EFFECTS OF OPEN-WATER DISPOSAL OF DREDGED MATERIAL ON BOTTOM TOPOGRAPHY ALONG TEXAS GULF COAST

by

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Analysis of hydrographic surveys of hopper dredge disposal areas in the Gulf of Mexico off the coast of Texas indicated that dumping at these sites had little effect on bottom topography. Apparently there are no definitive, discrete mounds of dredged material formed as a result of open-water disposal.
PREFACE

The study reported herein was the outgrowth of interpretations of data collected during a special survey of selected Corps of Engineers coastal dredged material disposal sites conducted and managed by the Environmental Effects Laboratory (EEL), U. S. Army Engineer Waterways Experiment Station (WES), as part of the Corps of Engineers' Dredged Material Research Program (DMRP).

The hydrographic surveys and dredging described herein were conducted from 1962 to 1973 by the U. S. Army Engineer District, Galveston. Mr. V. C. Keesecker, Galveston District, provided the information from the surveys. Data were analyzed by Messrs. R. E. Black, J. E. Lee, G. W. Hughes, and D. F. Bastian, WES, under the supervision of Mr. Bastian. Mr. Bastian prepared this report under the supervision of Dr. J. W. Keeley, Project Manager of the Aquatic Disposal Research Project, DMRP, EEL.

Director of WES during the preparation and publication of this report was COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.
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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
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<td>0.764555</td>
<td>cubic meters</td>
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<tr>
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</tr>
<tr>
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<td>meters</td>
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<td>inches</td>
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EFFECTS OF OPEN-WATER DISPOSAL OF DREDGED MATERIAL
ON BOTTOM TOPOGRAPHY ALONG TEXAS GULF COAST

PART I: INTRODUCTION

Background

1. Interest in the effects on ocean-bottom topography of open-water dredged material disposal has resulted in extensive research. Of basic concern is what happens to the dredged material once it is dumped from the hopper dredges into the open water. Pertinent records are sparse. Because geometry, hydraulic forces, meteorological conditions, and dredging requirements vary according to disposal site and time, any changes in bottom site topography are highly variable.

Purpose of Study

2. The purpose of the study reported herein was to analyse site survey data to yield information on the stability and growth rate of hopper dredge disposal areas along the Texas coast. Attention was focused on (a) the net change in bottom topography after a single disposal season and after several disposal seasons and (b) whether or not a definitive disposal mound was produced.

Study Method

3. Since the 1960's, the U. S. Army Engineer District, Galveston, has made hydrographic surveys of most of their hopper dredge disposal areas primarily to insure sufficient draft for the hopper dredges. Generally, the surveys were made prior to dredging operations and were in conjunction with surveys made to determine the condition of navigation channels. Fathometers were used and readings were corrected for tides. The disposal areas discussed herein are at Brazos Island, Port Mansfield, Matagorda, Freeport, and Port Aransas (Figure 1) on the Texas Gulf Coast, within the Galveston District.
4. Since the disposal areas along the Texas coast were of particular interest, contours of the five areas mentioned above were made at WES from survey data furnished by the Galveston District. Because the Galveston District usually marked only the shore-side and channel-side boundaries of the disposal areas, the other two sides had to be selected to obtain a basis of comparison between surveys. The selection was an arbitrary one, determined by the extent of the hydrographic survey. An effort was made to establish a comparable disposal area that was as large as possible. Occasionally this required extrapolation of contours.

5. Comparisons were made of changes of the average elevation of the disposal area with time. These comparisons are more significant when "before" and "after" dredge surveys are compared rather than when "after" and "after" surveys are compared (which is the most common case) because of the time intervals involved.* One difficulty in working with

* Normally hydrographic surveys were conducted soon after dredging was completed to insure adequate channel depth as required by contract. These surveys are referred to as "after" surveys by the Galveston District. On occasion, hydrographic surveys were conducted just prior to the initiation of dredging. These surveys are referred to as "before" surveys.
this method of comparison was that there were no records of the hopper dredge route as it dumped the dredged material. Therefore, the possibility exists that some portion of the material was dumped in an area outside of the boundaries shown in this study, due to the limited size of the areas contoured and the distance of travel required by the hopper dredge to empty its bins.

6. The survey was made by soundings taken from a boat operating in zigzag patterns perpendicular to the channel. In the few cases where an additional sounding-survey path was run in a zigzag pattern normal to the previously mentioned survey pattern the intersecting soundings were found to vary as much as 2 ft.* These additional survey patterns were not used.

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.
PART II: DISPOSAL OPERATIONS AND SEDIMENT TRANSPORT

Determination of Required Dumping Distances

7. The two hopper dredges operating regularly in the Galveston District are the MacKENZIE and the McFARLAND. On occasion, the LANGFITT has also been operated in the District. Facts about these dredges pertinent to this report are tabulated below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated Speed fps</th>
<th>Hopper Capacity cu yd</th>
<th>Draft Loaded ft</th>
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<tbody>
<tr>
<td>LANGFITT</td>
<td>17.6</td>
<td>23.2</td>
<td>--</td>
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<tr>
<td>MacKENZIE</td>
<td>17.6</td>
<td>19.5</td>
<td>1656</td>
</tr>
<tr>
<td>McFARLAND</td>
<td>20.4</td>
<td>22.2</td>
<td>3140</td>
</tr>
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</table>

8. The dredges operate up and down the channel. When the bins are full or when the dredge has obtained an optimum load, the dredge is taken to the disposal area, the bottom doors of the hopper bins are opened, and the dredged material falls from the bins while the speed of the dredge as it moves through the disposal area remains the same (i.e., the material is expelled from the hopper while the dredge is moving). Whether or not, or how much of, the material is dumped while the dredge is over the disposal area is unknown.

9. The path that a dredge takes while dumping is not recorded, but records are available from which the average length of the dumping path can be determined.

10. Data from a collection of charts entitled "Report of Operations - Hopper Dredges" allowed for various calculations which are presented herein as Table 1. Assuming that the maximum speed attained by the dredge during dumping is equal to or less than the average speed calculated for the dredge traveling to and from the dump (based on personal correspondence and observation), the maximum distance that the dredge would travel while dumping can be expressed as

\[ D_{\text{max}} = \bar{V} \times \frac{T_d}{\bar{V}} \]  

(1)
where

\[ D_{\text{max}} = \text{maximum distance dredge travels while dumping, miles} \]
\[ \bar{V} = \text{average velocity of dredge to and from dump site, mph} \]
\[ \bar{T}_d = \text{average time dumping per load hauled, hr} \]

11. This calculation for each project gives an idea of the size of disposal area needed to correspond to the operation of the hopper dredge. From Table 1 the average maximum distance the dredge would travel while dumping is 2.2 miles at Brazos, 1.4 miles at Port Mansfield, 1.9 miles at Matagorda, 1.9 miles at Corpus Christi, and 2.2 miles at Freeport. However, this tells nothing about the path of the dredge.

**Fate of Disposed Dredged Material**

12. In attempting to determine the fate of the dredged material once it is dumped from the dredge, there are two basic considerations. First, when and where does the material reach the sea bed. Second, once at the bed, how long and what percentage of the material reaching the bottom will remain in place.

**Initial release**

13. Corps of Engineers records for dredging at the study areas in the Galveston District excluding Freeport show that over 80 percent of all the material handled by hopper dredges is sand (see Table 2). Upon release from the bin, this sand drops in bulk with an imparted horizontal velocity equal to that of the hopper dredge. How far the sand has to fall from the hopper dredge and through what currents are important factors relating to the initial lateral transport of the sand.

14. Due to turbulence and shear stresses, the sand falls in a combination of three forms: solid bulk, slurry, and particulate. As the sand falls, the bulk material moves fastest with the surrounding slurry moving as a distinct density current. Eddies are formed and particulate matter is sheared from the slurry. Particles fall the slowest. The fall velocity \( W \) of various sizes and shapes of sand
particles is well documented. In the present situation, according to Graf,\(^1\) this is complicated since

If more than a single sphere moves through an unbound fluid system, a mutual interaction will be noticed. It has been observed that the settling velocity increases if only a few closely spaced particles move, and that the fall velocity is reduced (i.e. the drag increased), if many particles are dispersed throughout the fluid.

15. By making the gross assumption that given no ocean current, the particulate matter would observe its empirically determined fall velocity. From sieve analysis of samples taken aboard hopper dredges while dredging, the extreme low value for 20 percent finer by weight \(d_{20}\) and the extreme high value for the 80 percent finer by weight \(d_{80}\) for all study areas except Freeport are \(2.35 \times 10^{-3}\) in. and \(1.56 \times 10^{-1}\) in., respectively. The following tabulation presents the fall velocities and the expected time for these particles to reach the ocean floor, assuming that the hopper dredge has a draft of 21 ft and the water depth is 36 ft.

<table>
<thead>
<tr>
<th>(d_{20})</th>
<th>(d_{80})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size, in.</td>
<td>(2.35 \times 10^{-3})</td>
</tr>
<tr>
<td>Fall velocity (W), fps</td>
<td>0.008</td>
</tr>
<tr>
<td>Time of fall, sec</td>
<td>1888</td>
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</table>

The larger sand grains would reach the bottom in about 1 min, whereas the smaller sand would take up to 30 min.

16. Both the speed of the dredge and the velocity of the ocean currents impart a horizontal component to the falling sand, which prescribes a nonvertical path. Still ignoring turbulence, without knowing the vertical velocity distributions, prediction of the final target is difficult to pinpoint.

17. The final problem in predicting when and where the sand will fall is turbulence. Turbulence counterbalances the settling tendency of the particles. Depending upon the turbulence, the sand can remain suspended and be transported great distances.
18. In summary, the material released from the dredge falls in a combination of three forms: particulate, slurry, and bulk. The larger particles and that material falling in bulk and slurry can be expected to hit the bottom within a few minutes.

Suspension due to impact

19. As the sand hits the sea bed, turbulence and rebound occur. Some of the material is undoubtedly resuspended. Depending upon the concentration of the suspensions and local currents, this suspended material can be transported away from the disposal area.

Erosion of dredged material banks

20. The erosion of material from a dredged material bank is dependent upon the type and degree of compaction of the material, bed form, water viscosity, and magnitude of local currents. As the sand size under consideration (for all sites except Freeport) is greater than $7.48 \times 10^{-3}$ in., the effects of special properties of shape, packing, and cohesiveness are negligible. Thus, there is no armoring effect (Reference 3, p 152) as is observed with silts and clays. However, research has been able to show that in some situations benthos can stabilize the dredged material mound surface.

21. By neglecting the stabilizing effect of benthos, the erosion of the sand can be studied from strictly a fluid velocity standpoint. Simply stated, critical shear velocity is required to move bottom particles. Sediment motion is of two forms: bed load and suspended load.

22. To help evaluate what effect known currents will have upon the stability of the mound of dredged material it is necessary to know the size of particles, water viscosity, and bottom currents. With this information various competency curves (i.e. Shields Diagram) exist which can be used to determine if the material will be transported and in what form. By knowing the duration of current equal to or greater than the critical shear velocity, the amount of time the material will move can be predicted. But this tells nothing about the volume of material which would be transported; this requires the use of equations of motion and continuity for both water and sand. Unless the bank is large enough to change the local current patterns, material will be eroded
not only from the bank but also from the surrounding area. If the bank is composed of sands different from those of the surrounding area, then the bank will be subject to a different rate of attack. Some of the bank material will move and will be replaced simultaneously to some degree.

23. According to Morris and Wiggert, ordinary wave activity can move sand to depths of about 30 ft below the water surface. Since most of the disposal areas under consideration are in greater depths, ordinary wave activity should have little effect on the disposal area. Studies by Smith and Hopkins (Reference 3, p 172) and by Sternberg and McManus show that storm-generated currents have a pronounced effect on sediment movement even in depths greater than 200 ft. A logical conclusion is that storms in the Gulf of Mexico generate enough energy to produce pronounced effects on the bottom topography. The critical erosion velocity measured about 3 ft above the bed for sand ranging from $2.76 \times 10^{-3}$ to $1.57 \times 10^{-2}$ in. is about 1.5 fps with the cessation of movement velocity being even less.

Littoral drift

24. Littoral drift is the major classification of nearshore sediment movement. Disposed dredged material can be part of the littoral drift process, depending on location. If not directly, then it can be influenced by its proximity to the jetties and channel which interrupt the littoral process and result in topographical changes. Brunn and Lackey have concluded that up to about 400,000 to 500,000 cu yd a year pass a given point on part of the Texas shore.
PART III: SURVEYS OF DISPOSAL AREAS

Freeport

25. Hopper dredges operating at Freeport use the two disposal areas (A and B) shown in Figure 2. These areas are along both sides of the entrance channel and reach from sta -20+00 to sta -110+00. They parallel the channel 500 ft from the channel sides. There is no defined outside border (away from the channel). The northern disposal area, A, is used when the current is from south to north and the southern disposal area, B, is used when the current is from north to south.

26. The exterior boundary for both areas A and B was chosen such that the area of each measures 1,135,000 sq yd.* The results of only three surveys (Plate 1, Overlays 1 and 2)** were available; these surveys cover the period 1964-1966.† Between the first and third surveys, a total of 1,771,889 cu yd of dredged material was dumped. Despite this dumping, the average elevation of both disposal areas decreased about 0.5 ft. Table 3 presents the dates of the surveys and the corresponding disposal area bottom elevations, as well as the dates of dredging and the corresponding volume of material dumped.

27. The areas chosen for study are 5000 ft long and lie parallel to the channel. From records for 1968-1972 (see Table 1), the average length of travel required by the hopper dredge to empty its bins was calculated to be about 1.1 miles, which corresponds well with the modified length of the disposal area.

28. It is obvious that the disposal areas do not reflect the amounts of dredged material being dumped but instead show a tendency for the disposal areas to be scoured.

29. Two possible reasons for the lack of buildup are (a) the

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* The study areas had to be shortened to sta -70+000 because of the data available from the surveys.
** Transparent overlays for the disposal area maps are in the pocket on the inside back cover of this report.
† The disposal area contour maps were developed using Galveston District hopper dredge survey maps. The contouring was done at WES.
dredged material was 80 percent silt according to Galveston District maps and (b) there was a long time period between dredging and surveys. Once dumped from the bins, any material that remained particulate would stay in suspension for relatively long periods. This material could easily come to rest outside the disposal area. The material that reached the disposal area is erodible, and the rate of erosion is related to the cohesion, compaction, and water content of the disposed material. The second reason for lack of build up may be attributed to the 6-month to 1-yr lapse of time between dredging and subsequent surveys, during which time equilibrium of the bottom topography in the disposal area was probably achieved. However, neither reason explains the net deepening of the disposal area.

**Port Aransas-Corpus Christi**

30. At Port Aransas, hopper dredging is done in the jetty and outer bar channel. The dredged material is dumped in the designated disposal area bounded between sta 80+00 and sta 145+00 and 800 ft south of the south side of the outer bar channel (Figure 3). The area of analysis coincides with the District's boundaries set above. The width of the disposal area was chosen to be 1500 ft.

31. Data in Table 3 indicate a definite accretion trend in the area of study. From 1961 to 1973 the disposal area bottom elevation rose about 5 ft. Contoured areas can be compared by study of Plate 2 and Overlays 3-10.

**Brazos Island Harbor**

32. Hopper dredges at Brazos Island Harbor utilize a dump area north of the sea bar channel (Figure 4). The District has defined the southern channel and western shore boundaries of the disposal area. The southern boundary remained constant at 800 ft from the center line of the channel; the western boundary was extended seaward from sta -10+200 to sta -13+000 in 1966 to sta -15+00 in 1967.
Figure 3. Fort Aransas-Corpus Christi waterway hopper dredge disposal area
Figure 4. Brazos Island Harbor hopper dredge disposal area.
33. Because the western (shoreside) boundary was moved seaward twice during the period of study and because of the extent of soundings, two areas were defined for comparative study. The first area chosen (covering dredging from 1964 to 1967), designated Brazos I, was applied to Plate 3 and Overlays 11-15 because the disposal area was shifted as shown by Plate 4 and Overlays 16-18. This area is 5000 ft long starting at sta -10+200, and is 2000 ft wide. Table 3 presents the dates of surveys and the corresponding disposal area bottom elevations and the dates of dredging and the corresponding volume of material dumped. This area remained relatively stable during the period of study and showed no positive trend toward buildup of the disposal area.

34. The second area chosen, designated Brazos II (Plate 4, Overlays 16-18), covers the period of dredging from 1968 to 1970. Brazos II disposal area starts at sta -15+000 and extends 3200 ft seaward and is 2000 ft wide. Average hopper dredge dumping distances for the period 1969-1972 were calculated and found to be 1.2 miles, which is about twice the length of the chosen study area. Table 3 presents the dates of the survey and the corresponding disposal area bottom elevations and the dates of dredging and the corresponding volume of material dumped. The fathometer survey of 5 June 1968 yielded an average bottom elevation of -54.7 ft from 14-30 June; 228,103 cu yd of dredged material were dumped, but the 2 July fathometer survey shows an average bottom elevation of -55.4 ft. If the results of these surveys are correct, there was a net scour of 166,000 cu yd during this 18-day period. Subsequent surveys show a buildup trend.

Matagorda Ship Channel

35. The hopper dredge operating at Matagorda utilizes a disposal area south of the entrance channel as shown in Figure 5. This area is bounded on three sides, 1000 ft south of the south side of the channel and by sta -11+000 and sta -17+000. Since 1963, the disposal area shoreside limit has moved seaward from sta -8+000 because of shoaling off the ends of the jetties. During the 1960's, the project area was
Figure 5. Matagorda Ship Channel hopper dredge disposal area
going through a period of adjustment because of the cut made through the Matagorda Peninsula for the Matagorda Ship Channel. Whether or not it has stabilized is not known. The comparative study area is 6000 ft by 1000 ft as shown in Plate 5 and Overlays 19-26 and Plate 6 and Overlays 27-33. This agrees with the average computed required dumping distance of 1.2 miles.

36. The study area has had a buildup of about 7 ft between 1963 and 1971 as shown in Table 3. (Unexplainable is the survey of March 1968 immediately after disposal, which shows a net scour; a survey three months later, during which time there was no dredging, shows an accretion.)

Port Mansfield

37. At Port Mansfield the hopper dredge used two disposal areas until 1967, after which a single disposal area was used (see Figure 6). As defined by the District, these areas are on either side of the entrance channel, 825 ft from its center line; they start at sta 3+200 and there is no seaward limit. Only five surveys were available (Plate 7 and Overlays 34-37). Of these, only two show the south disposal area. For purposes of the study a common area of comparison was defined in the north disposal area shown in Figure 6. This area is 2000 by 1500 ft.

The average required dumping distance calculated from available records shown in Table 1 indicates that the chosen study area is too small. However, because of the limited extent of some of the surveys, the small size of area was necessary for comparison. The study area remained stable over the period of record from 1965 to 1970 with an average bottom elevation of -30 ft.
Figure 5. Port Mansfield Channel hopper dredge disposal areas
38. Three of the six navigation project hopper dredge disposal areas studied showed accretion, two were stable, and one showed a slight scour tendency. The Matagorda area showed the greatest change with about a 7-ft bottom elevation rise during a 9-yr period. The rise is attributed not only to dredge disposal but to adjustment of the area to the cut through Matagorda Peninsula. Because the studies focused only on the disposal areas nothing can be said about the surrounding areas. In all probability the surrounding areas experienced the same net change in bottom elevation. It appears that net changes in the bottom elevations are strongly related to the dynamics of the area involved. In addition, disposal areas are not physically marked resulting in a low probability of coinciding repetitive dumping paths of the hopper dredges. Because the dredging process takes such a long time, hydrodynamic forces tend to smooth out each individual disposal. In terms of significance, dumping has had little effect on bottom topography for the sites surveyed. There does not appear to be definitive disposal banks of dredged material.
REFERENCES


## Determination of Required Hypor Dredge Dumping Distances

<table>
<thead>
<tr>
<th>Dredge</th>
<th>Date of Operation</th>
<th>No. of Loads</th>
<th>Average Distance (miles)</th>
<th>Time to Dump (hr)</th>
<th>Total Distance (miles)</th>
<th>Average Speed (mph)</th>
<th>DUMPING Distance (miles)</th>
<th>Time Per Dump (hr)</th>
<th>Average Load (cu yd)</th>
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</thead>
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<td>A. MacKENZIE</td>
<td>Oct-Nov 68</td>
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<td>1.0</td>
<td>155</td>
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<td><strong>Port Aransas-Corpus Christi</strong></td>
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Grain-Size Distribution of Dredged Material

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Survey and Dredging Data

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**Port Mansfield**

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(Sheet 3 of 3)
CENTER LINE OF CHANNEL

NOTE: DASHED LINES INDICATE THAT CONTOURS WERE ESTIMATED.

CONTOURED DISPOSAL AREAS
FREEPORT HARBOR
JAN 1964

SCALE

1000 0 1000 2000 FT

PLATE 1
PLATE 2

NOTE: DASHED LINES INDICATE THAT CONTOURS WERE ESTIMATED.

PORT ARANSAS CORPUS CHRISTI
AUG 1961

SALINE 80 + 00

STA 145 + 00

CENTER LINE OF CHANNEL
CONToured DISPOSAL AREAS
MATAGORDA SHIP CHANNEL
MAR 1963

NOTE: DASHED LINES INDICATE THAT CONTOURS WERE ESTIMATED.

CENTER LINE OF CHANNEL

ST A-17+000

SCALE
500
0
500 1000 FT

PLATE 5
NOTE: DASHED LINES INDICATE THAT CONTOURS WERE ESTIMATED

CENTER LINE OF CHANNEL

UNITED STATES COAST GUARD
PORT MANSFIELD
OCT 1965

SCALE

500 0 500 1000 FT

PLATE 7

CCOUNTURED DISPOSAL AREAS
In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Bastian, David Fenwick
Effects of open-water disposal of dredged material on bottom topography along Texas Gulf Coast, by David F. Bastian. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1974.
1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper D-74-13)
Prepared for Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.
Includes bibliography.

1. Disposal areas. 2. Dredged material. 3. Dredge spoil. 4. Hydrographic surveys. 5. Ocean bottom. 6. Spoil disposal. 7. Submarine topography. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper D-74-13)
TA7.W34m no.D-74-13
CONTOURED DISPOSAL AREAS
FREEPORT HARBOR
OCT 1965

SCALE

OVERLAY 1
CONTOURED DISPOSAL AREAS
FREEPORT HARBOR
JUL 1966

SCALE
1000 0 1000 2000 FT

OVERLAY 2
CONTOURED DISPOSAL AREAS
BRAZOS I
MAY 1967

SCALE

500 0 500 1000 FT
CONTOURED DISPOSAL AREAS
MATAGORDA SHIP CHANNEL
FEB 1966
SCALE
500 0 500 1000 FT
CONTOURED DISPOSAL AREAS
MATAGORDA SHIP CHANNEL
OCT 1967
SCALE
500 0 500 1000 FT
CONTOURED DISPOSAL AREAS
MATAGORDA SHIP CHANNEL
AUG 1970
SCALE
500 0 500 1000 FT
STA - 1 + 000
26 22
24 30 32
STA - 11 + 000
OVERLAY 31
CONTOURED DISPOSAL AREAS
PORT MANSFIELD
APR 1969
SCALE
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