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Dredging Methods and Equipment

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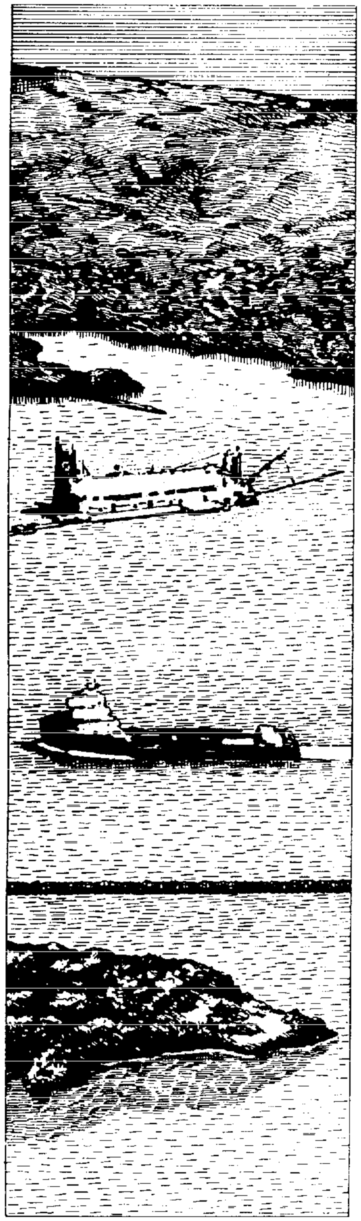

DREDGING RESEARCH PROGRAM

TECHNICAL REPORT DRP-95-10

DREDGE PLANT EQUIPMENT AND SYSTEMS PROCESSES; SUMMARY REPORT FOR TECHNICAL AREA 3

compiled by

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6 Synopsis

The research described in this report pertained to the improvement of debris resistance of eductors (jet pumps) for sand bypassing and evaluation of the concept of water-injection dredging, the conceptual design of a single-point mooring DPO facility for Corps hopper dredges, improved technologies for hopper-dredge production and process monitoring, and design modifications to hopper-dredge dragheads to increase production.

Improved Eductors for Sand Bypassing

One goal of the research program was to design an eductor that would maintain good performance in various types of debris. Submersible pumps appeared to offer several positive features that made them potentially attractive as eductor alternatives in special locations. Fluidizers are buried perforated pipes through which water is pumped and released from orifices, causing the overlying sand to liquify and flow toward the eductors.

Eductors and submersible pumps

Eductors are hydraulic pumps with no moving parts. They operate by using a supply (motive) water pump to provide high pressure flow at the eductor nozzle. As the jet contracts the surrounding fluid, momentum is exchanged in the mixer as the jet slows while it accelerates the surrounding fluid, entraining additional fluid into the jet. As the surrounding fluid is entrained by the jet, it pulls in additional fluid from outside the eductor.

Submersible centrifugal pumps are typically single-stage vertical pumps with discharge diameters that range from 4 to 12 in. Submersible pumps differ from conventional dredges in that the submersible pump is placed directly in the material to be removed. Obviously, the smaller and lighter the submersible pump, the greater the number of deployment options. Submersible pumps (depending on the deployment method) can be easily maneuvered into areas of limited access. A primary advantage of submersible pumps over eductors is that they do not require a clean-water source.

Field tests of eductors and submersible pumps

The objective of these controlled field tests was to determine the comparative production rate of the DRP eductor, the IRI eductor, and two commercially available submersible pumps (H&H Pump Company, Model PF50x8, and Toyo, Inc., Model DP-150B) under conditions similar to those in a coastal environment. Tests were conducted in clean sand and in a series of different debris combinations similar to those expected on open-ocean coasts.

In clean sand, performance of the DRP eductor and the IRI eductor was about the same. Performance in debris was a function of the type of debris. The grate and fluidizers on the DRP eductor allowed better production in stone and garbage bags/swim fin debris than the IRI eductor; however, the DRP eductor grate was more prone to clogging with wood than the IRI eductor. The H&H pump as tested was not well-suited to the types of debris tested. It was very susceptible to both rocks and wood. The Toyo pump performed the best overall and was only bettered by the IRI eductor when pumping in wood debris.

Field tests comparing production of the DRP eductor and the IRI eductor also were conducted at the existing IRI eductor location at Indian River Inlet, DE, sand-bypassing plant. The DRP eductor performed slightly better than the IRI eductor by about 11 percent without considering other factors.

Fluidizers

Fluidization is a process in which fluid is injected into a granular medium (typically sand), causing the grains to lift and separate. The design objective for a fluidization system is primarily to create a trench of a given cross section and length. The detailed procedure for designing a fluidizer system has been given by Weisman, Lennon, and Clausner (in preparation), including a family of design curves for choosing the appropriate flow rate based on the relative depth of burial of the pipe with respect to pipe diameter and on the relative particle size with respect to trench dimensions.

Water-Injection Dredging

WID is a concept new to the United States where shoal sediment is fluidized, causing it to flow by density or riverine currents to deeper areas where it does not affect navigation. WID is based on a simple concept: vessel-mounted pumps inject water directly into the sediment voids through low-pressure jets mounted on a long horizontal pipe. This fluidizes the sediment, creating a gravity-driven density current that can flow down very mild slopes. The density current transports shoal material to deeper water where it can settle without impeding navigation or will be carried farther away by stronger natural currents.

The DRP's mission of investigating new dredging technologies led successfully to the first prototype field demonstration of WID in the United States. Application in sand greater than 0.2-mm diam will be very site-specific, requiring nearby deeper water and a smooth downslope gradient. The lack of pipelines and swing wires greatly increases mobility of a WID vessel and reduces disruption of normal navigation traffic to a minimum. Routine use of WID in areas where in-water disposal is not normally practiced will require additional considerations.

Dredging Equipment for Nearshore/Onshore Placement

The Corps desired the capability for DPO of hopper dredges in open water to be able to respond to national emergencies (such as hurricanes) where the ability to quickly place sand on the beach is needed. Significant amounts of material dredged by the Corps could also be used beneficially if easier and less expensive means were available to deliver the dredged material to a site where it could be used.

DPO is a method of removing dredged material from hopper dredges, where the dredge moors to an anchored floating structure, buoy, or multiple buoy berths. An underwater pipeline extends from the DPO buoy to shore. Hoses are connected from the DPO buoy to the hopper-dredge discharge manifold. The dredge mixes the dredged material with water to form a slurry and pumps the slurry from its discharge manifold through the hoses to the anchored floating DPO buoy and on through the underwater pipeline toward shore (Clausner 1992a).

Design criteria

Design loads and system analysis were based on the displacement and draft of the largest of the Corps hopper dredges, the *Wheeler*. The maximum design mooring load was determined to be 100 kips. The system was designed for operation in a water depth of 30 to 45 ft; however, operation is possible in water depths up to 75 ft with a slight reduction in capabilities.

The CALM system was selected because of the ability to transport the components in truck-size packages and reassemble quickly. Also, it proved to be the least costly of alternatives to fabricate. The system is anchored by four anchor chains that are arranged 90 deg apart.

DPO buoy system

The DPO buoy is a capsule-shaped buoy that is 28 ft long by 11 ft 6 in. wide by 7 ft 6 in. deep. Although not the conventional shape of a mooring buoy, the shape was chosen to facilitate towing the buoy and placement on flatbed trucks. The buoy can be disassembled into four components: buoy hull, fluid piping, fluid swivel, and mooring table. The buoy hull serves as the foundation for the fluid piping.

The CALM system can be transported by truck, rail, or barge to the assembly location. Components of the system can be consolidated and transported on standard flatbed tractor-trailer rigs. The entire system can be transported by as few as seven trucks. For ocean transport, the entire system also can be arranged on a standard 60- by 120-ft cargo barge.

Technology for Monitoring and Increasing Dredge Payloads for Fine-Grain Sediments

Dredge hoppers and scows are commonly filled past the point of overflow to increase the load. Some Corps Districts routinely allow overflow to increase the load, while others do not because of actual or perceived environmental and/or economic reasons.

Economic loading and overflow of dredge hoppers and scows

Economic load is defined as 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. 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.

Methods to increase hopper-dredge payloads

As an alternative to overflowing a hopper to increase bin load, the objective of an investigation by Scott, Pankow, and Pratt (1992) was to evaluate the effectiveness of selected devices and techniques for increasing the fine-grained sediment payload in dredge hoppers.

Diffuser tests. A variety of diffuser designs were tested with the two kaolinite clay mixtures for various inflow rates into the hopper. Kaolinite clay was used as the test medium because it represented the finest sediment size found in prototype dredge hoppers and, therefore, the most difficult to settle out of suspension. Test results indicated very little or no economic load gain from the use of these devices for the two kaolinite clay mixtures tested.

Hydrocyclone tests. These devices were designed to concentrate the slurry solids before they are introduced into the hopper. Test results indicated that the hydrocyclone device was not successful in increasing the solids load in the hopper when used with a kaolinite clay suspension. Hardware requirements and subsequent required alterations to a working hopper dredge were not economically justifiable.

Inclined plate tests. Tests were reported by Scott, Pankow, and Pratt (1992) that investigated the effect of inclined baffle plates in a model hopper bin on the loading of fine-grained sediments. The inclined plates in the model hopper occupied only a small portion of the available volume, but added substantial weight to the hopper. For a practical application, it would be necessary to fabricate the plates out of low-density plastics or composite materials such as graphite-epoxy that possess the material strength and abrasion resistance to survive in a dredge-hopper environment.

Technologies for Hopper-Dredge Production and Process Monitoring

Objectives of the research by Scott et al. (1995) were to design, test, and implement hopper dredge monitoring systems to reliably calculate hopper dredge production based on both the average and direct methods of hopper density measurements. To meet these objectives, two monitoring systems were developed: (a) a monitoring system based on the average measurement of hopper density determined from the bin measure approach, and (b) a system for directly measuring slurry density in dredge hoppers based on the concept of electrical resistivity of sediments.

Automated load monitoring system

The ALMS method for determining average density in a dredge hopper is accomplished by measuring two dredge parameters: (a) the level of dredged material in the hopper, and (b) the draft of the dredge (Scott 1992b, 1994). The two instrumentation systems measure real-time hopper volume with two acoustic sensors and dredge displacement with two pressure transducers in the air bubbler lines. With the dredge ullage table, which relates hopper depth to hopper volume, the depth of material in the hopper can be converted to volume. The draft can be related to vessel displacement with a draft/displacement table typically available from the shipyard. The total weight of material in the hopper is equal to the weight of bin water in the hopper before the load is taken plus the slurry load added. This total weight divided by the volume that the material occupies in the hopper is the average density of the material in the hopper.

Electrical resistivity method

Density measurements using the resistivity principle involve introducing a current source through electrodes into a medium and measuring the potential across electrodes within the vicinity of current flow. Resistivity is defined as a function of input current, measured potential, and electrode configuration. For the resistivity probe developed by Scott (1992a), an array consisting of evenly spaced electrodes placed in a line is used. Four of the electrodes are utilized at any one time. Current is introduced into the two outer electrodes of the four being used at that time, and the potential is measured between the two inner electrodes. The electrical resistivity probe was installed and successfully demonstrated for field use onboard the hopper dredge *Wheeler*.

Improved Draghead Design

Dragheads presently used on hopper dredges do not maintain an optimum production in varying bed material types at various depths. The objectives of research by Brogdon, Banks, and Ashley (1994) were to develop more effective draghead designs for use in navigation channels consisting of compacted fine sands. Two different evaluations were conducted: (a) water jets with blades as a draghead enhancement device, and (b) a draghead fitted with uniform slots to enhance hydraulic efficiency to induce more material entrainment into the draghead.

Water jets and blades design

Laboratory tests to evaluate the effectiveness of water jets and blades to increase hopper-dredge production were conducted at WES in a flume 60 ft long, 10 ft wide, and 4 ft deep, with one section of a prototype-size model of the California-style draghead used on the hopper dredge *Wheeler*. The full-scale sectional model of a prototype draghead was used to alleviate similitude problems associated with scaling, especially those concerned with blade/bed material interactions and scaling of bed material particles. The sectional model of the draghead was 30 in. wide and 29 in. long, with one slot.

Test bed preparation. Gradation of the bed material tested closely matched the general characteristics of a typical dredging area. The D_{50} size of the test material was 0.075 mm (fine sand). The bed material was placed in the flume to a depth of 1.0 ft. Preparation of the bed prior to testing involved several steps, including compaction to desired density. Following final grading of the bed, cone penetrometer readings were taken at several locations in the bed test section to ensure compaction approximated prototype materials commonly found in Aransas Pass, TX.

Test results. All tests were conducted at constant speed (1 mph), and the results are presented by Brogdon et al. (1994) in terms of volume of material removed from the test section during passage of the draghead. Test results show that water jets with no blades (knives) can significantly increase dredging production when the dredge is operating at slow speeds. The addition of knives placed in front of water jets operating at different pressures further increases the efficiency of the dredging process.

Uniform-slots design

The objective of research by Banks and Alexander (in preparation) was to determine the feasibility of using a uniform placement of inflow slots around the perimeter of a California-style draghead to enhance dredge production.

Test program. Effectiveness of the inflow slots was evaluated by comparison of the production provided by an unmodified 1-to-6 model-to-prototype scaled model of a California-style draghead with the same style draghead enhanced by the addition of uniform slots (Uniform-Slot draghead) to provide better hydraulic entrance conditions and reduced energy head loss at the draghead. Comparison data for ascertaining which of the two model dragheads performed best consisted of determining the volume of bed material removed by the two different dragheads under identical test conditions in the laboratory facility.

Test results. Average results were obtained from 10 identical test runs each (average of 30 cross-section profiles) for the California-style draghead in the horizontal position (CALF), the California-style draghead in the 15-deg down position (CALD), the Uniform-Slot draghead in the horizontal position (USDF), and the Uniform-Slot draghead in the 15-deg down position (USDD).

The CALF draghead tests removed an average 1.897 cu ft of bed material from the 10-ft test section. The CALD draghead tests showed that an average of 2.923 cu ft of bed material was removed from the test section. The USDF draghead tests removed an average of 2.144 cu ft of bed material from the test section, while the USDD draghead tests removed an average of 2.525 cu ft of bed material.

The Uniform-Slot draghead in the horizontal position removed about 13 percent more bed material than the unmodified California-style draghead in the horizontal position. The Uniform-Slot draghead in the 15-deg down position removed about 33 percent more bed material than the unmodified California-style draghead in the horizontal position.