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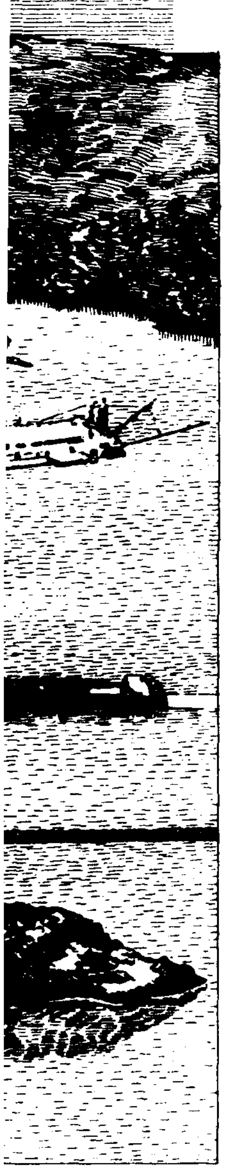

DREDGING RESEARCH PROGRAM

TECHNICAL REPORT DRP-90-1

PRACTICES AND PROBLEMS ASSOCIATED WITH ECONOMIC LOADING AND OVERFLOW OF DREDGE HOPPERS AND SCOWS

by

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- Area 1 - Analysis of Dredged Material Placed in Open Waters
- Area 2 - Material Properties Related to Navigation and Dredging
- Area 3 - Dredge Plant Equipment and Svstems Processes
- Area 4 - Vessel Positioning, Survey Controls, and Dredge Monitoring Systems
- Area 5 - Management of Dredging Projects

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Dredge hoppers and scows are commonly filled past the point of overflow to increase the load. Some Corps of Engineers Districts routinely allow overflow to increase the load, while others do not because of actual or perceived environmental and/or economic reasons. No formal Corps policies or regulations governing overflow have been established, mainly because the required studies have not been performed.

A survey of District practices indicates that the question of economic loading and overflow is governed by both project-specific considerations and restrictions imposed by resource agencies. Of 21 Districts with significant hopper or scow workloads, 14 reported restrictions on overflow. The majority of the restrictions were requested or imposed by resource agencies because of environmental concerns. In no case were project-specific data on overflow environmental effects available to support the need for restrictions or to technically justify overflow.

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Technical information related to economic loading of hopper dredges and scows and the nature of overflow is limited. The gain in hopper or scow load and the characteristics of the associated overflow are dependent on the characteristics of the material being dredged and the equipment being used. Overflow with hopper dredges is beneficial when sand is the predominant material because the settling velocity is high enough for the sand to rapidly settle in the hopper during the short filling time. The practice of overflowing when dredging silt and clay with conventional equipment and procedures is questionable because the sediment particle sizes are smaller and settling velocities are lower, which tend to cause the solids to stay in suspension longer.

There are no known studies focusing solely on the environmental effects of hopper and scow overflow. However, the environmental effects of overflow would logically be similar to those resulting from disposal of dredged material in open water or from the resuspension of sediment during dredging operations.

PREFACE

This study was conducted by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES). The study was sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), under Intra-Army Order for Reimbursable Services No. EB687D020, 20 January 1987, as a part of the Dredging Research Program (DRP), managed by the WES Coastal Engineering Research Center (CERC). HQUSACE Technical Monitors for the DRP were Messrs. Glenn Drummond, Vince Montante, Rixie Hardy, and John Parez. HQUSACE Advisors for the DRP were Messrs. M. K. Miles, Ben I. Kelly, and Don Pommer.

This report was prepared by Dr. Michael R. Palermo, Research Projects Group, Environmental Engineering Division (EED), EL, and Dr. Robert E. Randall, Texas A&M University, who was employed under an Intergovernmental Personnel Act agreement. Technical review of this report was performed by Mr. Allen M. Teeter, Estuaries Division, Hydraulics Laboratory, WES; Dr. Douglas G. Clarke, Environmental Resources Division, EL; and Messrs. David B. Mathis and Joe Wilson, HQUSACE. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

The 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. Ms. Virginia R. Pankow, HL, was the Manager of Technical Area 3, "Dredge Plant Equipment and System Processes." Program Manager of the DRP was Mr. E. Clark McNair, Jr., CERC; Assistant Program Manager, DRP, was Ms. Carolyn M. Holmes, CERC.

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

For further information on this report or on the Dredging Research Program, please contact Mr. E. Clark McNair, Program Manager, at (601) 634-2070.

CONTENTS

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

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

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
knots (international)	0.5144444	metres per second

SUMMARY

Dredge hoppers and scows are commonly filled past the point of overflow to increase the load. Some Corps of Engineers Districts routinely allow overflow to increase the load, while others do not because of actual or perceived environmental and/or economic reasons. No formal Corps policies or regulations governing overflow have been established, mainly because the required studies have not been performed.

A survey of District practices indicates that the question of economic loading and overflow is governed by both project-specific considerations and restrictions imposed by resource agencies. Of 21 Districts with significant hopper or scow workloads, 14 reported restrictions on overflow. In four cases, the restrictions were self-imposed for economic reasons. The majority of the restrictions were requested or imposed by resource agencies because of environmental concerns related to turbidity and/or suspended sediments, the presence of sediment contaminants, aesthetics, or depletion of dissolved oxygen. In no case were project-specific data on overflow environmental effects available to support the need for restrictions or to technically justify overflow.

Technical information related to economic loading of hopper dredges and scows and the nature of overflow is limited. The gain in hopper or scow load and the characteristics of the associated overflow are dependent on the characteristics of the material being dredged and the equipment being used. Factors influencing the character of scow overflow are 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.

Overflow with hopper dredges is beneficial when sand is the predominant material because the settling velocity is high enough for the sand to rapidly settle in the hopper during the short filling time. The practice of overflowing when dredging silt and clay with conventional equipment and procedures is questionable because the sediment particle sizes are smaller and settling velocities are lower, which tend to cause the solids to stay in suspension longer. Some studies indicate that short times of overflow are effective when dredging fine sediments, while others indicate that overflowing is not effective for this type of sediment. Modified equipment and/or operational procedures may be necessary to realize load gains for fine sediment overflows.

The potential environmental effects of overflow are due to increased water column turbidity/suspended solids concentrations, depression of dissolved oxygen, release of particle-associated contaminants, and/or aesthetic concerns. There are no known studies focusing solely on the environmental effects of hopper and scow overflow. However, the environmental effects of overflow would logically be similar to those resulting from disposal of dredged material in open water or from the resuspension of sediment during dredging operations.

PRACTICES AND PROBLEMS ASSOCIATED WITH ECONOMIC LOADING AND OVERFLOW OF DREDGE HOPPERS AND SCOWS

PART I: INTRODUCTION

Background

1. Dredge hoppers and scows are commonly filled past the point of overflow to increase the load. Some Corps of Engineers Districts routinely allow overflow to increase the load, while others do not because of actual or perceived environmental or economic reasons. No consistent Corps policies or regulations governing overflow practices have been established, mainly because the required studies have not been performed.

2. The gain in hopper or scow load and the characteristics of the associated overflow are dependent on the characteristics of the material being dredged and the equipment being used. There is little debate that the load can be increased by overflow if the material dredged is coarse-grained or forms clay balls, as commonly occurs with new work dredging. For fine-grained maintenance material, there is significant disagreement whether a load gain can be achieved by overflow.

3. Environmental considerations of overflow may be related to aesthetics, potential effects of water column turbidity, potential effects of deposition of solids, or potential effects of sediment-associated contaminants. These actual or perceived environmental effects have often resulted in criticism of Corps dredging operations or restrictions on overflow. In some instances, the "no-overflow" policies of some state regulatory agencies result in significant increases in project costs.

4. The lack of a consistent Corps policy regarding overflow has resulted in:

- a. Increased project costs in some instances.
- b. Lack of decision criteria with regard to when to allow or prohibit overflow.
- c. Confusion with regard to whether decisions on allowing overflow should be based on environmental or economic reasons or both.
- d. Confusion as to how the US Environmental Protection Agency's (USEPA) 404(b) guidelines apply to the environmental regulation of overflow.

5. The Headquarters, US Army Corps of Engineers (USACE), tasked the US Army Engineer Waterways Experiment Station to conduct a technical analysis of the issues identified in the above paragraphs. This report documents the results of that analysis and is intended to provide a technical basis for development of appropriate policy guidance on the overflow issue.

Purpose and Scope

6. The purpose of this report is to provide a technical analysis of pertinent issues concerning dredge hopper and scow economic loading and overflow. The analysis described in this report consists of a review of the technical literature, a survey of current Corps District practices, and a discussion of the associated issues. Alternatives are provided for use in developing an appropriate Corps policy on overflow.

PART II: LOADING AND OVERFLOW PROCESSES FOR DREDGE HOPPERS AND SCOWS

7. This part of the report contains a review of the technical aspects of loading and overflow processes for dredge hoppers and scows. The information was obtained from contacts with Corps Districts and from a review of the open technical literature.

8. The review of technical literature was based on readily available documents and on a computer search. Readily available Corps manuals and technical reports were obtained, and an initial literature search was conducted at the Texas A&M University library. A list of keywords was then developed for a computer search. The keywords were dredge, hopper, barge, scow, overflow, load, economic, instrumentation, measurement, monitoring, efficiency, sediment, losses, loading, filling, experimental, and curves. Combinations of keywords used in the computer search were: hopper dredge overflow, hopper loading efficiency, hopper economic load, instrumentation for measurement of economic load, hopper loading curves, hopper overflow losses, barge sediment load curves, experimental measurements of scow loading, and monitoring of hopper overflow losses. The computer search was conducted by the WES Information Technology Laboratory using the DIALOG search system. Data bases searched included Compendex, Water Resources Abstracts, Enviroline, Oceanic Abstracts, National Technical Information Service, and the Army Engineer Private File. The computer search netted only 10 citations from the open literature, all pertaining to hopper dredge loading and overflow.

Definitions

9. Definitions of selected terms for purposes of this report are given below for clarity and consistency.

a. Load gain - an increase in the weight of retained solids in a dredge hopper or scow.

b. Economic load - the load in a dredge hopper or scow that corresponds to the minimum unit dredging cost. Economic load is dependent on the material dredged, equipment used, distance to disposal site, and other site-specific factors. Economic load does not necessarily correspond to the maximum load or highest density load that can be obtained.

c. Overflow - a mixture of water and solids returned to the waterway from a dredge hopper or scow when filling is continued past the point at which the hopper or scow is full. This definition includes both the material discharged over the side portions of a hopper dredge and material that is discharged underwater through adjustable hopper skimmer/scupper arrangements.

d. Hopper dredge - a seagoing vessel that is equipped with propulsion machinery, dredge pumps, suction pipes, hoppers, and overflow system.

e. Turbidity - suspended solids in water that make the water unclear (muddy). Suspended solids usually result from stirred-up sediments.

f. Scow - dump scows without propulsion machinery, dredge pumps, or suction pipes. Scows are equipped for bottom dumping and are loaded by mechanical means (e.g., clamshell dredge). Other seagoing vessels (tugs) must bring the scow to the disposal site.

Description of Operations Involving Overflow

Hopper dredging

10. The function of a hopper dredge is to dredge material hydraulically from the bottom of navigation channels. At the beginning of a dredging cycle, the hopper may be partially filled with residual water. Dredging is conducted with the vessel under way at a speed of 1 to 3 knots* with the dragheads in contact with the bottom. The bottom sediments are entrained with the ambient water, lifted hydraulically by the dredge pumps, and discharged into the hoppers. Once the solids-water mixture (slurry) fills the hopper, the solid particles continue to settle in the hopper while the excess water passes overboard through the overflow system. When the desired load is attained, the dragarms are raised and the dredge transports the material to the disposal site. Here, the hoppers are unloaded through bottom opening doors or a split-hull mechanism. Upon completion of the unloading process, the doors are closed and the dredge returns to the dredging area to repeat the operating cycle. Descriptions of hopper dredges and their operation are available in Scheffauer (1954), Herbich (1975), and Engineer Manual (EM) 1110-2-5025 (USACE 1983). A photograph of a hopper dredge during an overflow operation involving fine sediment is shown as Figure 1.

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

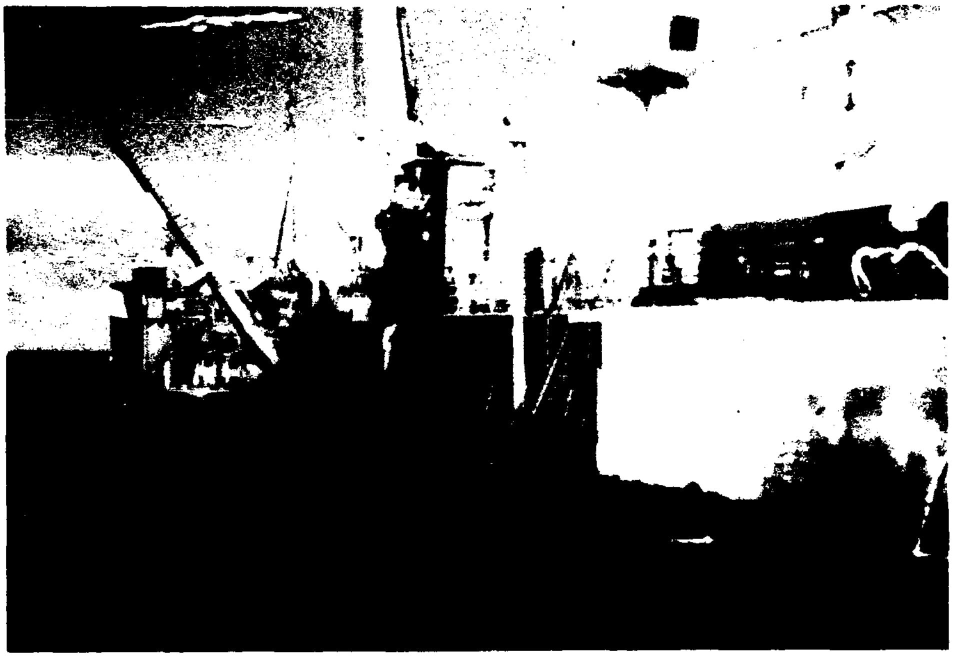


Figure 1. Hopper dredge operating with overflow

Clamshell and scow dredging

11. Scows or barges are normally used to transport material excavated with mechanical dredges. The scows usually are equipped for bottom dumping at the disposal site. The material is mechanically removed and placed in the scows, with little entrainment of water during the dredging cycle as compared with hydraulic dredging. Scows will be 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 spilled 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. A photograph of a scow loading operation involving overflow is shown as Figure 2.

Agitation dredging

12. Agitation dredging is a process that intentionally discharges overboard large quantities of fine-grained dredged material by pumping past the point of overflow or through ports below the waterline of specially equipped dredges, under the assumption that a major portion of the solids in the overflow will be transported and permanently deposited outside the navigation

Figure 2. Clamshell dredge filling scow with overflow

channel by tidal, river, or littoral currents (USACE 1983). Richardson (1984) describes considerations for agitation dredging. In general, this report is not concerned with those loading and overflow practices associated with agitation dredging.

Loading and Overflow of Hoppers

13. This section of the report focuses on the efficiency of the hopper dredge loading and overflow process. Improvement of the loading efficiency is one of the primary means for reducing the cost of dredging. Generally, it is desirable from a loading standpoint to continue the overflow process until the solids in the slurry mixture are no longer efficiently settling in the hopper and high solids concentrations are being discharged overboard through the overflow system. When the sediments are composed of sands or heavier material, the settling process within the hopper is generally efficient and the hopper can be nearly filled with settled solids before significant quantities of sand are contained in the overflow. In the case of silt and clay solids, the hoppers cannot be as effectively filled with settled solids before most of the solids exiting through the overflow system are at a concentration near

that being dredged and pumped. As a result, the efficiency of the overflow procedure when silt and clay sediments are being dredged is substantially less than that for sand or coarser material.

Existing Corps guidance

14. Guidance in EM 1110-2-5025 (USACE 1983) on economic loading and overflow for hopper dredges is as follows:

> The use of (overflow) methods is controlled to varying degrees by environmental legislation and the water quality certification permits required by the various states in which dredging is being accomplished. The environmental effects of these methods must be assessed on a project-by-project basis. If the material being dredged is clean sand, the percentage of solids in the overflow will be small and economic loading may be achieved by pumping past overflow. When contaminated sediments are to be dredged and adverse environmental effects have been identified, pumping past overflow is not recommended. In such cases, other types of dredges may be more suitable for removing the contaminated sediments from the channel prism. If hopper dredges are not allowed to pump past overflow in sediments that have good settling properties, the cost of dredging increases. The settling properties of silt and clay sediments may be such that only a minimal load increase would be achieved by pumping past overflow. Economic loading, i.e. the pumping time required for maximum production of the hopper dredge, should be determined for each project. These determinations, along with environmental considerations, should be used to establish the operation procedures for the hopper dredge."

This guidance is basic in nature; however, there is no detailed guidance on how to balance the potential economic benefits and potential environmental effects in reaching decisions related to overflow.

Economic load test

15. Instructions for hopper dredge operations are described in the "Manual of Instructions for Hopper Dredge Operations and Standard Reporting Procedures" (USACE 1953). Economic load tests are required at the beginning of dredging operations unless conditions in the area prevent the use of overflow procedures. These tests are used to determine the most economical operating cycle to use.

16. The economic load is the hopper load that is dredged and hauled in a single dredging cycle and yields the maximum rate of material removed from the project area at a minimum cost. For this test, the hopper load is measured periodically during loading using either the yardage meter or sounding and sampling techniques. The pumping, turning, and average or estimated disposal times are recorded and summed to obtain the total cycle time. The amount (cubic yards) of retained material per minute of total cycle time is computed from the load and total cycle time measurements. Next, the amount of

retained material per increment of pumping time is computed. The equivalence of these two values is the point of economic load. Therefore, the economic load is usually not the maximum load but depends upon a number of factors, one of which is the distance to the disposal site. Sample curves from an economic load test are shown in Figure 3. Curve 1 is the measured load, and curve 2 is the retained load per minute of total cycle time. Curve 3 is the cost per cubic yard of the measured load based upon an operating cost of $2.00 per total cycle minute. Curve 4 is the cubic yards retained per incremental pumping minute. The intersection of curves 2 and 4 establishes the point of economic loading. The economic load is 1,445 cu yd (Curve 1), and the economic pumping time is 76 min.

17. An economic load test was used in a special study to evaluate the hopper dredge overflow characteristics while dredging in the Mare Island Strait and Richmond Inner Harbor located in the San Francisco Bay area (US Army Engineer District (USAED), San Francisco 1976). The purpose of the study was to determine dredge efficiency with and without overflow and to evaluate the economic load point that included the number of cubic yards and the pumping time to reach that point. The loading curves were generated for the two locations as shown in Figures 4 and 5. The Mare Island Strait curve shows that the loading curve maximum and the cost/cubic yard minimum occurred approximately 2 min after overflow began. For the Richmond Inner Harbor, overflow was required for 18 min to reach economic load. Different shoal configurations, sediment, and salinity were cited as reasons for the difference in time to reach the economic load.

Load gains in hoppers

18. Scheffauer (1954). In past years, the Corps has incorporated features in the design of hopper dredges to enhance retention of solids in the hopper when dredging fine sediments. Scheffauer describes stilling systems designed for Corps hopper dredges and the resulting improvements in performance. A stilling plate system consisting of a grate covering the hopper was installed in the dredge *Taylor*, and performance was compared at six sites on the Great Lakes. Sediment for these projects was described as a mixture of fine sand, silt, and clay. The stilling system increased the solids retention in the hoppers and resulted in a savings in unit dredging cost. However, the percent solids in suspension was increased for four of the six sites. A vertical stilling box was installed on the dredge *San Pablo*, and its performance was compared with a conventional trough system in five tests. The vertical

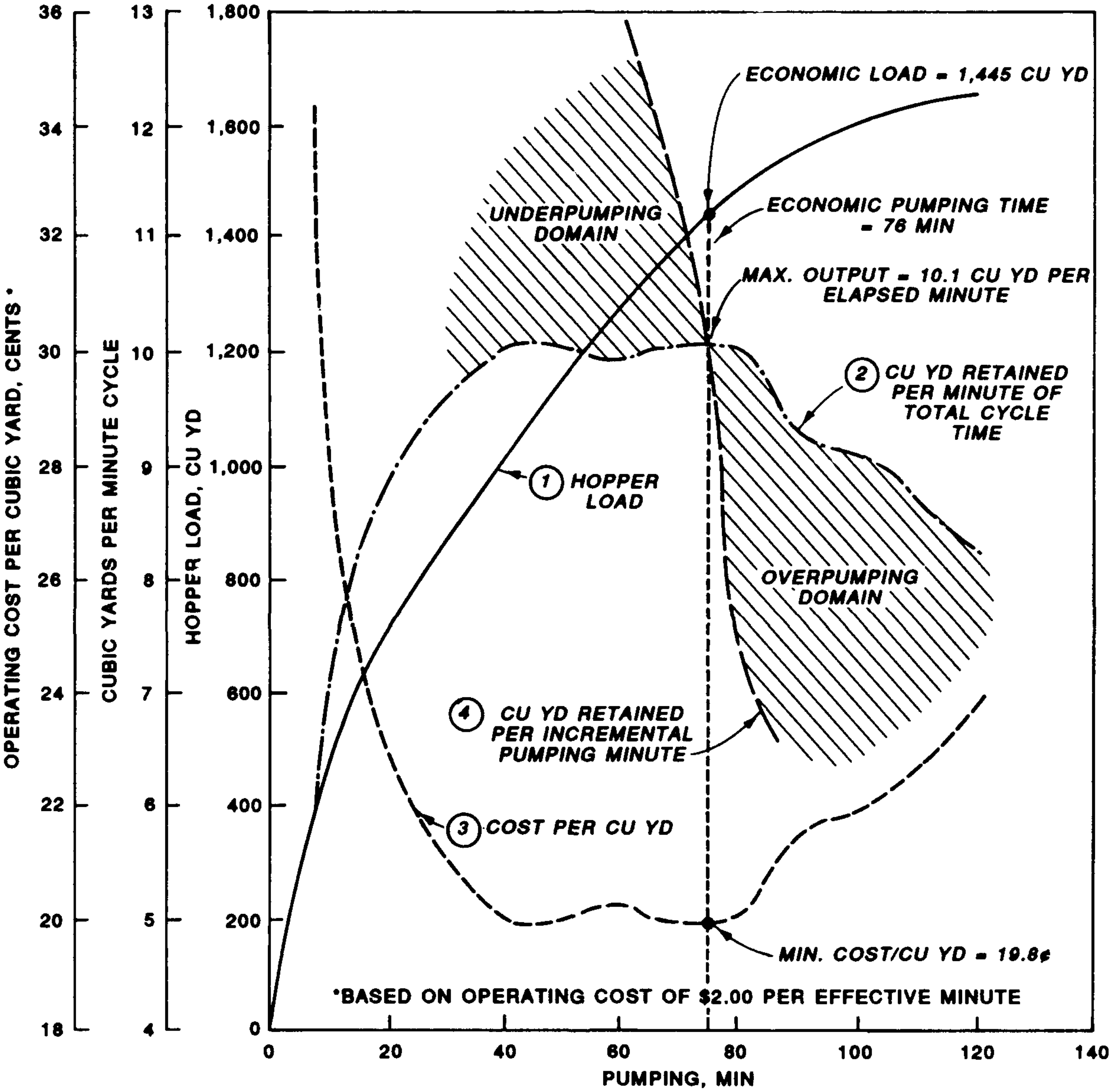


Figure 3. Sample economic load curves (after USACE 1953)

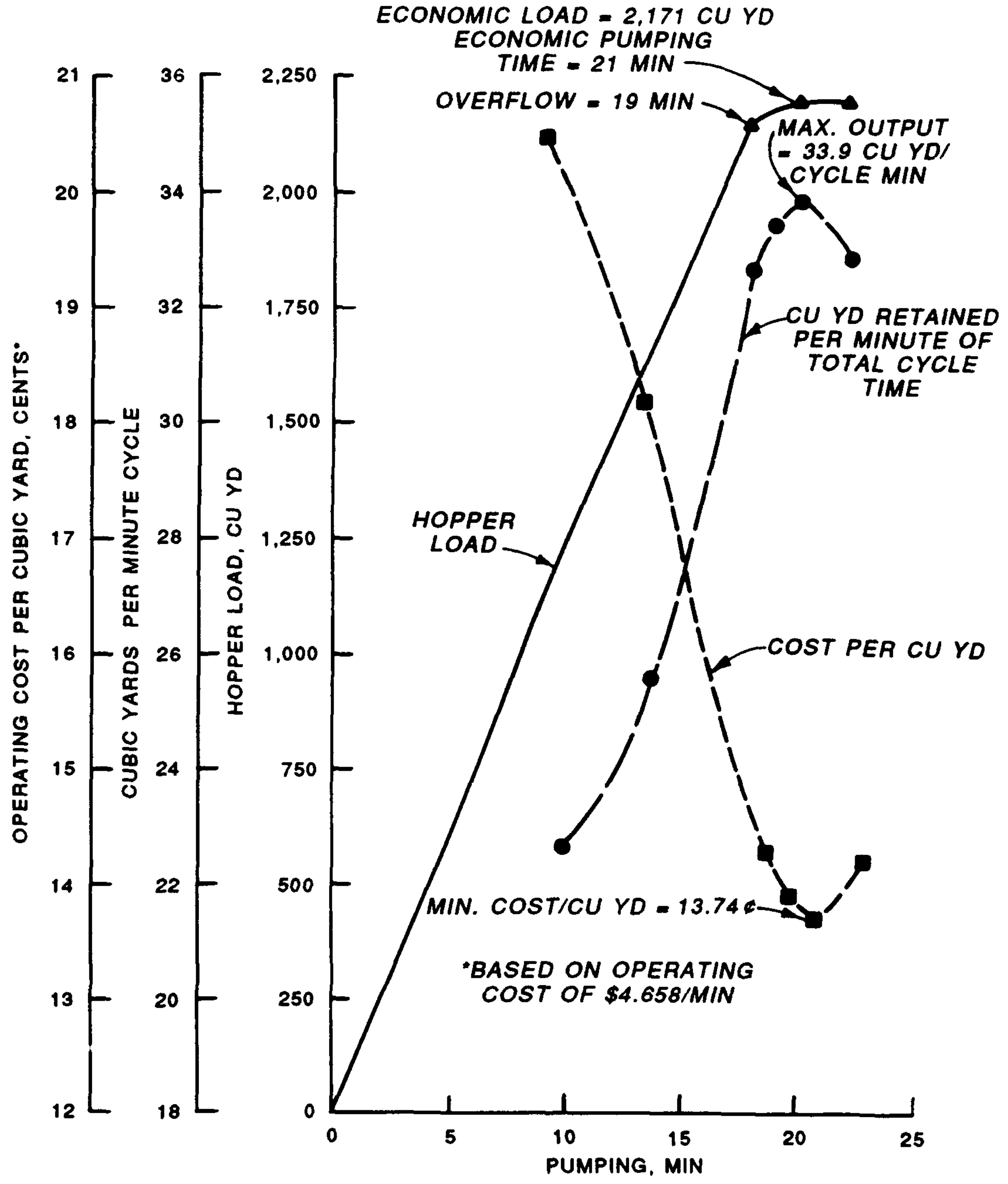


Figure 4. Economic load curve for Mare Island Strait (after USAED, San Francisco 1976)

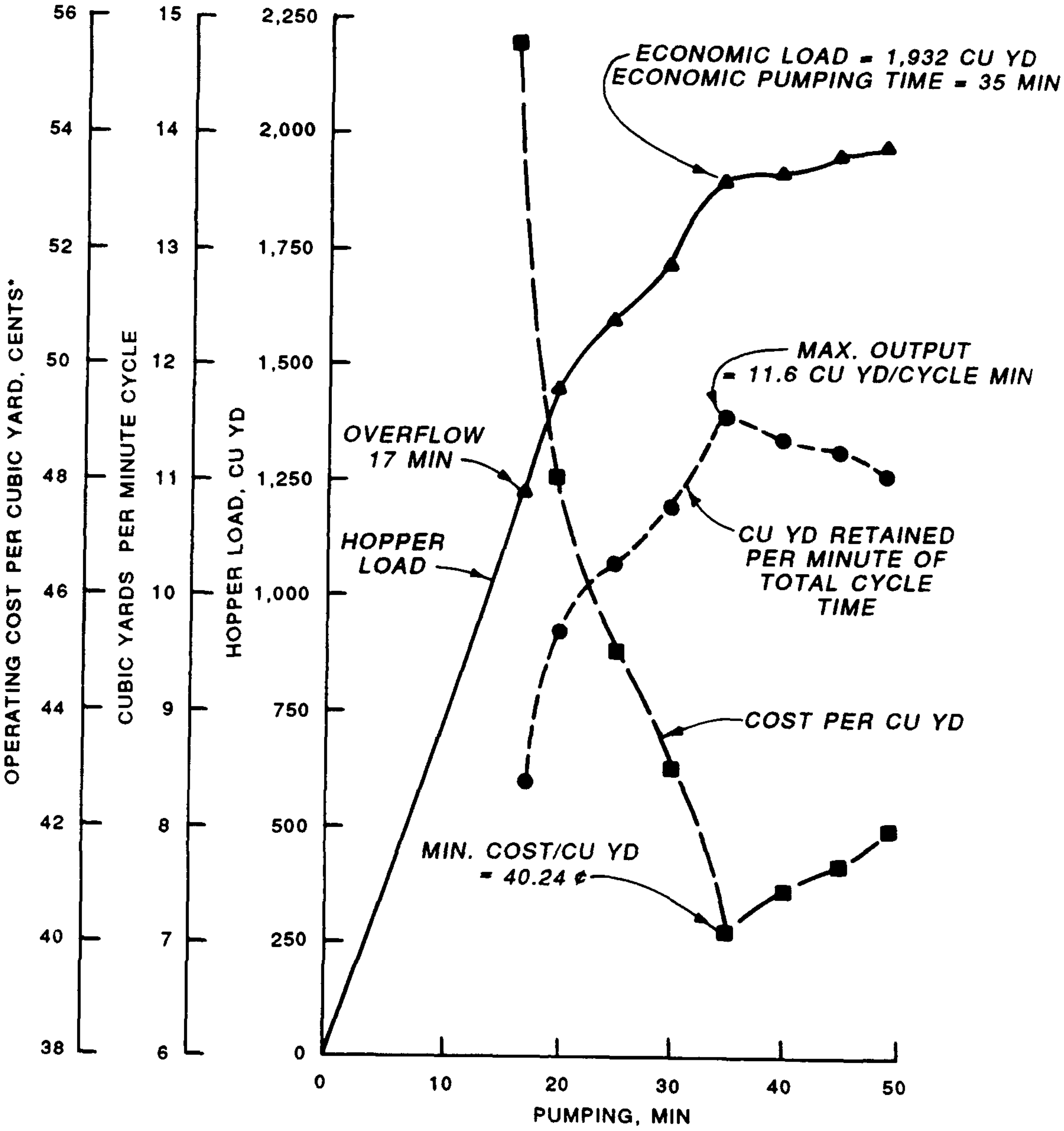


Figure 5. Economic load curve for Richmond Inner Harbor (after USAED, San Francisco 1976)

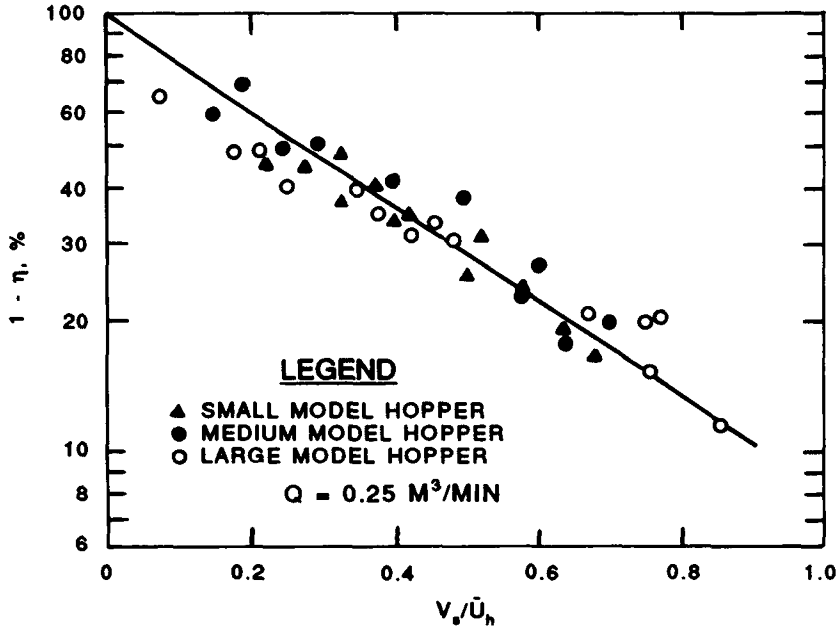
box resulted in a greater depth of settled solids in the hopper, and the percent solids in suspension ranged from 1 to 5 percent as compared with a range of 8 to 23 percent without the stilling box.

19. Yagi (1970). Theoretical and experimental studies of sedimentation in hoppers were conducted by Yagi. Loading efficiency was defined as the ratio of the quantity of discharged sediments to the quantity of deposited sediments over a unit time period. Many factors affect the settlement or deposition of dredged material in a hopper. Some of these are particle size, hopper capacity and opening area, settling velocity, flow velocity in the hopper, inflow characteristics of the slurry, overflow system, side friction in hopper, and capacity of dredge pump. Yagi (1970) developed expressions for loading efficiency applied to hopper dredges with overflow for both sand and soft muds.

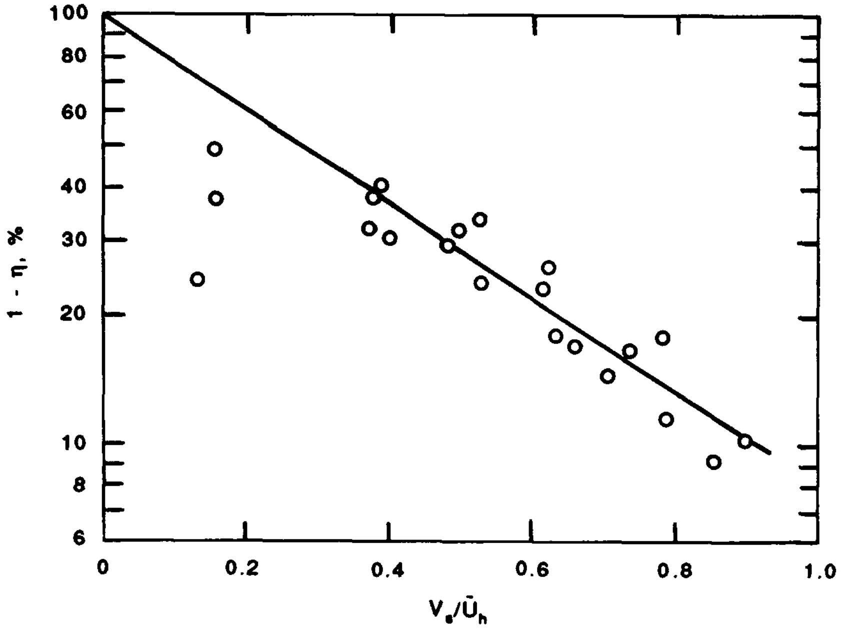
20. Experimental tests were conducted for three model hoppers, and field tests were conducted for one dredge. The material was fine sand, and its grain size ranged from 0.2 to 0.5 mm for the model tests and from 0.2 to 5 mm for the field test. The results showed the relationship between the loading efficiency and the ratio of the settling velocity to the horizontal velocity in the hopper, as illustrated in Figure 6. These results were obtained assuming no rescattering of the sediments after deposition in the hopper. The flow velocity was measured by an electromagnetic flowmeter and was assumed to be uniform in the hopper. Settling velocities for the average grain size were considered, although the lumping characteristics of silts and clays were not.

21. Economic loading was also discussed and included the operating times of one complete dredging cycle, which consisted of the loading time, turning times, hauling time to and from the disposal site, and disposal time. The method used by Yagi to determine economic loading point for silt and clay based upon field tests is illustrated in Figure 7. An economic load was attained 7 min after overflow began. It was concluded that overflow was not practical for silt and clay, and a higher concentration of the silt-clay-water mixture was recommended for increasing the load. In the case of coarse sand, the loading efficiency became nearly constant and, consequently, the loading was limited by the draft of the vessel.

22. Boogert (1973). Based on years of field research by IHC Holland, Boogert (1973) discusses the loading of hopper dredges, overflow losses, and influence of soil type on maximum loading time. Generally, the loading system



a. Model hopper tests



b. Test for dredge *Kaiho-Maru*

Figure 6. Relationship between loading efficiency (η) and the ratio of settling velocity (V_s) to hopper velocity ($\bar{U}_h$) (after Yagi 1970)

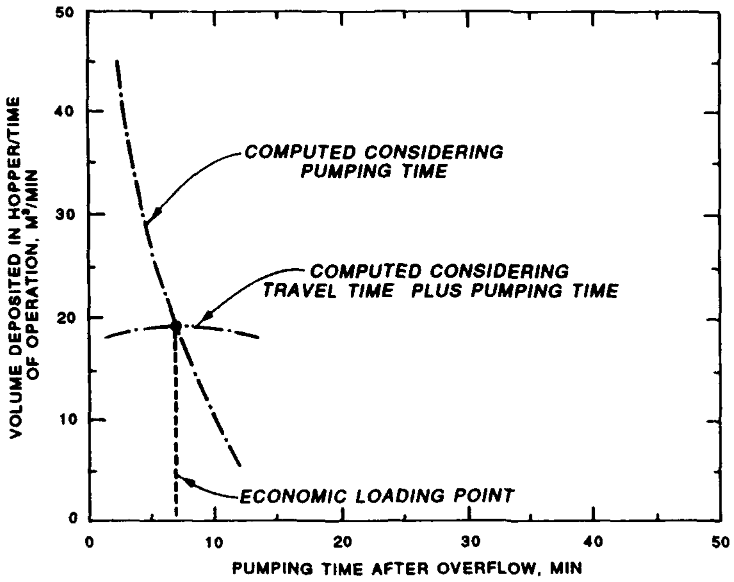


Figure 7. Economic load curve showing volume deposited in hopper per unit time of operation versus pumping time after overflow (after Yagi 1970)

is above the hopper and consists of a chute that directs the sand and water mixture from the dredge pumps to the hopper. An overflow system on the hopper permits excess water to flow overboard. The flow rate in the chute is kept above a minimum value, which permits the dredged material to be carried along with the water. When the flow enters the hopper, the flow rate decreases rapidly, and the dredged material settles to the bottom of the hopper. This process continues until the vessel is loaded or reaches a specific draft measurement.

23. Excess water from the slurry mixture is removed through the overflow system. Some of the dredged material does not settle in the hopper and flows overboard with the water via the overflow system, which is defined as the overflow loss. As the level of dredged material in the hopper bottom increases, the flow rate of the fluid above the material increases, which means the smaller dredged material particles will not settle and more material will be removed in the overflow process. Eventually, none of the incoming material will settle in the hopper, and the overflow losses will be 100 percent. At this point, the loading operation should be discontinued. Boogert (1973) shows a load curve (Figure 8) that was obtained from a self-registering loading indicator.

24. The type of dredged material, grain size, and distribution have a major influence on the overflow losses. The effect of very fine, medium, and coarse sand is illustrated in Figure 9, after the work of Boogert (1973).

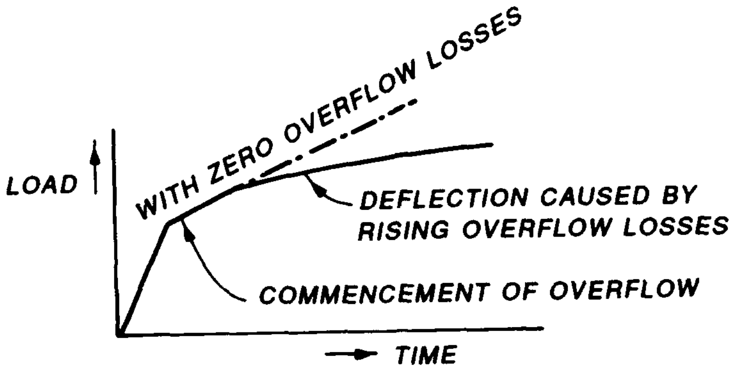


Figure 8. Typical load curves for a hopper dredge (after Boogert 1973)

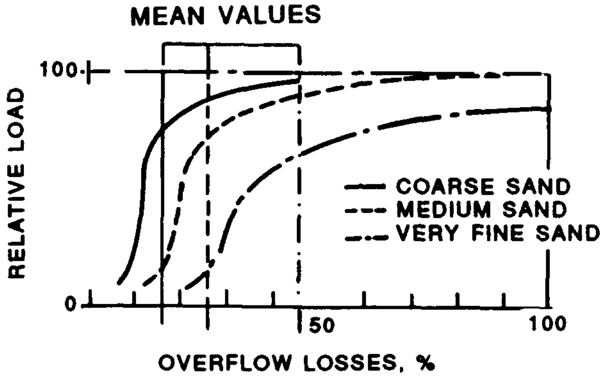


Figure 9. Effect of the type of dredged material on overflow losses (after Boogert 1973)

This figure shows that the hopper cannot be filled with very fine sand. When dredged material is clay or silt, overflow losses rise to 100 percent almost immediately after overflow begins. Boogert (1973) stated that, for this reason, loading normally stops as soon as overflow begins.

25. MTI Holland (undated). MTI Holland, the research and development laboratory of IHC Holland, investigated the overflow losses in the hopper loading process using a laboratory-scale model and discussed a mathematical model of the loading process. Sand was the only material considered in their study because silt remained in suspension, and therefore the loading process was normally stopped as soon as the overflow level was reached. A mathematical model was developed from the basic principles of equations of motion, continuity, and state. In the math model, the overflow loss was considered to be governed by turbulence, method of entry, position and design of the overflow structure, mixture velocity and velocity pattern, delivery rate of the dredge

pump, hopper geometry, erosion of settled sand in hopper, ship motions, sand settling rate, and concentration of solids in slurry. Model tests were conducted which satisfied the similarity of five dimensionless parameters (sand Reynolds number, sand Froude number, hopper Reynolds number, density ratio, and the particle diameter to hopper length ratio). The mathematical model was calibrated to the hopper model tests, and the computer was used to solve the model algorithms. The results yielded the optimum hopper shape and the overflow position based upon the dredge pump installation and the type of dredged material. The comparison of the mathematical model results and the physical model results was not shown. Also, the details of the math model useful for comparison with other models, laboratory tests, and field results were not shown.

26. Thorn (1975). An experimental field study was completed to evaluate the loading and consolidation of silt in a hopper dredge. This study used a Harwell silt-density probe to measure the depth-density profile of the hopper load. Riddell (1975) also reported using the Harwell probe for measuring density profiles of sediment on the bottom of estuaries and in hopper barges. The dredged material had particle diameters of 0.001 to 1.0 mm with low settling velocities. The results showed that for fine silt material there was no increase in the hopper load as a result of overflowing, and in fact, the overflowing resulted in a slightly smaller load than that with no overflow because of erosion in the hopper.

27. Thorn postulated that if the hopper load is allowed to consolidate, the overlying water can be removed and additional dredging can be completed, with the additional material placed on top of the consolidated material. Thorn measured the consolidation rate of fine silt material in a hopper and found it to be very slow. Additional dredging was completed after consolidation took place, and the new dredged material was added on top of the consolidated hopper load. As a result, the hopper load was increased, but the increased load did not compensate for the lost production time during the consolidation period. The conclusion of the Thorn (1975) study was that dredging of silt without overflow produced a greater cycle output than any other method. The dredge cycle output could be increased by increasing the slurry density pumped from the draghead.

28. DeBree (1977). DeBree describes model tests which showed that settlement of dredged material in the hopper depends on the height and velocity at which the material enters the hopper, the manner in which it enters the

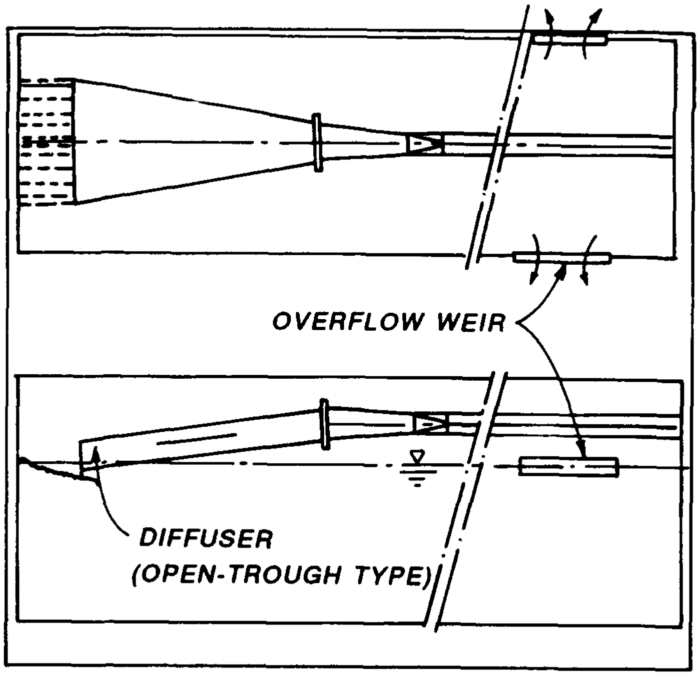
hopper, the horizontal velocity in the hopper, the length of the hopper, the settling velocity of the material, and the type and position of overflow weir. The overflow losses depend upon the nature of the dredged material, flow rate and density of the slurry, loading system, size and shape of hopper, and type of overflow system.

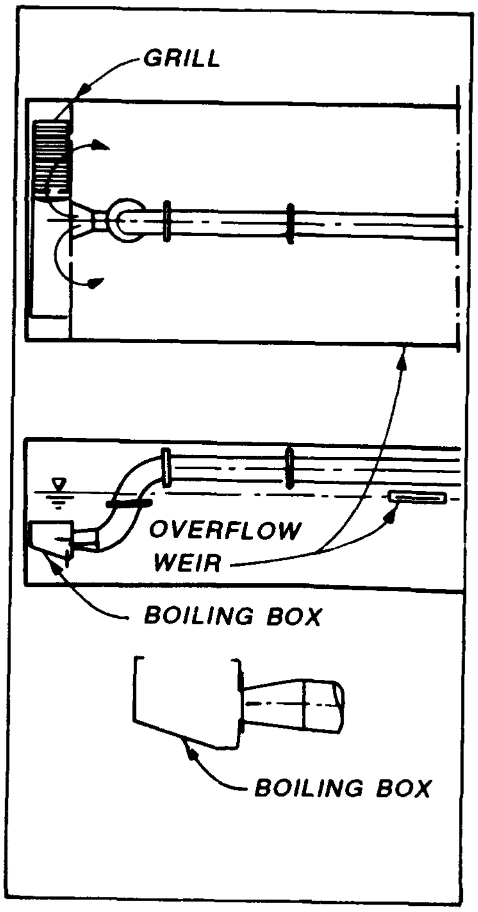
29. When dredged material consists of fine or very fine particles with low settling velocities, overflow losses are large. It was suggested that the density of the slurry be monitored at or near the draghead and that very low-density slurries be diverted from the hopper. The devices for this procedure were not reliable in 1977; however, the technology is believed to be currently available.

30. Creating favorable conditions for the settlement of the incoming solids is very important in reducing overflow losses. This is accomplished by reducing the energy of the slurry as it enters the hopper and forcing the slurry to move slowly toward the overflow structure. DeBree (1977) discusses three load systems: open diffuser, boiling box, and deep-loading diffuser. The open diffuser (Figure 10a) reduces the flow energy as the slurry enters the hopper just below the overflow level and near the rear of the hopper. Chains connected between the diffuser and the hopper wall further reduce the flow energy and prevent debris from entering the hopper. The boiling box (Figure 10b) is a closed box with a grill that acts as a diffuser and discharges the slurry well below the overflow level. The deep-loading system is a closed vertical diffuser extending deep into the hopper (Figure 10c), and the sediment bed is used to help reduce the incoming slurry velocity. The deep-loading system works best when working with low hopper loads, which occur when the dredged material is silt or fine sands. For coarse sands and higher hopper loads, the boiling box and open-diffuser systems perform best. Improvements are possible if a means were available for adjusting the height of the loading system during the filling process.

31. According to DeBree (1977), model tests have shown that long, narrow hoppers tend to minimize overflow losses, while wide hoppers tend to have uneven distribution of the sediment over the hopper width. Overflow losses are also minimized when the overflow structure is located 20 to 30 percent of the hopper length away from the end bulkhead. A center location of the overflow structure reduces the effect of surging water caused by ship rolling, but it is more expensive. The overflow structure must provide for a smooth flow pattern to prevent eddy formation.

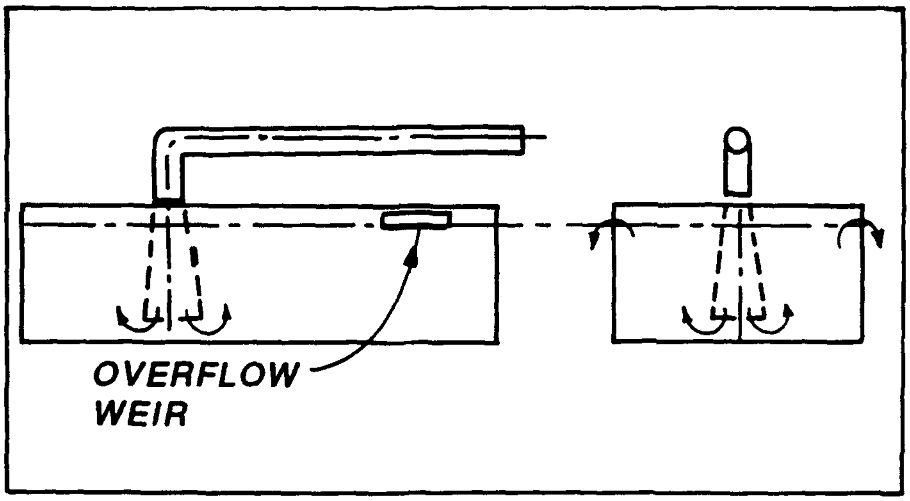
a. The IHC loading system uses open diffusers at the end of the delivery pipe just below the overflow level. Chains suspended behind the diffuser further reduce the speed of the incoming mixture and arrest debris that could damage the hopper





b. In the boiling box system, the slurry passes through a grill (arrows) before entering the hopper. This has the combined advantage of reducing the velocity of the flow and removing debris that could damage the hopper walls and doors

Figure 10. Schematic of open-diffuser, boiling box, and deep-loading systems (after DeBree 1977) (Continued)



c. The deep-loading system involves extending a vertical diffuser deep into the hopper and using the bed of sediment in the bottom to absorb the energy of the incoming mixture

Figure 10. (Concluded)

32. Volbeda (1983). More recently, Volbeda discussed the overflow effects when dredging very soft silts and clays and compared hopper dredging with and without overflow. In contrast to Boogert (1973), this study indicated that overflow dredging increased the overall density of the material in the hopper. The effect of overflow dredging on increasing the payload depends on the type and variation of the dredged materials, the dredging method, and type of draghead and chute. Volbeda stated that overflow dredging has a secondary advantage in that the overflow material sinks to the bottom and settles in ridges and gullies left by the draghead. Thus, it can be said that a deepening and flattening of the channel are attained in one operation.

33. A hypothetical project was used to illustrate the effect of overflow dredging on the cost. Ten million cubic metres of dredged material were to be removed and 60 min was the assumed time for disposing, turning, and sailing to and from the disposal site. In one dredging cycle, 2,000 cu m of material was removed with dredge pumps running for 20 min and no overflow. This resulted in a continuous rate of 25 cu m/min. For 15 min of overflow dredging, the continuous rate increased to 30 cu m/min. The percent reduction in cost was approximately 20 percent for the assumed project. The advantage of the reduced costs is accompanied by the disadvantage of increased turbidity.

34. Meyer et al. (1986). Meyer et al. described use of a gamma emitting probe to measure hopper load. They stated that the measurement of dredge displacement alone was not sufficient to evaluate optimum load, especially when dealing with fine sediments. Data obtained from loading measurements with the probe show the buildup of material in the hopper as a function of time. It was also determined that distribution of load varied from fore to aft in the hopper due to the nature of the loading system used. The probe was found to be suitable for use in optimizing loads for sandy sediments but inadequate for fine-grained sediments.

35. Rokosch, Van Vechgel, and van der Veen (1986). These investigators examined the use of displacement and pressure-based measurements for determining mixed loads, i.e., settled and suspended materials, in hoppers. The total load and suspended material in the load were separately determined with the aim that the rate of increase of total load minus suspended load could be a better yardstick for optimizing production. The results of this study indicated that the measurement of the degree of settlement in the hopper is an important indication of whether loading should be continued.

36. Cox, van Deursen, and Vehoeven (1986). These investigators examined relevant sediment properties as related to loading efficiency of a hopper dredge. Shear strength was described as an important factor in loading. For low-strength materials, high densities of slurry can be dredged, and concentrations in the hopper will be high. However, practically no additional settling in the hopper will occur. For higher shear strength materials, more water is entrained during dredging, and part of the silt will be transported in lumps. But because of the relatively high slurry density, additional settling in the hopper would be negligible. As shear strength further increases, slurry concentration will be low, but clay balls will form, with resulting high efficiency of settling in the hopper.

Hopper overflow characteristics

37. Barnard (1978). Barnard summarized data on the sources of turbidity generated by a hopper dredge with and without overflow. He stated that the most obvious source of near-surface turbidity is the overflow water. He also stated that although no increase in the hopper load may be achieved by the continued pumping of fine-grained sediment into filled hoppers, overflowing was (at least at that time) a common practice. Barnard also summarized measurements of solids concentrations in the vicinity of the dredge *Chester Harding* during maintenance operations in San Francisco Bay (USAED, San

Francisco 1976). These data indicated the presence of a double plume, with nearsurface turbidity generated by the overflow and near-bottom turbidity generated by the draghead (see Figure 11). Data from the dredge *Markham*, operating in Lake Huron (Pollack 1968), and *Goethals*, operating in Chesapeake Bay (JBF Scientific Corporation 1974), show a wide range of solids concentrations in the overflow and turbidity plumes (see Figure 12). Such data show an exponentially decreasing level of suspended solids with increasing distance from the dredge.

38. Hayes and Raymond (1984). Hayes and Raymond describe a field study of suspended solids generated by the hopper dredge *Essayons* with and without overflow. With no overflow, the suspended solids were not detected above ambient values at the surface or at middepth. A near-bottom plume was reported to be 200 ft wide and 3,500 ft long, with a maximum suspended solids value of 70 mg/ℓ above a previously established ambient. The suspended solids concentration generated with overflow was significantly higher. The surface plume with overflow was reported to be 200 ft wide and 4,000 ft long with suspended solids of 857 mg/ℓ at a point 100 ft from the dredge. This value was reduced to 100 mg/ℓ at a distance of 1,000 ft. The near-bottom plume was reported to be 400 ft wide and 8,500 ft long with suspended solids of 100 mg/ℓ at a distance of 1,500 ft from the dredge.

39. Flocculant injection. Barnard (1978) summarized the results of attempts to introduce flocculants into dredge hoppers to enhance the settling

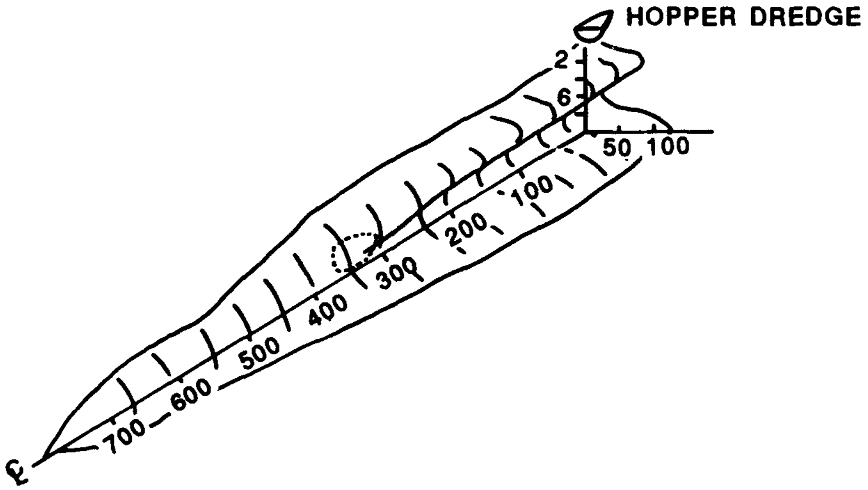


Figure 11. Hypothetical suspended solids plume downstream of a hopper dredge operation with overflow in San Francisco Bay. All distances in metres (USAED, San Francisco 1976)

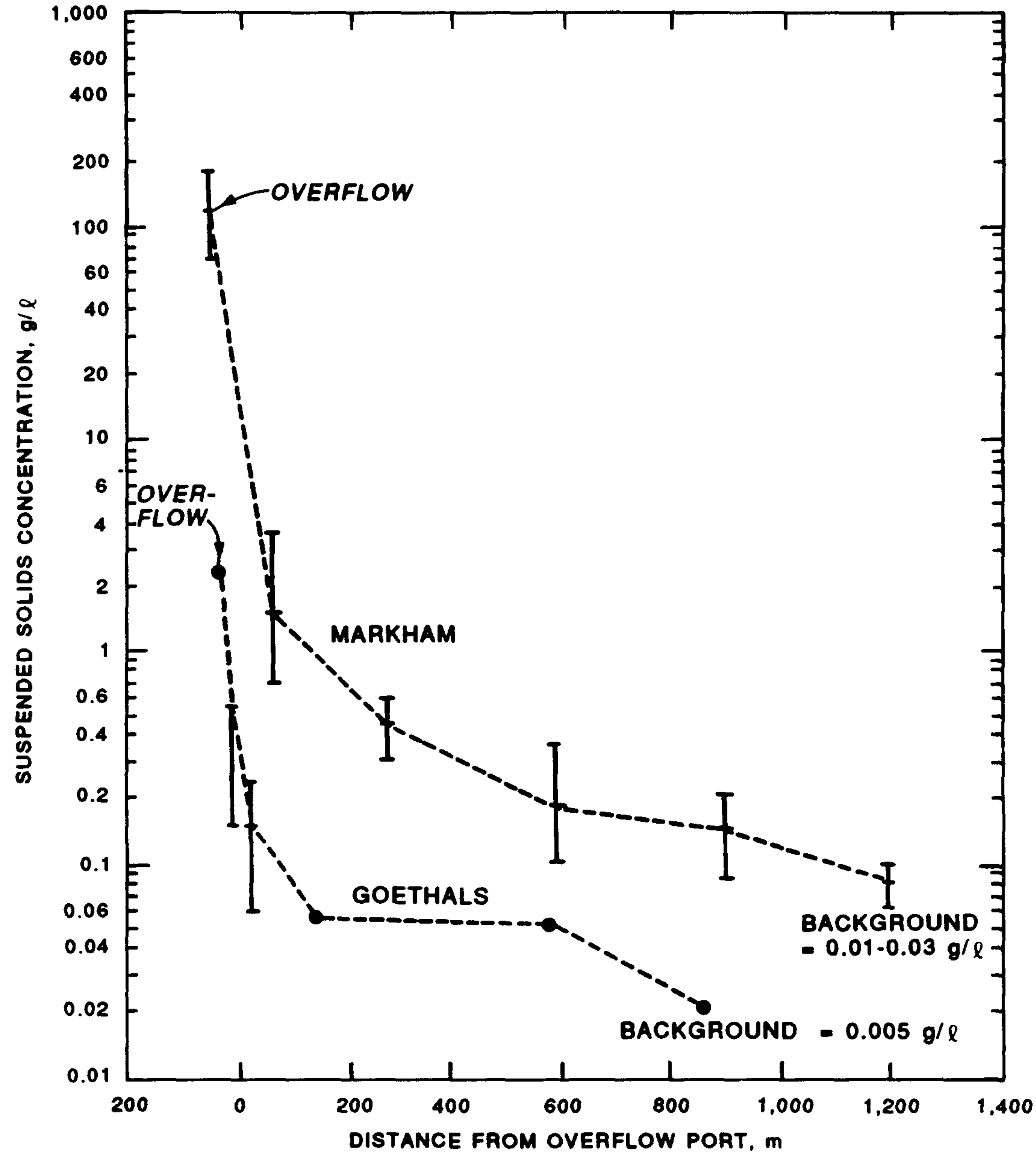


Figure 12. Relationship between concentration of suspended solids in the near-surface plume and distance downstream (Barnard 1978)

and decrease solids concentrations in overflow. These techniques were found to be generally ineffective due to the high solids content of the slurry (USAED, Philadelphia 1969; USAED, Portland 1973). Some benefit may be gained by addition of flocculant in the overflow, which would have a presumably lower solids concentration. Data for tests on treated overflow from the dredge *Markham* showed that a marginal increase in settling rate in the plume was realized (Pollack 1968).

40. Anti-turbidity overflow system. Ofuji and Ishimatsu (1976) report on an anti-turbidity overflow system (Figure 13) that has proved very effective in eliminating the turbidity at the sea surface caused by overflow. A device was designed which suppressed the generation of air bubbles by inserting an inclined baffle plate in the overflow chute. The overflow chute was designed so that it retained the overflow water for a time period long enough for the air bubbles to rise and vanish. Finally, the overflow was discharged through a submerged outlet. The system has been field tested and has proven very effective in eliminating the surface turbidity plume.

Loading and Overflow of Scows

41. Relatively little technical information is available on the loading and overflow of scows. Although several investigators have documented sediment resuspension due to clamshell operations, it is difficult to isolate the

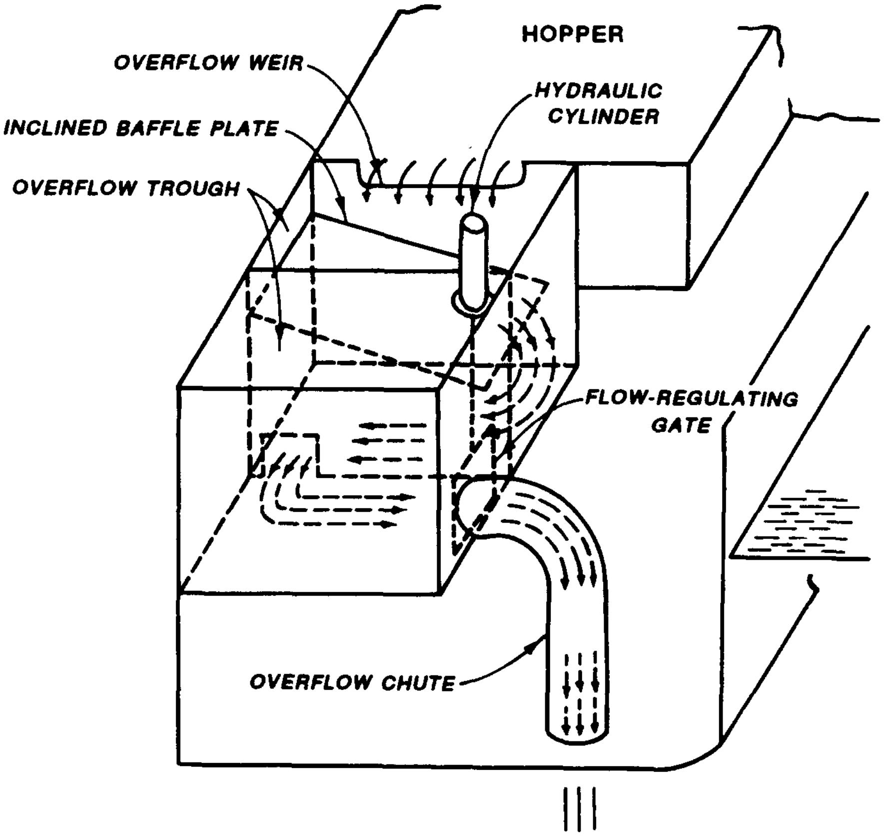


Figure 13. Anti-turbidity overflow system (after Ofuji and Ishimatsu 1976)

resuspension due to overflow and that due to the excavating action of the bucket.

42. Tavolaro (1984) characterized scow 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. It was determined that an average of approximately 2 percent of the dry mass of material placed in the barge will overflow. Tavolaro (1984) drew no conclusions with regard to the load gain achieved in the scows by overflowing.

Environmental Effects of Overflow

43. Concerns raised by resource agencies regarding overflow include potential effects due to increased water column turbidity/suspended solids concentrations, reductions in dissolved oxygen (DO) levels, and/or release of particle-associated contaminants. The effects of settled material on bottom-dwelling organisms have also been mentioned. However, environmental concerns with overflow are generally related to the potential water column effects. Aesthetic concerns about overflow have also been presented.

44. There are few studies focusing solely on the environmental effects of hopper and scow overflow. However, the environmental effects of overflow would logically be similar to those resulting from disposal of dredged material in open water or the resuspension of sediment during dredging operations. Information on such effects is broadly summarized in the following paragraphs.

Turbidity

45. The effects of turbidity/suspended solids have been studied for a variety of biological resources (Stern and Stickle 1978; Lunz and LaSalle 1986; LaSalle, in preparation). In general, turbidity effects are characterized as short term and localized. An exception is the potential for effects on sensitive resources such as oyster beds. Exposure conditions related to overflow operations would generally be less severe than for open-water disposal but may be greater than for resuspension due to dredging.

Contaminants

46. The potential for contaminant release in overflow has been evaluated only on a limited basis. The conditions affecting contaminant release to the dissolved form in overflow would be similar to those for open-water disposal of dredged material. Under such conditions, most contaminants normally present in the sediments would remain strongly associated with particles (Gambrell, Khalid, and Patrick 1978). It should be noted that the finer particles in the range of particle sizes dredged would normally be associated with the overflow. Such fine particles have a greater affinity for adsorbed contaminants.

47. Potential effects of contaminants are summarized in EM 1110-2-5025 (USACE 1983) and Francingues et al. (1985). Contaminant effects on biological resources can be either acute or chronic in nature and may be associated with water column or benthic organisms. There is little evidence of biologically significant release of contaminants from typical dredged material to the water column during or after dredging or disposal operations. Dissolved concentrations of contaminants may be increased somewhat over background conditions for a short time under very specific conditions, but there are generally no persistent, well-defined plumes at levels significantly greater than background concentrations. The potential for bioaccumulation of contaminants is dependent on a variety of factors relating to exposure, sediment and water characteristics, and the organisms involved. Little or no correlation exists between bulk analysis of sediments for contaminants and their environmental impact.

48. Elutriate and bioassay procedures are commonly used for evaluation of contaminant release, toxicity, and bioaccumulation for dredged material disposal (USEPA/USACE 1977). Strategies for their use in management and decision making have also been adopted by the Corps (Francingues et al. 1985; Peddicord et al., in preparation). Such techniques for prediction of contaminant effects are presently undergoing refinement, and their potential application to evaluate overflow effects is not known.

Dissolved oxygen depletion

49. In fine sediments, with little mixing and warm temperatures, dissolved oxygen (DO) reduction may occur with overflow. However, in most cases, DO reduction is not significant. It is a very site-specific issue.

Summary

50. A limited number of studies of hopper overflow dredging have been conducted, and most of those are concerned with loading efficiency. The efficiency of overflow dredging in soft sediments is a function of many interdependent factors. Some of these factors are the fluid flow mechanics inside the hopper, solid-liquid flow mechanics, variation in the physical characteristics of the dredged material, ship motion, location of the overflow structure, density of the slurry, and capacity of the dredge pump.

51. Overflow dredging is beneficial when sand is the predominant material because the settling velocity is high enough for the sand to settle in the hopper. The limiting factor is often the draft of the vessel rather than reaching economic loading through overflow. The practice of overflowing when dredging silt and clay with conventional equipment and procedures is questionable because the particle size and settling velocity are smaller and the solids tend to stay in suspension. Some studies indicate that short times of overflow are beneficial when dredging fine sediments, while others indicate that overflowing does not significantly increase loads for this type of sediment. Modified equipment or operational procedures may be necessary to realize load gains for fine sediment overflows.

52. Technical information on scow overflow is very limited. Factors influencing the character of scow overflow are 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.

53. The potential environmental effects of overflow from hoppers or scows are related to increased water column turbidity/suspended sediment concentrations, lowered DO, and the potential presence of sediment contaminants. Although studies focusing solely on the effects of overflow are limited, the effects of overflow are logically similar to those resulting from open-water disposal of dredged material and sediment resuspension due to dredging.

PART III: SURVEY OF DISTRICT PRACTICES

Methodology

54. This part of the report summarizes the practices of various Corps Districts regarding hopper and scow overflow. The information was initially obtained using the teleconferencing network DREDGENET. More detailed information was obtained in the form of written responses to a survey developed by the Water Resources Support Center, Fort Belvoir, VA. Practices are described only for Corps Districts that accomplish a significant portion of their dredging work with hopper or scow. Results of the survey are summarized in Table 1.

Lower Mississippi Valley Division

55. A large volume of material is dredged annually by hopper dredge in the New Orleans District. No restrictions on overflow are imposed. The data on overflow or loading characteristics are very limited. Agitation dredging is used extensively, especially at the Southwest Pass of the Mississippi River. The District reports that data on overflow could be developed but would be site specific and time specific; i.e., Calcasieu River and Pass and Southwest Pass have different characteristics, and flow characteristics vary with time during the year as well as from year to year.

Ohio River Division

Nashville District

56. The dredging volumes in the Nashville District are relatively small. About half the work is accomplished with hired labor using clamshell dredge and dump scows. No restrictions on the overflow of dredged material from dump scows are imposed. For economic reasons, scows are allowed to slightly overflow.

Pittsburgh District

57. The practice of overflowing loading scows was discontinued in the Pittsburgh District in 1972, when the State of Pennsylvania refused to issue a water quality certification for this activity. The basis for the restriction was turbidity and overall degradation of water quality.

Table 1

Summary of Overflow Restrictions by Corps Division/District

Division/District	Restriction	Basis for Restriction
Lower Miss. Valley		
New Orleans	No restrictions	
Ohio River		
Nashville	No restrictions	
Pittsburgh	Overflow from scows prohibited	Turbidity
North Atlantic		
Baltimore	Overflow prohibited in Maryland waters	Turbidity/ sedimentation/ contaminants
New York	No restrictions for Federal projects	
	Restricted on Hudson River, later relaxed	Contaminants
	Restricted for portions of New York Harbor	Turbidity/ contaminants
Norfolk	No restrictions on deep draft	
	Restriction on Norfolk 45-ft	Economics
	Restricted for bucket/scow	Turbidity/ contaminants
Philadelphia	Overflow restricted	Economics/ turbidity
North Central		
Buffalo	No restrictions	
Chicago	Scow overflow restricted in selected areas	Contaminants/ aesthetics
Detroit	Project-specific restrictions	Contaminants/ aesthetics
North Pacific		
Alaska	No restrictions	

(Continued)

Table 1 (Concluded)

Division/District	Restriction	Basis for Restriction
Portland	No restrictions on entrance channels	
	Project-specific restrictions	Contaminants/ DO depletion
Seattle	Project-specific restrictions	Contaminants/ turbidity/ DO depletion
Walla Walla	Overflow prohibited	Turbidity
South Atlantic		
Charleston	No restrictions	
Mobile	No restrictions on maintenance	
	Overflow prohibited in Mobile Harbor below 45 ft	Turbidity
Jacksonville	Project-specific restrictions	Economics/ turbidity/ sedimentation
Savannah	No restrictions	
Wilmington	No restrictions on entrance channels	
	Overflow prohibited for bucket/scow	Turbidity
South Pacific		
San Francisco	Overflow limited	
Southwestern		
Galveston	No restrictions	

North Atlantic Division

Baltimore District

58. Overflow from hoppers and scows is prohibited for all dredging contracts in the Baltimore District for the Baltimore Harbor and Channels Project in Maryland waters. However, overflow is permitted in contracts for the Baltimore Harbor and Channels Project located in Virginia waters. The restrictions in Maryland waters are generally imposed by the Maryland Department of Natural Resources, the Maryland Department of Health and Mental Hygiene, the National Marine Fisheries Service, the USEPA, and in some instances the US Fish and Wildlife Service.

59. Contaminants are a factor when sediments within Baltimore Harbor are being dredged. In general, overflow restrictions are based upon anticipated increased suspended solids levels in the water column (particularly when contaminants are involved), increased sedimentation on bottom areas such as oyster beds and fish spawning and nursery areas, the physical characteristics and quantity of material to be dredged, and the time of year the dredging is scheduled to occur. The resource agencies reference literature addressing the adverse environmental effects of increased levels of suspended solids in the water column and sedimentation on aquatic resources rather than studies dealing specifically with economic loading to support overflow restrictions.

60. The District has contracted to monitor the overflow of dredged material and resulting turbidity plume from hopper dredges performing new work dredging of the Rappahannock Shoal and York Spit Channels of the Baltimore Harbor and Channels 50-ft Project. The Maryland Environmental Service previously monitored water column turbidity generated by the overflow of dredged material through the skimmers on the dredge *Long Island*.

61. The District has not conducted any studies concerning the benefits of economic loading. However, the District's experience with clamshell and scow operations indicates that, for some contracts, restrictions on overflow have minimal adverse impacts on cost, result in a dredging operation that is more aesthetically pleasing to the public and environmentalists, and result in less sediment being returned to the channel and surrounding area. This is the case for contracts involving (a) shallow disposal areas or access channels to the disposal areas, (b) short haul distances to the disposal site, or (c) an operation in which dredge production and scow size are matched well enough to allow the tugs to return to the dredge before the next scow is filled.

New York District

62. Restrictions on overflow are not usually included in Federal navigation project contracts in the New York District. However, restrictions were recently placed on overflow from hopper dredge operations in the Hudson River Federal channel contract by the State of New York Department of Environmental Conservation (DEC). Also, monitoring was performed for hopper dredge overflow in the Wards Point Reach of the New York and New Jersey channels and for clamshell dredging and barge overflow in Bay Ridge and Red Hook Channels, New York, in lieu of overflow restrictions. In the case of the Hudson River, Wards Point Bend, and Bay Ridge Channel, state regulatory agencies imposed the restrictions or monitoring requirements as part of their Section 401 state water quality certification. The state water quality certificates, which required the monitoring, were made part of the contracts.

63. Overflow is not commonly practiced in some of the shallow recreational harbors in Long Island Sound. This is due to the shallow draft of the channels and because small scows are not generally available. The large scows used would hit bottom if filled to overflow. In the Long Island Sound, the restrictions were therefore self-imposed as an operational consideration because of draft limitations.

64. For the Hudson River dredging, "State Water Quality Standards" were the basis of the restriction. In past years, DEC had little experience with hopper dredge operations and dredging impacts in general. The water quality standards applied were therefore the standards normally applied to point sources. The District argued unsuccessfully that these standards were inappropriate for dredging operations. Particularly troublesome were standards for suspended solids (400 mg/ℓ) and settleable solids (0.1 ml/ℓ). This issue was resolved when the DEC agreed with a proposal to allow overflow provided the state standard for turbidity (500 JTU) was not exceeded.

65. For Bay Ridge Channel, the DEC had very general concerns that turbidity plumes would be extensive and undermine state water quality standards. For Wards Point Bend, the New Jersey Department of Environmental Protection was concerned that nutrient release from the hopper overflow could trigger a regional algal bloom or "red tide" in Raritan Bay.

66. For the Hudson River, monitoring of the overflow was conducted which demonstrated that water quality impacts were insignificant. As a result, the overflow restrictions were greatly relaxed by the state.

67. For Bay Ridge Channel and Wards Point Bend, monitoring of turbidity and nutrient release was performed (Tavolaro and Mansky 1985). As a result, monitoring of these two dredging projects has not been requested again.

68. The New York District has not studied the economic benefits of scow or hopper overflow; however, it is a common practice and is perceived to have economic benefit in most cases.

Norfolk District

69. Hopper overflow is allowed on all deep-draft channels within the Norfolk District, with the exception of the Norfolk Harbor 45-ft channel, where the prohibition is self-imposed for economic reasons. For this project, the prohibition is placed in the project plans and specifications.

70. The State of Virginia does, however, prohibit overflow as a matter of routine for clamshell and scow work. The basis for this prohibition is turbidity and the presence of contaminants. The District has limited scow work and deals with the prohibitions on a project-specific basis, having some success in getting restrictions lifted.

71. The Norfolk District placed restrictions on overflow, but only where there are no known economic benefits for overflowing. Restrictions are self-imposed for known economic reasons. The District has successfully resisted attempts by other agencies to arbitrarily impose restrictions by citing conclusive research on the impacts of turbidity and by conducting a monitoring program. In cases where material is extremely fine, there are no known benefits to overflow. Hence, overflow is not allowed.

Philadelphia District

72. Overflow of hopper dredges and scows is not permitted in any Philadelphia District dredging contracts. The Philadelphia District implemented a self-imposed program of no overflow in 1969 in the Delaware River. Since 1974, the District has included this restriction in public notices pursuant to Section 404, for all deep-draft navigation channels.

73. When this restriction was first imposed, it was done on the basis of reducing turbidity in the Delaware River. The Delaware River is a closed system, and the turbidity in the water resulted in reformation of shoals in the navigation channel. Over the years, the reduction of open rehandling and overflow in the Delaware River has decreased the yardage of dredging from 25 million cu yd/year to 4 million cu yd year. A similar rationale was applied in extending this policy to all other major District waterways. The material dredged is primarily light to medium silt; therefore, the benefit of

pumping beyond overflow is not as great as it would be with sand. Approximately a 10-percent increase in hopper loads is estimated to result by pumping beyond overflow on these projects.

North Central Division

Buffalo District

74. There are no restrictions on hopper or scow overflow in the Buffalo District. Hopper dredges are used on the Buffalo, Toledo, and Rochester projects, but the contractors do not overflow to any degree because the sediments are primarily fine-grained.

75. Resource agencies in the area have voiced objections to overflow because of perceived problems related to turbidity and the presence of fecal coliforms in the sediments (indicative of the possible presence of pathogens). The Buffalo District has recently completed a study of hopper overflow at Rochester in which samples of the overflow were taken.

Chicago District

76. Most of the dredging in Chicago District is mechanical with scows. Overflow is allowed for sediments destined for open-lake disposal, but overflow is restricted in urban areas and in instances where sediments are contaminated. In such cases, the sediments are rehandled mechanically into confined disposal facilities (CDFs). These restrictions are self-imposed by the District, but there is little data to support the need for the restrictions. In recent years, the District has allowed the contractor to fill a scow to overflow, let the scow stand for several hours, and then pump the surficial water from the scows to allow additional loading. This practice did not prove successful because little settling occurred in the surficial water for the fine-grained sediments involved.

Detroit District

77. The Detroit District self-imposed overflow restrictions as a positive step to keep dredging programs active in lieu of having agencies unfamiliar with the dredging process impose standards. No overflow was allowed in dredging areas containing sediment with polychlorinated biphenyls over 10 ppm and mercury over 1 ppm. The State of Michigan revised the Section 401(a) water quality certification in 1989 to restrict overflow in areas where polychlorinated biphenyls were over 1 ppm.

78. A study of overflow dredging in the Saginaw River was conducted in 1987. The study indicated that fine-grained sediments were released in the overflow but settled within 30 min of the passing of the dredge; however, the amount of overflow that occurred was limited. Monitoring of overflow dredging will be considered at the Saginaw River during future maintenance dredging.

79. The Detroit District does not compute the economic load data for contract hopper dredges. Overflow is allowed, provided the load increases significantly during the process. When the District operated Corps-owned hopper dredges, the standard economic load data provided only a part of the data needed for determining economic loading. With the elimination of most open-water disposal and especially convenient disposal locations, the economic dredging cycle for projects became the District's most useful tool. Minutes per cubic yard for a complete cycle became the most important measure of performance, and cubic yards retained per pumping minute was only one of several factors that had to be considered.

North Pacific Division

Alaska District

80. The Alaska District does not include any form of overflow restriction in its dredging contracts. Historically, a portion of the contract dredging has been accomplished by means of a clamshell dredge. No problems with scow overflow have been reported.

Portland District

81. The Portland District does not restrict overflow of hopper dredges at any of the coastal entrances, the Columbia River, the Umpqua River, or in most of Coos Bay. Overflow is restricted at river mile 14 to 15 in Coos Bay due to a concern regarding DO levels. This is at the upper end of the project with generally low flows. Overflow may be restricted in the future in Portland Harbor, river miles 8-11 of the Willamette River, depending on the results of tests for contaminants. Portland District has not made a distinction in overflow requirements for hopper dredge versus clamshell and scow operations.

82. Limits are self-imposed on overflow for the *Essayons* and *Yaquina* when working in silt materials for economic cycle. Economic load evaluations for the *Essayons* and *Yaquina* in sand and silty sand environments are planned.

Based on evaluation of load groups, the District does not consider overflow economical for silt.

Seattle District

83. In the Seattle District, overflow restrictions are imposed for dredging in Inner Grays Harbor and Lower Chehalis River. Water Quality Guidelines issued by the Washington State Department of Ecology are a part of the contract specifications for the annual Grays Harbor maintenance dredging contract, which involves hopper dredging of some 1.5 million cu yd. The Guidelines call for water quality conditions both inside and outside an established hopper dredge dilution zone and physical operational controls so no discharge is above the water surface. A contract requirement restricts pumping time on inner harbor and river work to 75 percent or less of the time required for the outer harbor (more sandy material) dredging. This requirement is established for the specific dredge and does eliminate agitation dredging of the fine sand silt in the inner project area.

84. The restrictions were developed by the State, based on Corps, USEPA, Port, and dredging industry input. These guidelines have been supplemented and revised as new information becomes available. An example is the increased hopper dredge operating period in the inner harbor by lowering the Chehalis River flow limit from 2,000 to 1,500 cfs.

85. The basis of the guidelines is the protection of the fishery resources of Grays Harbor. This harbor has a history of poor water quality, due to industrial discharges and low summer riverflow. The specifics as to DO criteria, dilution zones, dredging area limits, and the operating period based on riverflows were developed from field monitoring and other data.

86. Monitoring conducted by the Seattle District has not focused on the overflow itself, but rather the associated dredging/overflow-related water quality impact. Some monitoring of settleable solids in the overflow versus loading time has been conducted. However, considering the variation in material and contractor plant, the data cannot be used for determining actual impacts.

Walla Walla District

87. Hopper dredges have been used for work above the Lower Granite Dam. In dredging efforts during 1986 and 1987, the contractor was not allowed to overflow the hopper dredge. With agreement between the Washington State Department of Ecology (WDOE) and the contractor, two overflow "tests" were conducted during the 1986 project. This amounted to two hopper barge loads

and was conducted along with water quality monitoring by the District, WES, WDOE, and the University of Idaho.

88. The overflow restriction was imposed by WDOE as part of the conditions in the water quality certification and standards modification. These restrictions reflect concerns and input from various state and regional resource agencies and Indian tribes. Their objections were not supported with data to substantiate the request. However, because the projects were vital for flood control and navigation, the decision was made to assume the extra cost rather than lose time in lengthy studies on the effects of overflow.

89. Prior to the 1986 dredging, no hopper dredging had occurred in the Walla Walla District; therefore, an overflow operation had never been encountered. The District dredging policy in the confluence area of Clearwater River had included strictly upland disposal of sediments (a restriction imposed by the resource agencies). When an overflow operation was requested by the contractor for the 1986 dredging, it was immediately viewed as a type of in-water disposal and was not allowed. However, WDOE recognized the advantages of overflow and that available information on this type of operation was minimal. The WDOE agreed to allow an overflow test and, depending on the results, to possibly permit future overflow. The primary concern with in-water disposal (and overflow) at the time (1986) centered around the potential for impacts to an extremely sensitive system involving migrating anadromous fish.

South Atlantic Division

Charleston District

90. The Charleston District does not restrict overflow when hopper dredges are loading dredged material. This overflow policy applies both to contract and Government dredges. The District does not have data that describe the nature (physical or chemical) of the overflow; however, the District feels that liquid and suspended sediment phase bioassays that have been conducted on materials from the channel bottoms approximate the conditions that exist around an overflowing hopper dredge. The District does not have data describing the economic loading benefits associated with overflow.

Mobile District

91. Currently, the only dredging involving hopper loading in the Mobile District is conducted for maintenance of Gulf entrance channels. The

maintenance material is predominantly sand. The hoppers are allowed to overflow to economic load. This has been conducted with no significant environmental objections. No detailed studies have been conducted to determine the environmental impacts of the overflow operation due to the sandy nature of the dredged material and the nearness of the disposal areas to the dredging site.

92. Future deepening of Mobile Ship Channel, which includes dredging in Mobile Bay and the Gulf Entrance Channel, will also involve scow loading and transport of the material to the Gulf of Mexico. Traditionally, the Bay channel has been maintained by hydraulic pipeline dredge with placement of the material in open-water disposal areas adjacent to the channel. The decision for Gulf disposal of the deepening material and future maintenance material was based on the physical space required for the large amount of new work material and the strong environmental objections to continued open-water disposal of dredged material in Mobile Bay. "No overflow" was included in the plan as an environmental benefit; also, it was uncertain if overflow of the fine-grained bay material would result in a better economic load. The District is currently developing overflow test studies to determine loading characteristics and environmental impacts. These tests are a joint effort with the USEPA, Region IV. The WES is providing assistance in the overflow tests.

Jacksonville District

93. In the Jacksonville District, hopper/barge and clamshell operations are restricted from overflowing in some areas with predominantly silty materials. In some cases, the restrictions are self-imposed by the District for economic reasons. Past experience with Government hopper dredges working in the District indicates that, when hopper dredges overflow in a high-silt content material, the load of material is not substantially increased and turbidity is increased. The Florida Department of Environmental Regulation has also placed restrictions on the basis of turbidity and the presence of grass beds in the vicinity.

Savannah District

94. No restrictions on overflow are included in hopper dredging contracts. Due to the grain size of the material and the characteristics of the equipment used, overflow does improve the economic load.

Wilmington District

95. In the Wilmington District, hopper dredges are used primarily for ocean inlet-bar channel areas. No overflow restrictions are imposed.

96. Clamshell dredge/scow was used for the first time by the Wilmington District in Fiscal Year 1987. The State does not allow overflow of the transportation barges. The barge overflow restrictions are imposed by the North Carolina Division of Environmental Management through the denial of required Section 401 water quality certificates. Without a water quality certificate, the North Carolina Division of Coastal Management will not find the activity consistent with the North Carolina Coastal Management Program.

97. The overflow restriction is based primarily on turbidity and concerns about the potential effects on estuarine resources. The State water quality standard for turbidity for estuarine waters is 25 NTU (or discharge cannot increase turbidity above ambient if ambient is less than 25 NTU). The District has estimated that barge overflow will cause an increase in turbidity in receiving waters above State water quality standards and has indicated that an appropriate mixing zone must be established. The effect of overflow-caused turbidity on estuarine resources within the mixing zone remains as unresolved issue.

South Pacific Division

98. The San Francisco District has a specification clause that limits overflow from hopper dredges to 15 min. The paragraph reads as follows:

> Overflow Time. During hopper dredging, the time of overflow of water and dredged material from hopper bins shall be limited to the most economical load based on hopper load charts for hopper dredges, but in no case longer than 15 minutes. During clamshell or hydraulic dredging, the time of overflow of water and dredged material from the receiving barge or dump scow shall be limited to 10 percent of the time required to fill the container to the point of overflow, or 15 minutes, whichever is less. During transport to the disposal site, water and dredged material shall not be permitted to overflow or spill out of barges, hopper bins or dump scows. Containers having more than 10% loss in either draft or volume while transporting material to disposal site shall not be further utilized until repaired.

99. These restrictions are self-imposed by the District and are based on a combination of limitations that will provide an economic load and also control turbidity. Previous projects using Government hopper dredges indicated the 15-min overflow would produce an economic load, although this could vary from project to project.

100. To date, density and gradation are the only physical overflow items that are monitored. By monitoring the overflow, the contractor's

efficiency can be improved. By using the overflow information based on density, the contractor is able to determine when overflow has reached an optimum hopper density, at which time overflow is stopped. However, the contractor may also overflow less than the time specified.

Southwestern Division

101. Galveston District reported that no overflow restrictions are imposed and overflow data are not collected. However, water, sediment, elutriate, and grain-size data are collected prior to dredging.

Summary

102. The survey of District practices indicates that the question of economic loading and overflow is governed by both project-specific considerations and restrictions imposed by resource agencies. Of 21 Districts considered to have a significant hopper or scow dredging workload, 4 report restrictions for all work, 10 report restrictions for specific projects, and 7 report no restrictions.

103. In four cases, the restrictions were self-imposed for economic reasons. In all cases, these restrictions were imposed because it was felt that no load gain could be realized when dredging fine-grained sediments with hopper dredges. The consensus was that load gains could be obtained when dredging coarse-grained sediments. Data describing the loading gains achieved were few.

104. The majority of the restrictions were requested or imposed by resource agencies based on environmental concerns. The concerns forming the basis for the restrictions varied, and more than one was cited in many cases. These concerns included turbidity (cited in 10 cases), the presence of contaminants (8 cases), aesthetics (2 cases), and dissolved oxygen (2 cases). In no case were project-specific data on overflow effects available to support the need for restrictions. However, in several cases, the Districts indicated that resource agencies cited the open technical literature on the effects of turbidity or contaminants on resources as a basis for overflow restrictions.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

105. This part presents conclusions and recommendations related to economic loading and overflow based on the survey of District practices and the review of technical literature.

106. Major issues/questions relating to overflow are:

- a. Can a load gain be realized (and an economic load subsequently determined) if overflow is used under a given set of operational conditions for fine-grained material?
- b. What are the characteristics of the overflow and what are the potential environmental effects due to turbidity, increased suspended sediment concentration, lowered dissolved oxygen, or the presence of sediment-associated contaminants?

107. The decision to allow or prohibit overflow in a given case should be based on an evaluation of these questions. Unfortunately, arriving at a decision requires an evaluation of the trade-offs between potential economic benefits and potential environmental effects.

Loading Gains

Conclusions

108. The degree to which a load gain can be achieved by overflow of a hopper or scow is dependent on the characteristics of the material being dredged, the method of dredging (hydraulic or mechanical), and the design of the equipment used. Further, each of these considerations is interrelated in that the net effect on load gain is different for each combination of equipment and sediment type. Existing Corps guidance on economic loading is limited to description of the economic load test. However, use of such load test data in making decisions regarding overflow appears to be limited. There is no routinely applied method to predict the potential load gain achieved by overflow under a given set of conditions.

109. Hopper dredges operating in maintenance material. There is little question that loading gains can be achieved when hopper dredges are removing coarse-grained maintenance sediments (those with significant fractions of sand). However, there is uncertainty as to whether significant loading gains can be achieved when hopper dredges are operating in fine-grained maintenance sediments. The dominant viewpoint in the technical literature and evidenced

in the District survey is that practically no load gain can be achieved for this condition with existing equipment.

110. Hopper dredges operating in new work material. Hopper dredges are sometimes used for excavating new work material when the appropriate draghead is used. If the new work material is a consolidated clay with sufficient shear strength, some portion of the material will enter the hopper as intact clay balls. These balls settle quickly and accumulate in the hopper during overflow operation, allowing a load gain to be realized even though the material is considered fine-grained. The conditions required for formation of clay balls during dredging are not well documented.

111. Influence of hopper/loading system design. The degree to which material is retained in the hopper is sensitive to the design of the loading system and hopper. In recent years, strides have been made in dredge design to increase material retention. Dredges may be equipped with multiple inflow points, inflow points at multiple levels within the hopper, and various baffling or similar arrangements to reduce momentum and improve conditions for settling within the hopper. The details of such design features may be proprietary in nature.

112. Clamshell and scow. As compared with hopper dredges, relatively little is known of the load gains realized by scow overflow. The nature of the mechanical dredging operation allows the sediment to be removed in close to its in situ condition. This would hold true for both fine- and coarse-grained material and for both maintenance and new work material. Only residual water in the barge at the beginning of filling and excess water brought up with the bucket is overflowed. However, the solids content of scow overflow for various sediment types and operating conditions is not well documented. Since the mechanically removed material tends to clump, it is obvious that load gains can be realized by overflowing the excess water. Also, for some materials, it is possible to "stack" the material in the scow above the top of the gunnels, achieving further load gains.

Recommendations

113. The following recommendations regarding economic loading are made:

a. Develop techniques to predict the potential load gain in hoppers and scows under various conditions, which will provide guidance on when overflow can potentially achieve load gains.

b. Develop equipment and techniques to improve the efficiency of retention of material in hoppers and scows. This is a planned effort under the Dredging Research Program.

c. Exchange existing information (such as load test data) regarding when and to what degree load gains are achieved in hoppers and scows under various conditions.

Overflow Characteristics

Conclusions

114. Turbidity/suspended solids. The concentration of suspended solids in the overflow is dependent on the same parameters as the potential load gain. Obviously, the higher the relative gain in load, the lower the solids concentration in the overflow. The subsequent extent of water column turbidity and bottom deposition due to overflow is dependent on site-specific hydrodynamic conditions. There is presently no technique to predict the characteristics of overflow with respect to solids concentration or associated turbidity under a given set of conditions. For this reason, it is not possible to make a before-the-fact prediction of the overflow characteristics without performing extensive laboratory tests and numerical calculations.

115. Contaminants. The potential for contaminant release in overflow has undergone only limited evaluation. The conditions affecting contaminant release to the dissolved form in overflow would be similar to those for open-water disposal of dredged material. However, as for open-water disposal conditions, most contaminants normally present in the sediments would remain strongly associated with particles in the overflow. It should be noted that the finer particles in the range of particle sizes dredged would normally be associated with the overflow. Such fine particles have a greater affinity for adsorbed contaminants. Although elutriate procedures have been developed for evaluation of contaminant releases for dredged material disposal, their potential application to evaluate overflow is not presently known.

116. Environmental effects. The potential environmental effects of overflow are due to increased water column turbidity/suspended solids concentrations, settlement of suspended solids on benthic resources, DO reductions, and/or release of particle-associated contaminants. There are no known studies focusing solely on the environmental effects of hopper and scow overflow. However, the environmental effects of overflow would logically be similar to those resulting from disposal of dredged material in open water or the resuspension of sediment during dredging operations. In most cases, turbidity effects may be characterized as short term and localized. An exception is the

potential for effects on sensitive resources such as oyster beds. The exposure of such resources as a result of overflow operations would generally be less than for open-water disposal, but may be greater than for resuspension due to dredging.

117. Elutriate and bioassay procedures have been developed for evaluating contaminant release, toxicity, and bioaccumulation during dredged material disposal. Such techniques for prediction of contaminant effects are undergoing refinement, and their potential application to evaluate overflow effects is not known. However, the belief is that contaminant release does not generally occur.

Recommendations

118. The following recommendations regarding overflow characteristics are made:

- a. Develop guidance on prediction of overflow suspended solids concentrations, DO reduction, sedimentation effects, and contaminant concentrations under a variety of operating conditions.
- b. Evaluate existing and/or develop new tests and procedures for predicting the environmental effects and potential impacts of overflow on biological resources.

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