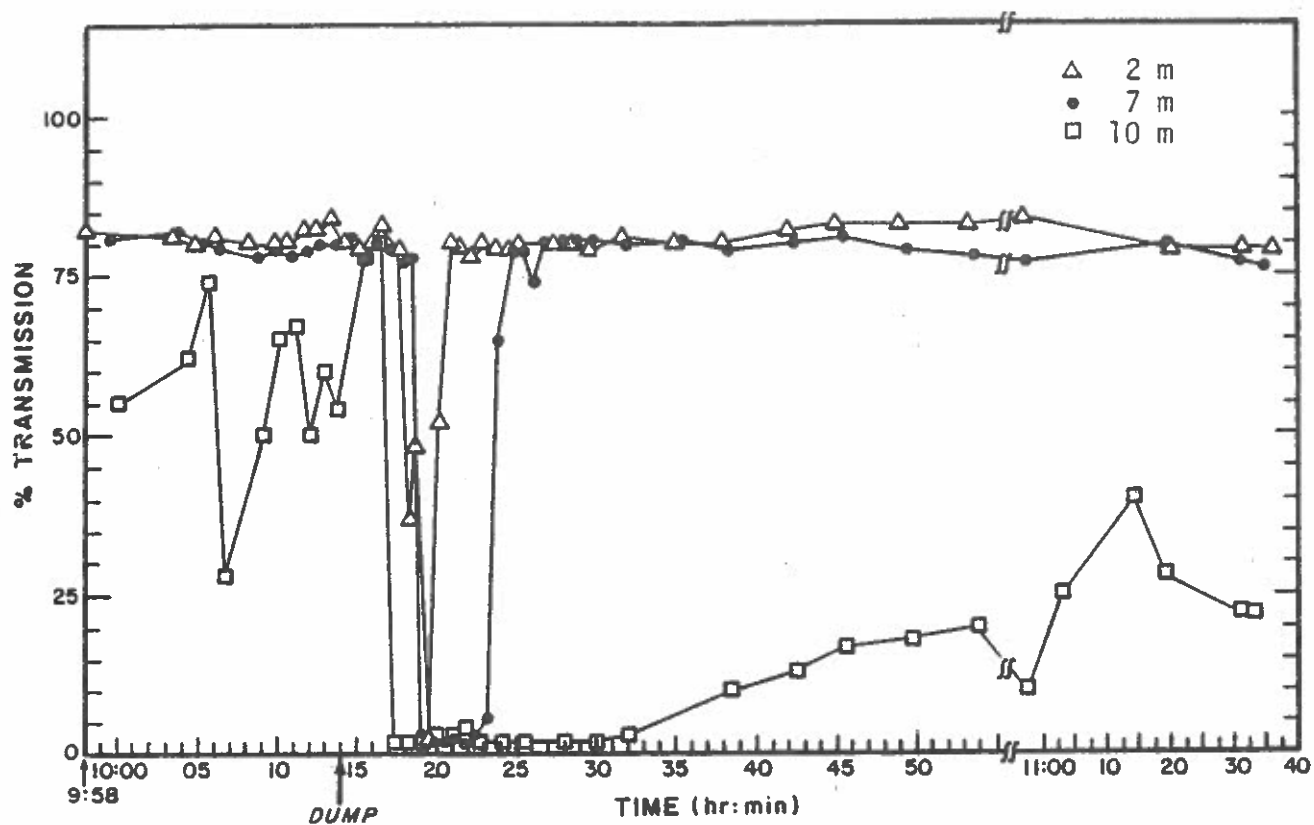


Figure 7. Percent Light Transmission: Texas City Channel  
Dump No. 2

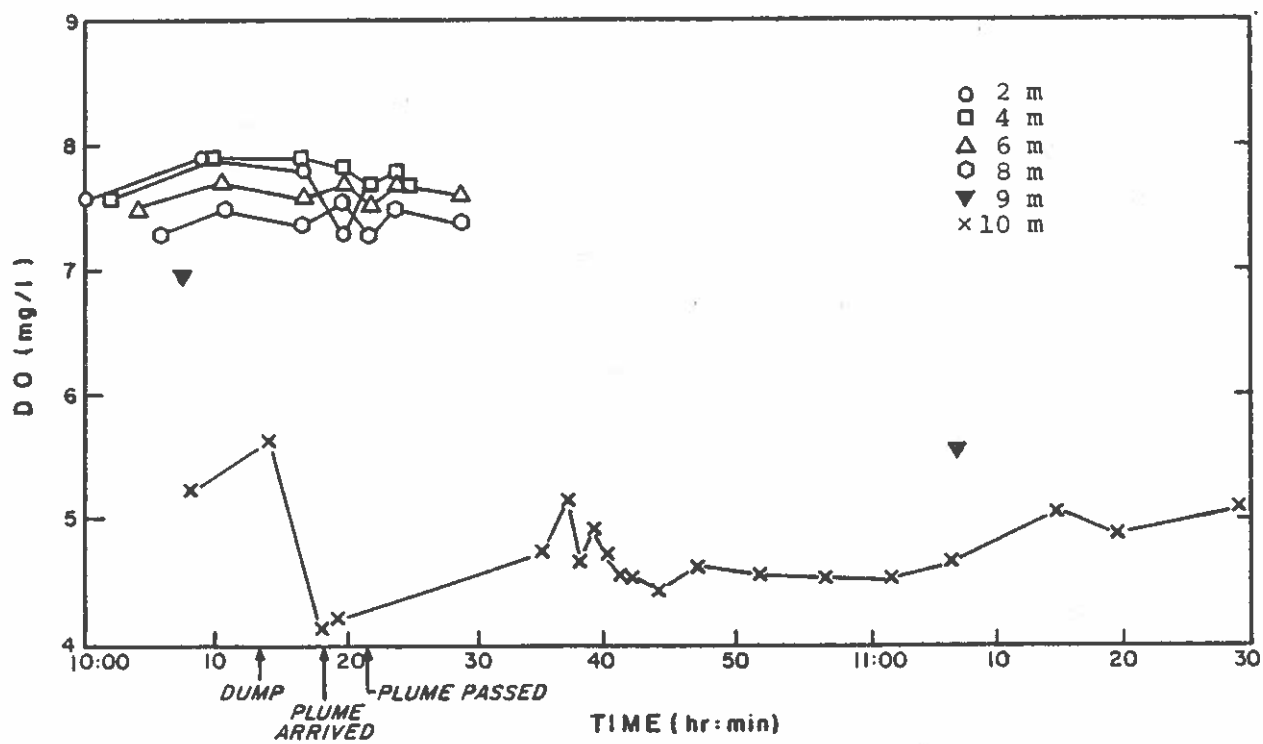


Figure 8. Dissolved Oxygen Concentrations: Texas City Channel  
Dump No. 2

Dissolved Oxygen. The pattern of dissolved oxygen concentrations at the 2 and 10 m depths (Figure 8) was essentially the same as the percent light transmission pattern during TCC Dump No. 2. The concentration change at the 2 m depth was minor, and the DO returned to pre-disposal level minutes after the disposal, while at the 10 m depth, it stayed below the pre-disposal level. DO readings were made only twice at the 9 m depth. At 1007 hrs the DO was 6.9 mg/l and at 1107 hrs it was 5.5 mg/l. Dissolved oxygen levels at 10 m at those times were 5.2 and 4.6 mg/l, respectively. It appears that measurable oxygen decrease occurred only in the bottom 2 m of the watercolumn.

Heavy Metals. Soluble heavy metal concentrations during TCC Dump No. 2 are presented in Table 26. There were no major releases of heavy metals during disposal. Apparent Ni increases were observed in the bottom water with the arrival of the bottom turbid plume. The concentrations decreased again 10 min later. There appeared to be some release of Zn, Cu, Hg, and Fe most of which occurred primarily in the bottom waters. By the end of sampling about 1.25 hrs after the dump, all concentrations had returned to ambient levels.

The concentration of manganese measured at 10:15:50 at 10.5 m was 838  $\mu\text{g/l}$ . This value was well outside the concentration range of this metal during this dump, and, as the sample was not taken in the turbid plume, it is suspected that the high value was due to contamination during collection or handling.

TABLE 26. SOLUBLE HEAVY METAL CONCENTRATIONS: TEXAS CITY  
CHANNEL DUMP NO. 2  
( $\mu\text{g/l}$ )

Time of Collection (hr:min:sec)	Depth (m)	Mn	Cr	Cd	Ni	Pb	Zn	Cu	Fe	Hg	As
9:58:30	1.5	14	<2	0.8	14.5	1.9	9.7	2.9	<5	0.002	<2
9:58:45	8	14	<2	0.8	14.5	2.4	5.3	2.5	11	0.002	<2
10:01:45	1.5	30	<2	0.8	14.5	1.9	2.3	2.5	5	0.006	<2
10:02:25	10.5	25	<2	0.8	3.1	2.4	13.1	3.0	18	0.016	<2
10:14 - Dump occurred											
10:14:15	8	<5	<2	0.6	12.2	6.8	12.9	4.8	459	0.002	<2
10:15:50	10.5	838	<2	0.9	6.8	0.9	22.7	2.6	13	0.002	<2
10:16:10	8	<5	<2	0.6	10.5	1.9	7.2	2.8	40	0.002	<2
10:16:45	8	14	<2	0.7	14.5	6.8	15.8	4.6	37	0.006	<2
10:18 - Surface turbid plume arrived at sampling station											
10:18:00	1.5	16	<2	0.8	4.1	0.9	4.2	4.3	17	0.002	<2
10:18:25	10.5	25	<2	1.1	4.7	2.4	16.9	6.1	9	0.002	<2
10:19:10	10.5	14	<2	1.0	12.9	1.9	8.7	6.0	109	0.016	<2
10:19:40	8	21	<2	0.7	16.2	2.7	7.4	9.4	212	0.006	<2
10:19:55	1.5	<5	<2	0.6	13.7	1.9	2.2	2.8	13	0.002	<2
10:20:10	10.5	14	<2	0.7	18.6	2.7	8.6	2.9	49	0.002	<2
10:20:50	1.5	14	<2	0.9	15.3	2.4	44.8	2.8	20	0.016	<2
10:21 - Surface turbid plume passed sampling station											
10:21:10	10.5	30	<2	1.2	15.3	2.4	17.7	7.5	74	0.012	<2
10:21:50	1.5	<5	<2	0.8	12.1	2.7	6.7	3.1	50	0.023	<2
10:22:45	1.5	30	<2	0.9	12.9	2.2	7.7	2.9	123	0.012	<2
10:23:45	8	19	<2	0.8	4.4	2.8	5.0	4.6	18	0.006	<2
10:24:35	10.5	31	<2	1.2	5.6	2.8	17.1	9.4	41	0.006	<2
10:25:00	8	14	<2	0.8	10.5	1.6	2.7	2.6	11	0.016	<2
10:26:35	10.5	<5	<2	1.0	11.3	2.4	10.2	6.8	98	0.016	<2
10:27:55	8	14	<2	0.9	15.3	2.2	4.8	2.5	10	0.016	<2
10:29:45	8	25	<2	0.7	3.3	2.0	6.5	3.5	13	0.016	<2
10:30:50	10.5	21	<2	0.7	17.0	2.7	9.3	8.9	22	0.006	<2
10:31:35	1.5	21	<2	0.8	12.1	2.2	10.3	3.4	5	0.016	<2
10:34:45	8	27	<2	0.7	3.6	0.9	1.5	2.4	<5	0.002	<2
10:35:10	10.5	10	<2	0.8	3.6	1.4	30.7	4.0	12	0.002	<2
10:39:50	10.5	27	<2	1.0	4.1	0.9	3.3	3.5	5	0.002	<2
10:43:10	8	25	<2	0.8	3.3	2.8	29.0	3.1	7	0.002	<2
10:43:30	10.5	21	<2	1.0	4.4	0.5	26.2	4.3	7	0.002	<2
10:48:00	1.5	32	<2	0.8	3.1	0.9	7.6	2.6	<5	0.002	<2
10:48:30	8	25	<2	0.8	5.0	2.4	11.8	3.1	10	0.002	<2
10:49:00	10.5	21	<2	0.8	3.4	0.9	4.8	3.2	<5	0.002	<2
10:55:50	10.5	10	<2	0.9	4.4	0.9	3.0	2.6	<5	0.002	<2
11:01:10	10.5	10	<2	0.8	4.4	0.9	1.8	2.6	<5	0.002	<2
11:07:25	10.5	19	<2	0.9	3.6	2.8	7.7	3.2	13	0.002	<2
11:13:30	10.5	10	<2	0.9	3.6	0.9	3.7	3.2	6	0.016	<2
11:17:30	1.5	25	<2	0.9	4.2	2.8	6.3	3.7	7	0.002	<2
11:18:00	8	25	<2	1.0	3.6	2.4	12.7	3.7	6	0.002	<2
11:18:15	10.5	25	<2	0.8	5.0	2.4	7.0	2.8	<5	0.002	<2
11:32:40	10.5	15	<2	0.8	3.3	2.4	12.3	3.8	6	0.002	<2



Nitrogen Compounds. Total ammonium concentrations are plotted as a function of time during TCC Dump No. 2, in Figure 9. Release of ammonium in the bottom water was observed with the passage of the bottom turbid plume (Figure 7), but the concentrations in the overlying water remained below 0.05 mg N/l except for one sample each of surface and

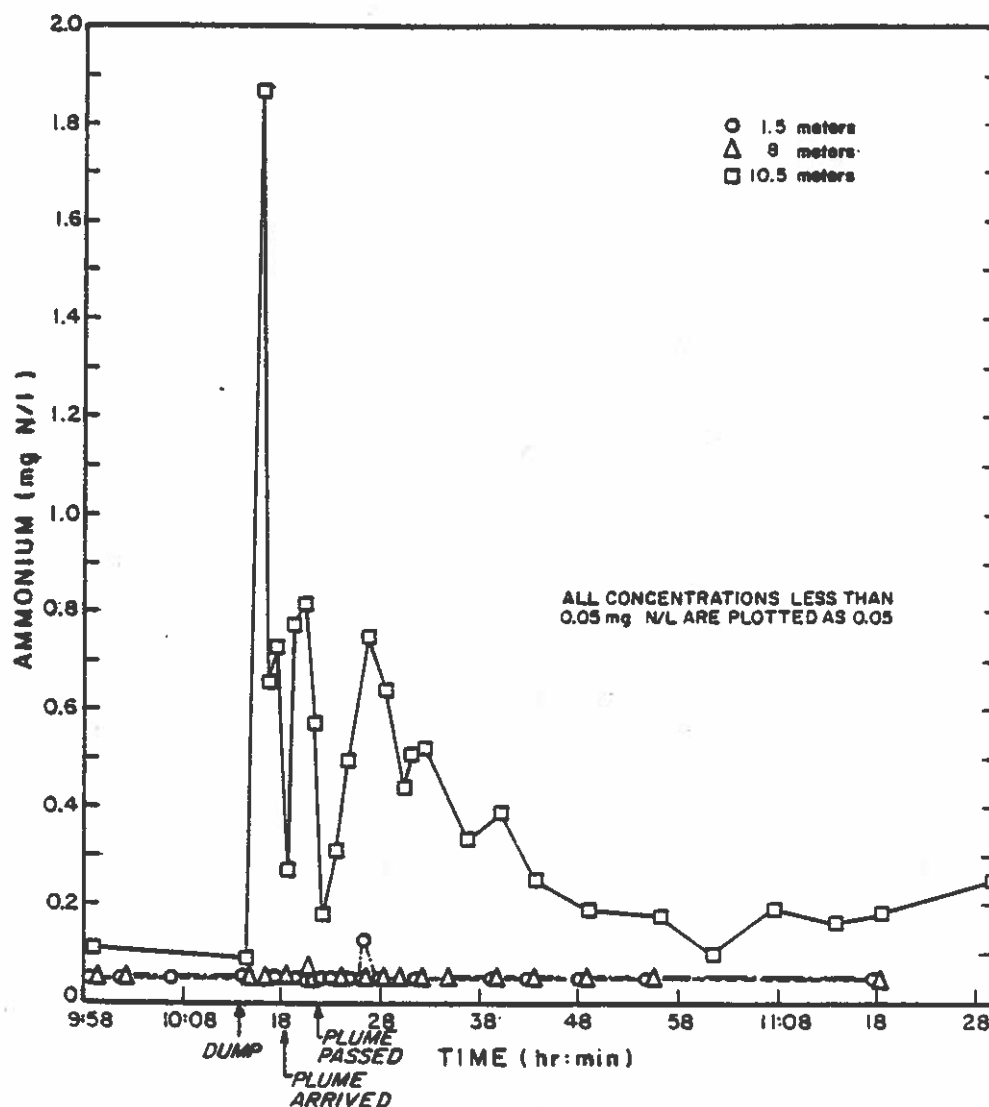


Figure 9. Ammonium Concentrations: Texas City Channel Dump No. 2

mid-depth water. The peak bottom water concentration persisted at the sampling location for less than 1 min. Organic N was apparently released in the bottom waters as a result of the disposal operation but returned to ambient levels 13 min after the surface turbid plume arrived at the sampling location. In the surface and mid-depth water, no discernible pattern could be observed.

Phosphorus Compounds. Concentrations of soluble orthophosphate during TCC Dump No. 2 are presented in Table 27. It appears that surface water soluble ortho P concentrations decreased slightly with the passage of the surface turbid plume, but increased with increasing turbidity at the other two depths monitored; at mid-depth the increase was only seen in one sample during the period of greatest turbidity. The bottom water soluble ortho P levels were variable but were consistently within or below the ambient range within 30 min after the disposal.

Organic Compounds. Seven composites of surface water samples collected before, during, and after the passage of the surface turbid plume were analyzed for soluble TOC, and oil and grease. One composite was of samples collected before the plume arrived; samples collected within the plume made up Composites 2 through 5. Two composites were made from samples collected after the plume had passed. The composites were centrifuged at 9000 rpm for 10 min to remove particulate matter but were not subjected to filtra-

TABLE 27. SOLUBLE ORTHOPHOSPHATE CONCENTRATIONS: TEXAS CITY CHANNEL DUMP NO. 2

Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)	Time of Collection (hr:min:sec)	Depth (m)	Soluble Orthophosphate (mg P/l)
9:58:30	1.5	0.070	10:22:45	1.5	0.044
9:59:00	10.5	0.072	10:23:45	8	0.076
10:01:45	1.5	0.10	10:24:35	10.5	0.17
10:02:00	8	0.11	10:25:00	8	0.049
10:02:25	10.5	0.097	10:26:35	10.5	0.086
	10:14:00 - Dump occurred.		10:27:55	8	0.049
10:14:15	8	0.084	10:29:45	8	0.077
10:14:25	10.5	0.067	10:30:50	10.5	0.14
10:15:50	10.5	0.56	10:31:35	1.5	0.045
10:16:10	8	0.019	10:34:45	8	0.058
10:16:45	8	0.053	10:35:10	10.5	0.070
	10:18:00 - Surface turbid plume arrived at sampling location.		10:39:50	10.5	0.069
10:18:00	1	0.096	10:43:10	8	0.10
10:18:25	10.5	0.18	10:43:30	10.5	0.14
10:19:10	10.5	0.084	10:48:00	1.5	0.079
10:19:40	8	0.14	10:48:30	8	0.021
10:10:55	1	0.061	10:49:00	10.5	0.041
10:20:10	10.5	0.35	10:55:50	10.5	0.070
10:20:50	5	0.062	11:01:10	10.5	0.076
	10:21:00 - Surface turbid plume passed sampling location.		11:07:25	10.5	0.072
10:21:10	10.5	0.054	11:13:30	10.5	0.064
10:21:50	1.5	0.054	11:17:30	1.5	0.049
	(Continued)		11:18:00	8	0.042
			11:18:15	10.5	0.026
			11:32:40	10.5	0.033

Soluble ortho P concentrations based on a single analysis  
of one sample.

tion in order to avoid the loss of oil and grease due to adherence to the filter. It is assumed that the total organic carbon (TOC), and oil and grease concentrations measured represent the soluble fraction of these two parameters.

Table 28 shows that the concentration of TOC in the composite of samples collected before the arrival of the plume was about 22 mg/l. The TOC concentrations in Composites 2

TABLE 28. CARBON AND OIL AND GREASE IN THE SURFACE WATER:  
TEXAS CITY DUMP NO. 2

Composite Number	Time (hr:sec)	Soluble TOC	Oil and Grease
		(mg/l)	
1	10:06 to 10:16	21.8	5.9
Surface turbid plume arrived at sampling location.			
2	10:16 to 10:17	20.8	7.1
3	10:18 to 10:22	19.7	4.6
4	10:24 to 10:26	15.2	8.6
5	10:27 to 10:31	27.2	6.1
Surface turbid plume passed sampling location.			
6	10:36 to 10:39	26.1	7.5
7	10:42 to 10:55	26.4	5.7

through 5 ranged from 15.2 to 27.2 mg/l with an average of 20.7. The two post-plume composite samples each contained about 26 mg/l TOC. The oil and grease content before the plume arrived was 5.9 mg/l. During passage of the plume, oil and grease concentrations fluctuated between 4.6 and 8.6 mg/l with an average of 6.6 mg/l. The two post-plume samples contained 7.5 and 5.7 mg/l, with an average of 6.6 mg/l.

Statistical analysis of variance was run on the Texas City TOC and oil and grease data. The results indicated that there was no significant difference, at a 95% confidence level, between concentrations of these two parameters before, during, or after passage of the surface turbid plume.

#### DISCUSSION

This study has shown that open water disposal-dumping of even highly contaminated dredged sediments, such as those derived from the Texas City Channel, does not represent a threat to watercolumn aquatic life or other beneficial uses of the Gulf of Mexico waters near Galveston, Texas. The conclusions from this study are in accord with the results of several other similar studies that were conducted at various locations in the U.S. as part of the Corps of Engineers' DMRP. As reported by Lee et al. (1978) and Jones and Lee (1978), with few exceptions, contaminants associated with U.S. waterway sediments are not released to the watercolumn upon open water disposal of dredged sediments. In general

these contaminants are tightly bound to the sediments. As discussed by Jones and Lee (1978), any contaminant release that did occur during a disposal operation was rapidly diluted to levels which are not toxic or otherwise adverse to watercolumn organisms at the disposal site. It would be rare that the open water disposal of dredged sediments would have an adverse impact on beneficial uses of the waters at or near a dredged sediment disposal site.

It is important to note, as discussed by Jones and Lee (1978), that the US EPA water quality criteria of the type released in 1976 (US EPA, 1976), and state water quality standards numerically equal to these criteria, are not valid tools by which to judge the potential adverse impact of contaminants' release in elutriate tests or to the open water disposal site watercolumn. This is because the US EPA criteria are generally chronic exposure, safe concentrations; when adopted as standards, they are generally applied to total contaminant concentrations. It is thereby assumed that aquatic organisms can receive a chronic - lifetime exposure to the contaminant, and that all of the contaminants are in forms that are available to aquatic life. It is well-known that many contaminants exist in aquatic systems in a variety of forms, only some of which are available to aquatic life. This is especially true in the case of the contaminants associated with dredged sediments because in general, particulate contaminants are not available to aquatic life. Therefore, relatively high concentrations of some particulate-associated

contaminants in dredged sediment may be present in the water-column without adverse effects on the aquatic life or other beneficial uses of the water.

As discussed by Jones and Lee (1978), Jones et al. (1979), and Lee et al. (1981a), the worst case, chronic exposure assumption used by the US EPA and many states causes US EPA criteria and state water quality standards to have little direct applicability to most dredged sediment disposal operations. In general, depending on the kind of organism, these criteria and standards are based on as much as a year or more exposure of the organism to the contaminant in a 100% available form. At the Galveston disposal site, the maximum exposure that an organism could obtain to contaminants released to the watercolumn during open water disposal would be in the order of a few minutes to an hour. Since aquatic organisms can be exposed to relatively high levels of contaminants for short periods of time without adverse impact, it is almost impossible for aquatic organisms to receive a sufficient exposure to contaminants released to the watercolumn during open water disposal of dredged sediment to be harmed by such disposal practices. For further discussion of these topics, consult Jones and Lee (1978).

It is important to emphasize that the Galveston, Texas studies as reported herein, as well as reported by Lee et al. (1978), all show that the elutriate test is a reliable tool to predict the direction and approximate amount of contaminants that would be released by open water disposal of

hydraulically dredged sediments. This test procedure should be used to detect potentially adverse situations. While, as noted above, it will be rare that such adverse situations occur, it is possible, especially when dredging takes place near certain types of industrial waste discharges and disposal is in areas with limited mixing-dilution, that an adverse situation could be encountered. If an elutriate test shows the release of contaminants to levels above the US EPA criteria or state water quality standards, then a hazard assessment evaluation should be performed of the type described by Lee and Jones (1981a) and Lee et al. (1981) to determine whether the apparently "excessive" contaminants represent a hazard to the beneficial use of the receiving waters. Factors such as duration of exposure, concentrations of available forms of contaminants, rate and extent of dilution, etc., must all be considered in determining whether release of contaminants during an elutriate test represents a potential hazard to aquatic life or other beneficial uses of the waters at the dredged sediment disposal site.

The studies reported in this paper are primarily directed toward watercolumn impacts arising during the release of contaminants during open water disposal operations. In addition to the concern about this situation, consideration must be given to the potential impact of the contaminants associated with the dredged sediments at the dredged material disposal site on benthic and epibenthic organisms that have colonized the disposal area sediments. This study, as well



as others, has shown that while there is some toxicity to laboratory test organisms associated with some dredged sediments, it is small compared to the toxicity that would occur if appreciable parts of the contaminants present in the sediments were available to the organisms. As discussed by Jones and Lee (1978), the benthic organism bioassay testing of dredged sediments is a tool that can signal potential problems. It is not an indicator of real problems that will occur upon open water disposal of dredged sediment. There is a wide variety of factors that influence the translation of laboratory-based toxicity tests to field conditions. The overall approaches that should be used to evaluate, on a site-specific basis, the significance that a certain level of toxicity found in dredged sediment bioassays in particular, and bioassays in general under laboratory conditions represents to the aquatic life and other beneficial uses at a dredged material disposal site, are discussed by Jones and Lee (1978) and Lee and Jones (1981b).

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