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EVALUATION OF LOADING AND DREDGED MATERIAL OVERFLOW FROM MECHANICALLY FILLED HOPPER BARGES IN MOBILE BAY, ALABAMA

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by

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Authorizing legislation for the deepening of navigation channels in Mobile Bay specifies that the new work dredged material and material from future maintenance dredging must be placed in an approved open-water disposal site in the Gulf of Mexico. Large mechanical dredges with clamshell buckets are being used for the new-work dredging. Hopper barges are loaded with the dredged material and transported by tug to the disposal site. Mechanical dredging is also the most likely technique for future maintenance. The economic loading of the hopper barges and the potential environmental impact associated with barge overflow during loading are important issues. A field study was therefore conducted to give site-specific information on the loading gains achieved by overflow and the characteristics of the overflow for conditions in Mobile Bay. (Continued)					
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The field study included data collection on dredge-operating characteristics, sampling and testing of material comprising the barge overflow, and monitoring the loading characteristics of the barges. The dredge CHICAGO (equipped with a 30-yd³ clamshell bucket) and 6,000-yd³ hopper barges were used during the study. Loads gained during three overflow tests were 4.1, 1.2, and 11.5 percent for overflow periods of 60, 24, and 65 minutes. For all three tests, the overflow ended with a significant amount of diluted slurry ponded in the barges, indicating that additional load gains would be possible with prolonged periods of overflow.

The solids concentrations of bucket material samples averaged 1,080 g/L, while that of the overflow was essentially constant for the entire period of overflow and averaged 80 g/L. The results indicate that retention of solids in the hopper barges occurs during the overflow process for mechanical dredging. The grain size analysis of overflow samples showed a larger fraction of finer material than that for bucket samples, with average grain sizes of 0.012 mm for overflow and 0.12 mm for bucket material, indicating that sorting of grain sizes occurs in the hopper barges during barge overflow using mechanical dredging techniques.

PREFACE

This report describes an evaluation of hopper barge loading and overflow characteristics for mechanical dredging conducted in Mobile Bay. This work was conducted by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES). Funding for WES was provided by the US Army Engineer District, Mobile, under Intra-Army Order for Reimbursable Services Nos. FC-89-0024, dated 14 Nov 88 and FC-90-0011, dated 27 November 1989. The Mobile District Project Manager for the study was Mr. Dewayne Imsand.

This study was conducted and the report was written by Dr. Michael R. Palermo, Research Projects Group, Environmental Engineering Division (EED), EL; and Mr. Paul A. Zappi, Water Resources Engineering Group, EED. The characterization of overflow samples was performed by the WES Geotechnical Laboratory. Technical review of this report was provided by Mr. Imsand, Mr. Donald Hayes, WREG, and Mr. Allen Teeter, Estuaries Division, WES Hydraulics Laboratory.

This study was conducted under the direct supervision of Dr. Raymond L. Montgomery, Chief, EED; and under the general supervision of Dr. John Harrison, Chief, EL.

COL Larry B. Fulton, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was the Technical Director.

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CONTENTS

PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC)	
UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Background	4
Purpose and Scope	4
Typical Clamshell Dredging and Barge Overflow Operations	6
PART II: DREDGING EQUIPMENT AND HOPPER	
BARGE-LOADING OPERATIONS	7
Dredging Equipment and Operations	7
Barge-Loading Characteristics	7
PART III: DREDGED MATERIAL AND OVERFLOW CHARACTERISTICS	10
Characteristics of In Situ Sediments	10
Characteristics of Material in Loaded Barges	10
Overflow Characteristics	12
PART IV: CONCLUSIONS AND RECOMMENDATIONS	14
REFERENCES	15
TABLES 1-2	

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
tons (2,000 lb, mass)	907.1847	kilograms

EVALUATION OF LOADING AND DREDGED MATERIAL OVERFLOW FROM MECHANICALLY FILLED HOPPER BARGES IN MOBILE BAY, ALABAMA

PART I: INTRODUCTION

Background

1. The US Army Engineer District, Mobile is dredging to deepen a 39-mile*-long navigation channel for Mobile Harbor. The channel extends from the Gulf of Mexico through Mobile Bay to the Port of Mobile (Figure 1). The bay section of the channel is being deepened to an authorized depth of 45 ft. The sediments to be dredged are primarily soft marine clays with some lenses of sand (US Army Engineer District, Mobile 1985).
2. Under legislative mandate, all dredged material from the deepening and from future maintenance dredging must be placed at an approved open-water disposal site in the Gulf. The dredging is being conducted using a large clamshell dredge to mechanically load hopper barges, which are then transported to the disposal site. This deepening is the first major use of mechanical clamshell equipment in Mobile Bay.
3. Loading past the point of overflow is commonly practiced to increase the load of hopper barges. However, resource agencies have objected to overflow of the barges during filling for the Mobile Bay work because of concerns regarding potential environmental effects. These concerns pertain to both the sediment suspended in the water column and the sediment deposited on the bottom resulting from the overflow. Such environmental concerns must be balanced against the potential for economic savings realized by overflow.
4. A comprehensive assessment of overflow and associated environmental effects for hydraulically loaded hopper barges has been completed (US Army Engineer Waterways Experiment Station, in preparation). The Mobile District subsequently requested that a follow-up evaluation for mechanically filled hopper barges be conducted.

Purpose and Scope

5. The purpose of this report is to document results of a study on clamshell dredging and hopper barge overflow for conditions in Mobile Bay. The purposes of the study were as follows:
 - a. Determine the loading gains in hopper barges due to overflow for mechanical dredging.
 - b. Determine the physical characteristics of the hopper barge overflow to include suspended solids concentrations and grain size distribution. This information could then be used to assess the potential environmental effect.
6. The study included data collection on dredge operating characteristics; sampling and testing of material in the loaded barges; sampling and testing of material comprising the barge overflow; and monitoring the loading characteristics of the barges.

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

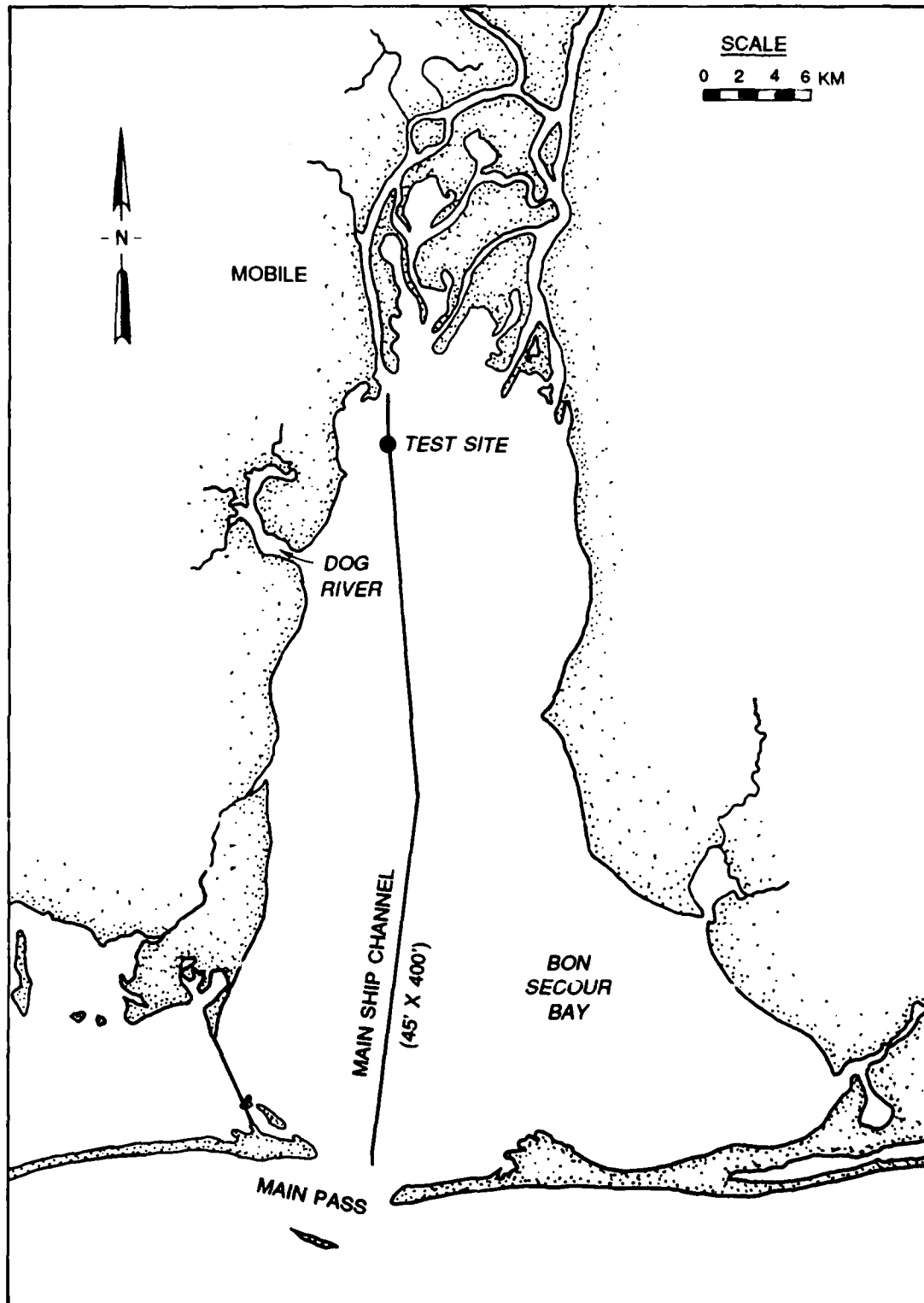


Figure 1. Location of navigation channels and location of test site in Mobile Bay (US Army Engineer Waterways Experiment Station, in preparation)

Typical Clamshell Dredging and Barge Overflow Operations

Clamshell dredging

7. Clamshell dredges are commonly used for operations in which the dredged material must be transported in barges to distant disposal areas. The material is removed by mechanical excavation with the clamshell bucket. The crane handling the bucket is mounted on a barge, which can be positioned using anchors or spuds. The material is placed directly into barges for transport. Twenty to thirty cycles or buckets per hour is typical, but production can vary considerably with characteristics of the material and digging depth. Some buckets may be heaped with excavated material, while others may be partially filled with excavated material and water trapped within the excavated material.

Barge overflow

8. Dredge barges or scows are normally used to transport material excavated with mechanical dredges. The barges are normally equipped for bottom dumping at the disposal site by use of a split-hull design or by bottom doors. Since the material is mechanically excavated from the channel bottom and placed in the scows, there is generally less entrainment of water during the dredging cycle as compared with hydraulic dredging. Scows are usually partially filled with residual water at the beginning of the filling cycle; therefore, the residual water is displaced as the scow is filled. If filling is continued past the point at which the scow is full, the overflow is discharged over the sides (sometimes called the coaming) of the scow. The overflow consists of a mixture of residual water, entrained water, and solids. Depending on the nature of the material dredged, the solids can be "stacked" in the scow above the level of overflow (Palermo and Randall 1989).

9. Only limited technical information is available on the load gains due to overflow or the characteristics of the overflow for mechanically filled barges. Tavolaro (1984) characterized barge overflow as a part of a more comprehensive sediment budget study for clamshell dredging and disposal activities. The volume and solids concentration of the overflow was measured for scows of varying size. A large variability in volume, water column solids concentration, and time of overflow was observed. Factors influencing the character of the overflow were intensity of dredging, degree of water entrainment during excavation, length of time of overflow, and the care with which material is placed in the scow. The water column suspended solids level due to overflow was found to be approximately equal to that resulting from the clamshell dredging operation. Tavolaro drew no conclusions relating to the load gain achieved in the scows by overflowing.

10. Palermo, Homziak, and Teeter (1990) described the results of a field study of overflow for mechanically filled barges for maintenance dredging conducted on the Cape Fear River at Sunny Point, North Carolina. The maintenance sediments dredged were fine-grained clays with traces of sand. Loading characteristics of the barges for both overflow and non-overflow conditions and potential gain in load due to overflow were determined for three barges. Load gains of up to 6.9 percent were realized during a limited period of overflow of approximately 15 min, and there was potential for additional load gains. The suspended solids concentration of the overflow increased with time of overflow. The grain size distribution of material retained in the barges and of the overflow indicated that a sorting process occurs in the barges during overflow, due to the winnowing of finer particles from the bucket material by drainage from the bucket and by agitation within the barge during material placement. This leads to the suspension of finer material in the slurry which comprises the overflow.

PART II: DREDGING OPERATIONS AND BARGE-LOADING CHARACTERISTICS

Dredging Equipment and Operations

11. During August 1989, Great Lakes Dredge and Dock Company was conducting dredging for the Mobile channel deepening using the mechanical dredge CHICAGO. The CHICAGO was recently constructed and is the largest mechanical dredge in the world. The plant is 232 ft long by 80 ft wide and weighs 6,000 tons. The dredge normally employs a 50-yd³ bucket, and construction of a 100-yd³ bucket is planned. The CHICAGO was equipped with a 30-yd³ bucket during this field study. A photograph of the dredge with 30-yd³ bucket is shown in Figure 2.

12. Two 6,000-yd³ split hull hopper barges were used for transport of dredged material to the disposal site during this field study. The depth of the barges at the center line is 26.5 ft from the top of the coaming. A photograph of one of the hopper barges is shown in Figure 3. All dredging for the channel-deepening contract was performed without overflow, except for the tests during the field study period.



Figure 3. A 6,000-yd³ hopper barge

using the 30-yd³ bucket. The cycle time during the period of overflow monitoring was approximately 35 buckets per hour and was consistent for each of the three tests. The location of the area dredged during the field study is indicated in Figure 1.

Barge-Loading Characteristics

Measurement technique

14. The barge load gain resulting from overflow was determined from measurements of the barge draft. Lead lines were used to measure the distance from the barge deck to the water level at opposite corners of the barge, and the average was used to determine draft. A relationship of load versus draft for the closed-hull position in salt water, shown in Figure 4, was furnished by the dredging contractor. This relationship was used to determine the weight of the load in tons

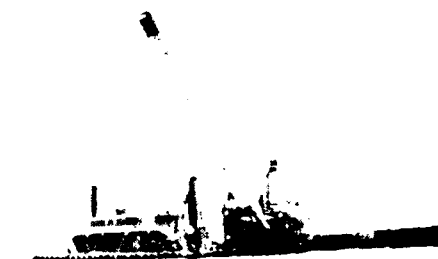


Figure 2. Mechanical dredge

13. Field monitoring of dredging operations with overflow was conducted during a 2-day period (2 August to 3 August 1989). During this 2-day period, the dredge was excavating material between average depths of 44 and 47 ft, and advanced from channel station 228+00 to 235+50, an approximate distance of 750 ft. The volumes dredged during these 2 days were 13,200 and 10,300 yd³ respectively. Three barges were filled past overflow during this period for purposes of monitoring and sampling, and are referred to herein as Tests 1, 2, and 3. The CHICAGO filled these barges to the point of overflow in approximately 7 hours

corresponding to observed draft. Drafts were observed and recorded during the barge-filling period, immediately prior to overflow and following completion of overflow.

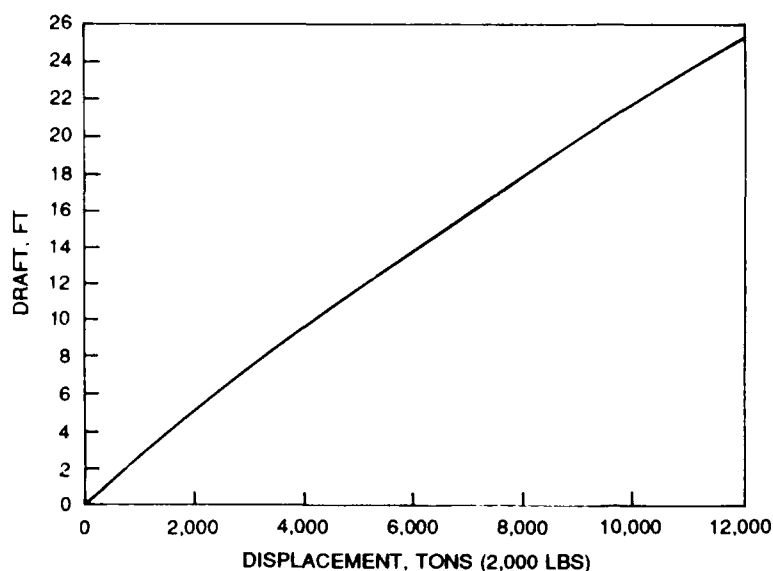


Figure 4. Relationship of load and draft for 6,000-yd³ hopper barge

Results based on draft measurements

15. The barge draft, load, and percent change in load following overflow for these tests are summarized in Table 1. The start of overflow was considered as the point at which material first began to spill over the barge coaming. The overflow period was ended either when the barge operator perceived an economic load or when an empty barge returned from the disposal site.

16. The period of overflow was 60, 24, and 65 min for Tests 1, 2, and 3, respectively. The average increase in draft over the testing period for each test is provided in Figures 5, 6, and 7. Based on these draft readings, the additional load gained during the overflow period was 350, 100, and 900 tons, representing a load gain of 4.1, 1.2, and 11.5 percent, respectively, over the load at the beginning of overflow. The observed differences in load gain for comparable overflow periods are likely due to differences in the densities of the material dredged.

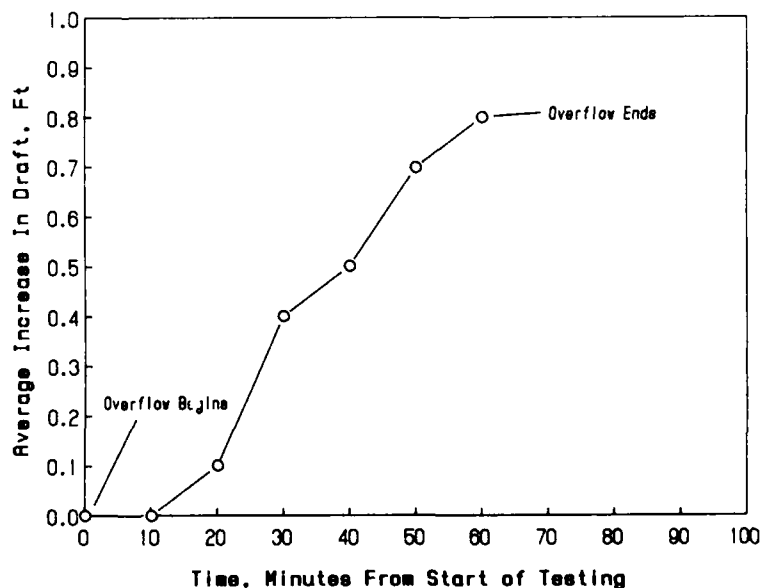


Figure 5. Load (displacement) versus time for Test 1

Figure 6. Load (displacement) versus time for Test 2

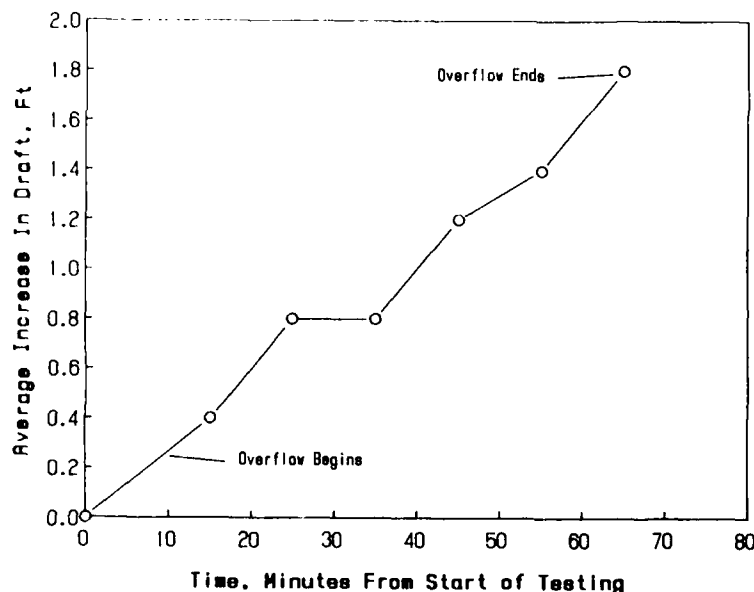
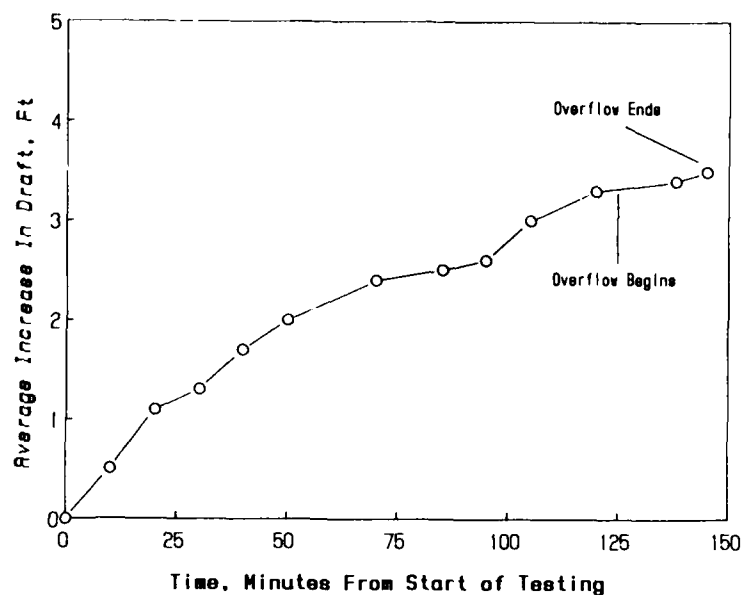


Figure 7. Load (displacement) versus time for Test 3

17. For all three tests, the overflow was ended with a significant amount of free water remaining in the barges. Therefore, the maximum possible load, i.e., the point at which no additional load was being gained by the overflow, was not measured. Based on visual observation, the relative volume of free water overflowed was approximately one half of the total in the barges at the beginning of overflow. The maximum possible load gain would therefore be approximately two times greater than that achieved in the tests. Considering the differences in measured load gain for comparable overflow periods in the three tests, the maximum possible load could be up to 25 percent.

PART III: DREDGED MATERIAL AND OVERFLOW CHARACTERISTICS

Characteristics of In Situ Sediments

18. The in situ sediment characteristics of the Mobile Bay channel sediments are generally described in the project General Design Memorandum (US Army Engineer District, Mobile 1985). Generalized sediment properties were determined by vibracore borings. In general, the channel sediments north of Galliard Island are a mixture of sands, silty sands, clayey sands, and sandy clays. The material becomes progressively finer from north to south. South of Galliard Island, the channel sediments are almost entirely soft marine clays. Visual classification of the vibracore borings taken at stations nearest the study reach indicated that the material at the 44 ft to 47 ft horizon was predominantly sand and clayey sand. However, no laboratory testing of the vibracore samples was performed for the borings near the study reach.

Characteristics of Material in Loaded Barges

Visual observations

19. As loaded buckets were raised above the water surface by the CHICAGO, water spilled from the lips of the bucket and from the top of the bucket. No heaped material above the top of the buckets was observed, indicating that the buckets were not fully penetrating into the sediment. As the buckets were placed into the barge, the relative volume of water in each load could be seen. For most buckets, the material was stiff near the bottom of the bucket with a thin slurry in the upper portion of the bucket. For some loads, sand was clearly visible at the bottom of the bucket.

20. As the barges were filled, a surface layer of slurry with the visual consistency of water accumulated in the barges. Once the barge filling progressed past a quarter to half full, the consolidated bucket material would quickly disappear beneath the water or slurry surface. There was no visible mounding of material above the slurry surface at the midpoint of filling, indicating the slurry layer had accumulated to a probable depth of at least several feet. Waves up to a foot high were formed in the surface water in the barge as each bucket was placed in the barge.

21. For all three tests, the operator placed the material at the midpoint of the barge in the early stages of filling, and only varied from that location if the barge began to list toward either end. This resulted in a mound of heaped material breaking the water surface inside the barge prior to overflow. In some instances, this mound extended across the entire barge width, creating two separate ponds of surface water in the barges. Once this mound reached a point where material could spill over the coaming, the operator placed material toward either end of the barge, maintaining a balanced load. Photographs of the barge-loading operation are shown in Figures 8 and 9.



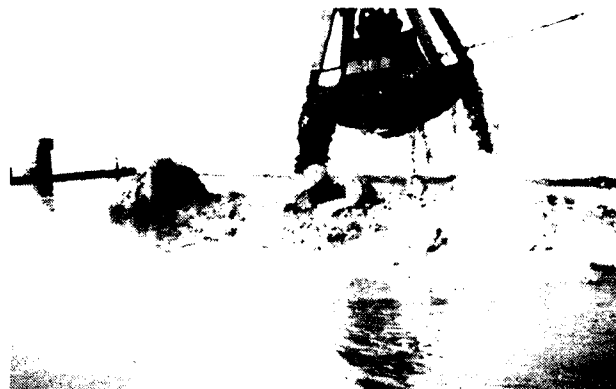
Figure 8. Barge-loading operation



Figure 9. Loaded barge

22. During the filling process, several bucket loads were released near the edge of the coaming, and small deposits of consolidated material from the buckets were left on the barge deck. This material was clearly clumped with no free water, and was considered representative of the material as excavated by the bucket. A total of four samples of this material were taken and analyzed for water content, Atterberg limits, and grain size.

23. The physical properties of the bucket material are given in Table 2. Two of the samples classified as sand or silty sand, while two others classified as clay. An example of the sandy bucket material is provided in Figure 10. The average solids concentration of the bucket material, based on the barge samples, was 1,080 g/L and ranged from 525 to 1,640 g/L. Grain-size distributions of the four bucket samples are shown in Figure 11. Two of the bucket samples were predominantly fine-grained material, and two were approximately 90-percent sand. The four bucket samples had an average grain size of 0.12 mm. The average of the two sand samples was 0.24 mm, while that for the two clay samples was 0.0071 mm.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

11

Overflow Characteristics

Visual observations

24. Overflow began when the waves formed by the buckets began to spill over the coaming. The overflow appeared to be a thin black slurry with only an occasional clump of material washed over the coaming. This indicated that the most dense portions of the clamshell material were accumulating on the bottom of the barge, and the slurry in the barges was displaced to the surface. Figure 12 is a photograph of the overflow material.

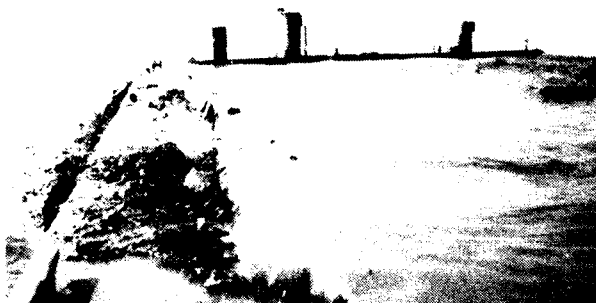


Figure 12. Overflow material

overflow. This was accomplished by filling the sample container while walking along the coaming. The filling procedure was accomplished such that the volume of the composite overflow sample taken from various points along the coaming was in proportion to the relative flow rate of the overflow at those points. This provided the most representative sample possible.

26. For all three tests, samples were taken at intervals of 5 to 10 min till the dredge operator elected to stop overflow. The overflow samples were analyzed for solids concentration and grain size. The overflow samples from each of the three tests were composited for Atterberg limit analysis.

Physical characteristics

27. The physical properties of the bucket material are given in Table 2. The composite of the overflow from all three tests was classified as an inorganic, highly plastic clay (CH). The solids concentrations of the overflow samples from all three tests are shown in Figure 13. This figure shows that the solids concentration of overflow was essentially constant with time, except for Test 1 in which the concentration increased during the last 10 min of overflow. The average overflow concentration for the three tests was 80 g/L. As shown in Figure 14, the grain size data from the overflow samples all fall within a narrow range. The overflow material was approximately 10-percent sand and had an average grain size of approximately 0.012 mm.

28. The grain size distribution of overflow samples shows less variability and finer grain size than the range of bucket samples. This indicates that some sorting of coarser sand particles within the barges occurred, due to the winnowing of finer particles from the bucket material by drainage from the bucket and by agitation within the barge during material placement.

Sampling and testing

25. Samples of the overflow were taken by directly filling wide-mouth 1-L sample containers at timed intervals during the overflow event. The sample containers were filled with a composite sample of the overflow along the entire length of barge coaming involved with the

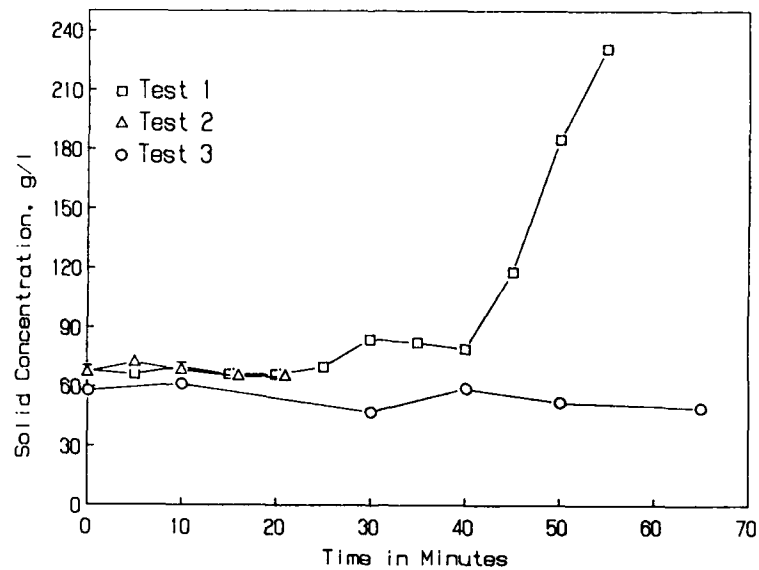


Figure 13. Overflow solids concentration versus time

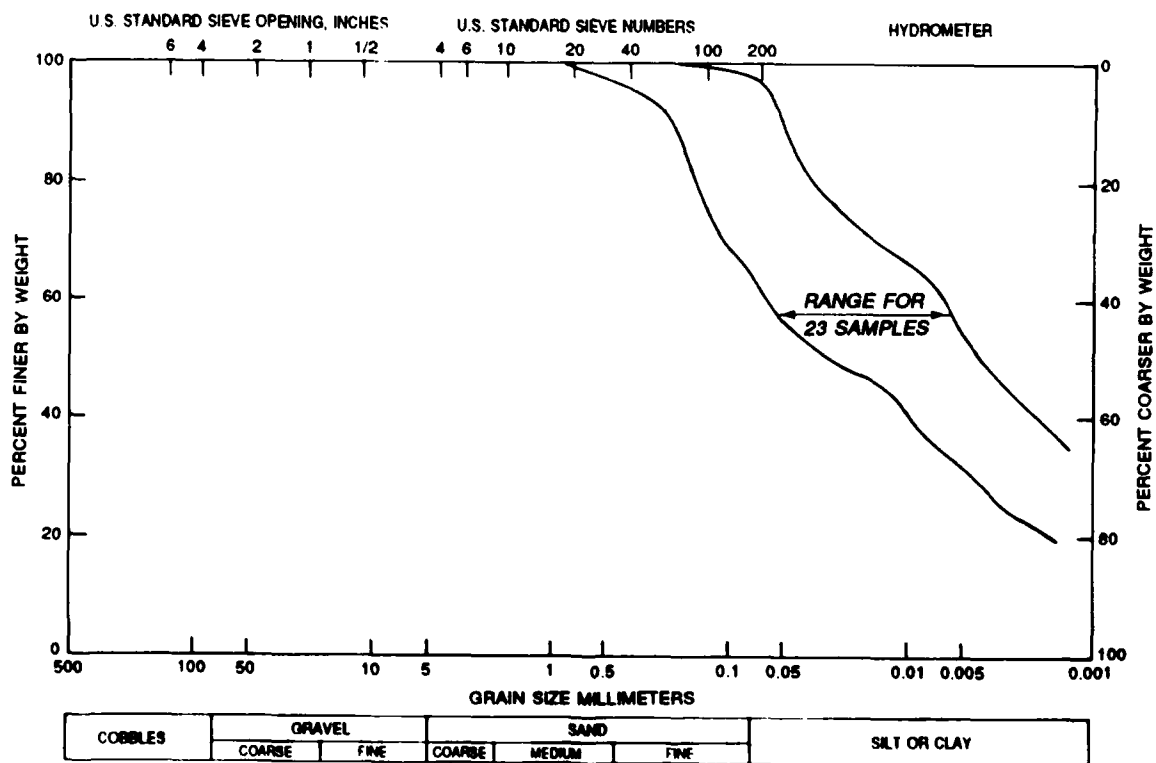


Figure 14. Grain-size distributions for overflow material

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

29. Based on the results of the field sampling and monitoring, the following conclusions regarding the hopper barge loading and overflow characteristics are made:

- a. The sediment dredged during this study was predominantly a clayey sand. The use of a 30-yd³ clamshell bucket for removal of the material resulted in buckets containing stiff material at essentially the in situ channel density in the lower portions of the bucket and slurry-like material in the upper portions of the bucket. The more fluid portions of the material were displaced toward the surface of the hopper barges, forming the overflow.
- b. The load gained during three overflow tests was 4.1, 1.2, and 11.5 percent for overflow periods of 60, 24, and 65 min. For all three tests, the overflow ended with a significant amount of surface slurry ponded in the barges, indicating that additional load gains would be possible with prolonged periods of overflow.
- c. The solids concentrations of bucket samples averaged 1,080 g/L, while that of the overflow was essentially constant for the entire period of overflow and averaged 80 g/L. These data indicate that retention of solids in the hopper barges occurs during the overflow process for mechanical dredging.
- d. The grain-size distribution of overflow samples was finer than that for bucket samples, with average grain sizes of 0.012 mm for overflow and 0.12 mm for bucket material. These data indicate that some sorting of grain sizes may occur in the hopper barges during overflow with mechanical dredging.

Recommendations

30. Based on the results of this study, the following recommendations are made:

- a. If clamshell equipment is used for later maintenance dredging for this project, similar evaluations of load gain resulting from overflow and characteristics of the overflow should be performed.
- b. Discussions should be initiated with concerned resource agencies to fully balance the environmental concerns associated with overflow and the potential for long-term economic advantages of overflow for future maintenance dredging.

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Table 1
Characteristics of Dredging Operation

Test Number	Time CST	Minutes After Overflow Begins	Cumulative Load Gain tons	Number of Buckets	Draft ft	Displacement tons = 2,000 lbs
1 8/2/89	0900	--*	--	--	19.1	8,600
	0910	10	0	6	19.1	8,600
	0920	20	50	7	19.2	8,650
	0930	30	200	7	19.5	8,800
	0940	40	250	7	19.6	8,850
	0950	50	300	5	19.8	9,000
	1000	60	350	6	19.9	9,050
2 8/3/89	0805	--**	--	--	15.7	6,900
	0815	--	--	--	16.2	7,150
	0825	--	--	--	16.8	7,450
	0835	--	--	--	17.0	7,550
	0845	--	--	6	17.4	7,750
	0855	--	--	--	17.7	7,900
	0915	--	--	--	18.1	8,100
	0930	--	--	--	18.2	8,150
	0940	--	--	--	18.3	8,200
	0950	--	--	6	18.7	8,400
	1005	--	--	--	19.0	8,550
	1023	13	50	--	19.1	8,600
	1030	20	100	--	19.2	8,650
3 8/3/89	1805	--†	--	--	17.6	7,850
	1820	5	200	--	18.0	8,050
	1830	15	400	--	18.4	8,250
	1840	25	400	--	18.4	8,250
	1850	35	600	--	18.8	8,450
	1900	45	700	--	19.0	8,550
	1910	55	900	--	19.4	8,750

* Overflow began at 0900 and ended at 1000.

** Overflow began at 1010 and ended at 1034.

† Overflow began at 1815 and ended at 1920.

Table 2
Physical Properties of Bucket and Overflow Samples

Test Number	Number of Samples	Atterberg Limits			USCS Classification	Average Solids Conc.*	Average D50**
		Liquid Limit, %	Plastic Limit, %	Plasticity Index, %		g/L	
Bucket Samples							
1	1	--	--	--	SM	1640	0.19
	1	90	30	60	CH	635	0.0067
2	1	83	26	57	CH	525	0.0075
3	1	--	--	--	SP	1520	0.28
Overflow Samples							
1	12	67	22	45	CH	98.9	0.010
					(66.0-231.1)	(0.0047-0.028)	
2	5	78	23	55	CH	67.5	0.010
					(65.2-72.4)	(0.007-0.015)	
3	6	81	26	55	CH	54.3	0.017
					(47.1-61.2)	(0.012-0.023)	

* D50 is the grain size for which 50 percent of the particles by weight are finer.

** Values in parentheses indicate the range of values.