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PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL DREDGING SEMINAR AND WEDA XIII ANNUAL MEETING

May 26-29, 1992
Mobile, Alabama

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*Manuscript not received.

TWENTY-FIFTH ANNUAL DREDGING SEMINAR

Stouffer Riverview Plaza, Mobile, Alabama
May 27, 1992

PROGRAM

May 27, 1992

8:15 - 3:00	REGISTRATION
	Moderator: Dr. John B. Herbich, Texas A&M University
9:00 - 9:35	**Comparative Assessment of DGPS Versus Microwave Ranging Positioning for Bathymetric Real Time Surveying** - J. Patterson, Mobile District, U.S. Army Corps of Engineers, Mobile, AL
9:35 - 10:10	**A Single Point Mooring for Direct Pump-out of Hopper Dredges** - W.A. Herbrich, SOFEC, Houston, TX and J.E. Clausner, USAE Waterways Experiment Station, Vicksburg, MS
10:10 - 10:45	**Break**
10:45 - 11:15	**Promising Technologies for Managing Highly Contaminated Sediment** - N.R. Francingues and D.E. Averett, Environmental Laboratory, USAE Waterways Experiment Station, Vicksburg, MS
11:15 - 1:20	**Lunch**
1:20 - 1:55	**Cavitation Versus Pump Eye Speed** - T.M. Turner, Turner Consulting, Inc., Sarasota, FL
1:55 - 2:30	**GEODREDG (GEOtechnical factors in DREDGing): A Knowledge Based Expert System** - S.J. Spigolon, SJS Corporation, Coos Bay, OR, R. Bakeer, Tulane University, Civil Engineering Department, New Orleans, LA and Jack Fowler, USAE Waterways Experiment Station, Vicksburg, MS
2:30 - 2:50	**Break**
2:50 - 3:25	**Application of the 1991 Ocean Disposal Testing Manual in the Southeast: A Continuing Process** - R. Pennington, U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL and Catherine Fox, US EPA, Atlanta, GA
3:25 - 4:00	**Behavior of Clay Balls in a Dredge Pipeline** - D. Leshchinsky, University of Delaware, Civil Engineering Department, Newark, DE, S.D. Richter, Century Engineering, Dover, DE and J. Fowler, USAE Waterways Experiment Station, Vicksburg, MS
4:00 - 4:30	**Using Vertical Strip Drains to Increase Storage Capacity of Craney Island Dredged Material Management Area** - T.D. Stark, Univ. of Illinois @ Urbana-Champaign, IL and J. Fowler, USAE Waterways Experiment Station, Vicksburg, MS
4:30	Adjourn

ACKNOWLEDGEMENT

The Seminar was arranged by Dr. John B. Herbich as part of the Center for Dredging Studies' professional development activity.

The Proceedings were assembled by Dr. Herbich and Ms. Joyce Hyden. Publication of the Proceedings was made possible by funding provided by the Center for Dredging Studies.

TWENTY-FIFTH ANNUAL DREDGING SEMINAR

Stouffer Riverview Plaza, Mobile, Alabama
May 27, 1992

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INTRODUCTION

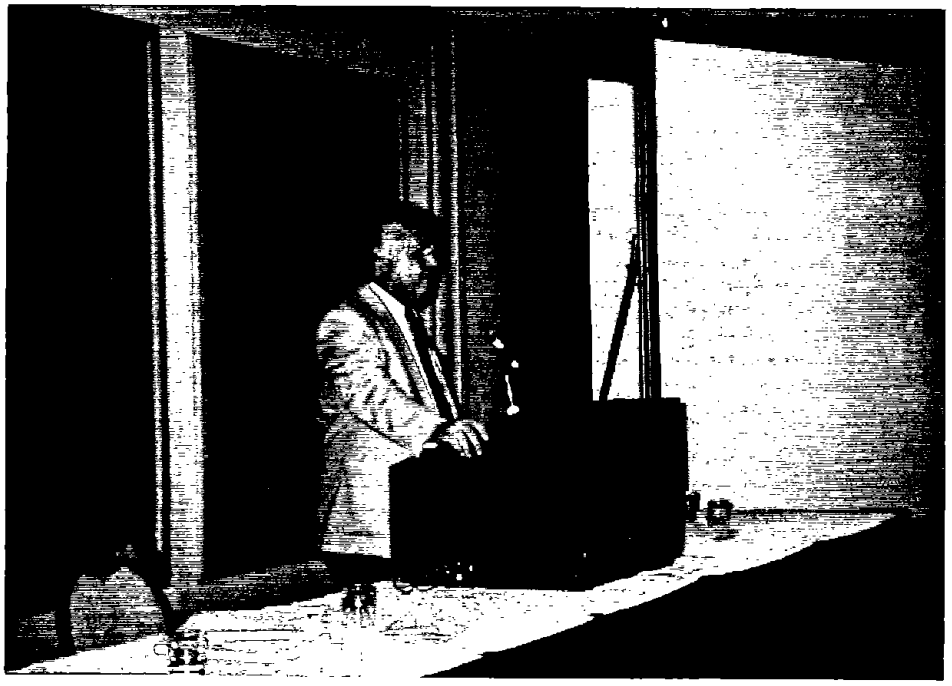
One of the activities of the Center for Dredging Studies is to organize and conduct an Annual Dredging Seminar. The first Seminar was held in New Orleans in 1968; this volume represents the Proceedings of the Twenty-Fifth Seminar. The purpose of the seminar is to disseminate recent research results, discuss case studies, and highlight any other topics of interest to the dredging industry.

The 1992 Dredging Seminar followed the same pattern.

COMPARATIVE ASSESSMENT OF DGPS VERSUS MICROWAVE RANGING POSITIONING FOR BATHYMETRIC REAL TIME SURVEYING

by

James V. Patterson



J. V. Patterson

ABSTRACT

The purpose of this paper is to discuss the results of comparison testing of Differential Geodetic Positioning Systems with the currently used Microwave Ranging System, and to compare a survey software system developed by Rowe Engineering with the system developed by the Waterways Experiment Station.

COMPARATIVE ASSESSMENT OF DGPS VERSUS MICROWAVE RANGING POSITIONING FOR BATHYMETRIC REAL TIME SURVEYING

James V. Patterson[1]

ABSTRACT

The purpose of this paper is to discuss the results of comparison testing of Differential Geodetic Positioning Systems with the currently used Microwave Ranging System, and to compare a survey software system developed by Rowe Engineering with the system developed by the Waterways Experimental Station.

INTRODUCTION

The Mobile Area Office of the U.S. Army Corps of Engineers performed test surveys using a Trimble 4000DL differential geodetic positioning system (DGPS) and the HGS software developed by Rowe Surveying and Engineering. An Innerspace 440/441 depth sounder/digitizer was used for depth collection.

OVERVIEW

Test surveys were performed under normal survey conditions on board the Corps survey vessels. Geodetic positions were acquired from the DGPS and converted to SPCS 83 X,Y positions in the software. Positional data was acquired on one second intervals and time tagged upon reception. Depth data was acquired simultaneously and positions were interpolated onto the depths acquired between position updates by linear time interpolation. A time skew was determined by making multiple passes along the same course from opposing directions. Incremental adjustments were made after each pass until the observed "shift" passed from one side to the other. A time skew (age) of 0.65 seconds was determined and applied to all positions acquired during the test surveys. This skew does not necessarily represent the age of the DGPS output, but

[1]Mobile District, U.S. Army Corps of Engineers, P.O. Box 2288, Mobile, AL 36628-0001.

rather reflects the total skew throughout the entire system; most significantly the time lag between computer commands and depth information received back at the computer.

DAY 1

All equipment was installed and the necessary links established between the DGPS and software. Corps personnel established third order monumentation on the roof of the building where the GPS antenna was mounted and along a predetermined shore test site (K-Mart parking lot) through conventional methods. The calculated coordinates were converted from SPCS 27, Alabama West zone to NAD 83 geodetic positions for the differential reference station on the roof of the Corps building using the CORPSCON software. Differential data was transmitted from the reference station at the Corps office to the remote or "roving" unit via a 10 watt VHF transmitter with the antenna mounted near the top of the 250' radio tower at the location. Transmitters, receivers, and modems were supplied by Trimble as part of their advertised package for a complete GPS surveying system.

The differential data was transmitted on one second intervals for all satellites in view. Static results at the site varied only +/- one foot from the previously established control points. Satisfied with the results from the initial test, a bathymetric survey was scheduled.

DAY 2

The DGPS system as previously described was assembled on board the Corps survey vessel "Gatlin" with the HGS software and an Innerspace 440/441 depth sounder/digitizer. Already installed on board was the microwave ranging system used for survey positioning. The range/range system was comprised of the Del Norte 542 microwave positioning system, HGS software, and an Innerspace 448 depth sounder. The depth sounders were connected to seperate 208 KHZ transducers mounted in the hull--each 2' on either side of the keel. Grid 386 laptop computers were used by both systems. Antennas for both the GPS receiver and the Del Norte microwave system were mounted on the same mast with the GPS receive antenna one foot above the microwave antenna. Two microwave remote units were set up to provide the ranging information and the system calibrated as recommended by the manufacturer. A monument located on a platform near the channel being surveyed was used as the calibration point for the range/range system. Ten parallel cross section lines were run simultaneously, with each line surveyed both directions with both systems on a section of the Mobile Ship Channel that had been recently dredged. The horizontal dilution of precision (HDOP) for the DGPS was monitored throughout the survey, and remained below a value of two (2). The results from each system were plotted with the HGS software in both plan and cross section views at 1"=250' for plan and 10' vertical and 100' horizontal for cross section scales. The difference in positional data and recorded depths between the two systems was

minor, as shown on the plots in figure 1.

DAY 3

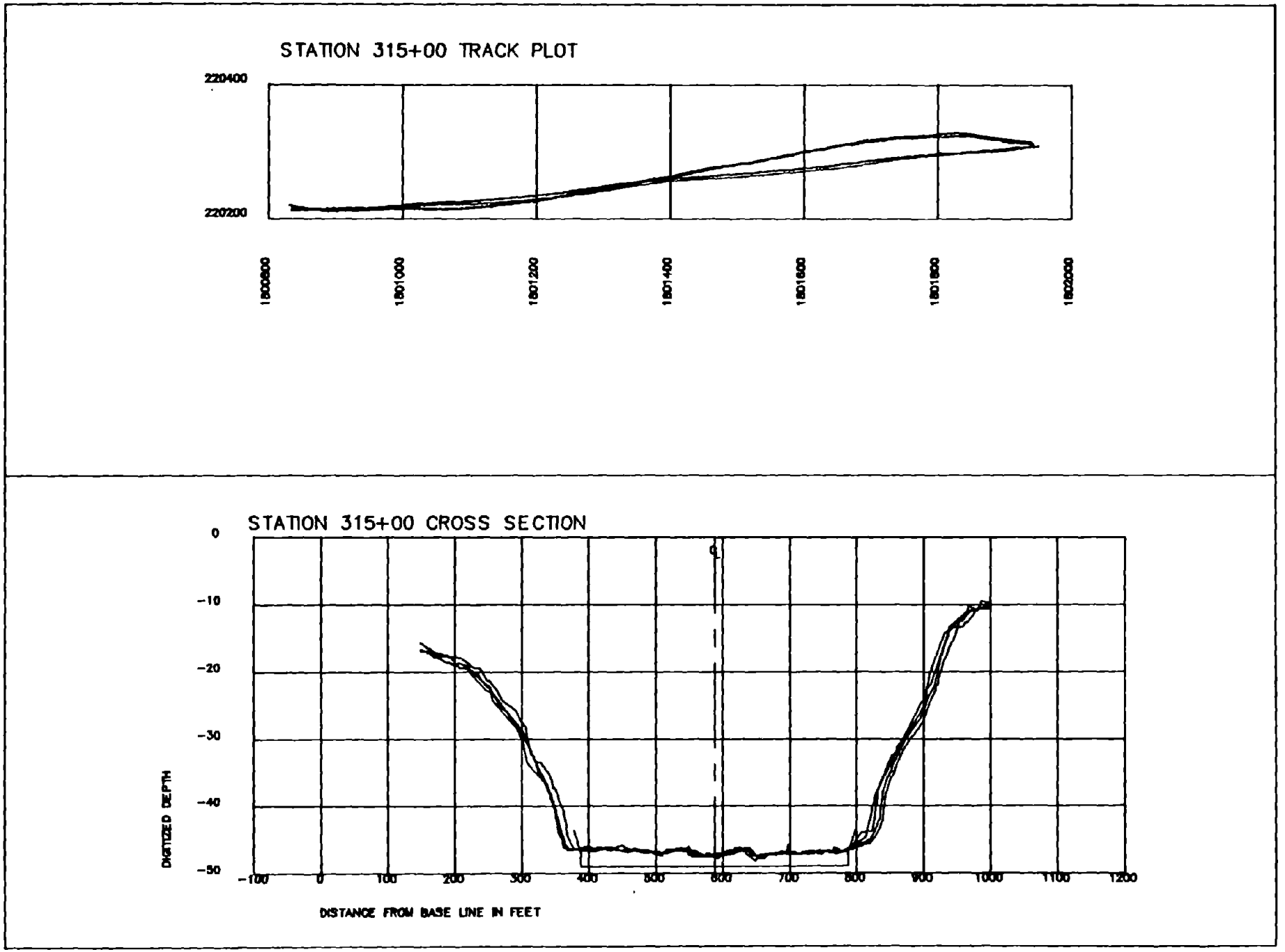
The final test that was conducted was a comparison between the WES survey software developed by Dr. Barry McCleave and the HGS software developed by Rowe Engineering. Accuracy and precision differences between WES (used as the comparison standard) and HGS were insignificant. The HGS system was significantly more user friendly. Also, HGS had some features that WES did not, such as a plan view displayed on the pilot steering and positioning indicator for the helmsman.

CONCLUSION

The observed difference between the DGPS and Microwave systems averaged much less than one (1) meter. While the result of this particular test does not verify the absolute accuracy of the DGPS positioning system, it does indicate that DGPS may very well be a viable alternative to conventional positioning systems for many types of surveys requiring real time positioning.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Charles Breeden and Mr. Tommy Hughes for their contribution in conducting the actual data collection, and the entire Mobile Area Office Team for their participation in making the test demonstrations possible.


STATION 315+00 TRACK PLOT
220400
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1801000
1801200
1801400
1801600
1801800
1802000
STATION 315+00 CROSS SECTION
0
-10
-20
-30
-40
-50
DIGITIZED DEPTH
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE FROM BASE LINE IN FEET

FIGURE 1

BIOGRAPHICAL SKETCH

James Patterson is a graduate of The University of South Alabama where he earned a B.A. degree in Communications Technology. Mr. Patterson served as an Electronic Technician in the U.S. Navy from 1966 to 1978, and has worked in the marine electronics field for six years. Following graduation he served as Engineering Technician for the College of Arts and Sciences at The University of South Alabama. Mr. Patterson joined the Corps' Mobile Area Office Team in November, 1990.

A SINGLE POINT MOORING FOR DIRECT PUMP-OUT OF HOPPER DREDGES

by

Wayne A. Herbrich and James E. Clausner

J. E. Clausner

ABSTRACT

The equipment utilized by Corps of Engineers (CE) or their contractors for direct pump-out (DPO) is not always suitable for open ocean pump-out. Equipment used to perform direct pump-out of hopper dredges was not specifically designed for this purpose, but was adapted to meet a specific need. With increasing numbers of beneficial uses of dredged material occurring, the Corps of Engineers contracted a study of commercially available mooring systems able to provide open ocean DPO for the U.S. hopper dredge fleet. This paper describes the adaptation of single point mooring (SPM) technology traditionally used for the export and import of oil for the DPO of hopper dredges.

A SINGLE POINT MOORING FOR

DIRECT PUMP-OUT OF HOPPER DREDGES

Wayne A. Herbrich[1] and James E. Clausner[2]

ABSTRACT

The equipment utilized by Corps of Engineers (CE) or their contractors for direct pump-out (DPO) is not always suitable for open ocean pump-out. Equipment used to perform direct pump-out of hopper dredges was not specifically designed for this purpose, but was adapted to meet a specific need. With increasing numbers of beneficial uses of dredged material occurring, the Corps of Engineers contracted a study of commercially available mooring systems able to provide open ocean DPO for the U.S. hopper dredge fleet. This paper describes the adaptation of single point mooring (SPM) technology traditionally used for the export and import of oil for the DPO of hopper dredges.

INTRODUCTION

The Corps of Engineers (CE) performs maintenance dredging with its four hopper dredges and contracts for maintenance dredging with fifteen industry hopper dredges. Annually the CE dredges about 250 million cubic yards of maintenance material from United States waterways. Significant amounts of this dredged material could be used for beneficial applications if an easier and less expensive means of delivering the dredged material to the site where it will be used were available. For example, clean sand could be placed on eroding beaches or fine grained materials could be used to supplement wetlands. The CE desires to increase beneficial uses of this dredged material by lowering the cost, thus making cost sharing with local sponsors a more attractive option. At present the CE does not have a unit suitable for open ocean direct pump-out and industry has only one.

The CE Dredging Research Program (DRP) is a six year, 35 million dollar effort to lower the CE one-half billion dollar annual dredging budget. The DRP includes a work unit to investigate improved methods and equipment for nearshore and onshore placement of dredged material. The major focus of this work unit is to investigate methods to allow material (primarily sand) removed by hopper dredges to be directly pumped from the dredge to the beach when working on open coasts. The CE currently has equipment to perform direct pump-out in more sheltered environments.

The CE contracted with SOFEC, Inc. to: a) describe several DPO systems capable of meeting CE requirements; b) with CE input select a single system which best met CE requirements; and c) provide a detailed preliminary design of the entire DPO system including the buoy, swivel, floating and underbuoy hoses, mooring hardware and suggested

[1]SOFEC, Inc., 6300 Rothway, Suite 100, Houston, TX 77040.
[2]U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

transportation and installation procedures. The intent of this effort was to allow a CE District Office or contractor with the need for such a system to use this design as a vehicle for developing final design drawings and fabrication of the DPO system.

This paper describes DPO concept, operating and design parameters for the DPO system, initial mooring systems capable of meeting these goals, and the final system selected. Short descriptions of how the system will be operated including transportation, assembly, and installation are provided.

DIRECT PUMP-OUT

Direct pump-out is a common method of removing dredge material from hopper dredges. A hopper dredge fills its hoppers as it dredges the sea floor. The dredge then moors to a structure, buoy or multiple buoy berth. Hoses connected to a pipeline running to shore are attached to the hopper dredge discharge manifold. The dredge mixes the dredge material with sea water to form a slurry and pumps the slurry from its discharge manifold through the hoses and pipeline to the designated discharge location.

DESIGN PARAMETERS

The mooring system was designed to be used by three CE hopper dredges, the USACE "Wheeler","Essayons" and "McFarland". Design loads and system analysis were based on the displacement and draft of the largest of the these vessels, the hopper dredge "Wheeler".

USACE "Wheeler"	Length	408.0 ft
	Beam	78.0 ft
	Draft	29.5 ft

Operational weather conditions were chosen to fit the maximum operating environment for the dredges. The mooring was designed for the following operational conditions.

Significant Wave Height	6.0 ft
Wind Velocity	30.0 Kt
Current Velocity	2.0 Kt

Survival conditions for the mooring system design are:

Significant Wave Height	10.0 ft
Wind Velocity	30.0 Kt
Current Velocity	2.0 Kt

Direction of the environment was chosen to be consistent with near shore conditions. Current was chosen parallel to the shoreline and the wind and waves perpendicular to the shoreline.

The mooring system was designed for operation in a minimum water depth of 30 ft and a maximum water depth of 45 ft.

Location of the mooring system from shore is limited by the pumping capacity of the dredge. In many instances, the hopper dredges are required to operate in water depths very close to their maximum drafts due

to the shallow slopes along parts of the inner continental shelf.

The following operational criteria was also required for the mooring design:

- Transportable by truck or rail
- Assembled rapidly
- Installed with a minimum of lift support
- Recoverable and reusable.

MOORING CONCEPTS

Four concepts were considered for mooring the hopper dredge.

- Guyed Tower
- Tension Leg Platform (TLP)
- Single Anchor Leg Mooring (SALM)
- Catenary Anchor Leg Mooring (CALM)

A CALM system was chosen for further study and preliminary design due to its ability to be transported in truck size packages, assembled quickly and proved to be the least costly to fabricate.

THE CALM SYSTEM

The CALM buoy in Figure 1 is a capsule shaped buoy which is 28'-0" long by 11'-6" wide by 7'-6" deep. Although not the conventional shape of a mooring buoy, the shape was chosen to facilitate towing the buoy and placement on truck flat beds. The buoy can be disassembled into the following four components.

- Buoy Hull
- Fluid Piping
- Fluid Swivel
- Mooring Table

The buoy hull serves as the foundation for the fluid piping. Slurry from the dredge enters the buoy through a floating hose connected to the fluid piping just above the water at the outer edge of the buoy. Piping is designed to contain a minimum amount of bends to reduce areas of high abrasion. Slurry travels through the piping to a fluid swivel. Slurry leaves the buoy through an under buoy hose which is connected to the fluid swivel and leads to a pipeline to the discharge area.

The fluid swivel is an in-line swivel currently used by the dredge industry. It contains bronze bushings which reduce the need for seals or the extensive need for maintenance that roller bearings would require. The lower end of the fluid swivel contains a quick release flange to assist in connecting the underbuoy hose.

Near the fluid piping/floating connection, a mooring pad eye is provided for the connection of a mooring hawser. The hawser transfers the mooring forces from the dredge to the buoy.

The buoy rotates about a shaft which runs through the centerwell of the buoy. The center shaft contains two permanently lubricated bronze bushings located at the top and bottom of the centerwell of the buoy. A 48" diameter flange is located at the bottom of the center shaft. The

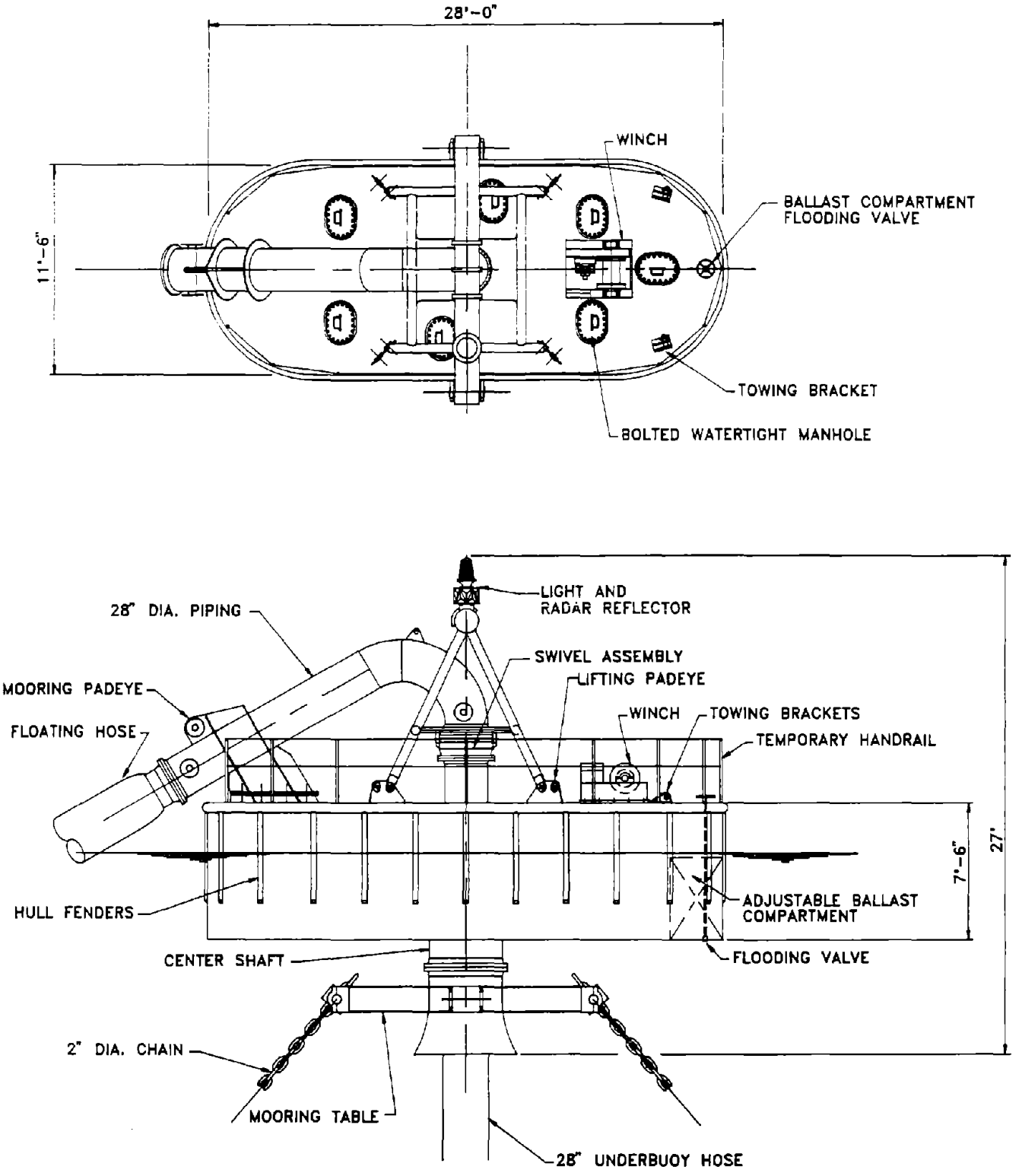

FIGURE 1. DREDGE MOORING PLAN AND ELEVATION

flange provides the mechanical connection between the buoy and the mooring table.

The mooring table extends below the buoy and provides locations for the connection of the mooring chains to the buoy. The mooring table also provides a bell fairing to reduce chafing of the under buoy hose.

Floating and under buoy hoses for this mooring system are standard commercially available hoses currently used in the dredging industry.

The mooring chains consist of four legs, each 600 ft, 2 in. diameter ORQ (Oil Rig Quality) stud link chain. Mooring anchors may either be 10,000 lb Navy Navmoor or 6,000 lb Bruce International FFTS anchor.

Figure 2 show the installed mooring system during the DPO process.

SYSTEM OPERATION

Transportation

The CALM system can be transported by truck, rail or barge to the assembly location. In Figure 3 the CALM buoy is packaged for transport by truck. Components of the system can be consolidated and transported on standard flat bed tractor trailer rigs. The entire system can be transported by as few as six trucks.

The entire system can also be arranged on a standard 60 ft X 120 ft cargo barge for ocean transportation.

Assembly

The CALM system is assembled by attaching the mooring platform to the 48 in. diameter flange located at the bottom of the buoy (Figure 4). The fluid swivel is then attached to the buoy top deck followed by the attachment of the piping to the fluid swivel and to the buoy deck at the outer edge of the buoy. The buoy is then lifted into the water by a shore based crane. For short tows, the floating hose can be attached to the piping prior to towing.

Installation

Once the CALM buoy is assembled, a tow tug will connect to the towing pad eyes on the buoy deck opposite the piping. The capsule shape of the buoy will allow the buoy to be towed at greater speeds and should prove to be a more stabile tow than a conventional cylindrical buoy.

As the buoy is under tow to the installation location, an anchor handling tug will be installing the four mooring legs and the mooring anchors. The tug will tension the chains to set the anchors prior to buoy arrival. Chains will be laid closely to the pipeline under buoy hose connection. Pickup buoys will be attached to each leg.

As the chains are being installed, the pipeline will be assembled on the shore, floated into position and lowered to the seafloor. Any pipeline stabilization required will be undertaken while the buoy chains are being attached.

When the buoy arrives at the installation location, the chain legs are attached to the mooring platform and tensioned until the proper chain catenary is achieved.

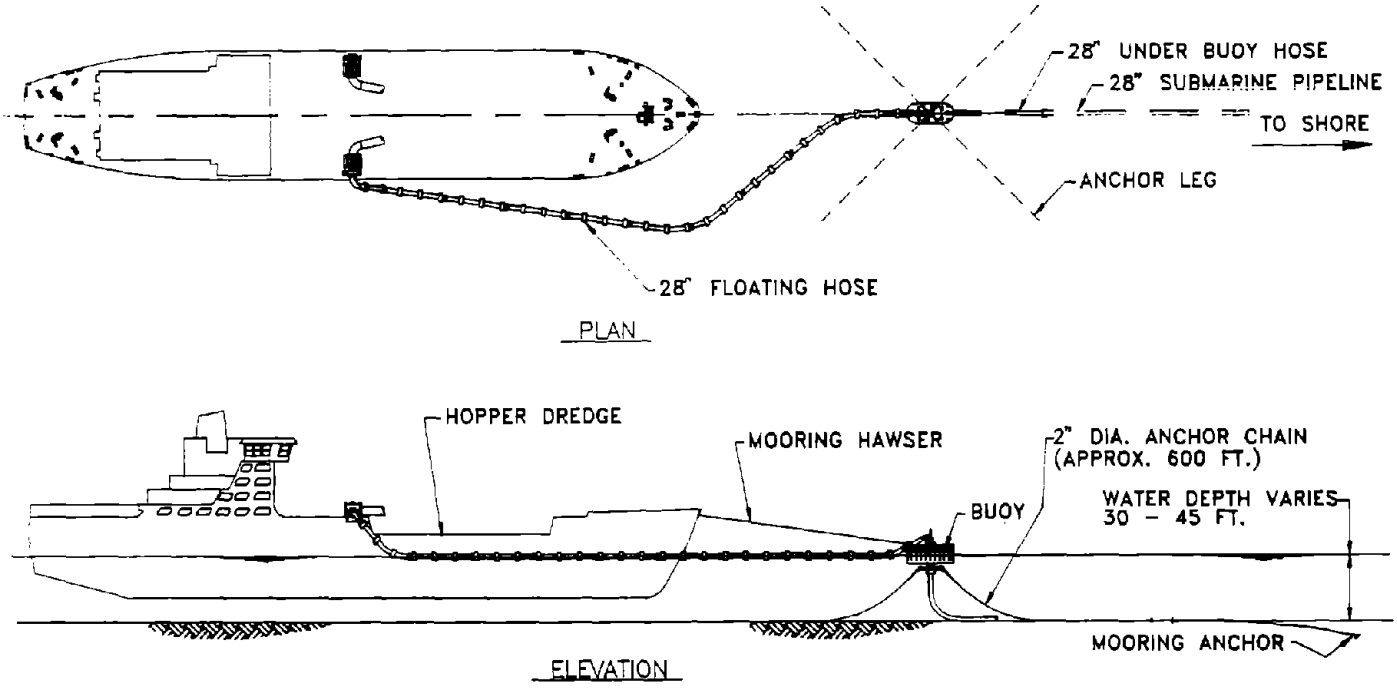

FIGURE 2. SYSTEM GENERAL ARRANGEMENT

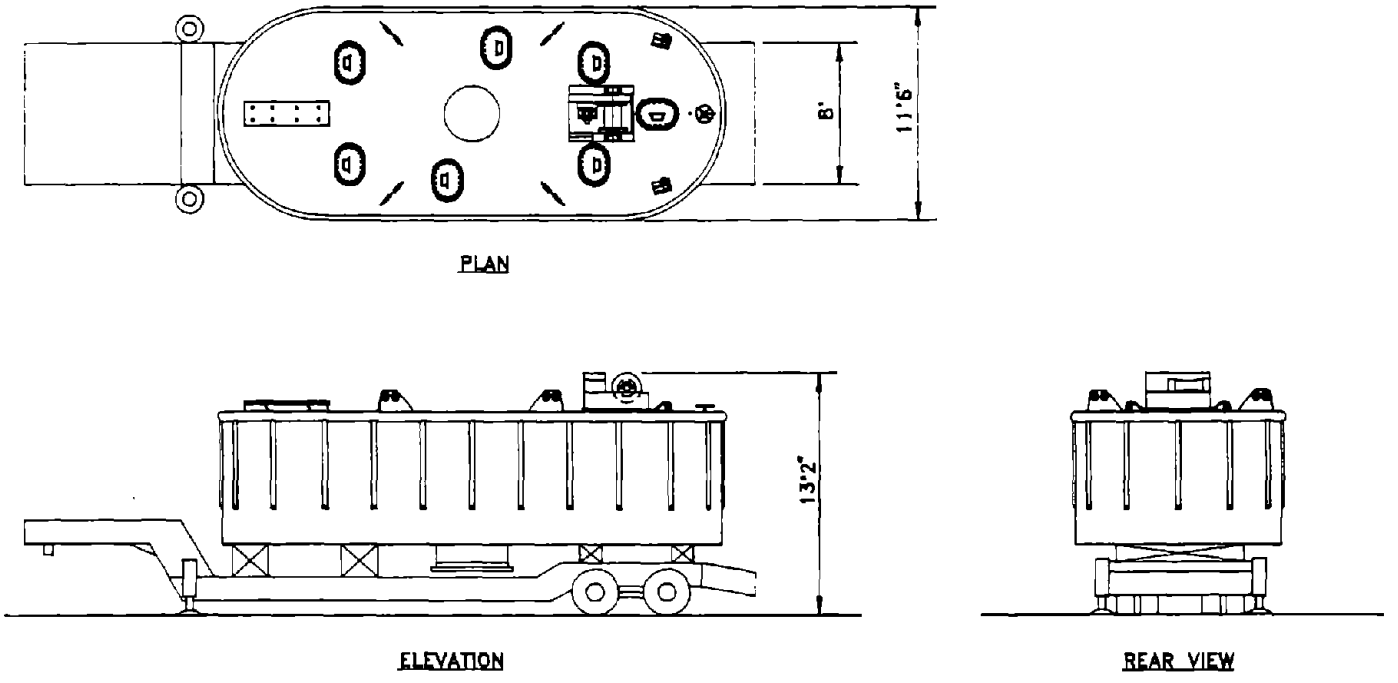

FIGURE 3. MOORING BUOY TRUCK TRANSPORT CONFIGURATION

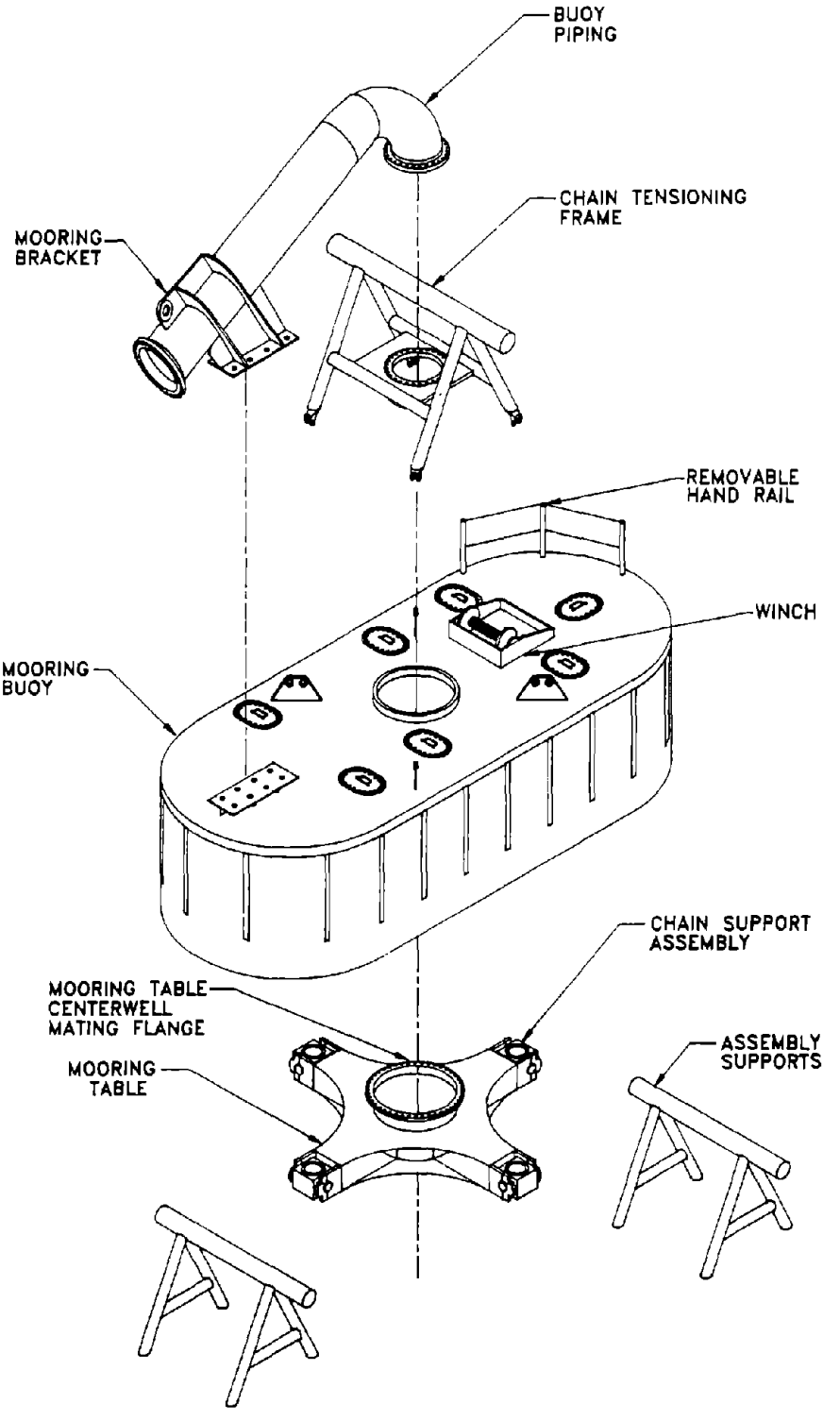

FIGURE 4. MOORING BUOY ASSEMBLY

The under buoy hoses are then pulled though the guide on the mooring platform and connected to the lower end of the fluid swivel. If the floating hoses were not installed at the shore, the connection is made between the floating hoses and the buoy piping.

The hawser is connected to the mooring pad eye to complete the system installation.

CONCLUSIONS

1. A detailed preliminary design for a DPO system for use with U.S. hopper dredges has been developed.

2. To meet operational requirements of use in shallow water (30 ft) and logistical requirements for rapid transport (light weight, easy assembly and truck transportable) a capsule shaped buoy using a CALM mooring system with a separate mooring system was designed. The buoy is 28'-0" long by 11'-6" wide by 7'-6" deep and weights approximately 30 short tons.

3. Subsequent detailed design and fabrication of this system will depend on CE District specific requirements.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the valuable input from the following SOFEC, Inc. staff: Mr. Jerry Blair (Senior Mechanical Engineer), Mr. Ron Kelm (Engineeering Manager), Mr. Charles O. Etheridge (Vice President of Engineering), Mr. Peter Poranski (Vice President of Research and Development), and Mr. David Brightwell (Director of SOFEC Defense Systems).

The authors wish to acknowledge the valuable assistance provided by Les Sonnenmark (Principal Engineer) of Phillips Cartner Co. Inc.

The following CE staff provided important contributions during development of this system: Messrs. Ron Kreh and Robert Johnson (Philadelphia District), Mr. John Kelly (New Orleans District), Mr. Jerry Gompers (Portland District), Mr. Thomas Chisholm (WES), and Ms. Virginia Pankow (IWR). Funding for this research was provided by the CE Dredging Research Program.
Permission to publish this information was granted by the Chief of Engineers.

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2. Blair, J., Herbrich W.A., Dredge Mooring Study, Recommended Design Report, Unpublished Corps of Engineers Report, July, 1991.

Biographical Sketch

Wayne A. Herbrich

Mr. Herbrich is a Project Manager with SOFEC, Inc. in Houston, Texas. He joined SOFEC in 1982 after working as a Structural Engineer for McDermott Engineering. He is the Assistant Project Manager for the Disconnectable Turret Mooring System Lufeng 13-1 Oil Field in the South China Sea. He is responsible for the purchasing, scheduling and administration for the turret mooring system. Mr. Herbrich received his Bachelor of Science in 1981 from Texas A&M University.

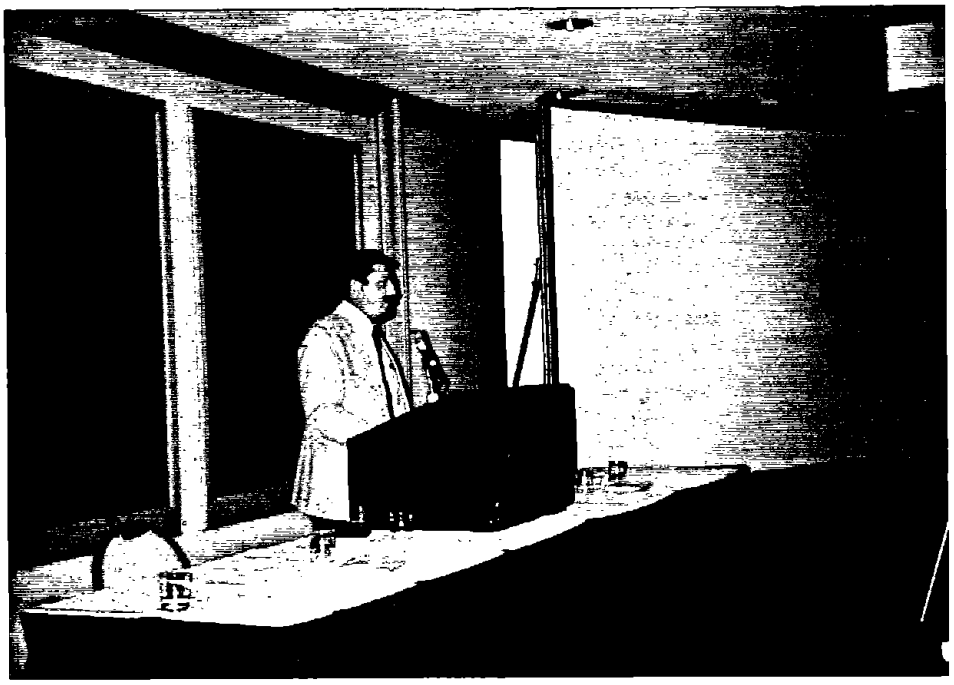
James E. Clausner

Mr. Clausner is a Hydraulic Engineer with the Coastal Structures and Evaluation Branch of the Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES). He joined CERC in 1981 after several years at the Naval Civil Engineering Laboratory where he was involved in design and testing of propellant embedment anchors and measuring submerged sediment properties. In his present position at WES, Mr. Clausner is responsible for research on sand bypassing projects and equipment and open water disposal site management and monitoring. Mr. Clausner received his BS (1974) and MS (1982) degrees in Ocean Engineering from Florida Institute of Technology. Mr. Clausner is a registered professional engineer in the State of Mississippi.

PROMISING TECHNOLOGIES FOR MANAGING HIGHLY CONTAMINATED SEDIMENTS

by

Norman R.Francingues, Jr. and Daniel E. Averett



N. R. Francingues, Jr.

ABSTRACT

The National Research Council's (NRC) Marine Board completed a study (NRC 1989) which concluded that "...Existing technology, including dredging and capping, are adequate for cleanup and remediation of contaminated sediment...However, most high-tech remedial technologies (i.e. those involving treatment of destruction) will probably be cost-effective in small areas and for sediments with relatively high levels of contamination; conversely, large-scale remedial technologies and extensive pre-remediation studies will often not be practical at small sites..."

This paper describes a general overview, non-removal and removal, containment and treatment technologies for contaminated sediments. The information presented has been summarized from a variety of studies and work conducted by the U.S. Army Corps of Engineers (Corps) and others over the years, including the Corps most recent study (Averett et al. 1990) in support of the EPA's Great Lakes National Program Office's (GLNPO) Assessment and Remediation of Contaminated Sediments (ARCS) Program. Examples are given where technology demonstrations have been conducted and are presently ongoing or planned.

Promising Technologies for Managing Highly Contaminated Sediment

by

Norman R. Francingues, Jr. and Daniel E. Averett[1]

ABSTRACT

The National Research Council's (NRC) Marine Board completed a study (NRC 1989) which concluded that "...Existing technology, including dredging and capping, are adequate for cleanup and remediation of contaminated sediment...However, most high-tech remedial technologies (i.e. those involving treatment or destruction) will probably be cost-effective in small areas and for sediments with relatively high levels of contamination; conversely, large-scale remedial technologies and extensive pre-remediation studies will often not be practical at small sites ..."

This paper describes in a general overview, non-removal and removal, containment and treatment technologies for contaminated sediments. The information presented has been summarized from a variety of studies and work conducted by the U.S. Army Corps of Engineers (Corps) and others over the years, including the Corps most recent study (Averett et.al., 1990) in support of the EPA's Great Lakes National Program Office's (GLNPO) Assessment and Remediation of Contaminated Sediments (ARCS) program. Examples are given where technology demonstrations have been conducted are presently ongoing or planned.

BACKGROUND

Contaminated sediments are frequently encountered in marine and fresh waters of the United States. The potentially large volumes of sediment requiring special management, to include remediation, limit the feasible engineering options to in situ or removal techniques. The technologies for managing contaminated sediment are classified according to the following hierarchy: alternatives, components, technologies, process options.

The alternatives for managing contaminated sediments are:

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- No action
- Contain in place
- Treat in place
- Remove and contain
- Remove and treat

NON-REMOVAL ALTERNATIVE

The options available for remediation of contaminated sediment in place are limited because of potential impacts to the water column and aquatic biota during implementation and because in situ demonstrations have been limited for most of the treatment options. Four categories are considered for non-removal: containment, treatment, no action, and restricted use. Although the latter two are not really technologies, they are included to indicate that certain actions should be considered even if remedial action is not taken.

Containment

Containment options considered for remediation of in situ sediment are clean sediment capping, articulating block mats constructed from permeable double-layered polypropylene or nylon panels filled with mortar (Armorform), geomembrane capping, and structural isolation. Capping as a control measure for contaminated dredged material has been widely practiced and evaluated. In contrast to the capping option that will be discussed as an open water disposal option, in situ capping does not involve removing the contaminated sediment from its existing location. This option is effective, economical, and constructable. Implementation can be a problem where water depths are insufficient to place a cap and still maintain other uses of the waterway or where hydrodynamic forces require armoring of the cap to maintain its stability. Armorform is a proprietary product that could be appropriate for small areas. Geomembrane capping is a poor choice because of unreliability and challenges for implementation. Structural isolation might include permanently closing off a portion of the waterway, rerouting flow, or construction of a new channel.

In situ treatment

In situ stabilization and grout injection are the only options for which documented field demonstrations for contaminated sediment was found. Japanese researchers have reported applying the Sil-B solidification technology to in situ sediment (Carusone and Hickman 1988). A small field application involved placement

of a bottomless box frame in the river bottom such that the river water trapped within the frame could be pumped out, followed by addition of the Sil-B agent to the exposed sediment and grab-bucket mixing of sediments with Sil-B agent.

No action

No action consists of leaving the contaminated sediment in place with the hopes that environmental degradation will not worsen until future remedial actions are feasible. In areas with highly contaminated sediment no action will likely result in continued impairments to water quality. A monitoring program should be established to insure that the rates of contaminant release and the area of influence of the contaminants are not increasing.

Restricted use

Restricted use options may include fencing and warning signs, navigation relocation, and restrictions on fish and wildlife. A combination of no action with restricted use was successfully used in the James River to manage the KEPONE problem. However, the driving considerations here were the enormous costs for remediation and the self-capping or natural covering of the contaminated sediment by sediment deposition.

REMOVAL ALTERNATIVE

The components for alternatives that require removal of contaminated sediments are:

- Excavation of sediment
- Transport of dredged material
- Pretreatment of dredged material
- Treatment of dredged material
- Disposal of dredged material
- Water (effluent and leachate) treatment

Factors that need to be considered when evaluating removal alternative technologies include:

- State of technology
- Availability
- Effectiveness
- Implementability
- Cost

Excavation Component

Principal concerns during excavation are the prevention of contaminant releases from the sediment being removed with subsequent transport of contaminants to previously uncontaminated area and efficient removal of contaminated sediment without excessive over-cutting. If unavoidable release occurs, undesirable impacts could result to the environment, costs, and public relations. Excessive depths of sediment removal increase the volume of material for treatment or disposal and increase costs. Technologies used during the excavation of contaminated sediment include the following:

- Selection of appropriate mechanical or hydraulic dredges
- Use of operational controls during excavation activities
- Deployment of barriers during sediment removal

Transport Component

Primary transportation methods used to move contaminated dredged sediment include pipelines, barges or scows and hopper dredges. Overland transport could also include railways and trucks.

Pretreatment Component

Pretreatment technologies are defined for the purpose of this talk as technologies that prepare dredged sediment for additional treatment or disposal. These technologies are designed to accelerate treatment in a confined disposal site, to reduce the water content of the dredged material, or to separate fractions of the sediment by particle size. Pretreatment technology process options are dewatering, particle classification and slurry injection. These processes are primarily applicable to hydraulically dredged sediment.

Treatment Component

Many of the process options are combined with other options and are components of a system that may involve multiple treatment processes to address multiple contaminant problems. Technology types for the treatment component are:

- Biological
- Chemical
- Extraction
- Immobilization
- Thermal

Biological processes

Biological degradation technologies use bacteria, fungi, or enzymes to break down PCBs, pesticides, and other organic constituents into innocuous or less toxic compounds. The microorganisms by be indigenous microbes, conventional mutants, or recombinant DNA products. Biodegradation processes have not been applied and evaluated for contaminated dredged material other than on a bench scale. Several of the conceptual processes are proprietary processes that may be available on a pilot scale, and new vendors continue to enter this market.

Because of the dependence of biological processes on carefully maintained environmental conditions, reliability of these processes is questionable. Implementability for most of these processes is difficult because of their developmental nature for contaminated sediment and because of long time periods and large systems that will likely be required for treatment of contaminated sediment.

Chemical processes

Chemical treatment technologies use chelating agents, bond cleavage, acid or base addition, chlorine displacement, oxidation, or reduction in the destruction, detoxification, or removal of contaminants found in the contaminated media. Only recently, a few of these technologies have been used for treatment of organic and heavy metal contaminants in sediment. Chemical treatment technologies considered promising include chelation, chemical hydrolysis, and detoxification.

Implementability for chemical processes is difficult because of materials handling and process control requirements that have not been fully demonstrated for application to dredged sediment. Costs for these processes have not been reported and are difficult to quantify, but they are expected to exceed $100 per cubic yard. Costs for these processes are not well known, but are expected to be between $200 to $300 per cubic yard.

Extraction processes

Extraction is the removal of contaminants from a medium by dissolution in a fluid that is later recovered and treated. Soil flushing and soil washing are other terms that are used to describe extraction processes. A key element of an extraction process is the ability to separate the contaminant from the solvent so that the solvent can be recovered for reuse in the process. Also important is the toxicity of the solvent. Most

processes require multiple extraction cycles to achieve high removal efficiencies. Follow-on treatment processes are required to treat or dispose of the concentrated contaminant stream.

Implementability for most of these processes is difficult because of the lack of full-scale development for handling sediment and the problems of solvent recovery and potential toxicity of residual solvents. Costs are not well documented, but are expected to exceed $100 per cubic yard.

Immobilization processes

Immobilization processes are defined as technologies that limit the mobility of contaminants for sediment placed in a confined site or disposal area. The environmental pathway most affected by these processes in transport of contaminants to the groundwater or surface water. Most of the immobilization processes fall into the category of solidification/stabilization (S/S) processes. Objectives of S/S are generally to improve the handling and physical characteristics of the material, decrease the surface area of the sediment mass across which transfer or loss of contaminants can occur, and/or limit the solubility of contaminants by pH adjustment or sorption phenomena.

Effectiveness of S/S processes is usually evaluated in terms of reduction of leaching potential. Reductions are process and contaminant specific with immobilization of some contaminants accompanied by increased mobility of other contaminants. Implementability for most of these processes is better than chemical or extraction processes because they are not as sensitive to process control conditions. The opportunity for in situ S/S within a CDF is also an advantage. Costs for these processes are generally less than $100 per cubic yard.

Thermal processes

The thermal type technologies are incineration processes, pyrolytic processes, vitrification processes, supercritical and wet air oxidation, and other processes that require heating the sediment several hundred or thousands of degrees above ambient. These processes are generally the more effective options for destroying organic contaminants, but they are also the more expensive. Costs for thermal processes range from several hundred dollars to over a thousand dollars per cubic yard.

Disposal Component

The disposal component provides for long term containment of contaminated dredged sediment or for containment or beneficial use of residual, relatively clean solids produced during pretreatment or treatment of contaminated dredged material.

Confined disposal facilities

Confined disposal facilities (CDFs) are engineered structures designed to retain dredged material solids and, in the case of hydraulic dredging, to provide acceptable suspended solids concentrations for discharges to receiving waters. CDFs may be located entirely upland above the water table, partially in-water adjacent to the shore, or completely surrounded by water. The principal design criteria of CDFs has been to retain as high a percentage of the fine-grained sediment particles as practical. This principal was based on the findings of the Dredged Material Research Program (DMRP) (Saucier et. al., 1978) that demonstrated that most chemical contaminants associated with sediments could be effectively contained through efficient solids containment. Since most contaminants in sediment remain attached to solid particles during dredging and placement in the CDF, CDFs are reasonably efficient processes for containment of contaminants. Contaminants are potentially lost via effluent, leachate through the bottom of the CDF, seepage through the CDF dikes, volatilization to the air and uptake by plants and animals living or feeding in the CDF. A number of control measures are available to minimize impacts of losses by these pathways.

A management strategy (Francingues, et. al., 1985) has been developed by the Corps that identifies standardized testing procedures for dredged materials to determine appropriate disposal controls. Presently the Corps and EPA are developing a combined approach or framework (USACE/EPA, 1991) to determine the environmental acceptability of various dredged material disposal alternatives which are applicable to contaminated sediments.

Open water disposal

In the last five years, methods to limit the mobility of pollutants in contaminated sediments disposed by open water methods have been demonstrated on the east and west coasts. Capping has been demonstrated as a technology for disposal of contaminated sediments in marine waters (NRC 1989, O'Connor 1987). Capping has been demonstrated for contaminated dredged material in Long Island Sound, New York Bight, Duwamish Waterway, One Tree

Island Marina, and Simpson Tacoma Kraft site in Puget Sound. The contained aquatic disposal option is an alternate method for shallow sites, where the disposal site is first excavated to construct a pit for placement and subsequent capping of the contaminated sediment. This option has been demonstrated for contaminated sediment in Rotterdam Harbor in the Netherlands and was piloted for the New Bedford Harbor Superfund Pilot Study.

To reduce short term effects on the water column during open water disposal, hydraulically dredged material may be discharged below the surface using a gravity downpipe (tremie) or submerged diffuser. Such equipment not only reduces effects on the upper water column, but it also assists in accurate placement of the contaminated material and the cap in the disposal site. An example of submerged diffuser placement is the dredging and capping operations conducted at the First Petroleum Harbour Rotterdam, Netherlands (d' Agremond et al. 1984).

Although these techniques may not be suitable for many highly contaminated sediments, they represent effective disposal options for most lightly to moderately contaminated sediments or process residuals. These options rate highly because of ease of implementation, lack of upland requirements, comparatively low costs, and highly effective contaminant containment efficiency. The principal disadvantages for the open water disposal options are the concern for impacts on ecosystems at the disposal site, long term stability and effectiveness of the cap, and the complications that may occur if remediation of the disposal site should ever be required in the future.

Water (Effluent/Leachate) Treatment

The objective of the water treatment component is to remove residual contaminants from the liquids produced as discharges from a CDF operation such as:

a. Effluent discharges from active CDF operations
b. Surface runoff
c. Leachate
d. Waters from dewatering or treatment processes

Contaminants in these streams will present a wide array of concentrations depending on their source, and individual sources are often highly variable in concentrations and flows. Most of the contaminants for these streams are associated with the suspended solids and will be removed by effective suspended solids removal. Another characteristic of these streams is their variety of contaminants, both organic and inorganic and traditional as well as potentially toxic contaminants. These characteristics may

require more than one treatment process. Commonly used wastewater treatment processes are available to achieve effluent limits for most contaminants. However, applications of treatment processes for dredged material effluents have been generally limited to removal of suspended solids and contaminants associated with these particulates.

Water treatment technologies can be classified as metals removal processes, organic treatment processes, and suspended solids removal processes. Many of these processes concentrate contaminants into another phase, which may require special treatment or disposal. Conventional contaminants, such as nutrients, ammonia, oxygen demanding materials, and oil and grease, may also be a concern for dredged material effluents. Most of the processes for dissolved organics removal are suitable for these contaminants.

SUMMARY AND CONCLUSIONS

The technologies considered promising for managing highly contaminated sediment can be categorized as either non-removal or removal. The technologies reviewed for this paper have been assessed for their effectiveness, implementability and order of magnitude costs, with other considerations such as whether it has been applied to dredged material and the status of availability. Cost of various treatment technologies range from under $100 per cubic yard to several hundred dollars per cubic yard depending upon the degree of detoxification or contaminant destruction required.

A number of the technologies have been selected for field pilot studies. Some of these are:

- Dredging with a modified Mudcat horizontal auger head, was demonstrated in the Welland River in Canada (Acres International Limited 1991).

- Pretreatment technologies such as particle separation or solids classification was evaluated at the Saginaw River site in Michigan (Turton 1991) and also at the Welland River site in Canada (Acres International Limited 1991).

- Biological treatment of 3000 cubic yards of PCB-contaminated sediments is being demonstrated in a pilot treatment facility at the Sheboygan River (Turton 1991). Biological treatment is also being considered for treating the fines from the hydrocyclone pretreatment demonstration at the Saginaw River site (Turton 1991).

- Solvent extraction using critical fluids such as propane in the CF Systems process and an amine (triethylamine) system used in the B.E.S.T. process have been piloted to remove polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Such sites include the New Bedford, Massachusetts and Bayou Bonfouca, Louisiana Superfund sites. Also planned is a pilot demonstration at the Grand Calumet/Indiana Harbor Canal Site in the Great Lakes (Turton 1991).

- Finally, two variations of the thermal desorption process are being demonstrated in the Great Lakes Buffalo River and Ashtabula River sites.

Based on the extensive review, the following conclusions have been made.

- Many processes and technologies are potentially available for contaminated sediment.

- Few processes have been actually applied on a field scale outside navigation dredging projects and Superfund sites.

- Most testing of treatment technologies has been done on a bench scale with limited pilot scale applications, although this is changing.

- The database for design of contaminated sediment management operations is primarily limited to navigation dredging and Superfund projects.

- Further testing and pilot demonstrations are needed to advance the technology data gaps to incorporate sediment remediation strategies.

- Costs for managing contaminated sediment, in large and possibly even small volumes, will be orders of magnitude more than costs of normal dredging operations.

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Biographical Sketch

Norman R. Francingues, Jr.

Mr. Francingues received his B.S. degree in Civil Engineering from Mississippi State University 1969, and his M.S. degree in Civil (Environmental) Engineering from Mississippi State University in 1971. He is a charter member of the Mississippi State Chapter of Chi Epsilon, an honorary civil engineering fraternity.

He is presently a supervisory environmental engineer and chief of the Water Supply and Waste Treatment Group, Environmental Engineering Division, Environmental Laboratory. At the U.S. Army Engineer Waterways Experiment Station (WES), his research experience covers wastewater management, environmental chemistry and monitoring, groundwater hydrology, water supply, civil and environmental engineering, and dredging and dredged material management. Mr. Francingues has been a principal leader and participant in the Corps of Engineers Wastewater Management and Dredged Material Research Programs, the Army's Installation Restoration and Pollution Abatement Programs, the Corps Superfund technical assistance support activities and the U.S. Environmental Protection Agency's Best Demonstrated Available Technology Program under the Resource Conservation and Recovery Act.

Mr. Francingues is the principal author of the Corps of Engineers "Management Strategy for the Disposal of Dredged Material" and the Long Term Management Strategy (LTMS) for navigation dredging projects.

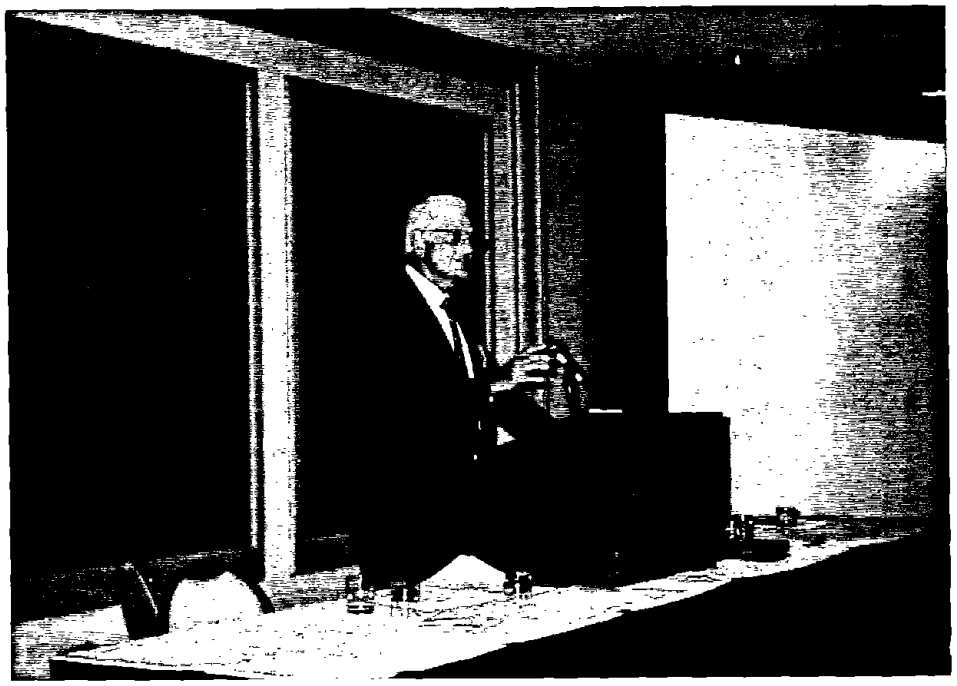
Prior to his position at WES, Mr. Francingues was an Environmental Engineer with the Design Branch of the Vicksburg District, Corps of Engineers, beginning his career with the Corps in 1971.

Mr. Francingues is a member of Chi Epsilon, the Water Pollution Control Federation, the American Society of Civil Engineers, the Permanent International Association of Navigation Congresses, and the Western Dredging Association. He has over seventy-five publications to his credit.

CAVITATION VERSUS PUMP EYE SPEED

by

Thomas M. Turner



T. M. Turner

ABSTRACT

Dredge pump cavitation can have a debilitating effect on the performance of a dredge. Much has been learned about the complex subject of cavitation, but its technical nature has intimidated many dredgemen and prevented a thorough understanding of the subject. As a result, there are many pumps in the dredging industry today which cannot operate at full speed and/or utilize the maximum HP rating of the pump drive.

A detailed understanding of the cavitation phenomenon is not necessary for the operating dredgeman to successfully avoid its debilitating effects. Recognition of the relationship of pump eye speed to the vacuum capability of the pump provides the designer and operator with the knowledge to minimize cavitation while utilizing the horsepower available. The proper pump configuration combined with the appropriate speed range (RPM) can limit the eye speed, allowing the operator to exploit the maximum capabilities of the pump.

The simple concepts outlined in the paper can lead the operator to improved pump performance and greater profits.

CAVITATION VERSUS PUMP EYE SPEED

by

Thomas M. Turner*

There are no good results of dredge pump cavitation; thus, it should be avoided whenever possible. Much has been learned and written about the theory of cavitation; however, the dredge operator's interest lies not so much in the theory, but in being able to predict and avoid the circumstances which cause it. It is with this in mind that this article was written, including the graph Cavitation Limits of Eye Speed Versus Vacuum.

Cavitation can have serious debilitating effects on the performance of a dredge pump. This phenomenon occurs when the static pressure in the suction line falls below the vapor pressure of the liquid being pumped, resulting in water vaporization which forms cavities in the slurry. These cavities later implode, often with audible effect, as well as physical stress and damage to the pump metal in the area of the implosion.

Perhaps the simplest concept of cavitation is to visualize the slurry entering the rotating impeller through the eye, where each impeller vane terminates at the periphery of the eye at the front shroud. As long as there is adequate suction head (pressure) to keep the slurry in close contact with the trailing surfaces of the moving vanes, all is well; however, as revolutions per minute (RPM) increases and vane velocity (eye speed) exceeds the ability of the slurry to keep up, the vane "runs away" from the slurry, forming pockets of water vapor (cavitation). Unless the dredge is equipped with a method to augment the suction head which is normally supplied by barometric pressure only, the dredge will inevitably encounter cavitation at some time.

When cavitation occurs, the pump tries to pump the water vapor, a fluid lighter than air. Since the pressure created by the pump is proportional to the specific gravity of the fluid being pumped, the pressure created with 100 percent vapor is so low as to be unmeasurable by normal dredge instruments. The practical effect of full cavitation is a cessation of liquid pumping. This not only stops dredge production (i.e. the transport of solids) but allows settlement of the suspended solids in the slurry, resulting in potential choking of the pipe.

The graph is a reasonable approximation of the capabilities of a well-designed dredge pump. It shows the relationship between the pump's eye speed and the maximum vacuum the pump can create. Eye speed is the peripheral velocity of the opening through the front shroud of the pump impeller, expressed in feet per second. Vacuum is the "negative pressure" as read by a gauge immediately ahead of the pump, expressed

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commonly in inches of mercury, but preferably in feet of water for ease in calculations. From the graph, it is obvious that as eye speed increases, vacuum capability decreases. Since vacuum increases as a function of slurry velocity and specific gravity (SG), it becomes apparent that the productivity and economics of the dredge is a function of the capability of the pump to create a high vacuum.

Examination of the graph discloses that at an eye speed of 30 ft/sec, the pump can create a vacuum of 27 inches of mercury (HG). At 40 ft/sec, the vacuum has dropped a small amount, so a logical question is "Should the pump always operate at a maximum of 30 ft/sec?" The answer is "no" in that as the eye speed is reduced, so is the peripheral tip speed of the impeller, which determines the head created by the pump. Since head is a function of the square of the tip speed, this means that at an eye speed of 30 ft/sec, the impeller tip generates a head only 56 percent of that at 40 ft/sec eye speed, and will pump only about 56 percent as far. Also since gallons per minute (GPM) varies directly as the pump speed, the GPM will be only 75 percent as high. Further, pump horsepower (HP) varies as the cube of RPM, so the HP utilized will only be 42 percent of that at 40 ft/sec. Obviously, the dredge designer must optimize the pump speed and HP for the project conditions to be encountered. The complexities of this process are beyond the scope of this article, but suffice it to say that a good compromise for eye speed is 40 ft/sec at full prime mover speed. Perhaps an inch of vacuum is lost versus 30 ft/sec, but this is small price for the increased capability in flow rate, head and productivity of a contract dredge. On short-line captive dredges, such as used in some aggregate operations, an eye speed of 30-40 ft/sec may be appropriate when using a standard, commercial pump.

Further examination of the graph discloses that at about 61 ft/sec eye speed, the pump has zero vacuum capability. Long before this point, however, the dredge pump has passed its maximum practical operating speed, because it must generate substantial vacuum in order to: a) pick up solids, b) generate velocity head, and c) overcome the losses in the suction line. We previously stated that 40 ft/sec is a good eye speed for a dredge pump; however, if the vacuum requirements never exceed 15 inches HG (e.g. a booster pump), the eye speed can be increased to about 55 ft/sec to take advantage of the longer line length capability. Also, a dredge pump with an eye speed of 45-50 ft/sec can function on long lines by lowering the vacuum to pick up less solids, and such dredges exist; however, the HP of the prime mover must be increased to handle the higher speed, which means that under "normal" project conditions, the available HP is not utilized. For a dredge often pumping against long lines, an eye speed between 40 and 45 ft/sec is not unreasonable; however, if a booster pump is used, the operation would be more effective if the dredge pump were designed for a maximum of 40 ft/sec.

Operators have noted that their dredge pump does not always cavitate at the same vacuum. The graph, with its formula for vacuum, demonstrates this. The formula states that vacuum expressed in feet of water equals barometric pressure (assumed as 34 ft) minus the net positive suction head <u>required</u> (NPSH<u>R</u>) plus the velocity head (velocity squared divided by 64.4). Net positive suction head (NPSH) is a concept

not essential to the average operator, so we can dismiss it by recognizing it as a calculated value of suction head required for the pump to operate under the given conditions. NPSHR is determined by the pump manufacturer from tests, and should be provided on the pump curves. NPSHR increases with eye size, and therefore, it is recommended that eye diameter never exceed the inside diameter of the suction pipe. Some operators have increased eye diameter in an effort to pass larger particles through the pump, but this comes at a high price and is seldom the most effective way to achieve the objective.

Most dredge pumps will generate a maximum head of 250 to 260 ft with a vane tip speed of 112 ft/sec. With an eye speed of 40 ft/sec, this provides a ratio of 112/40 = 2.8. This ratio of impeller diameter to eye diameter normally provides satisfactory performance if the pump speed and HP are properly assigned. An increase in tip speed allows longer lines but requires higher HP and results in higher wear, since wear is roughly a function of velocity cubed. A decrease in tip speed has the reverse effect.

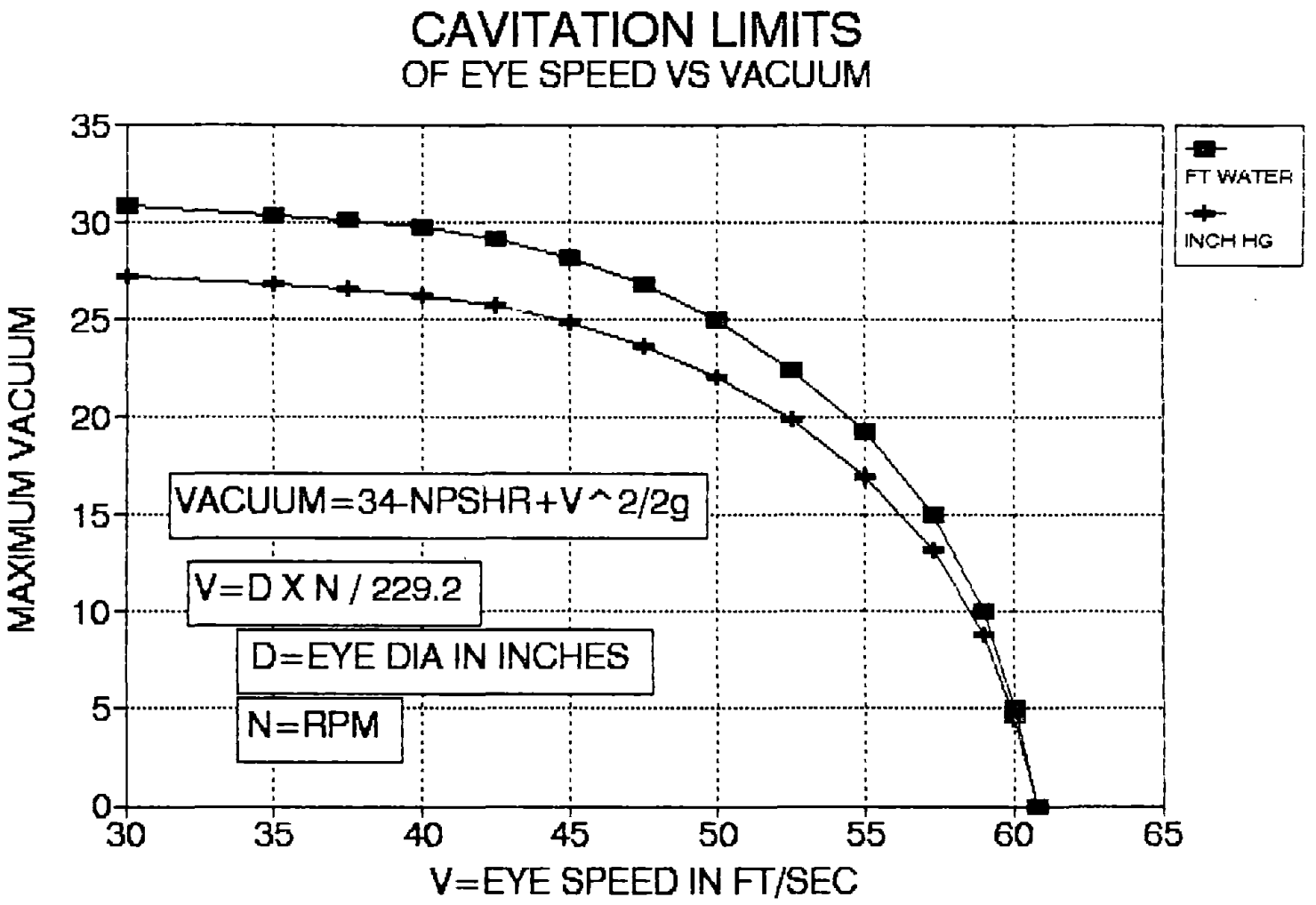
The HP demand of a given dredge pump is a function of the cube of the pump speed; it has also been determined that HP requirements vary with the 2.5 power of the dredge discharge line size. Using the 112 ft/sec tip speed (which provides one mile of pumping distance under many conditions) an excellent HP assignment can be calculated for contract dredges by raising the discharge line inside diameter (ID) to the 2.5 power. For example, the following rounded-off HPs apply:

Line ID	HP
12	500
16	1000
20	1800
24	2800
30	5000

Again, short line dredge HP can be reduced in direct relationship to the line length, if terminal elevation is converted into equivalent line length.

It is recognized that most dredge operators have no interest in becoming dredge designers, so the following rules-of-thumb for dredge pumps can be gleaned from this article:

1. Vacuum capability is reduced as eye speed increases.
2. Impeller eye speed should normally have a maximum of about 40 ft/sec.
3. Impeller tip speed should normally be about 112 ft/sec.
4. The ratio of impeller diameter to eye diameter should be about 2.8.
5. The eye diameter should not exceed the ID of the suction pipe.
6. The HP should equal the discharge line ID to the 2.5 power for contract dredges; lower HP for short line dredges.


CAVITATION LIMITS
OF EYE SPEED VS VACUUM
MAXIMUM VACUUM
35
30
25
20
15
10
5
0
30
35
40
45
50
55
60
65
V=EYE SPEED IN FT/SEC
FT WATER
INCH HG
VACUUM=34-NPSHR+V^2/2g
V=D X N / 229.2
D=EYE DIA IN INCHES
N=RPM

GEODREDG (GEOtechnical elements of DREDGing): A KNOWLEDGE BASED EXPERT SYSTEM

by

S. Joseph Spigolon, Reda Bakeer and Jack Fowler

S. J. Spigolon

ABSTRACT

Geotechnical engineers investigate and describe dredging sites using their own methods and terminology. Government estimators and dredging contractors use that information in preparing plans and estimates. The two groups often do not understand each others needs, methodology, and vocabulary. Inevitable turnover in personnel means the loss of the knowledge of experienced and talented persons These factors often lead to misinterpretation of the nature and extent of the sediments to be dredged, resulting in higher bid prices because of unknown or unclear risk and in unnecessary claims for changed conditions. Therefore, there is a need for retaining expert knowledge for the guidance and training of inexperienced personnel and for peer consultation among the experienced persons.

The work described in this paper is part of the Dredging Research Program (DRP) at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The specific work unit involves the development of geotechnical descriptors to indicate, or infer, dredgeability of sediments to be dredged.

Knowledge Based Expert Systems (KBES) are computer programs for problems that require expertise in a field for solution. Conventional programs use a generally fixed algorithm to solve numerical problems. A KBES uses a knowledge base of expertly-derived rules for its solutions. The knowledge base contains a database of facts and IF - AND - THEN rule statements that answers the types of questions a typical user will ask. The rules can incorporate judgement, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. The ability to add new or expanded knowledge to the knowledge base is a major feature of a KBES.

The proposed WES DRP dredging expert system is called GEODREDG (GEOtechnical elements of DREDGing). It uses a commercial expert system development program, LEVEL 5 OBJECT, operating within the Microsoft Windows environment on PC-DOS or MS-DOS personal computers. The only input needed is numbers and mouse-pointer selection from menus. This should greatly facilitate the use of the system by nontypists. At present, GEODREDG is under development and is based on previous work done in the DRP work unit. GEODREDG will contain prototypes of two subsystems: GEOSTRAT and DREDGABL.

The GEOSTRAT (GEOtechnical site investigation STRATegy) subsystem is for the use of engineers and geologists in the planning of a subsurface investigation for a dredging project. It provides guidance in the selection of field and laboratory tests appropriate for the estimation of site dredgeability.

The DREDGABL (Geotechnical components of DREDGeability) subsystem provides guidance in the interpretation of geotechnical descriptions of sediments in terms of their dredgeability properties. It is intended to be used by estimators and contractors.

GEODREDG (GEOtechnical factors in DREDGing): A KNOWLEDGE BASED EXPERT SYSTEM

by

by S. Joseph Spigolon[1], Reda M. Bakeer[2], and Jack Fowler[3]

INTRODUCTION

Geotechnical engineers typically plan and conduct the subsurface investigation of a proposed dredging site. They describe the physical properties of the sediments that appear to be present within the dredging prism and provide the geotechnical information to all interested parties. Dredging operations personnel, whether the government's or owner's estimator or planner or the contractor's staff, use the furnished geotechnical information in their estimating and planning.

The geotechnical engineers, when planning and executing their site investigation, may not be fully aware of the type of information the dredgers need about the sediments to be dredged. Work turnovers in personnel, or changes in their assignments, means that dredging-inexperienced geotechnical engineers can become involved in the subsurface investigation and the testing of sediments for dredging projects. The dredging-related knowledge of the more experienced geotechnical engineers is often not adequately transferred and is usually lost on retirement or position change.

The dredgers often do not fully understand the geotechnical information in the manner that it has been presented, and its limitations, and the expertise of those that do is also lost through turnover or retirement. Geotechnical engineering descriptions do not indicate "dredgeability" properties directly--any more than they indicate foundation or earthwork behavior properties directly. All require analysis and interpretation. This leads to possible misinterpretation of sediment-related risks, with resulting higher bid costs, and is often a cause of costly claims.

There is, therefore, a continuing need for the guidance and training of those persons lacking knowledge and experience in the dredgeability analysis of geotechnical data. For this reason, it is desirable to retain the expertise of the capable persons involved in

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dredging-related fields and make it available for use by the less experienced workers. Also, knowledgeable and experienced personnel can derive considerable benefit from consultation with their peers for review and as a cross-check on their own work. One very effective manner for retaining this knowledge and making it available to prospective users is a computerized knowledge-based expert system.

Background

The expert system computer programs described herein were developed in response to the needs of a work unit of the U.S. Army Corps of Engineers' Dredging Research Program (DRP). The DRP is being conducted by the USAE Waterways Experiment Station (WES), Vicksburg, MS. The objective of the work unit is the development of standard dredging-related geotechnical descriptors to indicate, or infer, the dredgeability of sediments. Previous reports in the work unit, and publications resulting from this work, consisted of literature reviews to:

- establish the needed type and form of geotechnical descriptors to indicate, or infer, the dredgeability of sediments (Dunlap 1989; Spigolon and Fowler 1988, 1989; Spigolon 1989); and

- define a geotechnical site investigation strategy for dredging projects that would provide the necessary geotechnical descriptors (Spigolon and Fowler 1990; Spigolon 1990).

Objective and Scope of the Study

It is the objective of the computerized systems discussed herein to provide recorded expertise and guidance from experts in their respective fields for:

- geotechnical engineers in the planning and execution of a subsurface investigation for a dredging project; and

- dredging estimators and planners for interpreting geotechnical site investigation data in terms of dredgeability.

Expert systems are computer programs capable of providing the necessary vehicle for recording the accumulated knowledge and experiences of experts, in a specific discipline, in a knowledge base and providing for interaction between the user and the knowledge base. Two related expert systems programs are being developed as part of an overall system to be known as GEODREDG (GEOtechnical factors in DREDGing):

- GEOSTRAT (GEOtechnical site investigation STRATegy) -- guidance in the planning and execution of subsurface investigations for dredging projects; and

- DREDGABL (Geotechnical components of DREDGeABiLity) -- guidance in the interpretation of geotechnical properties data for estimating the dredgeability of sediments. This program can utilize either geotechnical information provided by the user or can evaluate the dredgeability of samples described and recorded in a project database.

The following sections of this report present and discuss the work accomplished to date as part of the overall GEODREDG system. A brief discussion is given of computerized knowledge based expert systems and the criteria for the selection of a system for GEODREDG. As background for the presentation of the GEODREDG modules, the inter-relationship of the geotechnical engineering properties of sediments and dredgeability is presented. Finally, the rule structures for GEOSTRAT and for DREDGABL are given and discussed.

KNOWLEDGE-BASED EXPERT SYSTEMS

A Knowledge Based Expert System (KBES) is a computer program for the type of problem that requires expertise in a field for solution. Conventional programs tend to use algorithmic procedures in a pre-established sequence for processing data that are primarily numerical. The fixed algorithm is repeated as many times as necessary for evaluating new data. The information (knowledge) and the procedure for controlling it are integrated; this inhibits mid-run changes in procedure.

A KBES uses expertly-derived rules for its solutions; the rules can incorporate and process judgement, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. The knowledge base contains a database of facts and a series of IF - THEN rule statements that hopefully include all of the questions a typical user will ask. The control system (inference engine) is independent of the knowledge base, permitting simple editing and additions to the knowledge base.

The choice of the name -- Knowledge-Based Expert System -- derives from a combination of two sources of knowledge. A true Expert System (ES) records the expertise and judgement capacity of human experts, based in part on their remembered experiences, fuzzy reasoning, and ill-defined logic. This includes information and procedures that are valuable but are often intuitive and incapable of rigorous or experimental proof. A Knowledge-Based System (KBS) uses so-called "textbook" knowledge, that which has been compiled and is capable of

verification by mathematical rigor, by experimental evidence, or by common acceptance and use by the practitioners of a field.

Using a Knowledge Based Expert System

The components of a typical Knowledge Based Expert System are (Maher and Allen, 1987):

- Knowledge base -- contains the facts and expert-derived rules associated with the domain (subject matter) of the KBES.

- Context -- contains the information about the problem currently being solved; parameters of the problem and information generated by the KBES during solution of the problem.

- Inference mechanism -- contains control information for the KBES; uses the knowledge base to modify and expand the context.

- Knowledge acquisition facility -- an editor providing for creation and modification of the knowledge base.

- Explanation facility -- provides the user with information about the reasoning process and how a solution was reached.

- User interface -- provides for input of IF statements and output of THEN solutions; includes explanation and help facilities.

During a consultation, the KBES searches the knowledge base through a chain of IF - THEN rule statements. The logic of the IF statements may be altered by using such modifiers as AND, OR, or NOT, and the arguments may be either English words or phrases or numbers. The path through the matrix of rules is not pre-determined; rather, the path depends on the specific IF questions and on the generated THEN replies which lead to the next IF statement. The net effect is one of having an expert in a field answering the IF questions with a THEN reply, each presumably leading the user to the next IF question until the solution is reached.

Choice of an Expert System Shell for GEODREDG

A general purpose programming language can be, and has been, used to build a problem-solving system. Examples of such languages are PROLOG, C, LISP, and FORTRAN. However, the development of a KBES is greatly facilitated by an expert system shell (development framework). The criteria used for selection of a commercial KBES shell were:

- Hardware compatibility -- with the IBM PC-MSDOS type of personal computer machines;

- Implementation language -- natural English words;

- Convenient environment -- including user interface and explanation facilities;

- External interface -- with databases (dBase III+ and compatibles) and with spreadsheets (Lotus 1-2-3 and compatibles); and

- Reasonable initial cost and low cost for run-time versions; stability of shell vendor and continued availability of user help support.

The system chosen for use in the GEODREDG system was LEVEL5 OBJECT® (LEVEL5), available from Information Builders, Inc., 1250 Broadway, New York, NY 10001. LEVEL5 is, according to the vendor's User's Guide:

> ". . . an application development environment that combines expert system technologies, object-oriented programming, relational database models, hypertext capabilities, CASE, and graphical development and debugging tools. "LEVEL5 runs under and follows the conventions of Microsoft® Windows™. This windowing environment enables you to open multiple windows, size and arrange them on your screen, and have multiple software applications open at one time."

LEVEL5, running under the Windows environment, also provides for user friendly graphical interfaces and supports mouse input. This practically eliminates the need for the user to type words for data input or for consultations; only numbers and mouse-pointer selection from input menus is needed. This should greatly facilitate the use of the system by non-typists.

Knowledge Acquisition

There are two primary tasks in the building of a KBES. The first task is that of the person with expertise in computerized knowledge based expert systems, called the ***knowledge engineering expert***. The second task is that of the ***domain*** expert, the contributor to the knowledge base. In this case, it refers to the geotechnical engineer knowledgeable and experienced in dredging operations, simply referred to as the ***geotechnical engineering expert***. In the ideal knowledge base, there are multiple geotechnical engineering experts who either reinforce each other or present valid alternate solutions to problems.

The present prototype programs, GEOSTRAT and DREDGABL, were developed with the combined expertise of the authors. Dr. Reda Bakeer, Associate Professor of Civil Engineering, Tulane University, New Orleans, LA, was the ***knowledge engineering expert***. Dr. S. Joseph Spigolon, Engineering Consultant, SJS Corporation, Coos Bay, OR, served as the initial ***geotechnical engineering expert***. Dr. Bakeer and Dr. Fowler are geotechnical engineers and were able to bring that knowledge to the system as a check on the rules prepared by Spigolon.

The rules developed for the GEOSTRAT and DREDGABL modules represent the personal expertise of Dr. Spigolon that was developed through professional experiences and research studies and, therefore, reflect his personal biases. It is most desirable that the present rules be critically reviewed by other geotechnical engineering and dredging experts and expanded or modified, as needed.

GEOTECHNICAL PROPERTIES AFFECTING DREDGEABILITY

Before discussing GEOSTRAT and DREDGABL, it is desirable that the relationship between the engineering properties of sediments, as determined by geotechnical engineers, and the dredgeability of the sediments in terms useful to dredgers be established. The following summary discussion is intended as background information, presenting terminology and concepts used in the KBES programs.

Dredgeability is defined as the facility with which an underwater soil sediment or rock can be excavated, removed, transported, and deposited with respect to known or assumed equipment, methods, and in situ material characteristics. There are several independent variables that affect dredgeability (Bray 1979):

- Equipment type and rated capacity;
- Physical properties of the soil or rock;
- Geometry of the site;
- Cycle factors;
- Management and crew efficiency;
- Equipment breakdowns; and
- External delay factors.

Stages of the Dredging Process

The process of dredging an underwater sediment typically occurs in four stages:

- Dislodgement -- loosening or excavation of material from the its location at or below the bottom;
- Removal -- movement of the excavated material from the bottom up to the pump or transport system;
- Transport -- movement of the material from the excavation/removal site to the disposal site; and
- Disposal -- discharge of the material on a land or into a water disposal area.

Dredging Mechanisms and Equipment

Dredging equipment uses one, or a combination of hydraulic, pneumatic, or mechanical systems. The mechanisms useful for accomplishing the four stages of dredging are dependent on the characteristics of the sediment to be dredged. The dredging mechanisms in common use are listed in Table 1. The mechanisms used by common types of dredging equipment are listed in Table 2. The generic types of dredging equipment are those listed in the current dredging fleet issue of *World Dredging, Mining and Construction*.

Geotechnical Properties Affecting Dredgeabilty

Although the configuration of the equipment and the stage of dredging can be communicated reliably between geotechnical engineers and dredgers, the expected dredgeability character of the sediment to be dredged is not directly evident, or directly inferred, from the engineering descriptions. Based on the mechanisms discussed in Tables 1 and 2, the significant dredgeability properties of soil and rock sediments are:

- Excavation Stage: Suctionability, erodibility, cuttability, friability, rock hardness, scoopability, and underwater slope stability (flowability).
- Removal and Transport Stages: Pumpability (affected by rheologic properties of slurry), abrasiveness, stickiness (affects clay balling), sedimentation rate, and bulking.
- Deposition Stage: Dumpability (friability and stickiness), sedimentation rate, amount of bulking, and compactibility.

Table 1 Dredging Mechanisms	
Excavation Mechanisms	
Direct Suction	Suction is applied to a pipe inserted into extremely soft soil. External pressure causes the soil to enter the pipe as a soft mass at nearly 100% of in-situ volume, i.e., with no excess water.
Hydraulic Erosion	The flow of a high velocity, high volume water stream across the surface of a clean granular material causes scour, which pushes and lifts the grains into the water stream. Due to the high volume of water required, the resulting slurry contains much less than 100% of in situ volume, i.e., low solids content.
Mechanical Dislodgement -- Cutting	If soil/rock is dense granular, friable (easily crumbled or pulverized), or cohesive, cutting it with a rotating or fixed blade or ripping it with plows or knives moves the soil/rock particles into a water stream to form a low solids content slurry.
Mechanical Dislodgement -- Scooping	In space restricted areas or locations where hydraulic excavation is not feasible, scooping of the soil/rock may be done with a bucket, shovel, or clamshell.
Removal Mechanisms	
Hydraulic Pipeline	A suction pipeline is used to move the soft mass or the hydraulic slurry from the excavation area at the bottom to the pumping system.
Mechanical Containers	A bucket, scoop, shovel, clamshell, bucket ladder, bucketwheel, or other container is used to move the material from the bottom to the surface; often this is the same device used for excavation.
Transport Mechanisms	
Hydraulic Pipeline	The particles, clumps of material, or clay balls, are pumped in a pipeline as a hydraulic slurry.
Mechanical Containers	The material is moved in the hold of a hopper ship, a barge (self propelled or towed), or a land based device such as a truck or conveyor belt.

(continued)

Table 1 (concluded)	
Disposal Mechanisms	
Hydraulic Pipeline	The pipeline slurry is directly discharged into a land or water disposal area.
Mechanical Devices	Materials are discharged from mechanical containers by: bottom discharge from hopper ship or barge; direct dumping from the transport unit; mechanical removal using a scraper, bucket, clamshell, or high pressure water stream.

The geotechnical engineering characteristics of a sediment needed for the evaluation of its dredgeability properties are:

- In Situ Strength -- the consistency of cohesive soils, compactness of granular soils, degree of cementation of cemented soils, or the compressive strength of rock;
- In Situ Density -- including water content; very useful for fluid mud evaluation;
- Grain Size Distribution -- including median size, maximum size, and amount of fines;
- Grain Shape and Hardness -- for granular materials only;
- Atterberg Limits -- for cohesive and mixed grain soils, the plasticity of the -40 screen fraction;
- Organic Matter -- presence and amount of organic matter and shells.

The in-situ strength characteristics of the sediment determine the dredgeability during the excavation (dislodgement) stage. The appropriate field or laboratory tests for establishment of the in-situ strength depends on the grain material characteristics. The strength of cohesive soils and of organic soils is dependent primarily on density, stress history, and plasticity, which reflects the clay content and clay mineralogy. The shear strength of granular soils depends primarily on relative compactness, grain size distribution, and grain shape. The strength of rock depends on mineralogy and on the degree of induration.

After dislodgement, the in-situ structure is thoroughly disturbed and only the grain material properties are of concern for dredgeability properties. These are the grain size distribution, plasticity (reflecting clay amount and type), grain shape and hardness, and the amount of organics, shells, and debris. Not all material characteristics affect every stage of dredging in every type of equipment.

Table 2

Characteristics of Dredging Equipment

Dredge Type	Excavation Method	Removal Method	Transport Method	Disposal Method
Suction Dredges				
Trailing Suction Hopper	Direct suction; Hydraulic erosion; Mechanical dislodgement.	Hydraulic suction.	Sedimentation in vessel hopper; vessel moves to disposal site.	Bottom dump or side discharge from hopper ship or barge.
Suction Hopper	Direct suction; Hydraulic erosion.	Hydraulic suction.	Soil settles in vessel hopper; vessel moves to disposal site.	Bottom dump or side discharge from hopper ship or barge.
Cutter Suction	Mechanical dislodgement (rotary cutter)	Hydraulic suction.	Pipeline as a slurry.	On land or in water site as a slurry.
Suction	Direct suction.	Hydraulic suction.	Pipeline as a slurry.	On land or in water site as a slurry.
Suction Dustpan	Direct suction; Erosion using water jets	Hydraulic suction.	Pipeline as a slurry.	On land or in water site as a slurry.
Bucket Wheel Suction	Mechanical dislodgement (cutting by buckets)	Hydraulic suction.	Pipeline as a slurry; Sediment. in a hopper	On land or in water site as a slurry.
Bucket (Mechanical) Dredges				
Bucket Ladder	Mechanical dislodgement (cutting by buckets)	Series of buckets.	Barge.	Bottom dump or using scraper.
Floating Grab/ Clamshell	Mechanical dislodgement (cutting by clamshell)	Clamshell bucket.	Barge or land-based belt or trucks.	Bottom dump or using scraper.
Bucket Dipper	Mechanical dislodgement (cut by dipper bucket)	Dipper bucket.	Barge or land-based belt or trucks.	Bottom dump or using scraper.
Grab Hopper	Mechanical dislodgement (cutting by clamshell)	Clamshell bucket.	Soil settles in vessel hopper; vessel moves to disposal site.	Bottom dump or side discharge from hopper ship or barge.
Bucket Backhoe	Mechanical dislodgement (cutting by backhoe)	Backhoe bucket.	Barge or land-based belt or trucks.	Bottom dump or using scraper.

THE GEODREDG EXPERT SYSTEM PROGRAMS

The programs whose development is being discussed in this report are inter-related. GEOSTRAT is expected to provide the guidance for selection of a site investigation strategy, including a recommended suite of field and laboratory tests, to provide the information necessary for evaluation of dredgeability of the sediments. DREDGABL is intended to serve the planner or estimator as a personal geotechnical engineering and dredging expert, available to interpret geotechnical site investigation data in terms of the dredgeability properties of interest.

GEOSTRAT (GEOtechnical site investigation STRATegy)

GEOSTRAT is intended to be used by persons somewhat familiar with basic geotechnical site investigation and testing methods, such as a Corps of Engineers civil engineer, a geologist assigned to a geotechnical engineering group, or a senior geotechnical technician. GEOSTRAT may also be used by dredging contractors; in this case, it is expected they would use a private geotechnical firm who also would have someone familiar with basic site investigation and testing methods. The system is not intended to be a primary teaching tool, although it could serve as a reference or as a refresher for experienced persons or as an aid in training inexperienced personnel. It would take much more than this program has to offer to teach geotechnical engineering exploration, sampling, and testing methods to anyone without the necessary background.

GEOSTRAT assumes that all prior (pre-existing) information about the site has been evaluated and that a tentative general subsurface profile has been developed. The prior information may have come from one, or both, of a review of existing geological and geotechnical data from the vicinity of the project site and a geophysical survey of the site. Therefore, at any exploration point location where a test pit or boring will be made, a general idea of the sediment profile should already exist, even if it is erroneous. The sediment types expected to be present at the point site include one or more of those in Table 3.

The consultation process starts with the assumption that one or more of the sediment types of Table 3 is present and that the stratification is moderately well known. Provision is made for incomplete information, requiring only that the site be known to be soft (soil) or hard (rock). It is reasonable to require this assumption; this demands that every effort be made to assemble and evaluate the pre-existing information and to use geophysical surveys wherever they are feasible. The choice of an expected profile causes GEOSTRAT to limit its consultation process only to those topics that apply to the specific sediment types and to exclude all others. If the profile estimation is wrong, then a return to the program for re-evaluation with updated information will be necessary.

Table 3.

Characteristics of Basic Sediment Types
(After Spigolon 1989)

Fluid Mud	Found at surface of "bottom" in harbors and other areas of slow current. Extremely low shear strength; has no unconfined compressive strength; physically behaves like a fluid, i.e., sample will not retain its shape. The solids are mainly silt and clay of low to high plasticity, but may have some very fine sand. Invariably has a very low density and very high water content.
Highly Organic Soils	Peat, humus, and swamp soils are typical. Typically have a spongy consistency, a high water content, and are dark brown to black color, although the color alone is not an indicator. Usually have an organic odor in a fresh sample or in wet sample that has been heated. Have a fibrous to amorphous texture and often contain vegetable matter (sticks, leaves, etc.).
Cohesive Soil	These are massive fine-grained soils, typically firm to hard clays and silty clays of medium to high plasticity. Not friable. Have sufficient density and clay content to have unconfined compressive strength. Exhibit plasticity, cohesiveness, and dry strength. Little or no grain-grain contact; shear strength derives from density, stress history, and amount and type of clay.
Friable Granular Soil	Material is mixed-grain soils <u>or</u> low plasticity friable soils, such as small gravel, sand, silt with appreciable clay content. Strength derives from combination of grain-to-grain friction and cohesion due to clay. Friable due to low plasticity of -No. 40 fraction.
Clean Granular Soil	Material is gravel, sand, or coarse silt with little or no plasticity; will not stand unconfined if dry. Maximum size is 3 inches (76 mm). Grain to grain contact dominates the engineering behavior. Shear strength derives from relative density, grain angularity, and lack of fines. Will densify with vibration and will not stand unconfined if dry. Exhibit moderate to high friability.
Cobbles and Boulders	Individual grains between 3 inches (76 mm) to 12 inches are cobbles and over 12 inches (305 mm) in diameter are boulders. Material is dominantly blasted rock fragments, or natural boulders and cobbles; deposit typically contains mixture with gravel, sand, and fines; usually insignificant amounts of nonplastic fines. Usually dense and shear strength derives almost entirely from grain to grain contact.

(continued)

Table 3 (concluded)	
Shale and Cemented Soil	Highly compressed clays (shale) or rock-like soils cemented with iron oxide, lime, silica, calcium, or magnesia; have unconfined compressive strength below that of hard rock. When cut or ripped, usually fragment into small particles.
Rock and Coral	Rock is massive, solid (non-granular), inorganic mineral matter with an unconfined compressive strength exceeding about 1000 kPa (10 Tsf). Coral consists of living calcareous organisms usually formed into a massive offshore reef. Hard rock and coral require blasting to break the mass into particles that can be removed by normal dredging equipment. Softer rock and coral capable of being easily cut or ripped into small fragments.

All field and/or laboratory tests that are appropriate to the specific sediment type and location, and needed for dredgeability evaluation, are recommended. The clear superiority of one method over another, if it exists, is presented. The suitability and need for a specific platform, fixed or a floating, is presented. Future versions of this program are expected to include provisions for using cost data in the evaluations.

Conduct of a GEOSTRAT Session

A typical GEOSTRAT consultation session, using the run-only version of LEVEL5 under the Windows environment, will encounter the following series of screens:

1. Opening Screens. The initial screens include a Logo screen, a Purpose (Objective) screen, and a Disclaimer screen. These are common to all sessions.

2. Session Objective Screen. Table 4 is displayed. A directive is shown, stating: "Select among the following exploration (sampling and testing) objectives for this GEOSTRAT session". A mouse is used to depress one of the "SELECT" buttons on the screen. This constitutes the first "IF" statement of the selection rule. If an explanation of the rationale or background for a selection is desired, the "HELP" button is depressed with the mouse. Another screen appears with text, figures, and literature references appropriate to the topic. After the user is finished with the HELP screen, another button is depressed with the mouse to return to the Session Objective screen and a selection can then be made. After selection, LEVEL5 moves to "Sediment Type Selection."

Table 4 Screen for Selecting Objective of GEOSTRAT Session		
Select Button	Type of Exploration	Help Button
SELECT	REGULAR - ALL TESTS -- Field sampling and testing for in situ strength, density, and material identification properties.	HELP
SELECT	LIMITED - DENSITY ONLY -- Field sampling and testing for in situ density only.	HELP
SELECT	LIMITED - REPRESENTATIVE SAMPLING ONLY -- Field sampling and testing for material identification properties only.	HELP
SELECT	LIMITED - ROCK SURFACE ONLY -- Search for rock surface profile below overburden only.	HELP
SELECT	LIMITED - MATERIAL IDENTIFICATION TESTS ONLY -- Recommended laboratory/field tests for material identification properties only.	HELP

3. Sediment Type Selection Screen. Table 5 is displayed. A directive is shown, stating "Select among the following sediment types". This choice is the second part of the rule statement that says "AND IF." Again, HELP buttons are available to provide explanation screens for each of the choices. After selection of a sediment type, LEVEL5 moves to a site condition selection.

4. Suggested Field Sampling and Testing Groups. After selection of a sediment type, LEVEL5 searches the knowledge base and displays ALL of the field sampling and testing combinations that are appropriate. This is the "THEN" portion of the rule. All of the potentially feasible sampling and testing methods available to LEVEL5 at the present time are shown in Table 6.

Each combination is preceded by a SELECT button and followed by a HELP button as in the previous screens, to be activated by a mouse. The HELP selection, as before, provides discussion in the forms of text, figures, and literature references. Selection of any of the sampling and testing groups leads to a Site Conditions screen.

Table 5 Screen for Selection of Sediment Type		
Select Button	Expected Sediment Type	Help Button
SELECT	UNKNOWN (SOIL) - Probably is soil: mainly gravel, sand, silt, or clay; non-cemented; may be organic.	HELP
SELECT	UNKNOWN (ROCK) - Probably is rock: mainly cobbles, boulders, shale, cemented soil, or rock.	HELP
SELECT	UNKNOWN (ANY) - May be any kind of sediment.	HELP
SELECT	KNOWN - Fluid Mud	HELP
SELECT	KNOWN - Highly Organic Soil	HELP
SELECT	KNOWN - Cohesive Soil	HELP
SELECT	KNOWN - Friable Granular (Mixed Grain) Soil	HELP
SELECT	KNOWN - Clean Granular (Cohesionless) Soil	HELP
SELECT	KNOWN - Boulders and Cobbles	HELP
SELECT	KNOWN - Shale or Cemented Soils	HELP
SELECT	KNOWN - Rock or Coral	HELP

5. Site Condition Screen. This screen is used if a field exploration session is used. Two mouse selections are made on this screen for evaluating the type of field sampling and testing platform to be used:

DEPTH OF WATER AT BOTTOM IS:

- o < 25 ft (Shallow)
- o > 25 ft (Deep)

EXPECTED ROUGHNESS OF WATER AT TEST SITE IS:

- o Calm
- o Rough

6. Suggested Field Exploration Equipment. Given a combination of Sampling and Field Testing method and the Site Condition, LEVEL5 displays all of the feasible Sample Depth Access Methods and Platform combinations, selected from the available choices listed in Table 7. HELP buttons are available for explanations of the choices.

Table 6

Sediment Sampling and Testing Methods

SEDIMENT SAMPLING METHODS:

Undisturbed, thin wall tube sampler
Undisturbed, diamond-tipped core barrel sampler
Disturbed, SPT split-spoon sampler
Disturbed, large diameter thick wall tube sampler
Disturbed, projectile (gravity or explosive) sampler
Disturbed, vibrating tube sampler
Disturbed, bucket auger sampler
Disturbed, surface (grab, scoop, or bucket) sampler
Disturbed, liquid sludge sampler
No Sample

TEST METHODS FOR IN SITU STRENGTH:

Standard Penetration Test (SPT)
Static Cone Penetration Test (CPT)
Field Vane Shear Test (VST)
Dynamic penetrometer test, thick wall tube
Dynamic penetrometer test, solid cone
Penetration rate of vibro-corer
Deceleration rate of projectile tube
Hand-held sounding rod test
Hand penetrometer test or Torvane test on intact sample
Unconfined compression test of clay sample
Laboratory vane shear test of undisturbed clay sample
Shear test of re-densified sand sample
Drilling Parameter Recorder (DPR) test of rock
Diver Operated Rebound (Schmidt) Hammer test of rock
Unconfined compression test of rock core
Splitting tensile test of rock core
Point load test of rock core

TEST METHODS FOR IN SITU DENSITY:

Geophysical - towed nuclear gauge density device
Geophysical - acoustic impedance density method
Static nuclear gauge density probe
Density of undisturbed soil sample or drilled rock core
Resuspended density of sand sample

MATERIAL PROPERTIES TESTS OF SAMPLE:

Coarse grain size distribution (mechanical sieve analysis)
Fine grain size distribution (hydrometer, decantation, pipette)
Atterberg limits (liquid and plastic limits)
Ash content test for organics
Visual-Manual (ASTM D2488) tests of cohesive soil
Visual-Manual (ASTM D2488) tests of granular soil
Reconsolidated density of sand sample
Bulk density of undisturbed sample
Water content (oven dry or calcium carbide)
Specific gravity of grains
Specific gravity of in situ water

Table 7 Field Sampling and Testing Equipment
METHODS FOR REACHING (ACCESSING) SAMPLING DEPTH: Test pit or trench Cased boring, machine operated - wash, rotary, bucket auger, flight auger Cased boring, hand operated - wash, bucket auger Cased boring, rock drill bit Hollow stem auger Vibrating tube corer Projectile tube, gravity or explosive Diver at bottom, operating from surface vessel Bottom surface sample, operated from surface None required, self boring
FIELD SAMPLING AND TESTING PLATFORMS: Bottom (spud) supported, fixed, moveable platform Floating platforms - barges, pontoons, ships Submersible, bottom supported, surface operated machine Diver, operating on bottom

7. Suggested Material Identification Tests. The final screen displays all of the suggested tests for identification of the disturbed sample material, chosen from the list in Table 6, for a KNOWN sediment type. HELP buttons are also available for reference.

DREDGABL (Geotechnical components of DREDGeABiLity)

DREDGABL is planned to serve as an interpreter of sample test and observation data for estimators and planners, whether Corps of Engineers or contractor, in terms of dredgeability. It can also demonstrate to the geotechnical engineers and geologists involved in a dredging project site investigation what the important sediment properties are for dredging. Only the direct effect of soil type and character on dredgeability is considered, separate from all other factors that affect dredging productivity, such as equipment characteristics, water depth, weather, tides, traffic, personnel problems, equipment maintenance, and so forth.

After the appropriate entry of geotechnical data, using the numeric entry pad or a mouse, DREDGABL evaluates the data for each of the dredgeability properties listed above. DREDGABL then displays its evaluations, along with the rationale for each evaluation, and stores the results for future reference. Future versions of DREDGABL may be developed to evaluate the dredgeability properties of the sample with respect only to a specific dredge of a type shown in Table 2.

The rules for evaluation used in DREDGABL are in the following form. The rule statements are used as appropriate to the sediment type listed in Table 3:

IF relative consistency of a cohesive or organic soil is:
OR relative compactness of a granular soil is:
OR relative cementation of a shale or cemented soil is:
OR strength of a rock or coral is:

AND in situ density is:
AND median grain size is:
AND maximum grain size is:
AND percent fines (pass. no. 200 screen) is:
AND coefficient of uniformity, Cu, is:
AND coefficient of curvature, Cc, is:
AND grain angularity is:
AND grain shape is:
AND grain or rock hardness is:
AND liquid limit is:
AND plasticity index is:
AND organic content is:
AND shell content is:

THEN estimated relative suctionability is:
THEN estimated relative erodibility is:
THEN estimated relative cuttability is:
THEN estimated relative friability is:
THEN estimated relative scoopability (digability) is:
THEN estimated relative flowability (underwater slope stability) is:
THEN estimated relative pumpability is:
THEN estimated relative pipeline abrasiveness is:
THEN estimated relative clay balling capacity is:
THEN estimated relative stickiness is:
THEN estimated relative sedimentation rate in a hopper is:
THEN estimated relative bulking factor is:
THEN estimated relative sedimentation rate in a disposal area is:
THEN estimated relative mechanical compactibility is:

The rules for evaluation operate internally in the LEVEL5 program to consider all of that sample's properties that affect each of the specific dredgeability mechanisms. Each of the guidance displays contains a HELP button next to the expert opinion. Depressing the button with the mouse causes a screen to be shown in which the rationale for the opinion is given. Care is taken to differentiate between factual information and the expert's interpretation of the facts.

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BIODATA

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Dr. Bakeer has authored or co-authored over 30 technical papers and 6 technical reports, has made 12 presentations at conferences, and has presented 5 short courses, all in the fields of geotechnical engineering, computer solutions to geotechnical problems, geotechnical information systems, and knowledge-based expert systems.

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Dr. Fowler has authored or co-authored 37 technical publications and 23 papers. He has also been technical contributor to 21 technical publications in the fields of geophysics, soil dynamics, soil mechanics, dredging, soil erosion, soil and structure interaction, pile supported foundations, and seismic wave propagation phenomena.

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Spigolon worked for Pittsburgh Testing Laboratory in St. Louis, MO, as a construction materials inspector in 1954. In 1955-58, he did graduate work, taught, and did highway research at the University of Mississippi. He attended the University of Illinois from 1958-60. From 1960-1964, Dr. Spigolon returned to the University of Mississippi as Assistant and Associate Professor. In 1964 he was employed at Memphis State University as Professor of Civil Engineering where he taught until 1969. From 1969-72 he was Director of Engineering for Barrow Agee Laboratories, Memphis, TN. During 1972 to 1980 he owned and operated Spigolon Engineering Laboratories (later Spigolon-DISC) in Memphis. After a short period (1981-83) of teaching at Memphis State, Dr. Spigolon returned to the private practice of geotechnical engineering in Memphis, TN, and Coos Bay, OR.

Dr. Spigolon is coauthor of an engineering materials text and is the author of 18 published research reports and professional papers, six unpublished research reports, and over 500 geotechnical engineering and structural failure analysis reports submitted to commercial clients. He is a registered professional engineer in Mississippi, Oregon, and Tennessee.

APPLICATION OF THE 1991 OCEAN DISPOSAL TESTING MANUAL IN THE SOUTHEAST: A CONTINUING PROCESS

by

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ABSTRACT

Last year the U.S. Army Corps of Engineers (COE), in conjunction with the U.S. Environmental Protection Agency (EPA), published the final version of the "Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual" (the "Greenbook"). The purpose of the manual is to provide guidance on procedures used to evaluate the potential contaminated environmental impact of the ocean disposal of dredged material. Since its publication, the COE and EPA have worked together to apply the new dredged material testing procedures in the Southeast. The purpose of this paper is to describe the successes and difficulties experienced thus far, including; increased inter-agency coordination, selection of sampling locations, chemicals of concern, test organisms, reference sediments and interpretation of data. Examples will be presented from projects recently completed or currently underway.

Application of the 1991 Ocean Disposal Testing Manual in the Southeast: A Continuing Process

by

Robert J. Pennington[1] and Catherine Fox[2]

INTRODUCTION

In February 1991 the second edition of the "Testing Manual for Evaluation of Dredged Material Proposed for Ocean Disposal", better know as the Green Book, became effective, replacing the 1977 edition. The new manual, and an increase in the intensity of review of ocean disposal activities by both Environmental Protection Agency (EPA) Regions II, in New York, and IV in Atlanta, greatly changed the program for testing and evaluating dredged material for Ocean disposal in the Jacksonville District of the U. S. Army Corps of Engineers (District). This paper examines some of the problems experienced during the first year implementing the 1991 Green Book, with examples from case studies in the Southeast, and offers some observations on the present state of evaluation procedures.

THE PROBLEMS

Detection Limits. What constitutes needed and obtainable detection limits for chemical analysis of elutriates, sediments and tissue has been debated. What limits are needed is of secondary importance to what detection limits can be obtained by the average contract laboratory facility. In some cases project managers may be asking for detection limits that cannot be obtained.

Reference Stations. Where to locate stations in relation to the disposal area, and the number of samples stations needed to produce a useful reference station value, have been the subject of discussion. However, the most complex problem concerning reference stations comes when deciding on an acceptable lower limit of values for reference station bioassays. This problem is not discussed in the Green Book and, presumably there is no lower limit; however, EPA is uncomfortable with low reference station values.

Number of Samples. The number of stations to be sampled at an individual project has also been a topic of concern. EPA wants information that is statistically valid and that represents sound science. The Corps has similar concerns, but must work within a budget. One sample per 10,000 cubic yards of dredged material may be desirable to meet the statistical requirements of a research level project, but at $5,000-$10,000 total cost per sample, this is out of the realm of fiscal possibility.

Tiered Testing. Where little or no material other than sand, gravel and rock is

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to be dredged, the need to do any testing, not alone extensive chemical analysis of material or bioassay, is questionable. This is justified by both the MPRSA and the 1991 Green Book's tiered approach. However, there has been a reluctance on the part of EPA to accept tiered testing because in many cases the data base is old or non-existent or was collected under the 1977 Green Book.

Test Organisms for Bioassay. The most difficult problem and far reaching changes that have been encountered have been changes in recommended bioassay organisms. Early in 1991 the District developed its first bioassay species list based on species suggested by the 1991 Green Book, the District's bioassay contractor's experience, the availability of organisms and perceived environmental suitability of organisms. The list was unsuitable to EPA. After some discussion, a list was developed by EPA's Athens Laboratory and submitted to the District. The list provided five test species for elutriate and sediment bioassays that met the requirements of the Green Book. The list was comprised of:

For elutriate bioassay.

Mysidopsis bahia - Bay mysid
Menidia beryllina - A fish, the Tidewater Silversides
Crassostrea virginica - Oyster (Larval Stage)

For Sediment Bioassay.

Mysidopsis bahia - Bay mysid
Ampelisca abdita - Infaunal amphipod.

This list was eventually adopted in coordination with both Regions II and IV, and has been used for all testing done in 1991-92.

Ampelisca abdita is the critical species on this list. *Ampelisca abdita* is an infaunal amphipod, ie, it lives in the sediment, and the inclusion of an infaunal amphipod is strongly recommended by the 1991 Green Book, claiming they are:

1. Sensitive to benthic impact.
2. Readily available.
3. Tolerant of a wide range of sediment grain sizes.
4. Tolerant of a wide range of laboratory exposure conditions.
5. Ecologically relevant to most dredged-material disposal sites.

Repeatability. Lastly, it is worth considering what the data obtained in the projects suggests about the repeatability of bioassays in general. Although sediment evaluation must be applied science, it is supposedly based on sound scientific fact. By definition then, this work is should be consistently repeatable, or it is of questionable validity.

TEST RESULTS

The results of three projects evaluated in 1991 are used to highlight and discuss the problems.

Elutriate Bioassay. Elutriate bioassays of 96 or 48 hours in three concentrations (10, 50 and 100%) with five replicates at each concentration, have been run for all projects. Results have ranged from 30% survivorship to 94%

survivorship for the test organisms.

Canaveral Harbor Sediment Bioassay. The first project evaluated under the 1991 Green Book was Canaveral Harbor, at Cape Canaveral, Brevard County, Florida. The sediments demonstrated low to moderate levels of contamination with heavy metals and traces of organic contaminants. Ten test stations were sampled and a single reference station sample was taken one half mile north of the ocean dredged material disposal site (ODMDS) which is located five miles off-shore. The data for sediment bioassay for *Mysidopsis bahia* and *Ampelisca abdita* are displayed in tables 1 and 2 respectively .

Table 1: Results of 1991 10-day sediment bioassay using *Mysidopsis bahia* for sediments from Canaveral Harbor, Florida. Expressed as average percent survival of five replicates of 20 animals each.

Control	93%
Reference	63%
Station 1	91%
Station 2	87%
Station 3	89%
Station 4	79%
Station 5	98%
Station 6	95%
Station 7	85%
Station 8	93%
Station 9	80%
Station 10	57%

Mysidopsis bahia results presented no problems. The control was adequate, ie., it exceeded 90% survivorship as required by the Green Book. All test stations were within 10% of the reference station and statistically valid. The District and EPA Region IV concluded that all stations were suitable for disposal in the Canaveral ODMDS.

Problems were encountered with the *Ampelisca abdita* bioassay. The control did not equal or exceed 90% the first two times the test was run. A third test was successful. Test results for three test runs for sediment bioassay from Canaveral Harbor are shown in table 2.

On the third run the control survivorship was 93% and the reference 55%. All stations were within 20% of, or exceeded the reference station survivorship as required for *Ampelisca abdita*.

Miami River Sediment Bioassay. The second project involved evaluating sediments from the Miami River. Chemical analysis demonstrated that the sediments were contaminated with moderately high levels of lead and traces of organic contaminants. A single reference station sample was taken in approximately 500 feet of water one mile south (upstream) of the ODMDS which is located on the western periphery of the Gulf Stream near Miami. Reference station sediments were analyzed for heavy metals, pesticides, and PAHs. No organic contaminants were found at detection limits and heavy metals were not significant. The results of sediment bioassay for *Mysidopsis bahia* and *Ampelisca abdita* are present in table 3.

Table 2. Results of three rounds of 10-day sediment bioassay using Ampelisca abdita for sediments from Canaveral Harbor, Florida, 1991. Expressed as average percent survival of five replicates of 20 animals each.

	1ST RD	2ND RD	3RD RD
Control	83%	70%	93%
Reference	80%	66%	55%
Station 1	78%	57%	66%
Station 2	38%	51%	92%
Station 3	65%	60%	69%
Station 4	83%	72%	85%
Station 5	95%	78%	81%
Station 6	86%	77%	84%
Station 7	44%	66%	71%
Station 8	40%	60%	75%
Station 9	50%	70%	94%
Station 10	84%	78%	74%

The results shown in table 3 for Mysidopsis bahia demonstrate an acceptable control station survivorship (96%). The reference station is what might be expected from a clean site (85%). Four sample stations 6,7,8 and 9 are not within 10% of the reference and would not be suitable for ocean disposal.

The Ampelisca abdita reference station bioassay had only a 5% survival rate. This was unexpected, particularly in light of the clean nature of the sediment and the Mysidopsis bahia reference station survivorship value of 85%. Conversations with the bioassay contractor indicated that all Ampelisca abdita reference station replicates had problems because of the grain size of the sediment.

The reference station data were discarded and sample station data compared to the control station. All stations failed. In view of the very low survivorship at all seven stations, reinforced by the failure of Mysidopsis bahia at four of seven stations, no retesting of the reference station was planned. Ocean disposal is no longer planned for these sediments.

Table 3: Results of 10-day sediment bioassay using Mysidopsis bahia and Ampelisca abdita for evaluation of sediments from the Miami River, Miami, Florida, 1991. Expressed as average percent survival of five replicates of 20 animals each.

	Mysidopsis bahia	Ampelisca abdita
Control	96%	96%
Reference	85%	5%
Station LM-0	76%	9%
Station LM-3	83%	2%
Station MRS-6	66%	54%
Station LM-7	60%	12%
Station LM-8	74%	18%
Station LM-9	8%	48%
Station LM-10	86%	5%

Rio Puerto Nuevo Bioassay. The last example project presented is that of bioassay testing for the Rio Puerto Nuevo project in San Juan, Puerto Rico. This small previously channelized river in San Juan, and a small drainage ditch tributary, were sampled at seven stations. The reference station value presented is an average of five stations sampled and tested individually. These reference stations were located offshore near the San Juan ODMDS in water to 1200 feet deep.

In this series of bioassays, six of seven sediment samples tested with Ampelisca were satisfactory. Only station seven was more than 20% below the reference station value. The results are presented in table 4.

Table 4: Results of 10-day sediment bioassay using Ampelisca abdita to evaluate sediments from the Rio Puerto Nuevo, San Juan, Puerto Rico, 1991. Expressed as average percent survival of five replicates of 20 animals each. Double figures are duplicate tests.

	Ampelisca abdita
Control	95%
Reference	67%
Station 1	51%
Station 2	73%
Station 3	64%
Station 4	70%
Station 5	79%/79%
Station 6	74%/64%
Station 7	23%

The problem now appeared to be with Mysidopsis bahia. As can be seen in the first column of table 5, none of the seven stations had acceptable values, including the duplicates run of stations 5 and 6. All seven stations were resampled and the sediments bioassay for Mysidopsis bahia repeated. Two series of bioassays for all seven stations were conducted by independent laboratories. The results shown in the second column of table 5 are remarkably different than the first round of testing.

Table 5: Results of three 10-day sediment bioassays using Mysidopsis bahia to evaluate sediments from the Rio Puerto Nuevo, San Juan, Puerto Nuevo, 1991. Expressed as average percent survival of five replicates of 20 animals each. Double figures are duplicate tests.

	First Bioassay	Second Bioassay
Control	93%	97%
Reference	87%	-
Station 1	54%	87%/94%
Station 2	49%	94%/92%
Station 3	51%	91%/88%
Station 4	42%	82%/91%
Station 5	23%/48%	85%/65%
Station 6	11%/47%	95%/88%
Station 7	43%	85%/91%

All stations scored high and are within 20% of the reference station.

DISCUSSION

Detection Limits. Concern over detection limits has been set aside with the promise that a national detection limits list will be jointly prepared by EPA and the U. S. Army Corps of Engineers.

Reference Stations. Generally, agreement has been reached following Green Book guidelines, and stations have been located upstream from and away from the direct influence of previously used disposal areas and in the same or similar environment, usually as defined by depth. Initially one station was used, but problems with reference station values have caused the numbers of stations sampled to be increased to a figure that can be subjected to some statistical validation, i.e. three to five stations. This is evident in the five reference stations sampled at the San Juan ODMDS.

The problem of a lower acceptable limit for reference stations is critical and has not been answered or completely addressed. At Canaveral the final reference station value for the *Ampelisca abdita* bioassays was 55%. For *Mysidopsis bahia* the reference station was 63%. This means that stations with bioassay values as low as 35% for *Ampelisca abdita* and 53% for *Mysidopsis bahia* could be suitable for ocean disposal.

At Miami River, the reference station bioassay had a survivorship of 5%. No sample station could fail when compared to this bench mark. If the reference station value had not been discarded because of other difficulties, ie, test animals dying because of grain size incompatibility, what, other than common sense, would have demanded that this value be discarded? And if that is the case, where does common sense start? Sooner or later, at some project, a valid reference station value will be established in the 20-30% range and the current guidelines will not be adequate to prevent disagreement.

Number of Samples. In general the District has increased the number of samples it takes and EPA has been realistic in considering what is fiscally possible. Breaking a project down into segments based on the potential for contamination, ie, type of sediment, point sources of contamination and so forth, and then locating three to five stations in each segment, has helped eliminate disagreement over how many samples must be taken for some arbitrary number of cubic yards.

At large projects, when pre-project sediment data has been limited, we have reduced the samples subjected to complete analysis, by first collecting a large numbers of reconnaissance samples with a grab. The recon samples have then been analyzed for settling rate and grain size. Complete analysis has then been done on a second set of samples taken with a vibracore in areas with high silt and clay content. In this fashion, overall testing costs have been reduced.

Tiered Testing. With a data base is that admittedly old, and with the goal of establishing a baseline of data compatible with the 1991 Green Book, the District has been doing evaluations at the tier III level for all projects. As a new data

base accumulates, this situation should change and tier I or II reviews should suffice.

Elutriate Bioassay. The elutriate bioassays have proved to be of very little use. When diluted using the ADDAMS DUMP model, all values have been adequate for ocean disposal. It is difficult to imagine a situation where elutriate bioassays would fail and sediment bioassays would pass. The continued use of this test, though required by the MPRSA, is expensive and of questionable value.

Sediments Bioassay - Canaveral Harbor. Sediment bioassays are the critical, and seemingly, the limiting, bioassay test. The *Mysidopsis bahia* test, which was familiar to the bioassay contractor and used animals obtained from cultured stock, went well and offered no problems as is demonstrated in table 1. Nine of ten stations exceeded the reference station value of 63% survivorship. None was more than 10% below the reference station value. The only problem was the reference station value, which coming from offshore ocean site, is lower than expected. As discussed above, EPA region IV was uncomfortable with this value.

In the *Ampelisca abdita* bioassays, three tests were run before the required 90% survival could be obtained in the control. After the second series of tests was run, and the control survivorship dropped from 83% to 70%, discussions were held with the contract bioassay laboratory to determine the source of the problem. Bioassay personnel indicted that the test organisms appeared to be in poor condition. The animals were being purchased from a supplier collecting on the northeast Atlantic Coast. Another laboratory confirmed the poor condition of the *Ampelisca abdita* received from the same source. Another source of the *Ampelisca abdita* was then found from a West coast supplier and the third round of bioassays conducted. The sediment for the third round of testing used was from the same sample used in round two. This sediment had been held for over two weeks but less than the six weeks maximum recommended by the Green Book. On the third try the control station exceeded the required 90% survival. Apparently, problems with the first run were caused by problems in handling *Ampelisca abdita* and test animal vitality. By the second run the problems seem to have been confined to test animal vitality.

Sediments Bioassay - Miami River.

While the results for *Mysidopsis bahia* were easily interpreted, the *Ampelisca abdita* bioassays are a different matter. The reference station had only a 5% survivorship. This may have been a result of there being inadequate fine grain material in the sediment sample. Indeed the grain size analysis shows that this material had few fines. *Ampelisca abdita* is an animal of fine grain sediments. It uses bodily secretions and fine grain sediment to construct a tube in which it lives (Mills, 1967). Conversations with the bioassay contractor indicated that in all reference station replicates, *Ampelisca abdita* individuals were observed to fail to build tubes and bury into the sediment. The animals were eventually caught in the surface tension and died (Barry A. Vittor, Barry Vittor and Associates, Inc., pers. comm.).

Despite the problems with the reference station, the sample stations and control station results were considered valid. Seven of seven stations failed. Values were as low as 2% and 5% survivorship.

As a way to review the increased sensitivity of the 1991 Green Book test organisms against the 1977 Green Book test organisms, it is interesting to note that previous testing on Miami River sediments had been conducted by the District in 1988 under the old Green Book. Results had suggested good prospects for ocean disposal of this material. Only one problem station had been identified where low survivorship had occurred in the sediment bioassay for Penaeus aztecus, the brown shrimp. The species used and results of the 1988 bioassay are shown in table 6. Although this evaluation was nearly completed and on the verge of being acceptable, new testing was conducted because of technical complaints raised by EPA and other conservation agencies. Station 3 was retested and six new stations were tested in 1991 under the 1991 Green Book using the five new test species. Of 14 separate bioassays conducted using Mysidopsis bahia and Ampelisca abdita eleven failed. The indication is that the new suite of test organisms and procedures is more sensitive than those used previously.

Table 6: Results of 10-day sediment bioassay using Mercenaria mercenaria, Nereis virens and Penaeus aztecus for Evaluation of Sediments from the Miami River, Miami, Florida, 1988. Expressed as average percent survival of five replicates of 20 animals each.

	M. mercenaria	N. Virens	Penaeus aztecus
Control	92%	99%	98%
Station LM1	96%	93%	92%
Station LM2	100%	92%	85%
Station LM3	98%	92%	58%
Station LM4	96%	93%	96%
Station LM5	98%	97%	92%
Station LM6	98%	87%	83%

Sediment Bioassay for Rio Puerto Nuevo. The point of interest with the Rio Puerto Nuevo bioassay testing is the apparent lack of repeatability of the bioassay technique. The first Mysidopsis bahia bioassay appeared to be valid with all stations failing (table 5). The control was adequate (93%) and the reference station value was not offensive (87%). A second trip to the field was necessary to collect sediment for the second round of bioassays. The Rio Puerto Nuevo is small with many surrounding landmarks. It is easy to return to within a few feet of a previous sample station. Assuming that the second samples were taken in approximately the same location as the first samples, i.e. within 20 feet and probably closer, the repeatability, and hence the scientific validity of applied bioassays as a method of evaluating material for ocean disposal, may well be suspect.

CONCLUSIONS

1. The national detection limits list for sediments and tissues now being developed jointly by EPA and the Army's Waterways Experiment Station will establish national guidelines and eliminate opportunities for disagreement.

2. Reference station samples should be taken at at least three sites until a bank of reference data is built. Then the average of as many valid stations as are available should be used. Problems associated with very low reference

station values need to be examined.

3. The number of stations tested will continue to be a compromise of funding versus test validity. Breaking projects down into segments based on contamination potential, and identifying and eliminating tests of sandy material, can reduce the number of sample sites needed and help avoid the urge to demand large numbers of samples per cubic yard of material to be dredged.

4. Full use of tiered testing will become reality after a new data base is established.

5. The elutriate bioassays are of seemingly little importance and consideration should be given to dropping this test method.

6. As demonstrated at the Miami River, where previous bioassays using the 1977 Greek Book test organism had passed for the most part, but where Mysidopsis bahia results were poor and Ampelisca abdita failed completely, the new test organisms represent a more sensitive gage of sediment contamination.

7. The suitability of Ampelisca abdita as test organisms can be reviewed based on its claimed merits.

The question of test organism availability is more complex than just being able to find a healthy supply of animals. Initial supplies of Ampelisca abdita, used for the Canaveral Harbor project, proved to be in poor condition. Another source was found and there are now several good sources. However, the issue here is not one of the availability of supplies of animals taken from the wild. It is the use of any wild-caught stock of animals that is questionable. There is presently not a source of cultured Ampelisca abdita. Bioassay organisms should ideally be from known laboratory cultures, not from animals of unknown lineage, caught for one test on one coast and for another test 3,000 miles away in a different ocean. The data obtained using wild-caught stocks is too susceptible to variation due to differences in population genetics, disease, and seasonal changes in animal condition and other factors perhaps unrecognized. The fate of vital projects costing millions of dollars should not be subjected to such unknowns.

Claimed tolerance to grain size is a another important issue that has not been satisfactorily answered. Ampelisca abdita is a animal found in soft, silty sediments, and as suggested by the Miami River reference station results, large grain sandy material lacking fine sediment can have severe effect on survivorship. In order to compensate for this problem, we have established a protocol of collecting sufficient sediment to run a retest. At the first sign of tube construction problems, the test will be stopped. The test will then be started again with new animals and reference sediments mixed with 25% control sediment. This has not yet been tried. If the solution to mix in 25% control sediment works, we will then have to address the question of the validity of test results after diluting the reference sediment with control material.

The problem of tolerance to laboratory conditions seems, after an initial learning period, to have been resolved. Competent bioassay firms should be able to handle this animal with little difficulty once they have established their

technique. The question of ecological relevance of the infaunal amphipod is also still unresolved and has been a source of considerable peer debate regarding test species selection. It seems to the authors that this debate is misguided. The purpose of conducting bioassays of sediment for ocean disposal is to test the toxicity of dredged sediment, not to test habitat differences. In many cases these sediments will be taken from one marine or estuarine ecosystem and deposited in a very different environment. Ecological relevance is not the question. The question is the use of a test organism of suitable sensitivity that will provide information on sediment toxicity. This data should be comparable with data from other widely diverse sites. The only way this can be done is with a universal test animal, a "white rat" or a "miner's canary". Ampelisca abdita, coupled with one or more sediment test organisms, seems as good if not better than most for this task, if the noise of unknowns, such as grain size, can be filtered out. Excluding unknowns would be greatly aided by the use of stock laboratory cultures of test organisms with known characteristics.

Lastly, the issue of repeatability needs to be addressed in depth. At Canaveral Harbor, reference station bioassays using Ampelisca abdita and sediment samples taken from the same site, varied from 55% to 70% to 80%. At Rio Puerto Nuevo, Mysidopsis bahia bioassay values differed significantly from one test run to another. Results like these cause the repeatability of bioassays to be questioned. Work being done on this subject indicates bioassay results can vary between stations separated by a few meters and that the toxicity of sediments is influenced by the way sediments are handled and whether sediment integrity is maintained (P. Winger, U. S. Fish and Wildlife Service, Field Research Station, University of Georgia, pers. comm.). Without repeatability, confidence in the bioassays procedures, regardless of the test species used, cannot be high.

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Biographical Sketch

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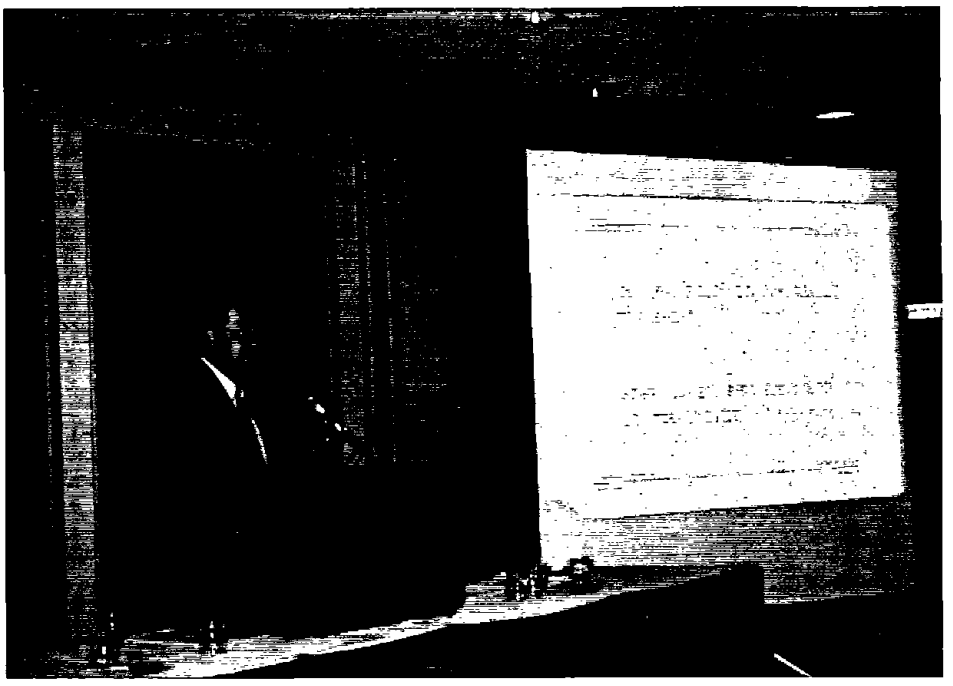
Mr. Pennington is the Ocean Disposal Coordinator for the Jacksonville District of the U.S. Army Corps of Engineers. He has been with the District since January 1990. Previously, he served 12 years with the U.S. Fish and Wildlife Service as a fish and wildlife biologist and wetlands evaluation and contaminants specialist.

BEHAVIOR OF CLAY BALLS IN A DREDGE PIPELINE*

by

Dov Leshchinsky, Stephen D. Richter and Jack Fowler



D. Leshchinsky

ABSTRACT

Laboratory tests on synthesized clay specimens, conducted under conditions simulating a dredge pipeline, indicate that plasticity and density have significant effects on the formation of clay balls. The tests also show that, to a limited extent, the velocity of the slurry in the dredge pipeline can control these balls survival. Test results are condensed into predictive charts relating the rate of clay lumps degradation and the plasticity index, the density and the velocity. If these relationships are shown to be valid in the field, then additional tests can easily be done to expand the scope of cases studied. Consequently, useful information for planning new-construction dredging in clayey sites, addressing factors such as equipment, dredged material containment, rate of excavation and costs, will become readily available. Determination of the necessary input data to use the established relationships is simple and inexpensive.

*Judged by the Papers' Committee to be the best paper presented at this Conference.

BEHAVIOR OF CLAY BALLS IN A DREDGE PIPELINE

by

Dov Leshchinsky[1], Stephen D. Richter[2], Jack Fowler[3]

ABSTRACT

Laboratory tests on synthesized clay specimens, conducted under conditions simulating a dredge pipeline, indicate that plasticity and density have significant effects on the formation of clay balls. The tests also show that, to a limited extent, the velocity of the slurry in the dredge pipeline can control these balls survival. Test results are condensed into predictive charts relating the rate of clay lumps degradation and the plasticity index, the density and the velocity. If these relationships are shown to be valid in the field, then additional tests can easily be done to expand the scope of cases studied. Consequently, useful information for planning new-construction dredging in clayey sites, addressing factors such as equipment, dredged material containment, rate of excavation and costs, will become readily available. Determination of the necessary input data to use the established relationships is simple and inexpensive.

INTRODUCTION

Degradation of dredged clay lumps, transported hydraulically in a dredge pipeline, varies widely. Friable clays slurrify rapidly after being excavated by the cutterhead. Stiff or highly plastic clays may deform into a ball shape (Fig. 1) while being dragged in the dredge pipeline. The phenomenon of clay balling may or may not be beneficial, depending on the application. For example, if a containment dike is to be constructed using hydraulic fill, clay balling out of stiff clay is desirable since construction then is feasible (Fig. 2). On the other hand, clay balls slow down the transport

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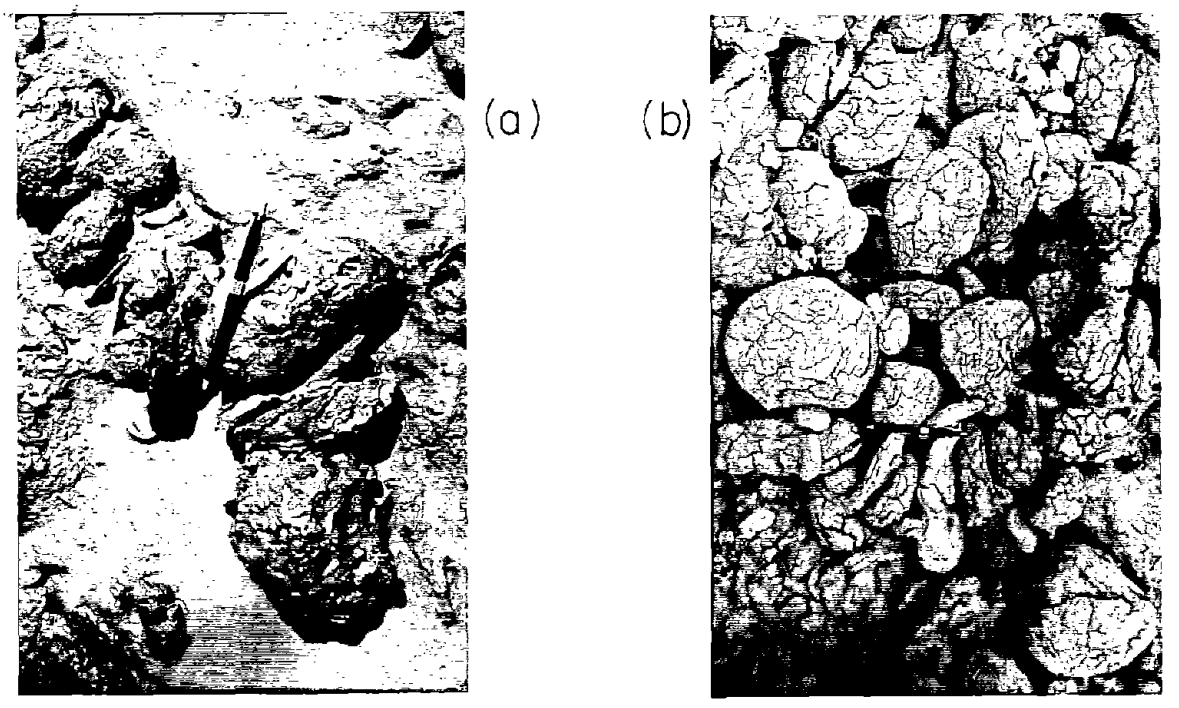


Figure 1. Clay balls: (a) soft, and (b) stiff.

Figure 2. Steep dike constructed of stiff clay balls.

process; i.e., the volume of solids in water may decrease by an order of magnitude, typically from about 50% to about 5%. In extreme cases, when the pumping head is insufficient or when the dredge pipeline is long, clay balls may settle and clog the pipe. Thus, knowledge of the behavior of dredged clay balls may enable one to assess the anticipated transporting difficulty and, possibly, to plan the dredged material containment. Even the selection of a cutterhead may be related to the degradation rate of excavated clay lumps; i.e., it can be selected so as to produce the proper initial lump size thus controlling the ball size at the containment area.

This paper presents results obtained from laboratory tests conducted on synthesized clay lumps subjected to simulated conditions of a dredge pipeline. Based on these results, empirical relationships between the clay ball degradation rate and the plasticity, density and the average velocity in the dredge pipeline, are established.

LABORATORY DEVICE AND TESTING PROCEDURE

When transported hydraulically, clay balls are dragged slowly over the bottom of the dredge pipe while slurrified materials flow rapidly above as a suspension (Fig. 3). To simulate the interaction between a clay ball, the pipe and the fluid turbulence, the apparatus shown in Fig. 4 was assembled. Generally, it resembles the device reported by Lord and Isaac (1988). The interaction simulating device consists of a sheet metal drum (40 cm in diameter and in length) with screened ends. The inner wall of the drum was lined with a sandpaper, 50 grit, to simulate the abrasive actions of the pipe and the rapidly flowing slurry on the rolling and sliding lumps. The drum was suspended in a Plexiglas container that was filled up with clear tap water, submerging half the drum. A well-defined clay lump was inserted through an opening in the screen. A variable speed electric motor, engaged to the drum through a shaft, spun the drum. The drum was rotated, for each clay specimen, at a constant speed up to a selected agitation time. After the selected time had elapsed, the motor was stopped and the specimen's intact

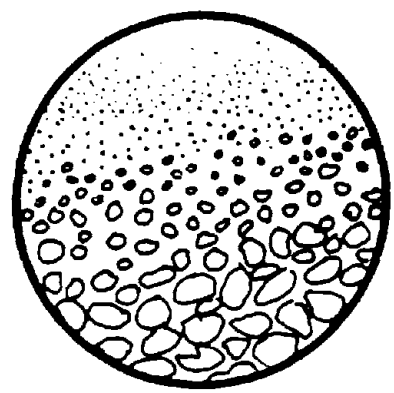
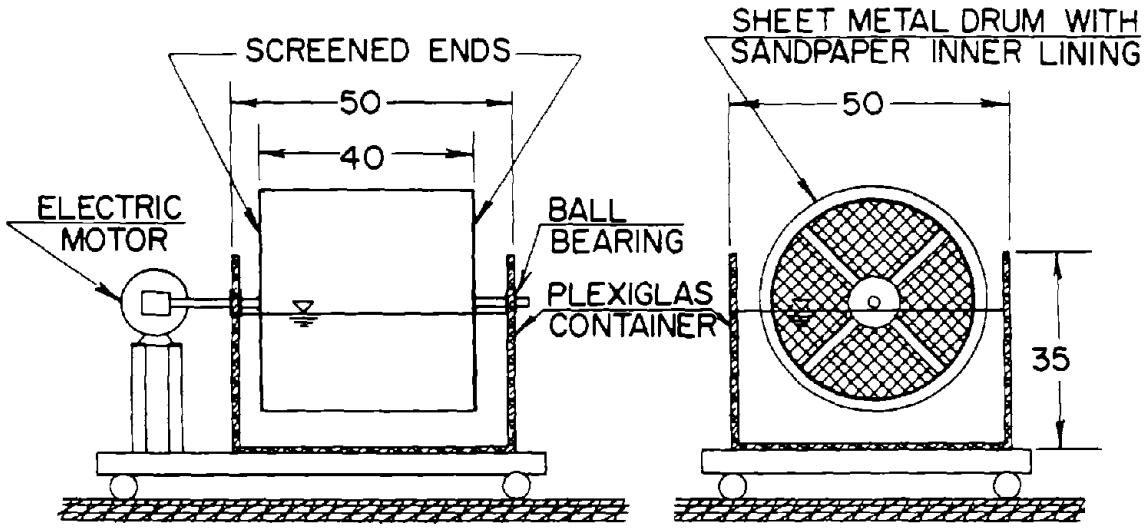


Figure 3. Distribution of segregated sediments in pipeline (Turner, 1984).



All units are in Centimeters

Figure 4. Testing device.

portion removed (Fig. 5). This portion was then oven-dried and weighed to determine the degradation (i.e., the percent, by weight, of material that has slurrified) due to exposure to the simulated hydraulic transport environment.

Tests were conducted at three distinctive tangential velocities of the drum: 0.75, 1.5 and 2.25 m/sec (i.e., 2.5, 5 and 7.5 ft/sec). These values are assumed to reflect the average relative velocities between the slowly dragged clay balls and the dredge pipe.

Additional details about the testing technique are given by Leshchinsky, Richter and Fowler (1992). This reference includes also information about other testing techniques.

SYNTHESIZED SPECIMENS

Clay balls, tested in the drum, were prepared by mixing kaolinite and bentonite. By varying the proportion of the components, synthesized clay possessing a prescribed plasticity could be tested. Tests indicated that beyond 10% bentonite in mixture, the clay balls exhibited insignificant degradation under the simulated hydraulic conditions. Therefore, the relevant range of bentonite in mixture was limited to 10%. Fig. 6 shows the Atterberg limits (ASTM D4318) as a function of bentonite in mixture. These easily determined limits have the following engineering meaning. The

liquid limit, LL, signifies the water content at which the clay turns into a heavy liquid (i.e., slurrifies); the plastic limit, PL, indicates the water content at which the clay turns from a semisolid into a plastic material. The plasticity index, PI, is defined as PI = LL - PL and it signifies the range of moisture content in which the clay keeps its integrity as a plastic lump. In their natural state, all dredged clays possess water content, ω_n, equal or greater than the plastic limit (i.e., $\omega_n \geq$ PL). Consequently, PI is the maximum possible increase in water content of the cut lump before its slurrification occurs (i.e., before its water content increases, due to loosening during transport, above LL), thus making it reasonable to expect a correlation between degradation and the plasticity index.

Figure 5. Removal of intact lump from testing device.

Based on the standard Proctor compaction test (ASTM D698, method A), it was determined that the maximum dry density varies between 14.0 and 13.7 kN/m^3, for 0 and 10% bentonite in mixture, respectively. The corresponding optimal moisture contents varied between 29 and 31%. At its maximum density, the synthesized clay can be classified as "stiff". At 80% of its maximum density, the clay may be characterized as "soft" to "medium-stiff". The density (or stiffness) is directly related to the voids ratio of the material, or alternatively, if the clay is submerged, to the natural water content, ω_n, of

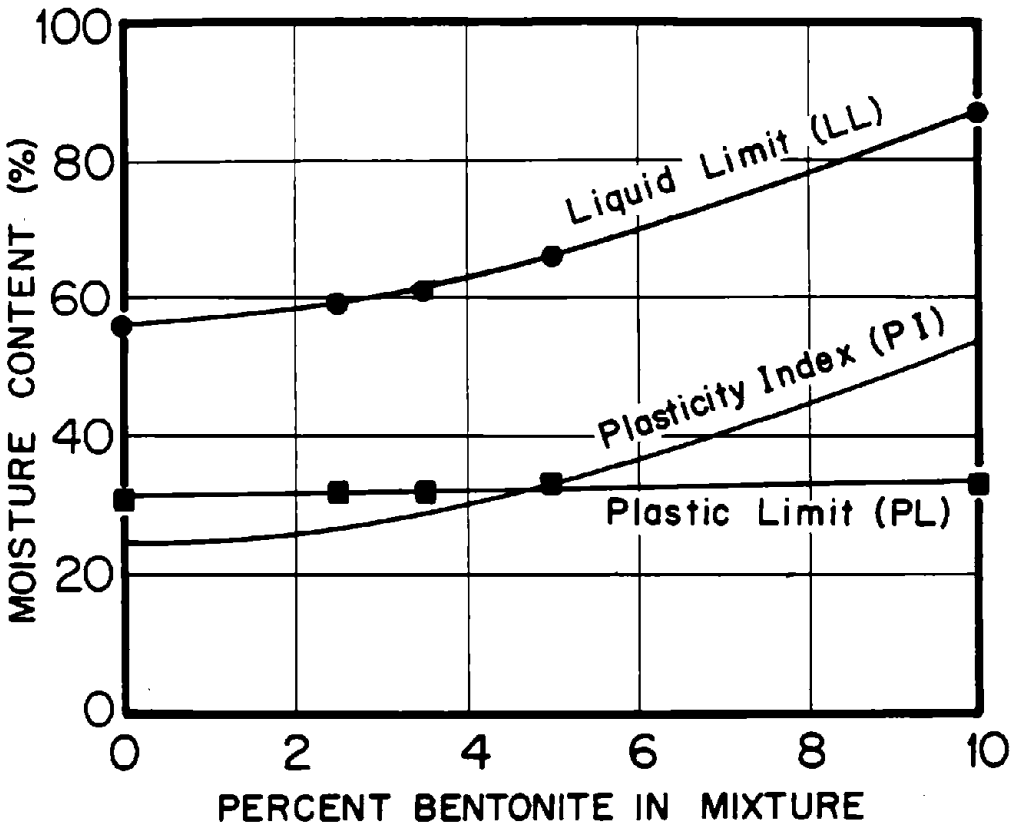
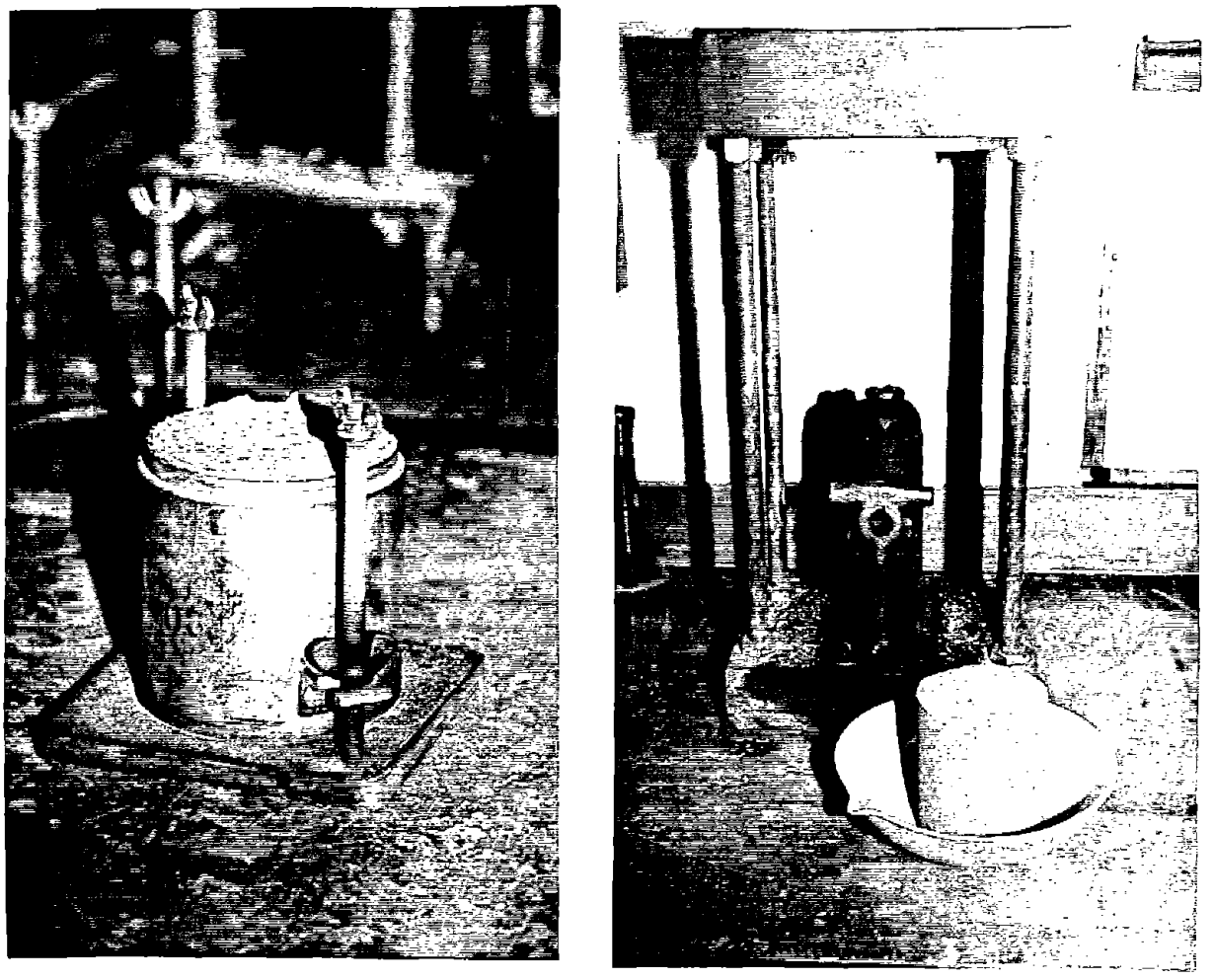


Figure 6. Atterberg limits as function of percent bentonite.

the clay. It seems reasonable to expect a correlation between degradation and stiffness (or initial density of clay balls). Such a correlation will supplement the correlation with regard to PI, relating degradation to natural water content (indirectly) and its maximum possible increase. Hence, tests were conducted on specimens at three different initial dry densities: 80, 90 and 100% of the maximum Proctor density value. These percentages are termed "Relative Compaction", R_c (i.e., R_c=80, 90 and 100%), signifying the clay consistency with regard to stiffness.

Specimens were prepared as follows. Bentonite and kaolinite mixture was proportioned to produce the desired PI. Water was added to the mixture to yield the Proctor's optimal moisture content. The wet mixture was then statically compacted in a Proctor mold (4" diameter and 4½" height; Fig. 7a), using an hydraulic jack, to the desired dry density (i.e., to R_c = 80% or 90% or 100%). The specimen extruded from the mold (Fig. 7b) was then used as the synthesized clay ball possessing a prescribed PI and R_c.



(a) (b)

Figure 7. (a) Compacted specimen in Proctor mold, and (b) extruded specimen.

TEST RESULTS

Fig. 8 shows the typical appearance of over-dried clay balls specimens after being subjected to the drum agitation. Results of one set of tests are presented in Fig. 9. It illustrates the data on specimens having a plasticity index, PI, of 25% agitated at a drum tangential velocity, v_t, of 2.25 m/sec (7.5 ft/sec). Note that v_t presumably signifies the average relative velocity between the dragged ball and the dredge pipe. The "Remaining Intact Material" represents the dry weight of the intact portion of the specimen after

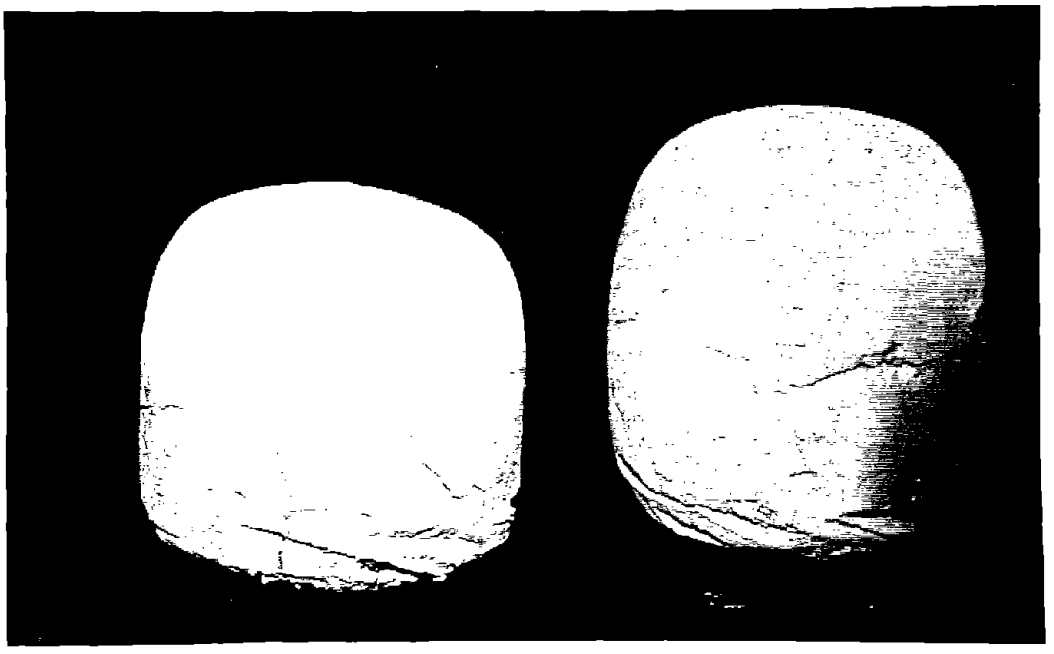


Figure 8. Appearance of specimens turned into clay balls.

agitation divided by its initial dry weight. Additional and more detailed test results are given elsewhere (Richter and Leshchinsky, 1992).

A straight-line fitting for the data points in Fig. 9 seems reasonable. The slope of the fitted line signifies the rate of ball degradation as a function of R_c, PI and v_t. This rate may be an important design parameter, allowing one, for example, to assess the ball size at the end of the dredge pipeline.

The fitted slopes for all test results (see Leshchinsky, Richter and Fowler, 1992) were plotted in Figures 10a, b and c versus the transport velocity and as a function of plasticity and compactness. Once the simulated test results are validated, these figures can be considered as design or predictive charts. One can then estimate from Fig. 10 the required transport velocity of cut lumps, in a given pipe (diameter and length), so as to attain a maximum production (i.e., excavation) rate without the formation of clay balls. One can select a cutterhead so as to produce lumps that will slurrify or, conversely, will maintain a bulky size so that a containment dike could be constructed at the disposal area. This estimation can be accomplished based on easily

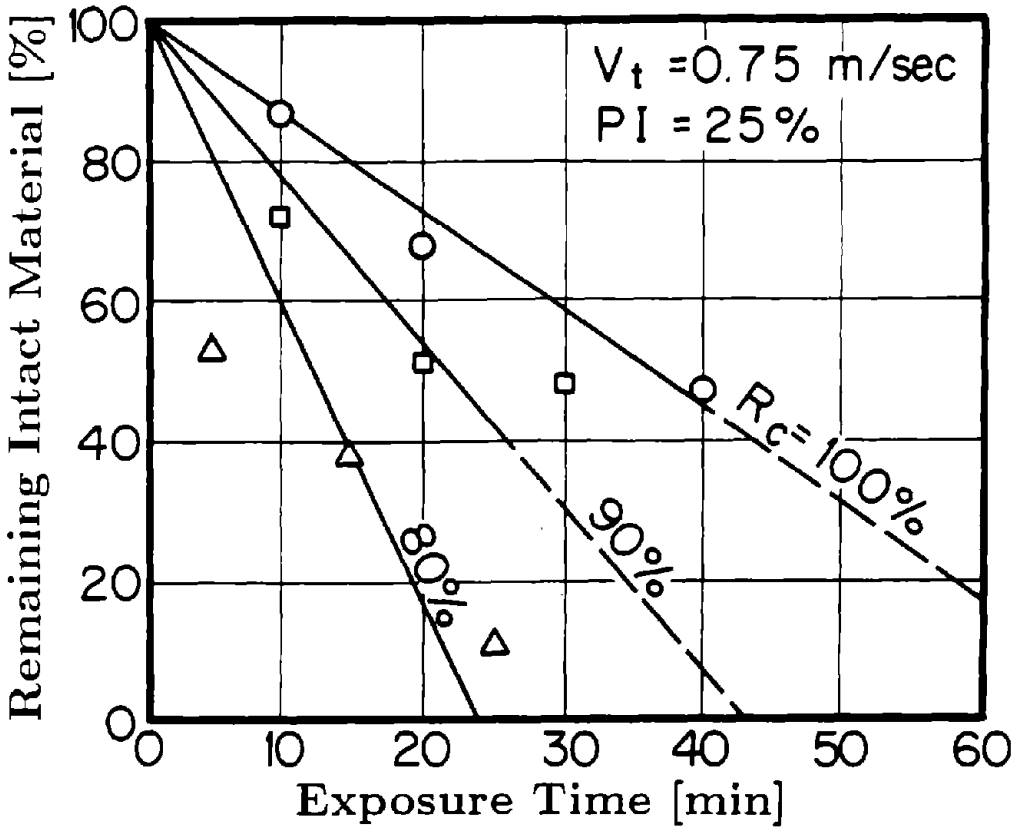


Figure 9. Typical test results.

characterized in-situ properties: plasticity (PI) and compactness (R_c).

Fig. 10 shows that decreasing PI or increasing v_t may increase significantly the rate of degradation. At low density (i.e., soft clay), plasticity plays a major role. At high density (i.e., stiff clay), however, the rate of degradation is virtually independent of plasticity as long as PI>25%.

CONCLUSIONS

The results obtained from laboratory tests on synthesized clay specimens, conducted in a simulated hydraulic transport environment, show that plasticity and density (or stiffness) have significant effects on the balls rate of degradation. For very dense material, the degradation rate was found to be

negligible at any plasticity index greater than 25%. Rates of degradation for highly to moderately dense clays, having plasticity indices between 25% and 35%, are rather slow. As the plasticity index increases above 35%, the degradation rate rapidly becomes negligible.

The test results indicate the likelihood of clay balls formation; i.e., when will clay lumps exhibit little degradation or slurrification. For example, if the criterion for clay balls formation is a degradation rate of 5% per minute (i.e., at this rate a clay ball of a specified size will be delivered at the end of a given dredge pipe), then Fig. 10a indicates that at v_t = 1 m/sec (3.3 ft/sec) the PI must exceed 30% for soft clay. Increasing the transport velocity will require higher PI. Fig. 10a also implies that an increase of PI from 25% to 35% drastically decreases the degradation rate. Fig. 10c indicates that for PI>25%, clay balls are likely to develop in stiff clay. This supplements the information provided previously by Verbeek (1984) about the formation of clay balls.

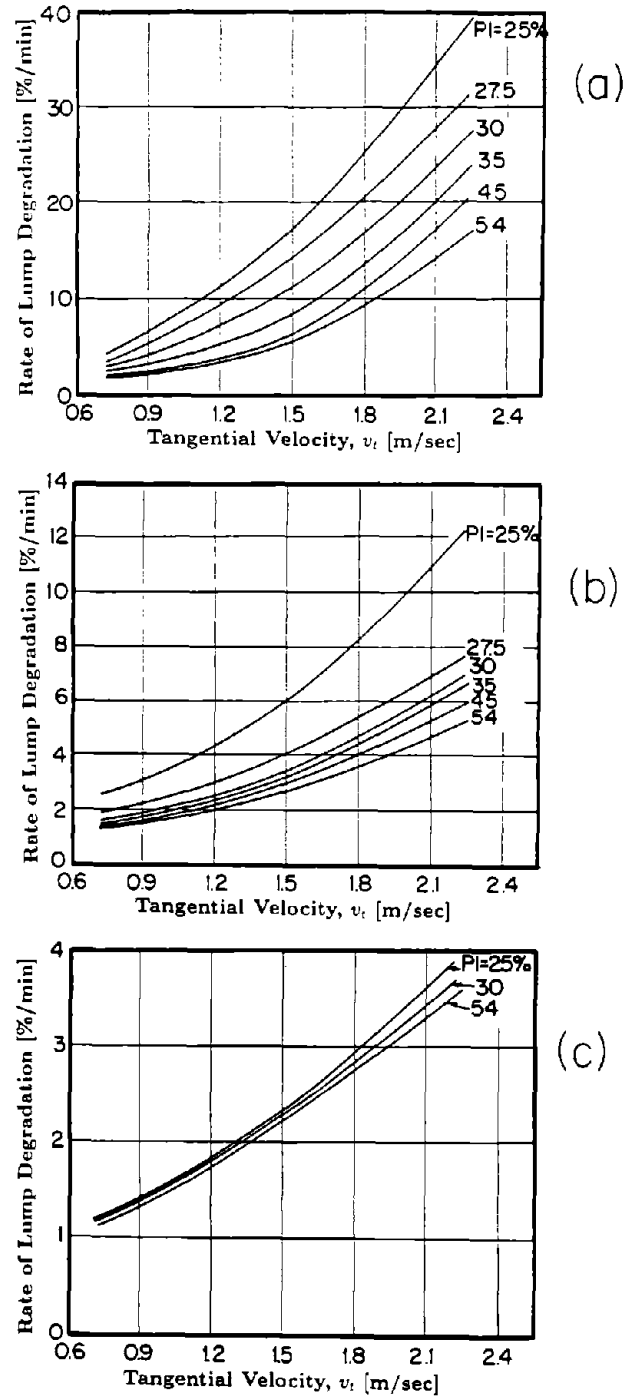


Figure 10. Summary of test results: (a) soft clay, (b) medium clay, and (c) stiff clay.

ACKNOWLEDGEMENTS

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Biographical Sketch

Dov Leshchinsky

Dr. Leshchinsky is presently an associate professor of Civil Engineering at the University of Delaware in Newark. He received the B.Sc. and M.Sc. in Civil Engineering from Technion-Israel Institute of Technology, in 1976 and 1979 and Ph.D. in Geotechnical Engineering from the University of Illinois at Chicago in 1982.

Dr. Leshchinsky has sixteen years of research experience in academia, government and industry. His research interests include slope stability analysis, geosynthetic reinforcement, earth structure engineering, and geotechnical aspects of dredged materials. He has served as consultant to various government and industry entities. For the past twelve years, Dr. Leshchinsky has taught graduate and undergraduate courses in geotechnical engineering.

USING VERTICAL STRIP DRAINS TO INCREASE THE STORAGE CAPACITY OF CRANEY ISLAND DREDGED MATERIAL MANAGEMENT AREA

by

Timothy D. Stark and Jack Fowler

T. D. Stark

ABSTRACT

The Craney Island Dredged Material Management Areas is a 2,200-acre confined disposal area located near Norfolk, Virginia. An extensive consolidation and desiccation analysis showed that the current capacity of Craney Island will be exhausted by the year 2000. Since The perimeter dikes are at their maximum height and the Virginia State Legislature ruled that Craney Island cannot be expanded or replaced, new techniques for increasing the storage capacity of Craney Island were sought.

Piezometers recently-installed in the perimeter dikes at Craney Island revealed that large excess pore-water pressures existing the dredged fill and underlying foundation clay. The excess pore-water pressures in the foundation clay presently exceed the ground surface by about 25 ft. The dissipation of these excess pore-water pressures will result in substantial consolidation settlement, an thus increased storage capacity. The time rate of consolidation is controlled by the permeability of a soil and the maximum length of drainage path. Since altering the permeability of a soil in situ is not practical, vertical strip drains are being used to reduce the drainage path to accelerate consolidation.

The use of vertical strip drains to consolidate the dredged fill and soft foundation clay will provide the following important benefits to Craney Island: 1) reduce the time required for consolidation resulting in a rapid increase in storage capacity, and 2) consolidation of the dredged fill and underlying foundation clay causing a substantial increase in their soil shear strength. This strength gain will allow the perimeter dikes to be constructed to higher elevations without setbacks or stability berms.

In summary, the installation of vertical strip drains will reduce the height of the dredged fill and soft foundation clay allowing a new disposal area to be constructed on top of the existing disposal area. The installed strip drains will also accelerate consolidation of dredged fill and foundation clay as new dredged material is placed.

USING VERTICAL STRIP DRAINS TO INCREASE STORAGE CAPACITY OF CRANEY ISLAND DREDGED MATERIAL MANAGEMENT AREA

by: Timothy D. Stark[1] and Jack Fowler[2]

INTRODUCTION

Fine-grained dredged material usually enters a confined disposal area in a slurry consisting of 10 to 25 percent soil particles. After the slurry flows over the disposal area, the fine-grained material starts undergoing sedimentation. At some point in the sedimentation process, the soil particles begin touching each other and eventually a continuous soil matrix is created. Further settlement is controlled by the rate at which water can be expelled from the soil matrix. This densification process is governed by a process called primary consolidation. At the start of primary consolidation, the soil matrix is very soft and usually has a void ratio of 10 to 20 and a saturated unit weight of 65 to 75 pounds per cubic foot.

Primary consolidation is caused by excess pore-water pressures forcing water out of the soil matrix. The excess pore-water pressures are induced by the weight of overlying dredged material and are in addition to the natural hydrostatic water pressures. Once the excess pore-water pressures have dissipated and consolidation is completed, a hydrostatic condition is established in which no flow or consolidation occurs.

The time required for 90 percent consolidation to occur can be estimated using Terzaghi's one-dimensional consolidation equation, $t_{90\%} = (0.848 \times H_{dr}^2)/(C_v)$, where H_{dr} is the maximum length of drainage path and C_v is the vertical coefficient of consolidation. This equation shows that the time required for consolidation is controlled by the coefficient of consolidation, that is, permeability, of

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the soil matrix and maximum length of drainage path that the water must travel to exit the soil matrix.

As water exits the soil matrix, the volume of the matrix decreases, causing an increase in storage capacity and soil shear strength within the disposal facility. The main objective of installing vertical strip drains in confined disposal areas is to reduce the length of the drainage path, accelerating the settlement rate and strength gain of the dredged fill or foundation soil.

USE OF VERTICAL STRIP DRAINS AT CRANEY ISLAND DREDGED MATERIAL MANAGEMENT AREA

The Craney Island Dredged Material Management Area is a 2,200-acre confined disposal area located near Norfolk, Virginia. Dredged material has been placed in the disposal area almost continuously since it was completed in 1957. The original design was for an initial capacity of about 100 million cubic yards and a 20-year life for the facility.

Increased dredging in the Norfolk channel has required the capacity of Craney Island to be increased through three major dike raising efforts. The dikes were raised from elevation +8 feet to elevation +17 feet mean low water (mlw) in 1969, to elevation +26 feet mlw in 1980, and to elevation +34 feet mlw in 1988. The final dike raising required the placement of a 1,000-foot-wide underwater stability berm along the outer toe of the west perimeter dike and large dike setbacks along the north and east perimeter dikes to ensure stability of the perimeter dikes (Figure 1). The dike setbacks are usually 200 to 300 feet, which results in approximately 20 to 30 acres of lost storage capacity during each dike raising.

Interior dikes were built within Craney Island to create three containment areas to improve sedimentation in the compartment being filled and allow the other two compartments to desiccate and consolidate faster. Desiccation will be accelerated by the removal or evaporation of surface water and will increase the amount of consolidation because the effective density of the soil increases as the pore-water evaporates. Construction of the interior dikes was completed in 1983. On the average, 4 to

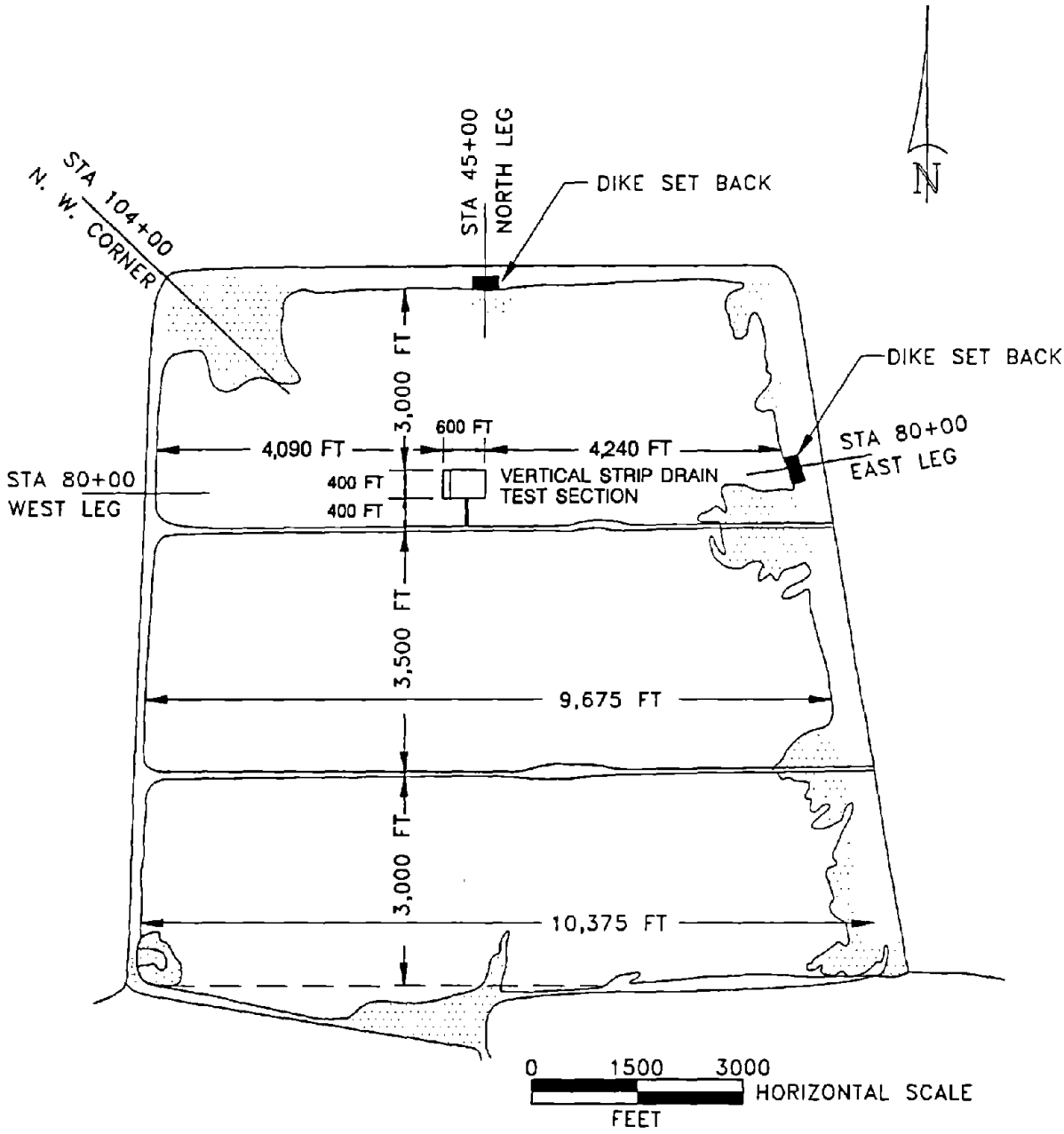

Figure 1. Plan View of Craney Island and Location of Vertical Strip Drain Test Section

5 million cubic yards of dredged fill is placed in a compartment each year. Dredging results in a net increase in dredged fill thickness of 3 to 6 feet per year in each compartment being filled, or about 1 to 2 feet overall.

The U.S. Army Engineer Waterways Experiment Station conducted an extensive consolidation and desiccation analysis to predict the life expectancy of Craney Island (Palermo and Schaefer 1990). This study revealed that the current capacity of Craney Island will be exhausted by the year 2000. Since the perimeter dikes are at their maximum height and the Virginia State Legislature ruled that Craney Island cannot be expanded or replaced, new techniques for increasing the storage capacity of Craney Island were sought.

Piezometers recently installed in the perimeter dikes at Craney Island revealed that large excess pore-water pressures exist in the dredged fill and soft foundation clay. Figure 2 shows that the excess pore-water pressures in the foundation clay typically exceed the ground surface by 20 to 25 feet. The cross section shown in Figure 2 is representative of Station 104+00 at the northwest corner of Craney Island (Figure 1). The piezometric levels shown in Figure 2 were measured in January, 1992.

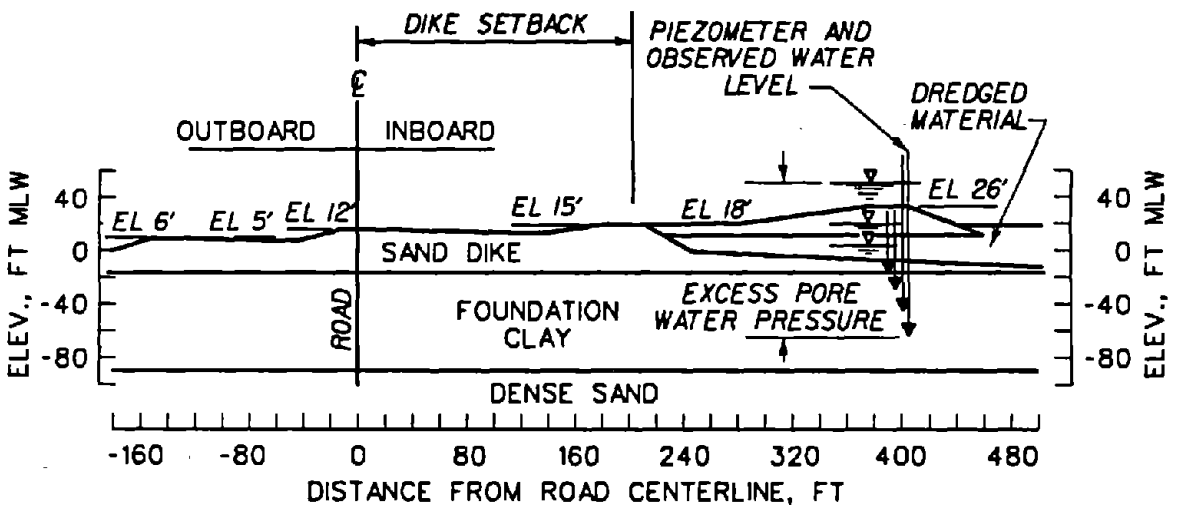

Figure 2. Typical profile of Perimeter Dikes and Excess Pore-Water Pressures at Craney Island

The dissipation of these excess pore-water pressures will result in substantial consolidation settlement and thus increased storage capacity. The rate of consolidation is controlled by the permeability of the soil and the maximum length of drainage path, as given by Terzaghi's equation presented earlier. Since altering the permeability of a soil in situ is not practical, techniques were sought to decrease the drainage path to accelerate consolidation.

Figure 3 shows the generalized subsurface profile at Craney Island. The maximum vertical drainage path in the foundation clay is approximately 55 feet. The installation of vertical strip drains, as shown in Figure 4, will result in radial flow instead of vertical flow. As a result, the maximum drainage path will be reduced to one-half of the strip drain spacing instead of one-half of the compressible layer thickness. This reduction is significant since the rate of consolidation is a function of the length of drainage path squared. The shorter drainage path will result in a substantial reduction in the time required to consolidate the dredged fill and underlying foundation clay. It should be noted that if Craney Island were not underlain by a permeable dense sand, the compressible layer would be singly drained and the maximum drainage path would be 110 feet.

STRIP DRAIN TECHNOLOGY

In the last 5 to 10 years, vertical strip drains have replaced conventional sand drains as the preferred method to speed up the consolidation of soft cohesive soils. Most strip drains are modelled after the cardboard strip drain developed by Kjellman (1948). Strip drains are band-shaped and have a rectangular cross section approximately 4 inches wide and 0.15 to 0.20 inch thick. A plastic core with grooves, studs, or channels is surrounded by a filter fabric. The filter fabric is most commonly a nonwoven geotextile. The core carries the excess pore water to the ground surface or underlying drainage layer, and the filter fabric keeps soil particles from entering the core.

Vertical strip drains have been used in many projects throughout the United States to accelerate consolidation of soft cohesive soils, including the recent expansion of the Port of Los Angeles, the Seagirt project in Baltimore

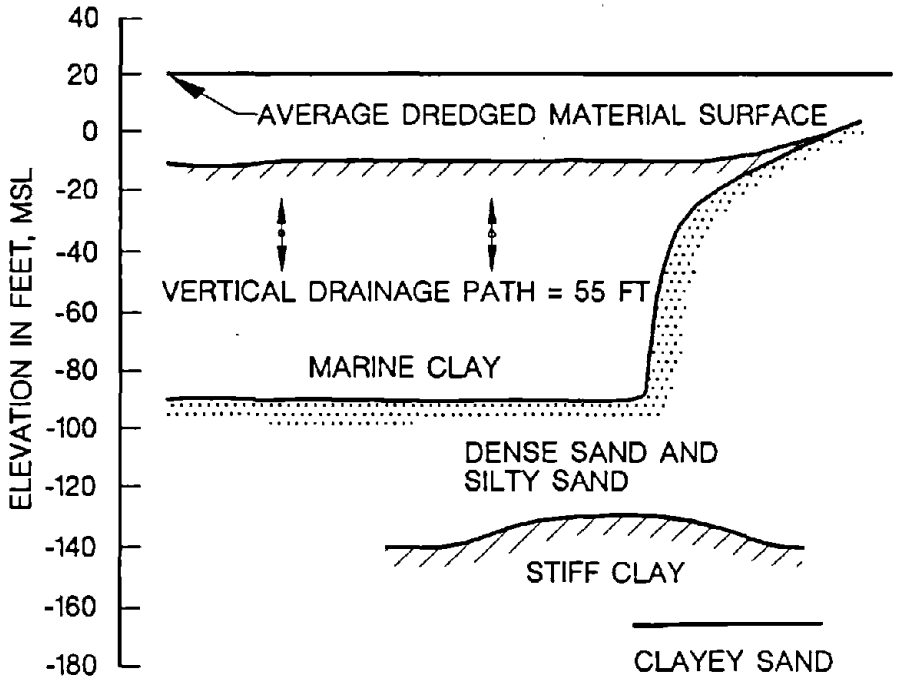

Figure 3. Generalized Subsurface Profile at Craney Island

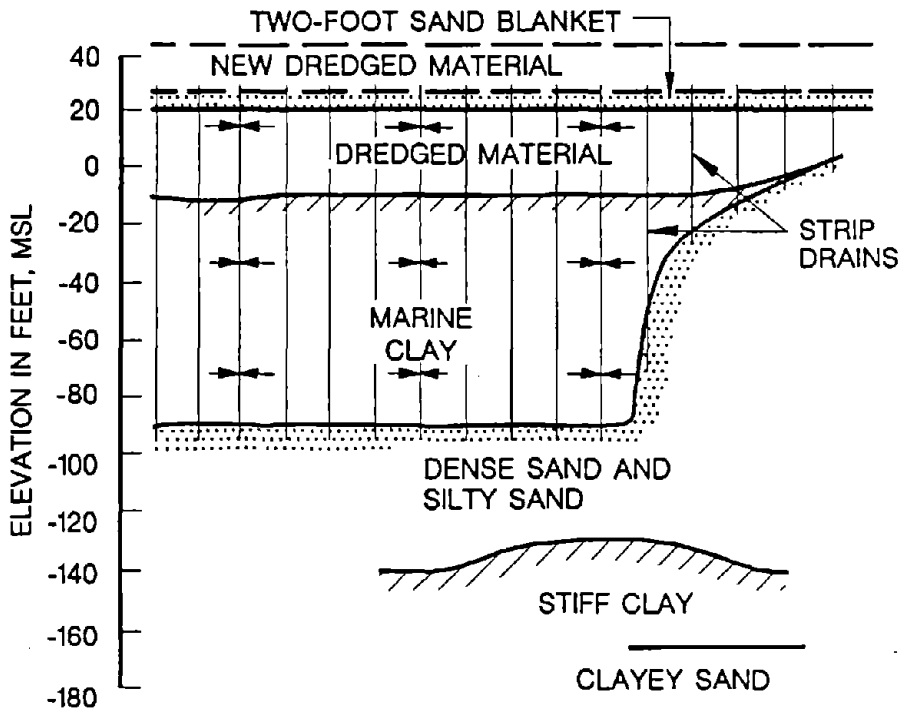

Figure 4. Radial Drainage Pattern Using Vertical Strip Drains

Harbor, the construction of dredged material containment areas in the Delaware River near Wilmington, Delaware, and the New Bedford Superfund site, New Bedford, Massachusetts.

Vertical strip drains are easily installed using equipment that exerts a ground pressure as low as 1.5 to 2 pounds per square inch. It is anticipated that a well-developed desiccated crust can support the required equipment. The installed cost of vertical strip drains is usually $0.50 to $0.60 per lineal foot. The time required for consolidation of the dredged fill and foundation clay is controlled by the spacing of the drains. Therefore, value engineering can be used to determine the optimal spacing of the drains to produce a certain increase in settlement, that is, storage capacity, in a specified time.

The strip drains arrive at the site in large rolls and are installed using a hollow mandrel (Figure 5). The end of the strip drain is threaded down the inside of the mandrel, which must be as long as the depth to which the strip drains are to be installed. At the bottom of the mandrel, the strip drain is threaded through a baseplate and inserted into the mandrel (Figure 6). The baseplate is used to keep the strip drain at the bottom of the mandrel to prevent soil from entering the mandrel during the insertion process and to keep the strip drain at the desired depth as the mandrel is withdrawn. When the mandrel is withdrawn from the ground, the strip drain is cut, and the process is repeated at the next location. This insertion cycle is very rapid (1 to 3 minutes) and only strip drains, baseplates, and a cutting tool are required.

At Craney Island it is anticipated that strip drains will initially be installed in north compartment (Figure 1). The remaining two compartments have sufficient capacity to receive dredged material for several years. After the strip drains accelerate consolidation in the first compartment, this compartment will be used for disposal while strip drains are installed in another compartment and the third compartment undergoes desiccation to support the strip drain equipment. Installation of strip drains will continue until strip drains have been installed in all three compartments. A drainage blanket, composed of dredged sand, may be used to remove the expelled water from the site, act as a drainage layer for future dredged material, and support, if necessary, the strip drain equipment. The strip drains will be pushed through the sand drainage blanket into the permeable foundation sands.

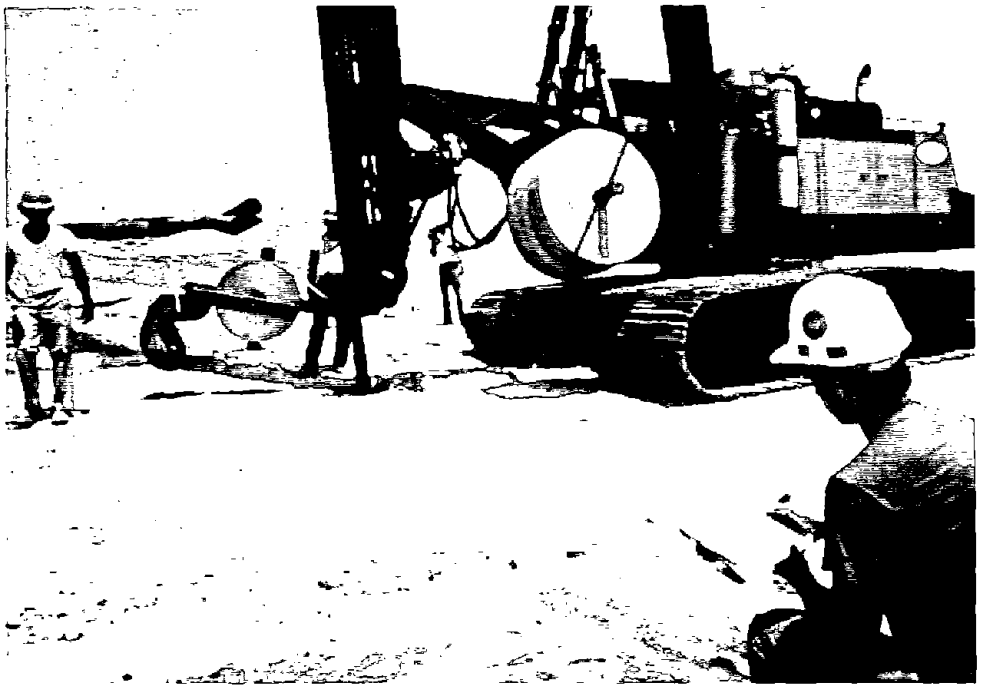

Figure 5. Typical Vertical Strip Drain Installation Equipment

Figure 6. Vertical Strip Drain Installation Procedure

This installation procedure will allow the expelled water to exit the strip drains at the sand drainage blanket and the underlying dense sand. A network of drainage pipes may also be required to aid the removal of water from the site if the permeability of the sand blanket is not adequate.

CRANEY ISLAND VERTICAL STRIP DRAIN TEST SECTION

A field test is being constructed in the north compartment to evaluate the effectiveness of vertical strip drains in consolidating the dredged material and foundation clay, to verify strip drain design assumptions, and to investigate the feasibility of installing vertical strip drains without a sand blanket. It can be seen from Figure 1 that the test section is 400 ft by 600 ft and divided into two sections. A two foot thick sand blanket has been pumped into the main area, which is 400 ft by 500 ft. A sand blanket was not placed in the mobility test section, which is 100 ft by 400 ft and located on the west side of the test section. The mobility test section will be used to determine if the low ground pressure equipment can operate on the desiccated crust without a sand blanket.

The vertical strip drains in the mobility section will be connected to horizontal strip drains or four inch perforated pipe on the ground surface. Each vertical strip drain will be connected to a horizontal strip drain or perforated pipe to promote drainage to the surrounding perimeter trench. Both horizontal strip drains and perforated pipe are being used to evaluate their effectiveness in conveying water from the test section to the surrounding perimeter trench and their ease of installation. It is anticipated that the vertical strip drains will be installed in the main and mobility test sections during the summer of 1992.

CONCLUSIONS

Using vertical strip drains to consolidate dredged fill and soft foundation soils will significantly reduce the time required for consolidation, resulting in a rapid increase in storage capacity and a large increase in soil shear

strength. This strength gain will allow perimeter dikes to be constructed to higher elevations without setbacks or stability berms.

The installation of vertical strip drains will reduce the height of existing disposal areas, allowing a new disposal area to be constructed on top of the existing area. The installed strip drains also will accelerate consolidation of the existing dredged fill and foundation clay as new dredged material and perimeter dikes are placed.

ACKNOWLEDGMENTS

The authors wish to acknowledge Messrs. Ronn Vann, Tom Friberg, Dave Pezza, Matt Byrne, and Sam McGee of the U.S. Army Engineer Norfolk District for their assistance in preparing this paper.

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Biographical Sketch

Timothy D. Stark

Dr. Stark received his B.S. from the University of Delaware (with honors) in Civil Engineering in 1981; M.E. in Geotechnical Engineering from the University of California at Berkeley in 1984 and Ph.D., in Geotechnical Engineering from Virginia Polytechnic Institute & State University in 1987.

Dr. Stark is presently an Assistant Professor of Civil Engineering with the University of Illinois at Urbana-Champaign. From 1981-83 he was employed by Woodward-Clyde Consultants as a geotechnical engineer and was an Assistant Professor of Civil Engineering at San Diego State University from 1987-91.

Dr. Stark was recently honored by the American Society of Civil Engineers with the Arthur Casagrande Professional Development Award and has numerous other honors to his credit.

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Stouffer Riverview Plaza, Mobile, Alabama
May 28-29, 1992

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REMARKS

MAJOR DENNIS W. HEUER
WESTERN DREDGING ASSOCIATION ANNUAL MEETING
MOBILE, ALABAMA
MAY 28, 1992

Good morning. It is certainly my pleasure to join you this morning on behalf of the Mobile District.

I would like to take just a few minutes to introduce you to the Mobile District and describe some important initiatives we have recently completed or have underway.

Those of you who attended the dredging seminar yesterday heard Jim Patterson of the Mobile Area Office discuss our initiatives in hydrographic surveying and later today Hugh McClellan from our Planning and Environmental Resources Division will present one of the district's top initiatives on dredging an d environmentally sustainable development.

The Mobile District has about 1,800 employees, including over 500 scientific and engineering personnel. The work force is split roughly 50-50 between our field offices and the district office. Our annual payroll is about $74 million.

Our combined civil works and military workload for FY 92 is over $468 million with an estimated workload of $432 million in FY 93, which begins in October.

The military boundary of the district covers a four-state region as well as Central and South America.

We work closely with our Air Force, Army, and Navy partners to provide quality engineering services.

Mobile District's civil works boundaries cover 96,000 square miles in Alabama, Mississippi, Georgia and Florida. We maintain six deep-draft harbors, 21 shallow-draft projects, five navigation systems, 22 dams with navigation locks, and operate five non-navigation dams for flood control, hydropower, and water supply. There are 2,00 miles of improved waterways in the Mobile District.

Our total operation and maintenance program for this fiscal year will amount to $120 million. Of this amount, $72 million will be spent on navigation features. We will have 18 dredging contracts this year -- three for new work (Gulfport, Dauphin Island, and Bayou la Batre), two for the navy (Pascagoula and Mobile), and 13 for O&M work. They range in value from $118,000 at Dauphin Island to $36 million at Gulfport deepening.

We will use a combination of pipeline, hopper and bucket dredges in the 118 contracts. Six of the contracts will be rental and 12 contracts will be fixed price. So far we have awarded 13 contracts this fiscal year. Three are scheduled in the third quarter and two in the fourth quarter.

The annual inland dredging program is underway for the Black Warrior-Tombigbee Rivers with Folk and Mike Hooks; the Tenn-Tom Waterway with T. L. James; the Apalachicola, Chattahoochee, and Flint Rivers with Cone Construction; and the Alabama-Coosa Rivers with T. L. James at approximately $10 million.

There will be 13 contracts for dredging in the coastal area at an estimated cost of $56 million.

Along with our traditional O&M dredging work we have undertaken major deepening projects authorized by the Water Resources Development Act of 1986. These projects include:

The deepening of Mobile Harbor from 40 to 45 feet at a cost of $37 million. Great Lakes Dredge & Dock removed about 20 million cubic yards of material from the channel. The project was completed in May 1990. Annual maintenance dredging in Mobile River runs about $2 million, in the Bay around $ 3 million, and the Bar about $1 million. Dredging of the Theodore Channel costs $2.6 million every other year.

A $36 million contract to deepen Gulfport Harbor from 30 to 35 feet was awarded last month to a joint venture of Great Lakes and Gulf Coast Trailing.

This effort will include a national demonstration on use of thin-layer open water disposal. Completion of this dredging is scheduled for November 1993. The thin=layer demonstration will start this summer with monitoring continuing through 1996.

Bayou La Batre Harbor in Alabama will be deepened from 12 to 18 feet. A contract is scheduled to be advertised in July. The project will involve dredging over 2.1 million cubic yards of material.

Channel improvements are in the works for Pascagoula Harbor, Miss., with contract advertisement scheduled for FY 94.

We have also been active in providing environmental and dredging support to the Navy for the Gulf Coast Homeport Group.

A $2.1 million contract was awarded to T. L. James in January 1992 for deepening the channels for the Naval Station Pascagoula and work is scheduled to be completed in August. The Naval Station facilities are located on Singing River Island, a former dredging material disposal site.

Work for the Navy was completed last Fall at Pensacola Harbor and was accomplished in three contracts totaling $29.5 million.

Dredging for the Arrival of Vessels at Naval Station Mobile is presently being performed by Bean Dredging. The $5.9 million contract, including maintenance dredging of the Theodore Channel, is scheduled for completion in October of this year.

So, as you can see, we are a large district with a big dredging mission. To the dredging contractors, their suppliers and dredging product manufacturers -- you are a key element to the success of that workload -- since you are our partners in construction.

We at the Mobile District have an active interest in the information exchange that is taking place this week and appreciate the opportunity to participate in this event.

Thank you.

DREDGING TECHNOLOGY TRANSFER: SPECIAL PROJECTS

Russell K. Tillman[1], Thomas R. Patin[2], Joseph R. Wilson[3]

INTRODUCTION

By using a wide range of communication tools, such as videos and computer technology, diverse audiences associated with dredging can be effectively and economically reached through innovative packaging of state-of-the-art technology. New dredging ideas and concepts have been economically packaged and delivered to targeted selected audiences for maximum returns.

This paper presents some recent efforts by the Corps of Engineers to implement dredging technology transfer vehicles such as public awareness, a lexicon of dredging terms, demonstration disks and videos. This is a combined effort of the Corps of Engineers' Dredging and Navigation Branch, Environmental Effects of Dredging Programs (EEDP), and Dredging Research Program (DRP) in expectation of delivering a diversity of technical products to a wide array of dredging customers. This paper also presents lessons learned to date from these efforts and possible future directions.

DREDGING PUBLIC AWARENESS

There is a need to communicate the credibility, importance, and reliability of dredging technology to the Corps' peripheral audiences. This peripheral audience, consisting of other elements, may not be familiar with dredging technology or with the economic importance of navigation. Because much of this audience has a voice in the planning and conducting dredging operations, our inability to successfully communicate this technology can have devastating effects on the ability to perform even the most basic dredging activities. Today, proponents of navigation and port expansion efforts must weave their way through an intricate web of laws which govern everything from the planning process through project completion, which could in many instances involve environmental mitigation. Port projects must pass review by numerous regulatory agencies: federal, state, and local. Project critics can challenge port planners and regulatory officials, administratively and in court, for

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[2] Environmental Effects of Dredging Programs, Environmental Laboratory, USAE Waterways Experiment Station, Vicksburg, MS.

[3] Dredging and Navigation Branch, Headquarters, U.S. Army Corps of Engineers, Washington DC.

failing to meet demanding scientific and legal criteria (Kagan 1991). The system can sometimes be cumbersome, fragmented, adversarial, legalistic, time-consuming, and costly. One approach out of many of informing these peripheral audiences, as well as amending this process towards a better balance, is to convey public awareness on the need and state-of-the-art of dredging technology.

The Dredging and Navigation Branch, US Army Corps of Engineers has initiated a dredging public awareness program to communicate advances in dredging technology. By using a variety of communication techniques and vehicles, the objective of this endeavor is to enhance the dredging knowledge of peripheral audiences associated with dredging activities. Topics will center not only on dredging and dredged material placement, but the role of navigation and ports in the US economy. In addition, specific results from research and development sector such as beneficial uses of dredged material, techniques for dredging and managing contaminated sediments, and long-term planning for dredging will be presented in various forms. While the scientific methodology of these efforts have been evaluated and assessed by scientific peer review and packaged for Corps and industry's use, no concerted effort has been made to refine the results for a layman's understanding.

This public awareness program to address these deficiencies is presently in its infancy. To date, videos and exhibits are being planned and developed for specific audience uses. A video, entitled "America's Ports: Open Channels to Trade" presents the economic necessity for navigation, ports, and dredging (Wilson 1992). For instance, the video attempts to put the need for dredging in a somewhat different light. It presents parallel discussions with the continued need for interstate highway development, expansion, and maintenance (that is the public has seen and expects interstate highway maintenance, although we cannot see it, dredges are simply maintaining our water highways and are accomplishing it with the use of the best techniques available). The video also shows that dredging and dredged material placement are not haphazard operations. Environmentally acceptable management strategies are applied for dredging projects. Additional videos are planned which will discuss specific aspects of dredging.

Numerous display themes have been exhibited at dredging-related conferences (Figure 1). Existing technology has allowed displays to deliver a customized dredging message towards the special audience of each specific conference. This customizing of messages helps reduce potential confusion of message that sometimes occurs with a more generalized method. Displays presently exist for:

a. Managing contaminated sediments

b. Dredging Research Program overview

c. Why dredge? (Economics of Dredging)

d. Dredging and Navigation Branch overview

e. Various Dredging Research Program technical areas

f. Sea turtles studies associated with hopper dredging

g. Long-term management strategy for dredging

h. Beneficial uses of dredged material (planned)

In addition to public awareness videos, one-page summaries on Waterways Experiment Station dredging-related technical reports will be prepared for distribution with the reports (Figure 2). These one page summaries will not only provide a quick overview of the work, but will also include information on the necessity for the work and how the report findings fit in the overall dredging and navigation picture. A point of contact is also provided for additional information. These summaries will be written to provide readers, who are unfamiliar with dredging, a better understanding of the need for the research, as well as clearly state in layman terms the findings.

DREDGING LEXICON

The Corps' Dredging and Navigation Branch has asked Waterways Experiment Station to help assist in preparing a lexicon of dredging terms. Development of a dredging lexicon began over five years ago. The main purpose of this lexicon is to serve as a central source of dredging terms for both Corps and non-Corps dredging entities. The Corps plans to publish it as an appendix to ER 1130-2-307, "Dredging Policies and Practices, Interim Guidance." The lexicon will be designed to serve as a desk reference for the dredging community and the general public by serving as a readily available central source for rapidly clarifying dredging terms. The lexicon will include figures, sketches, maps, and photographs to communication complex terms. In addition, a list of dredging acronyms and legislation affecting dredging will be provided for use. The lexicon will focus on the follow areas of dredging terms:

a. Dredging plant

b. Dredging equipment

c. Contaminated sediments

d. Regulatory

e. Geotechnical

f. Hydrographic survey

e. Positioning equipment

f. Dredging and disposal management

g. Dredging contract terms

h. Environmental management

i. Et cetera

The initial lexicon will be distributed as a Corps Engineer Pamphlet or Engineer Circular with a one-year shelf life. During this time, non-Corps entities may provide input to the terms and definitions.

DEMONSTRATION DISKS

The DRP has recently prepared a new product called Demonstration Disks. This product demonstrates numerical model capabilities through the use of a work-at-your-own-pace PC-based slide show. Demonstration disks are designed to fill a gap in communicating the capabilities of dredging numerical models. Each demonstration provides the objective of the program, required input, and output received. Real-world examples are provided to help clarify capabilities. Presently a demonstration disk for three models used to predict the short and long-term fate of dredged material placed in open water has been distributed to DRP customers. Other demonstration disks are planned for future numerical modeling applications.

DREDGING TECHNICAL VIDEOS

The Corps has used technical videos to successfully communicate dredging technology to a wide, but technically oriented audience. While these videos may be too technical for general audiences, these videos have been used to communicate concepts to a broad base of the dredging community. These videos have allowed quick understanding of newly developed techniques or proposed technology. The recent advent of computer animation technology has allowed difficult subject matters to be clearly presented in videos. To date the DRP has prepared the following videos:

a. The Dredging Research Program (An Overview)

b. Plume Tracking off Mobile, Alabama

c. Submersible Pump Technology

d. The Silent Inspector

e. Protecting Sea Turtles through Improved Hopper Dredge Operations

f. The SUPERTANK Project

g. PLUMES Experiment, Tylers Beach, VA

LESSONS LEARNED AND FUTURE DIRECTIONS

The ability to successfully communicate dredging technology is a continuing process. Promoters of technology transfer should continually search for new methods to transfer results. In addition, the need to develop obtainable and measurable performance objectives is encourage for evaluating progress during the course of a technology transfer program.

Several suggestions are warranted when attempting to reach the peripheral dredging audience. First, considerable efforts should be made to correctly identify and clarify the intended message that is to be delivered to this audience. Next, the audience must be targeted before delivery of technology transfer product. This message should be short and simple. It should also be enticing, that is the viewer should want to obtain more information about the subject.

ACKNOWLEDGEMENT

The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the Dredging Research Program of the United States Army Corps of Engineers by the Waterways Experiment Station. Permission was granted by the Chief of Engineers to publish this information.

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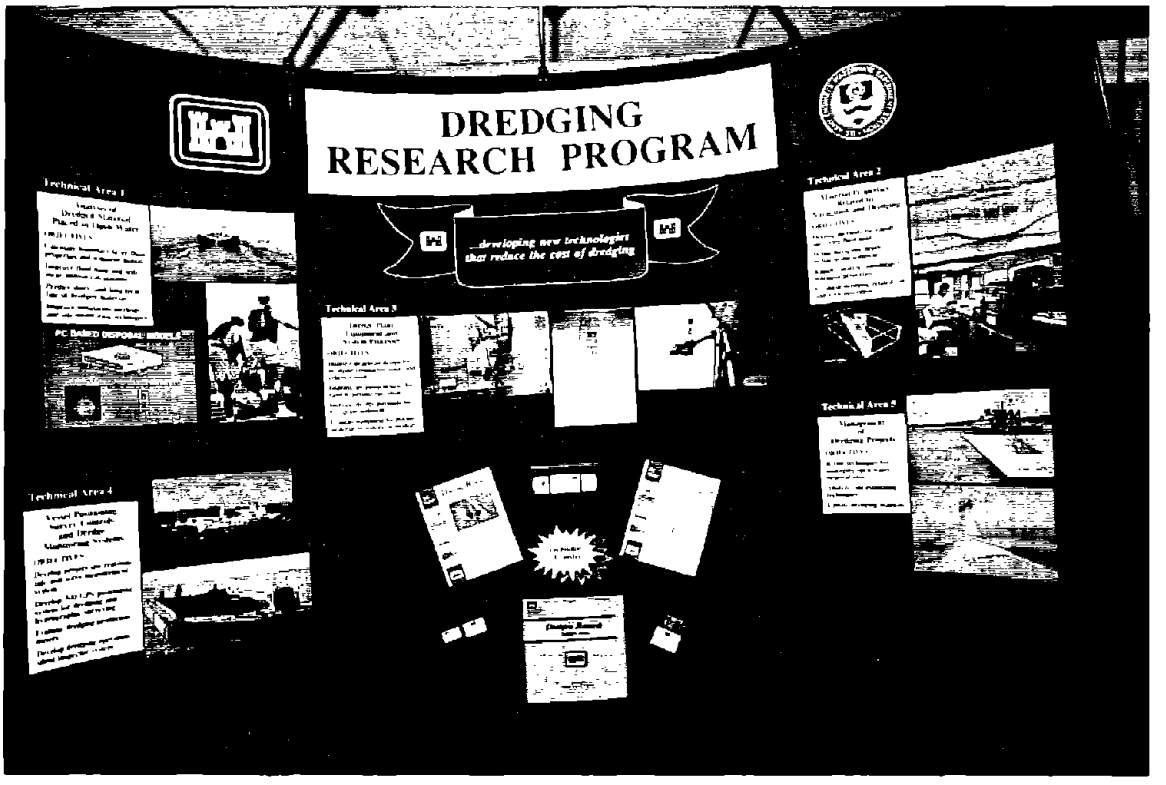
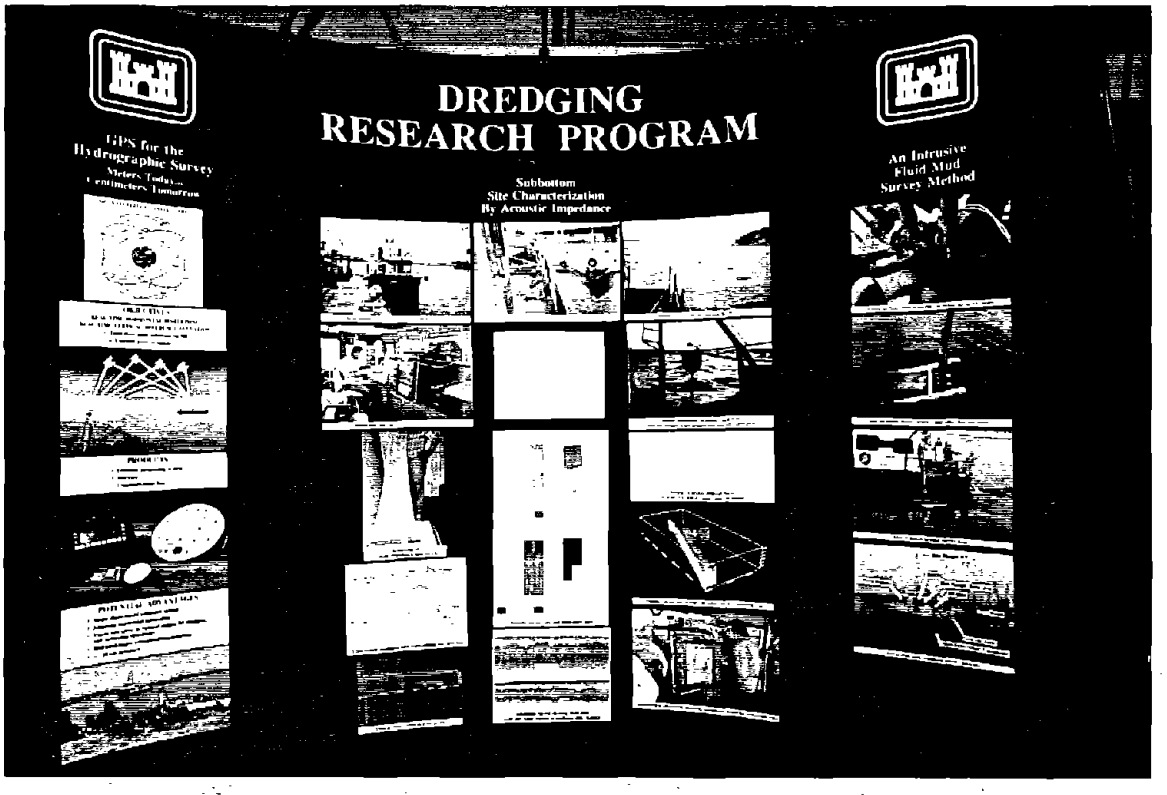
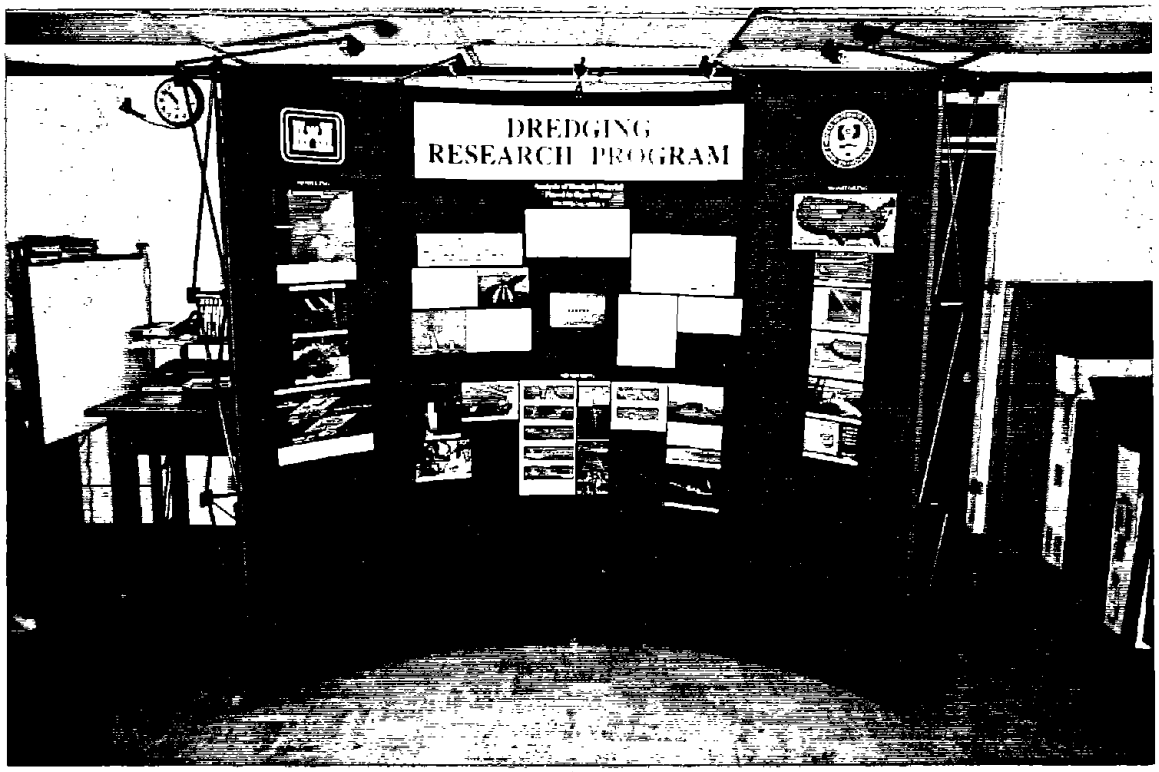

DREDGING
RESEARCH PROGRAM
...developing new technologies that reduce the cost of dredging
Technical Area 1
Technical Area 2
Technical Area 3
Technical Area 4
Technical Area 5


DREDGING
RESEARCH PROGRAM
GPS for the Hydrographic Survey
Meters Today... Centimeters Tomorrow
Subbottom Site Characterization By Acoustic Impedance
An Intrusive Fluid Mud Survey Method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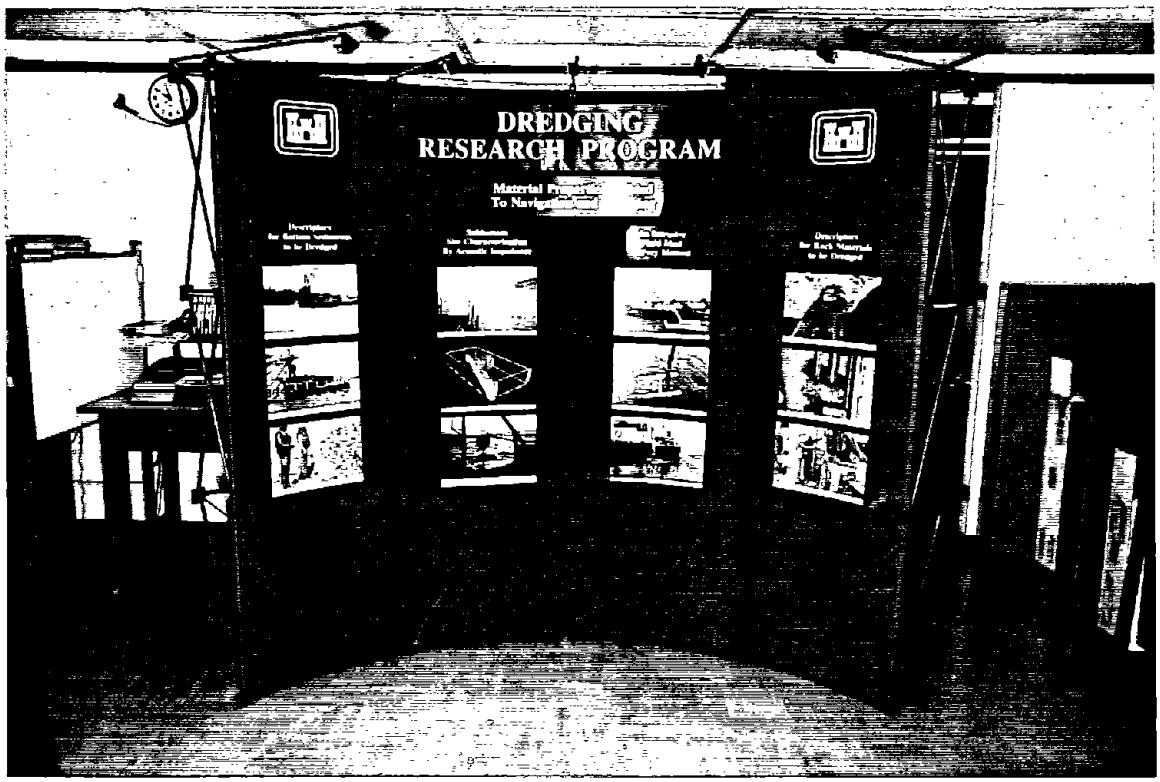
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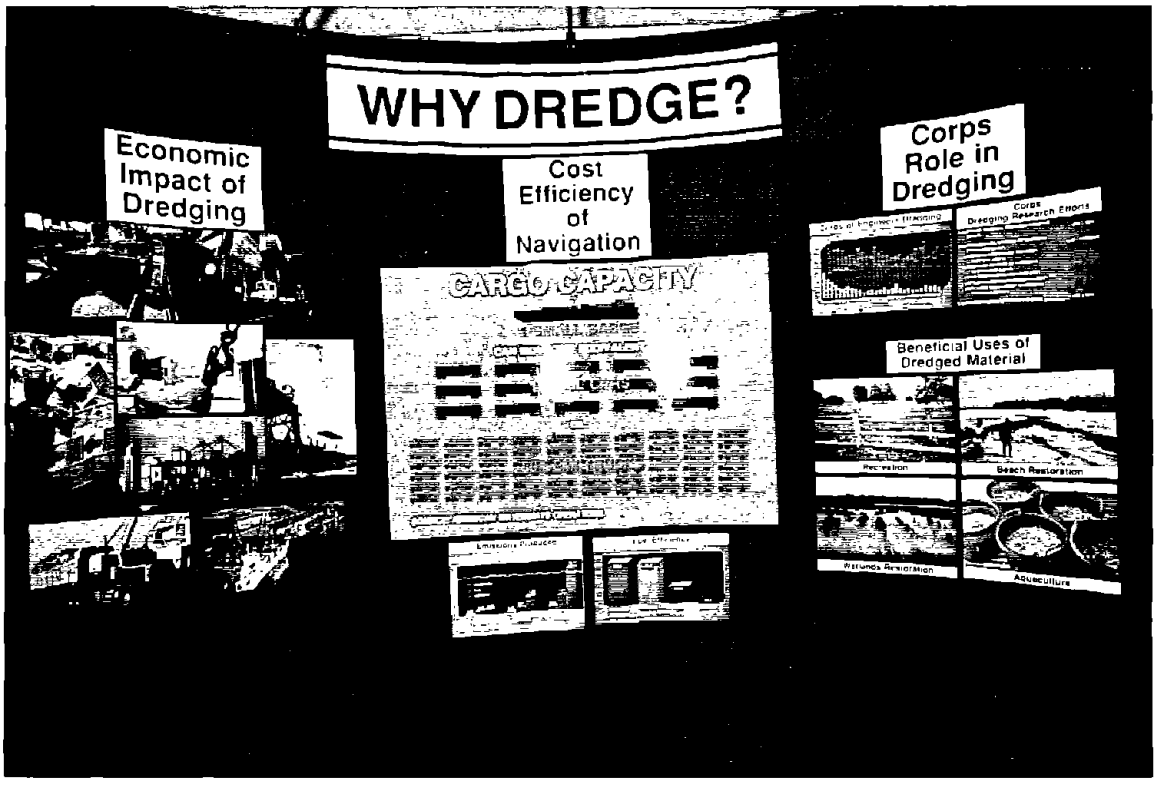
WHY DREDGE?
Economic Impact of Dredging
Cost Efficiency of Navigation
CARGO CAPACITY
Corps Role in Dredging
Corps Research Efforts
Beneficial Uses of Dredged Material
Recreation
Beach Restoration
Wetlands Restoration
Aquaculture

DREDGING & NAVIGATION BRANCH
NAVIGATION SECTION FUNCTIONS
TECHNICAL ASSISTANCE SECTION FUNCTIONS
DREDGING SECTION FUNCTIONS

DESIGN PROCEDURE FOR CAPPING CONTAMINATED SEDIMENTS

by

Michael R. Palermo

M. R. Palermo

DESIGN PROCEDURE FOR CAPPING CONTAMINATED SEDIMENTS

by
Michael R. Palermo[1]

BACKGROUND

Capping is the controlled accurate placement of contaminated material at an open water site, followed by a covering or cap of clean isolating material. For purposes of this paper, the term "contaminated" refers to material found to be unacceptable for unrestricted open water disposal because of potential contaminant effects, while the term "clean" refers to material found to be acceptable for such disposal.

Capping is considered an appropriate contaminant control measure for benthic effects in the Corps dredging regulations (33 CFR 335-338) and supporting technical guidelines (Francingues et al. 1985) and is recognized by the London Dumping Convention as a management technique to "rapidly render harmless" otherwise unsuitable materials. Level bottom capping (LBC) may be defined as the placement of a contaminated material on the bottom in a mounded configuration and the subsequent covering of the mound with clean sediment. Contained aquatic disposal (CAD) is similar to LBC but with the additional provision of some form of lateral confinement (e.g. placement in bottom depressions, or behind subaqueous berms) to minimize spread of the materials on the bottom. Capping is also an alternative for remediation of contaminated sediments in-place. In this situation, the contaminated sediments are not dredged, but a cap of clean material is placed over the sediments in-situ. This procedure is termed in-situ capping (ISC).

Capping at open water sites began in the late 1970's, and a number of capping operations under a variety of disposal conditions have been accomplished to include LBC, CAD, and ISC. Conventional dredged material disposal equipment and techniques are frequently used for a capping project, but these practices must be controlled more precisely than for conventional disposal.

This paper describes the major design requirements for a capping project and the sequence in which the design requirements should be considered. The procedures and sequence include evaluation of capping and contaminated sediments, site selection, equipment and placement

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techniques, mixing and dispersion during placement, required capping sediment thickness, material spread and mounding during placement, cap stability, and monitoring.

DESIGN REQUIREMENTS

Capping should not be viewed merely as a sequencing of placement operations. A capping operation should be treated as an engineered project with carefully considered design, construction, and monitoring to ensure that the design is adequate. The basic criteria for a successful capping operation is simply that the cap thickness required to isolate the contaminated material from the environment be successfully placed and maintained.

The flowchart shown in Figure 1 illustrates the major design requirements for a capping project and the sequence in which the design requirements should be considered (Palermo 1991a). There is a strong interdependence between all components of design for a capping project. For example, the initial consideration of a capping site and placement techniques for both the contaminated and capping materials will strongly influence all subsequent evaluations, and these initial choices must also be compatible for a successful project (Shields and Montgomery 1984).

By following an efficient sequence of activities for design of a capping project, unnecessary data collection and evaluations can be avoided. General descriptions of the various design requirements are given below in order corresponding to the recommended design sequence. The numbered blocks in the flowchart are referenced in the text in parentheses. Additional information on many of the design activities can be found in the references.

Gather project data (1)

The first step in any project design is to gather and evaluate the existing data. For a capping project, such data would normally include surveys of the dredging area, existing data on the contaminated sediment, and data on potential disposal sites. Once the existing data have been gathered, three main aspects of capping design must be examined: a) aspects related to characterization and placement of the contaminated material, b) aspects related to the characterization and placement of the capping material, and c) aspects related to the capping site under consideration. Each of these aspects must be initially examined in a parallel fashion (2), (3), and (4). Further, the

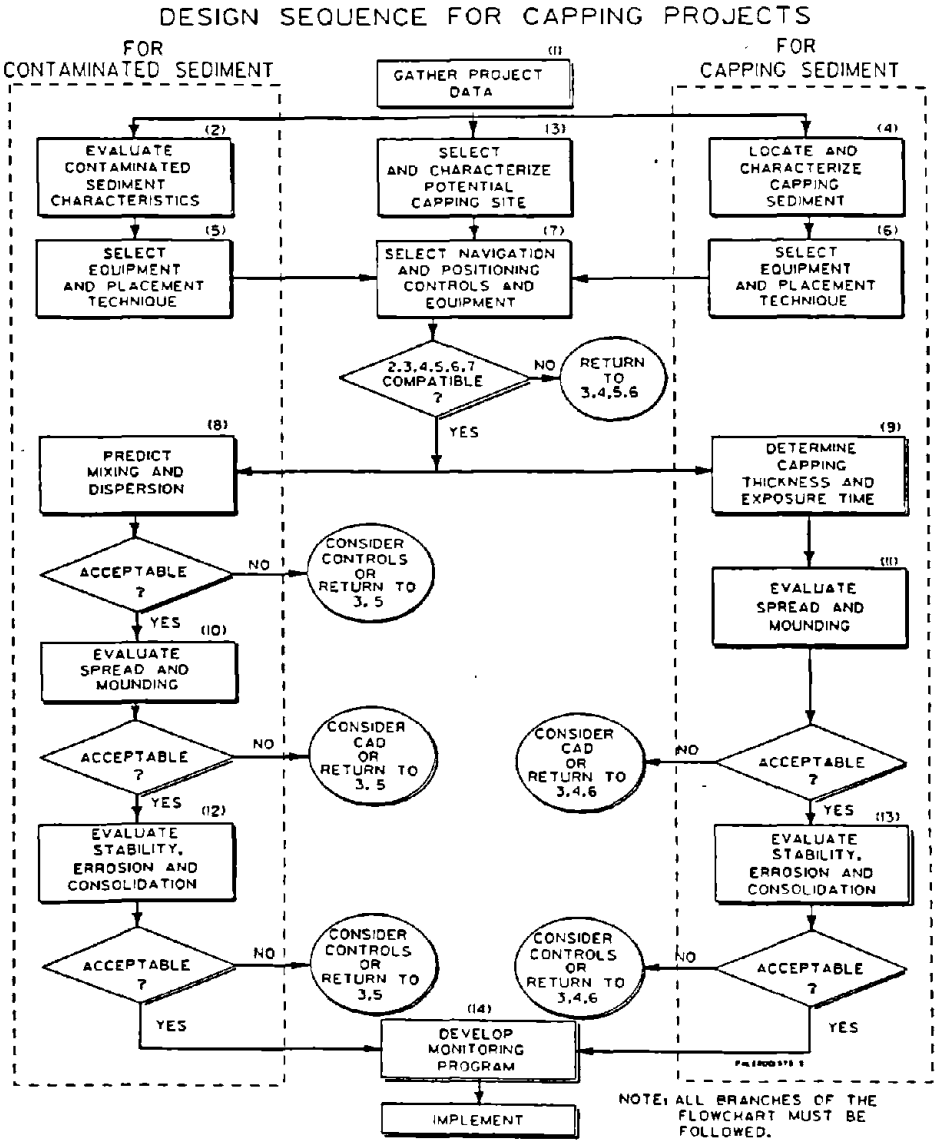

Figure 1. Flowchart illustrating design sequence for capping projects.

interrelationship and compatibility of these three aspects of the design are critical. For ISC projects, in which the contaminated sediments are left in place, the design activities related to placement of contaminated material are not a consideration, but the interrelationship and compatibility of capping material placement, characteristics of the in-situ contaminated material, and site conditions are equally important.

Characterize contaminated sediment (2)

The contaminated sediment must be characterized from a physical, chemical, and biological standpoint. Physical characteristics are of importance in determining the behavior of the material during and following placement at a capping site. In-situ volume (to be dredged), in-situ density (or water content), cohesiveness, and grain size distribution are needed for evaluations of dispersion and spread during placement, mounding characteristics and long-term stability and resistance to erosion. These data should be developed using standard techniques. Some chemical and biological characterization of the contaminated sediment will normally be performed as a part of the overall evaluation for suitability for open water disposal (EPA and USACE 1991). Chemical characterization of the contaminated sediment may include a sediment chemical inventory and standard elutriate test results. The sediment chemical inventory is useful in determining contaminants of concern and in development of appropriate chemical elements of a monitoring program to determine capping effectiveness. Elutriate data are sometimes used in estimating the potential effects on water quality due to placement of the contaminated material. Biological characterization may include water column bioassays, benthic bioassays, and bioaccumulation tests. The results of these biological tests are useful in determining potential water column effects during placement and acceptable exposure times before placement of the cap begins.

Selection of a potential capping site (3)

The selection of a potential site for capping is subject to the same constraints and tradeoffs as any other open water disposal site. The major considerations in site selection include: bathymetry, currents, water depths, water column density stratification, bottom sediment characteristics, and operational requirements such as distance, sea state, etc. However, over and above the normal considerations, the capping site should be in a relatively low-energy environment with little potential for erosion of the cap (Palermo 1991b).

Bathymetry forming a natural depression will tend to confine the material, resulting in a CAD project. Placement of material on steep bottom slopes should generally be avoided for a capping project. Water column currents effect the degree of dispersion during placement and the location of the mound with respect to the point of discharge. Of more importance are the bottom currents which could potentially cause resuspension and erosion of the mound and cap. The effects of storm-induced waves on bottom current velocities should also be considered. Water depth is of particular interest in evaluating the potential suitability of a site for capping operations (Palermo 1989). The deeper the water depth at the site, the greater the potential for water entrainment and dispersion during placement. However, deeper water depths also generally provide more stable conditions on the bottom with less potential for erosion. Numerical models for evaluation of dispersion and spread (8) and (10) and for sediment transport and erosion (12) and (13) can aid in evaluation of alternative sites.

Selection and characterization of capping sediment (4)

Unlike the contaminated sediment, the capping sediment used in a capping project may be a matter of choice. For economic reasons, a capping sediment is usually taken from an area which also requires dredging. If this is the case, there may be a choice between projects, and scheduling of the dredging is an important consideration. In other cases, removal of bottom sediments from areas adjacent to the capping site may be considered. If CAD is under consideration, removal of material to create CAD cells and stockpiling for later use in the capping operation can be considered (Sumeri 1989).

The capping sediment should be characterized as described above for the contaminated sediment. However, the capping sediment must be one which is acceptable for unrestricted open water disposal (i.e. a "clean" sediment). The evaluation of a potential capping sediment for open water disposal acceptability would be accomplished using appropriate techniques under either Section 404 or Section 103. Physical characteristics of the capping sediment are also of particular interest in capping design. Density (or water content), grain size distribution, and cohesiveness of the capping sediment must be evaluated. The characteristics of the capping sediment should be compatible with the contaminated sediment, considering the placement technique for both. Previous studies have shown that both fine-grained materials and sandy materials can be effective capping materials.

Equipment and placement technique for contaminated sediment (5)

A variety of equipment types and placement techniques have been used for capping projects. The important factors in placement of the contaminated material are reducing water column dispersion and bottom spread to the greatest possible extent. This minimizes the release of contaminants during placement and provides for easier capping. For LBC the dredging equipment and placement technique for contaminated sediment must result in a tight, compact mound which is easily capped, and this is most easily accomplished with mechanical dredging and barge release. If CAD is under consideration, hydraulic placement of the contaminated material may be acceptable.

Specialized equipment and placement techniques can also be considered to increase control during placement and reduce potential dispersion and spread of contaminated material. These might include use of submerged diffusers or submerged discharge points for hydraulic pipeline placement, hopper dredge pumpdown with diffuser, or gravity-fed tremie for mechanical or hydraulic placement (Palermo 1991c).

Equipment and placement technique for capping sediment (6)

The major design requirement in selection of equipment and placement of the cap is the need for controlled accurate placement and the resulting density and rate of application of capping material. In general, the cap material should be placed so that it accumulates in a layer covering the contaminated material. The use of equipment or placement rates which might result in the capping material displacing or mixing with the previously placed contaminated material should be avoided. Placement of capping material at equal or lesser density than the contaminated material would generally meet this requirement. Specialized equipment and placement techniques can be considered to increase control of capping material placement. The movement of submerged diffusers, submerged discharge points, split-hull barges, or tremies can be controlled to spread capping material over an area to a required thickness (Sumeri 1989, Palermo 1991c).

Selection of navigation and positioning equipment and controls (7)

Controlled and accurate placement of both the contaminated and capping material is an integral part of a successful capping project. Once the dredging equipment and placement techniques and potential capping site have been selected, the needs for navigation and positioning equipment and controls can be addressed. The objective here is to place the material (whether by the bargeload, hopperload or by

pipeline) at the desired location in a consistently accurate manner so that mounding can occur and so that adequate coverage by the cap can be attained. State-of-the-art equipment and techniques should be employed to assure accurate point placement to the extent deemed necessary. Taut-moored buoys, mooring barges, various acoustical positioning devices, and computer assisted, real-time helmsman's aids should be considered. Diligent inspection of operations to insure compliance with specifications is essential.

Evaluate compatibility of site, materials, and equipment

At this point in the design, the contaminated material has been characterized, a capping sediment has been selected and characterized, equipment and placement techniques have been selected for both materials, and navigation and positioning needs have been addressed. These essential components of the design (3), (4), (5), (6), and (7) should now be examined as a whole with compatibility in mind.

A major consideration in compatibility is an acceptable match of equipment and placement techniques for contaminated and capping material. For example, if the contaminated material were mechanically dredged and release from barges, the capping material could be similarly placed or could be placed hydraulically. However, if the contaminated material were hydraulically placed, then only hydraulic placement of the capping material may be appropriate due to the potentially low shear strength of the contaminated material.

Compatible scheduling of the contaminated material placement and capping operation is essential. The exposure of the contaminated material to the environment and need to allow consolidation of the contaminated material to occur prior to cap placement (9) must be balanced in scheduling both placement operations. Availability of equipment and funding and the possibility of equipment breakdowns or other delays should be considered in determining if the capping schedule is compatible with the contaminated material placement schedule.

If the components are compatible, additional and more detailed design requirements can be addressed. If there is a lack of compatibility at this point, a different capping site (3), a different capping sediment (4), or different placement equipment and techniques (5) and (6) must be considered. A close examination of the project design components at this decision point is essential before performing the more detailed and costly evaluations which come later in the design process.

Predict mixing and dispersion of contaminated sediment (8)

If water column effects during placement of the contaminated material are of concern, an evaluation in accordance with Section 404 or Section 103 should be performed. Such an evaluation may involve comparison of predicted water column contaminant concentrations with water quality criteria or predicted water column dredged material concentrations with bioassay test results. Use of available mathematical models to predict the water column dispersion and mixing would be an integral part of such evaluations (EPA and USACE 1991 and Johnson 1990). In addition, the prediction would indicate what portion of the contaminated material would be released during placement and would not eventually be capped. If barge release or hopper dredge release is used, the model would also indicate the initial spread of a single bargeload. This information would be used in determining the mounding characteristics for the entire contaminated material volume to be placed. If water column release is unacceptable, control measures could be considered to reduce the potential for water column effects, or other dredging equipment and placement techniques (5) or use of another capping site (3) could be considered. Control measures could include use of a submerged discharge point, submerged diffuser, tremie pipe, hopper dredge pumpdown or similar equipment.

Determine the required cap thickness and exposure time (9)

The cap must be designed to chemically and biologically isolate the contaminated material from the aquatic environment. The determination of the minimum required cap thickness is dependent on the physical and chemical properties of the contaminated and capping sediments, the potential for bioturbation of the cap by aquatic organisms, and the potential for consolidation and erosion of the cap material. Laboratory tests have been developed to determine the thickness of a capping sediment required to chemically isolate a contaminated sediment from the overlying water column (Sturgis and Gunnison 1988). These tests can also be performed in the presence of bioturbating organisms (Brannon 1985). An evaluation of the potential for colonization of the capped site by bioturbating organisms and the behavior of those organisms with respect to intensity and depth of burrowing must be made. The minimum required cap thickness is considered the thickness required for chemical isolation plus that thickness of bioturbation associated with organisms likely to colonize the site in significant numbers.

The integrity of the cap from the standpoint of physical changes in cap thickness and long-term migration of contaminants through the cap should also be considered. The potential for a physical reduction in

cap thickness due to the effects of consolidation and erosion of the contaminated material (12) and the cap (13) can be evaluated once the overall size and configuration of the capped mound is determined. The design cap thickness can then be adjusted such that the minimum required cap thickness is maintained.

Most of the consolidation of the contaminated material will occur within a few weeks of placement, and the cap placement could be delayed an appropriate time period to allow the majority of consolidation to occur. Such a delay also holds advantage from the standpoint of resistance of the contaminated deposit to displacement during cap placement. However, a delay exposes the contaminated material to the environment. An appropriate delay between contaminated material placement and capping must balance environmental exposure with the engineering requirements of stability and the scheduling constraints of the dredging required for capping.

There is potential for long-term migration of contaminants through the cap due to consolidation of the contaminated material and due to the diffusion process. The techniques for evaluation of consolidation (Poindexter-Rollings 1990) can be used to estimate the cap thickness potentially effected by the movement of contaminated pore water (Brannon and Poindexter-Rollings 1990). The effect of long-term diffusion on the design cap thickness would normally be negligible, because long-term diffusion of contaminants through a cap is an extremely slow process and contaminants would be adsorbed to the clean cap material particles. If deemed necessary, an evaluation of contaminant transport by diffusion can be made (Lerman 1979).

The test for chemical isolation has determined the minimum required cap thickness to be on the order of one foot for most sediments tested to date. Bioturbation depths are highly variable, but would be on the order of one to two feet for most organisms which would populate a site in great numbers. Considering the fact that small thicknesses of materials cannot be easily placed by conventional dredging operations, the minimum cap thickness for most projects will therefore be on the order of 3 to 4 feet plus an appropriate allowance for potential erosion and consolidation.

Evaluate spread and mounding (10) and (11)

An evaluation of the mound geometry to include contaminated material mound and cap will influence the design of the cap and volume of capping material required. The smaller the "footprint" of the contaminated material as placed, the less volume of capping material will be required to achieve a given cap thickness. For LBC sites, the

spread and development of the contaminated material mound is dependent on the physical characteristics of the material (grain size and cohesion) and the placement technique used (hydraulic placement will result in greater spread than mechanical placement). Assuming that the material from multiple bargeloads or pipeline can be accurately placed at a single point, the angle of repose taken by the material and the total volume placed will dictate the mound spread. However, little data are available on the volume changes resulting from entrainment of water during open water placement or the shear strengths of dredged material initially deposited in open water sites. For this reason, estimates of mound spread have been made based on the observed characteristics of previous mounds created with similar placement techniques and similar sediments.

Evaluate stability, erosion, and consolidation (12) and (13)

The deposit of contaminated dredged material must be stable against excessive erosion and resuspension of material prior to placement of the cap. The cap material must be stable against long-term erosion for the required cap thickness to be maintained. The potential for resuspension and erosion is dependent on bottom current velocity, potential for wave induced currents, sediment particle size, and sediment cohesion. Site selection criteria as described above would normally result in a site with low bottom current velocity and little potential for erosion. However, if the material is hydraulically placed, a thorough analysis of the potential for resuspension and erosion should be performed. Available methods for evaluation of erosion potential range from simple analytical techniques to numerical modeling (Dortch et al 1990, Teeter 1992). In the analysis of erosion, the effects of self-armoring due to the winnowing away of finer particles should be considered.

Consolidation of the mound of contaminated material should be examined for its effect on mound slopes and volume occupied within the disposal site. In general, consolidation of the contaminated mound will result in more stable conditions. The same is true for consolidation of the cap material. However, consolidation of the cap results in a reduced cap thickness. Therefore the potential for cap consolidation should be considered in the overall design of the cap thickness. Techniques have recently been developed for evaluation of consolidation of mounds (Poindexter 1989 and Poindexter-Rollings 1990).

If the potential for erosion and consolidation of either the contaminated material or cap is unacceptable, an alternate site (3), alternate capping sediment (4), or alternate placement techniques for the contaminated material (5) or cap material (6) can be considered.

Control measures such as incorporating an erosion resistent layer in the cap design can also be evaluated.

Develop a monitoring program (14)

A monitoring program should be considered as a part of any capping project design. The main objectives of monitoring would normally be: a) to insure that the contaminated sediment is placed as intended and with acceptable levels of contaminant release, b) to insure that the cap is placed as intended and the required capping thickness is maintained, and c) to insure that the cap is effective in isolating the contaminated material from the environment. Monitoring plans for capping projects should include a more intensive effort during and shortly after placement operations, with a declining level of effort in future years. Physical, chemical, and biological elements may be included in a monitoring plan. In all cases, the objectives of the monitoring effort and any remedial actions to be considered as a result of the monitoring should be clearly defined as a part of the overall project design (Palermo, Fredette, and Randall 1992).

SUMMARY AND CONCLUSIONS

A capping operation should be treated as an engineered project with carefully considered design, construction, and monitoring to ensure that the design is adequate. The design requirements for a capping project include characterization of both contaminated and capping sediments, selection of an appropriate site, selection of compatible equipment and placement techniques, prediction of mixing and dispersion during placement, determination of the required capping sediment thickness, prediction of material spread and mounding during placement, evaluation cap stability against erosion and bioturbation, and development of a monitoring program. There is a strong interdependence between all components of design for a capping project. By following an efficient sequence of activities for design of a capping project, unnecessary data collection and evaluations can be avoided and a fully integrated design will result.

ACKNOWLEDGEMENT

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A WATERBORNE GEOPHYSICAL TECHNICQUE FOR IMPROVED PLANNING AND MONITORING OF DREDGING PROJECTS

by

Keith J. Sjostrom, Richard G. McGee and Robert F. Ballard, Jr.

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A WATERBORNE GEOPHYSICAL TECHNIQUE FOR IMPROVED PLANNING AND MONITORING OF DREDGING PROJECTS

Keith J. Sjostrom, Richard G. McGee and Robert F. Ballard, Jr.*

INTRODUCTION

Each year, the U.S. Army Corps of Engineers spends millions of dollars world-wide on river and harbor maintenance and ship channel realignment projects. Currently, the Corps relies on drilling and laboratory testing programs to assess marine sediments in terms of material type, density, and thickness for the purposes of characterizing proposed dredging sites. But sampling and coring programs are costly, provide only discontinuous information about material characteristics, and cannot effectively address situations where actual subbottom conditions are highly variable.

In an effort to improve subbottom characterization and dredging efficiency, the Corps of Engineers launched a major research and development initiative called the Dredging Research Program (DRP). The U.S. Army Engineer Waterways Experiment Station (WES) heads this initiative. The focus of one of the DRP work units is to remotely and efficiently determine characteristics of subbottom marine sediments using impedance calculations from seismic reflection information together with limited in situ sampling.

THE ACOUSTIC IMPEDANCE METHOD

The acoustic impedance method is a modification of the seismic reflection technique commonly used in offshore oil exploration but tailored to shallow water environments. As energy generated from an acoustic source, in the form of a plane wave, arrives at a boundary between two layers of differing material properties, part of the energy will be reflected back towards the surface and part transmitted downward (see Figure 1). Portions of the transmitted energy will undergo absorption or attenuation in the layer while the remainder propagates through to the next stratigraphic boundary. Ratios between transmitted and reflected energy, called reflection coefficients, are dependent on the density and velocity of the material through which

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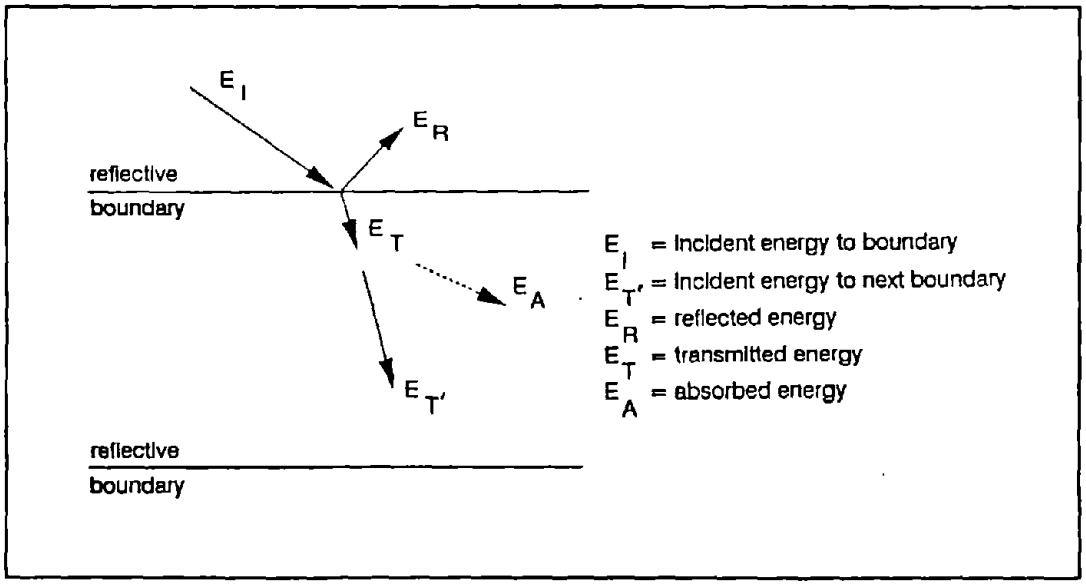

Figure 1. Energy Path Schematic.

the energy is propagating. The product of the transmission velocity and density of the material is the acoustic impedance and represents the influence of the material's characteristics on the reflected and transmitted wave energy.

The relationship between acoustic impedance and specific soil properties is empirically based on world averages of impedance versus sediment characteristics (Hamilton, 1970, 1972; Hamilton and Bachman, 1982). Development of statistical models (Caulfield and Yim, 1983) establish relationships between the computed acoustic impedance and specific soil properties (porosity, density, bulk modulus, etc.) for sediments within various natural marine environments and allow identification and characterization of the subbottom layers.

DATA ACQUISITION AND ANALYSIS

A source of acoustic energy deployed just below the water surface generates acoustic waves that propagate downward through the water column and sediments. High-resolution profiling systems specifically designed for shallow water use and operating at frequencies below 12 kilohertz (kHz) are typically used. As a rule, lower operating frequencies allow greater energy penetration into the subbottom but lack the vertical resolution of higher frequency systems.

As the transmitted energy propagates through sediment of varying densities and acoustic velocities, energy is reflected at geologic boundaries where there is a distinct contrast in the acoustic impedance between layers. Reflected signals are amplified, filtered, and recorded with a specially designed shallow seismic, digital data acquisition system developed in conjunction with Caulfield Engineering (Caulfield, 1991b). The system also provides real-time presentation of the seismic signal for acquisition quality control.

Due to the non-uniqueness of seismic reflection signatures, several combinations of geologic conditions could conceiveably yield similar signal characteristics and computed impedance values. But in specific geologic regions such as Mississippi Sound or San Francisco Bay, differing sediment units usually have a characteristic and relatively narrow range of impedance values. Therefore, using calibration procedures incorporating local core data, seismic reflection data are processed at known sample locations to yield acoustic impedance values of the reflection horizons. Estimates of in-situ density are derived from the computed impedance values and correlated with ground truth information (see Figure 2). Testing to date has shown that density

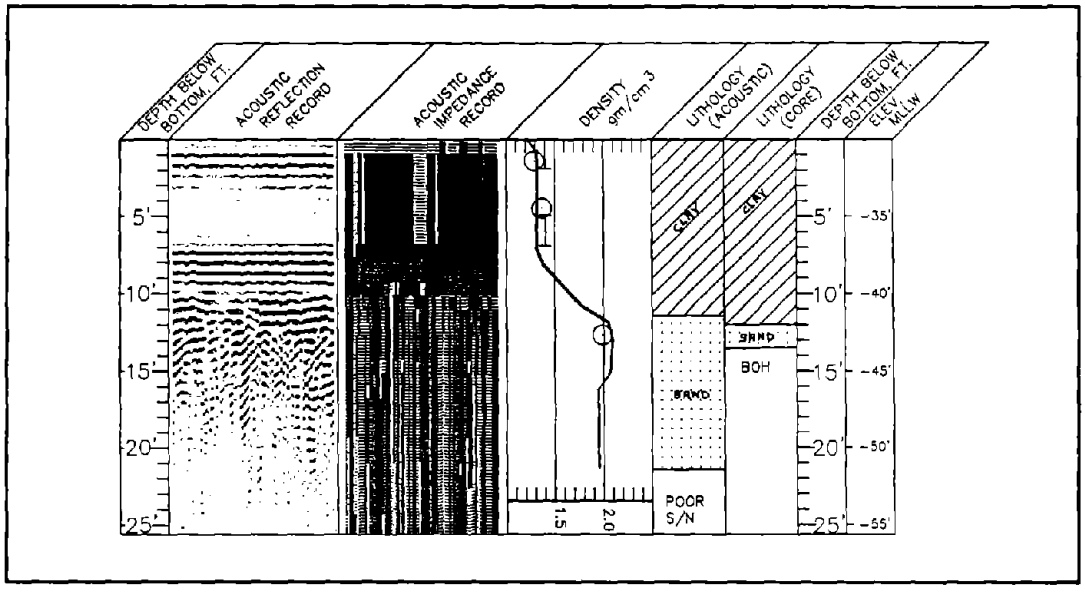

Figure 2. Typical subbottom calibration.

estimates to within five percent of in situ values are obtained (Ballard and McGee, 1991). A plot of the impedance function versus

laboratory measurements of density from core samples taken in Mississippi Sound are presented in Figure 3.

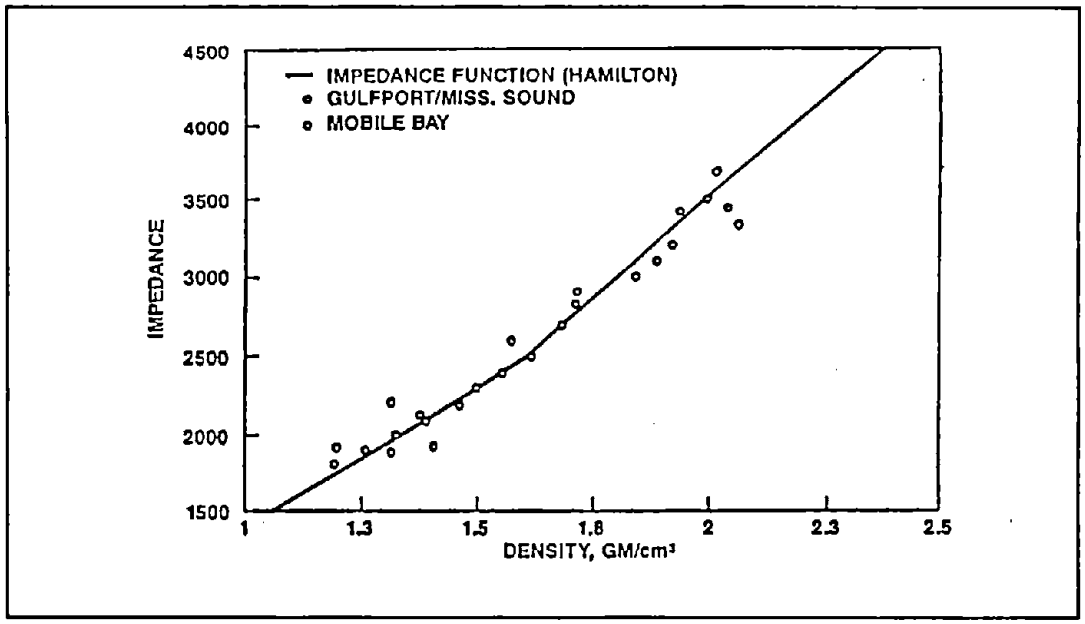

Figure 3. Computed Impedance versus in-situ density.

Upon determination of the reflection coefficients and impedance function at known locations, the virtually continuous seismic profiles are processed. The single-channel, digitally recorded data are read into the processing software, developed with Caulfield Engineering (Caulfield, 1991a), and corrected for transmission losses due to spherical spreading and compensated for absorption losses in each layer. Classical multilayer algorithms are used to compute equivalent reflection coefficients and impedances along the profile. This in turn provides density estimates of the shallow subbottom layers and classifies the lithostratigraphy (Hamilton, 1972; Caulfield and Yim, 1983). The results are corrected for tidal fluctuations and correlated with survey positioning data. Presentation of results are in the form of annotated amplitude cross-sections or two- and three-dimensional views color-coded according to material density.

An acoustic impedance survey has been conducted in the Gulfport Ship Channel, MS in support of a proposed channel realignment. Computed sediment density values within the project area are displayed in a color-coded, three-dimensional (3-D) view as shown in Figure 4 with 'yellow' indicative of material having densities ranging from 1.07 to 1.4 g/cc. It should be noted that the publication format does not

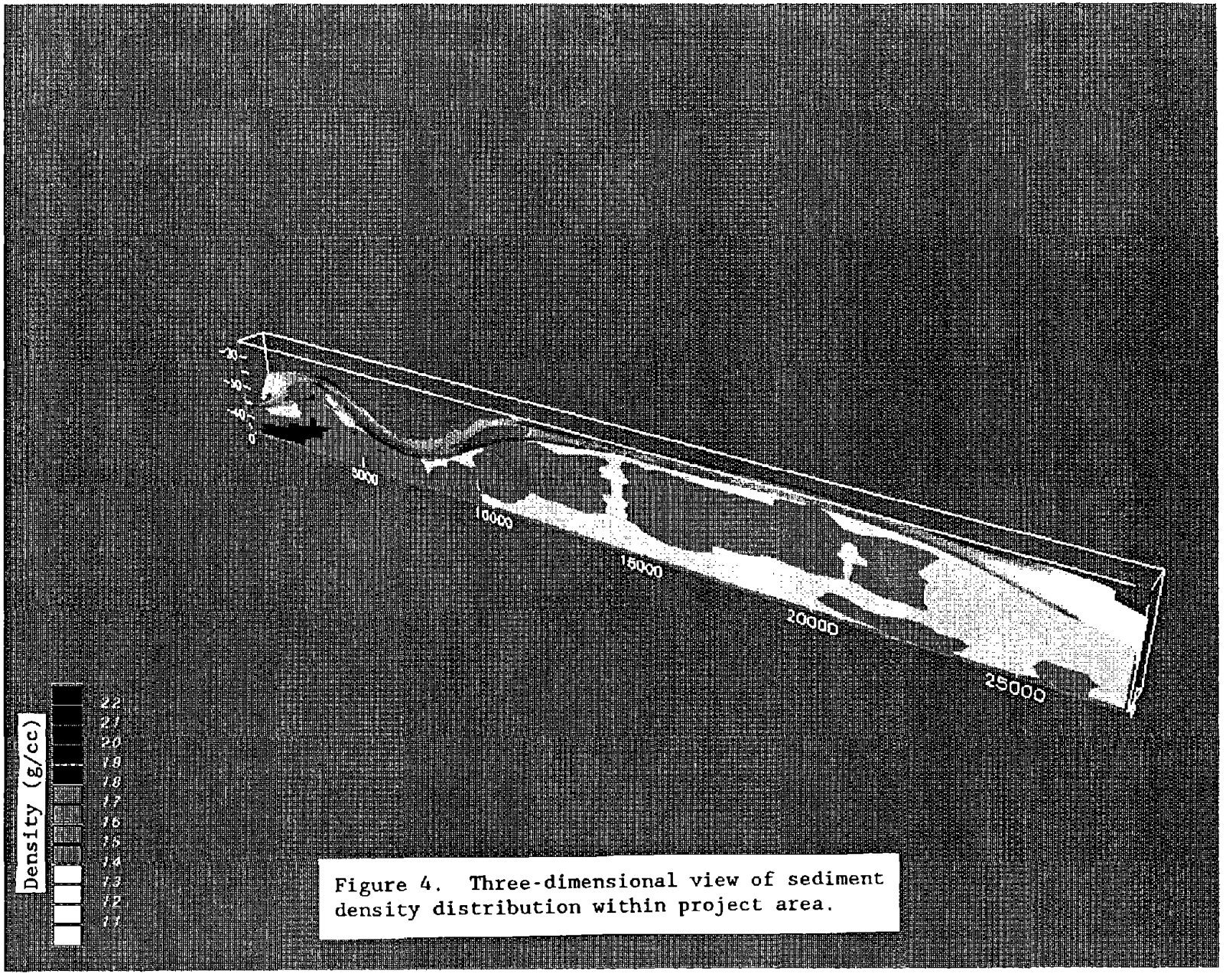

Figure 4. Three-dimensional view of sediment density distribution within project area.

allow for color presentation of results and, therefore, all displays are black and white copies of the color originals. Three profile views, extracted from the 3-D view and digitized, are illustrated in Figure 5 with survey line 9 positioned along the center line of the proposed channel. The displays delineate the extent of the pertinent density zones and virtually continuous data coverage greatly decreases the possibility of significant material changes going undetected. In addition, volume estimates of materials to be removed through dredging were provided.

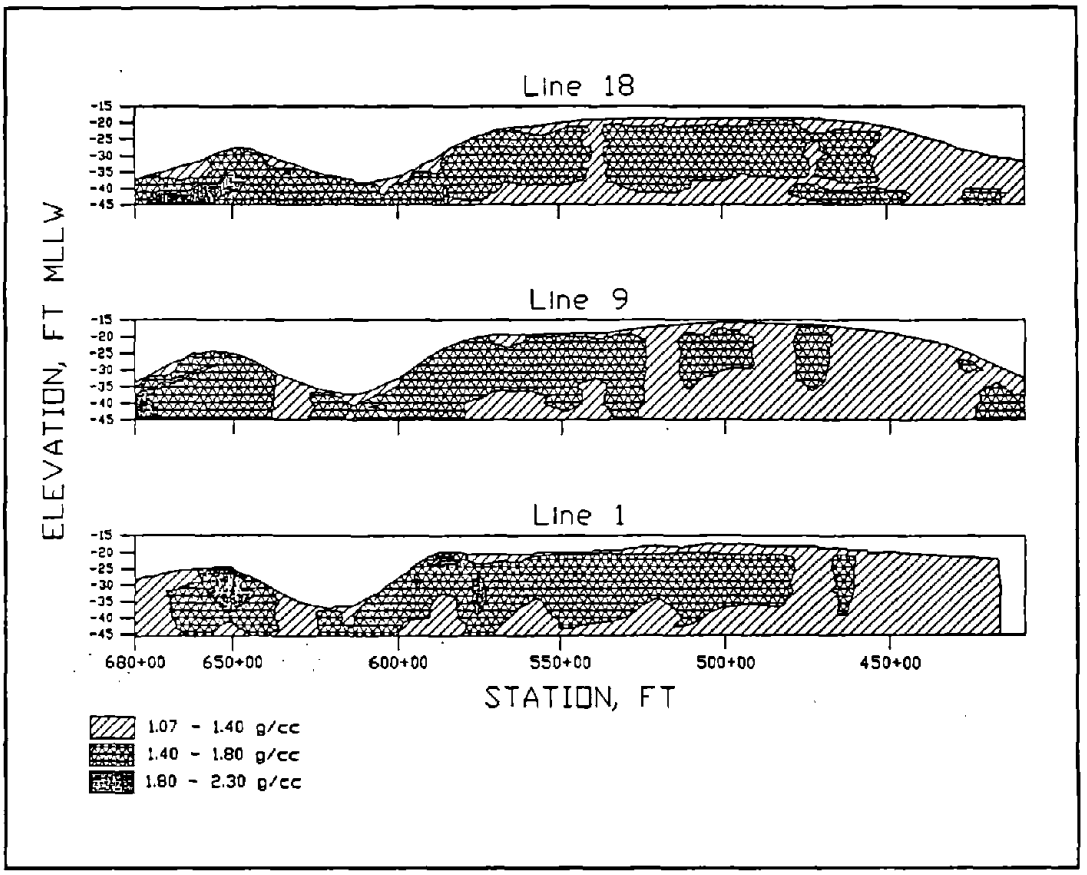

Figure 5. Density profiles of project area.

SUMMARY

In its present state of development, acoustic impedance processing of seismic reflection data provides an accurate, continuous

description of the bottom and subbottom marine sediment characteristics in a rapid, cost-effective manner. Results from properly calibrated surveys have been used to provide Corps' Districts and dredging contractors with:

1) density estimates of the marine sediments,
2) continuous subbottom information for planning and designing dredging and sampling programs,
3) estimates of the volume and type of material to be removed through dredging, and, most of all,
4) a detailed and continuous geologic database for aiding long-term planning of future work.

This technique, however, is not limited to sediment characterization, but can also provide essential information on the:

1) location of marine sand deposits for beach replenishment,
2) long-term monitoring of dredged material disposal areas,
3) delineation of submarine geologic formations,
4) detection of submarine features such as pipelines or other dredging hazards, and
5) identification of fluid mud in navigable waterways.

Acoustic impedance information, if properly implemented in the project planning stages, provides valuable data on the distribution and extent of differing marine sediments, aids in locating optimal placements of sampling cores, and supplements previously obtained soil borings by providing continuous profile coverage of sediment characteristics between sample locations.

ACKNOWLEDGMENT

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Robert F. Ballard, Jr. received his B.S. degree in Physics from Mississippi College before beginning his 32 year career as a geophysicist at the Waterways Experiment Station. Current research involves the application of waterborne geophysical techniques to engineering problems.

A COMPREHENSIVE FRAMEWORK FOR THE MANAGEMENT OF AQUATIC SITES FOR DISPOSAL OF DREDGED MATERIAL

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ABSTRACT

The management of aquatic sites for the disposal of dredged material is of critical importance. The costs and potential operational and environmental effects of inadequate disposal site management are considerable. The US Environmental Protection Agency (USEPA) and the US Army Corps of Engineers (USACE) share responsibility for ensuring that dredged material disposal into the aquatic environment is occurring in an environmentally acceptable manner and are currently working together to develop a comprehensive framework for the management of dredged material disposal at aquatic sites.

Management of dredged material disposal at aquatic sites consists of site designation, dredged material evaluation, dredging and disposal monitoring, and evaluation of all information to ensure the environmental acceptability of the disposal. Integral to every aspect of dredged material disposal management is staying focused on the critical resources identified during site designation (or at a time later as new information is attained), which could be adversely affected by disposal operations; equally important, proper site management can ensure that operational objectives for the use of the site are not hampered when such objectives are considered at every stage in site management. Impact predictions need to be developed which describe the relationship between disposal actions and expected operational or environmental effects. Tiered or stepwise actions can then be taken to avoid and/or mitigate impacts as well as to monitor the occurrence and extent of unavoidable or unexpected impacts; these actions may include special permit conditions, disposal practices, monitoring designs and methodologies, or analysis techniques.

INTRODUCTION

The USACE and other dredgers excavate over 450 million cubic yards of sediment each year to maintain and improve the Nation's more than 25,000 miles of navigable waterways. These waterways serve over 150 commercial ports and more than 400 small boat harbors, which are valuable for commercial, defense, and recreational purposes. Of all the sediment dredged annually, about 150 million cubic yards are disposed

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into the aquatic environment; although this figure does not include material disposed into wetland, confined aquatic or upland disposal sites, the principles discussed in this paper could be applied to the management of these types of sites as well.

The proper management of aquatic dredged material disposal sites is of critical importance to their continued viability. As sources and categories of material other than dredged material that have been traditionally disposed of in the aquatic environment become more tightly regulated (e.g., non-point source discharges) or are banned from disposal altogether (e.g., ocean dumping of sewage sludge and industrial waste), scrutiny of the potential adverse effects of dredged material disposal can be expected to increase. However, proper site management is not only designed to address environmental concerns; operational concerns, such as maximizing site capacity and avoiding conflicts in the use of the site and its surroundings, are also integral components of proper site management.

Legislative Authorities

The disposal[3] of dredged material into the aquatic environment is regulated under either the Federal Water Pollution Control Act Amendments of 1972, also called the Clean Water Act (CWA), or the Marine Protection, Research and Sanctuaries Act (MPRSA) depending on the location of the disposal site. An important feature common to both statutes is that the USEPA and the USACE are directed to share responsibility for the management of aquatic dredged material disposal sites. The pertinent aspects of each statute follow.

The Clean Water Act. The CWA regulates the discharge of dredged or fill material into the waters of the United States. Section 404 of the CWA requires the USEPA, in conjunction with the USACE, to promulgate Guidelines to be used in the evaluation of proposed dredged material discharges. The purpose of the Guidelines is to ensure that the proposed discharge will not result in unacceptable adverse environmental impacts to the waters of the United States. The USACE is assigned the responsibility for applying the Guidelines to each proposed discharge and, if in compliance with the Guidelines and other factors (e.g., the public interest, other applicable statutes, etc.), for permitting such discharge. The USEPA and the USACE also have authority to identify sites in advance that are either suitable or unsuitable for the discharge of dredged or fill material. In addition to reviewing project proposals, USEPA has the authority under Section 404(c) to veto proposed discharges which would result in unacceptable adverse effects to certain aquatic resources. The USEPA Guidelines are contained in 40 Code of Federal Regulations (CFR) Part 230.

The Marine Protection, Research and Sanctuaries Act. The MPRSA regulates the dumping of all matter, including dredged material, into the ocean. Section 102 of the MPRSA requires that USEPA, in consultation with USACE, develop Criteria that must be complied with before any proposed ocean dumping activity is allowed to proceed.

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[3]"Disposal" is used throughout this paper in a general sense. It is noted that each statute possesses a term-of-art in this regard: the CWA regulates the "discharge" of dredged material; the MPRSA, "dumping".

Section 103 of the MPRSA assigns to the USACE the responsibility for authorizing the ocean dumping of dredged material. In evaluating proposed ocean dumping activities, the USACE is required to determine whether such proposals comply with the Criteria. The Act requires that EPA independently review the proposed ocean dumping activity for compliance with the Criteria; if USEPA determines the Criteria are not met, dumping may not occur without a waiver of the Criteria by the USEPA Administrator. In addition, the USEPA has authority under Section 102 to designate sites that are either suitable or unsuitable for the dumping of dredged material. The USACE is required to use such suitable sites when available and feasible; when use of such a site is not feasible, the USACE is authorized to select a site, provided it complies with the Criteria and USEPA concurs. The USEPA Criteria are contained in 40 CFR 220-229.

Figure 1 illustrates the geographical jurisdiction of the CWA and the MPRSA. As shown in this figure, there is an overlap of jurisdiction within the territorial sea. Dredged material proposed for disposal in the territorial sea is regulated under MPRSA. Dredged material discharged as fill (e.g., beach nourishment, island creation, or underwater structures) in the territorial sea is regulated under the CWA.

SITE MANAGEMENT

What is Site Management? The goal of site management is to control the use of aquatic disposal sites so that operational and environmental conditions at the site remain acceptable for the intended use of the site. In its broadest sense, site management consists of:

- Designating[4] sites for the disposal of dredged material
- Evaluating proposals for aquatic disposal to assure compliance with the Guidelines or Criteria, as appropriate
- Regulating times, rates, and methods of dredged material disposal and the quantity and type of dredged material that may be disposed
- Developing and implementing effective monitoring programs for the site
- Evaluating the effect of dredged material disposal at the site
- Enforcing compliance with the applicable statute, site restrictions, or permit conditions
- Modifying site use or designation, based on monitoring data, to bring the site into compliance with site management objectives
- Implementing closure requirements and procedures when the site is no longer needed or usable to ensure the long term environmental intergity of the site

The USEPA and the USACE Headquarters have the general responsibilities for promulgating aquatic disposal regulations and developing National policy and technical guidance. Regional offices of the USEPA and District or Division offices of the USACE have been delegated most of the local management responsibilities.

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[4]"Designation" is used throughout this paper in a general sense to refer to "Specifying" a site under the CWA; and, "Designating" a site by USEPA or "Selecting" a site by the USACE under the MPRSA.

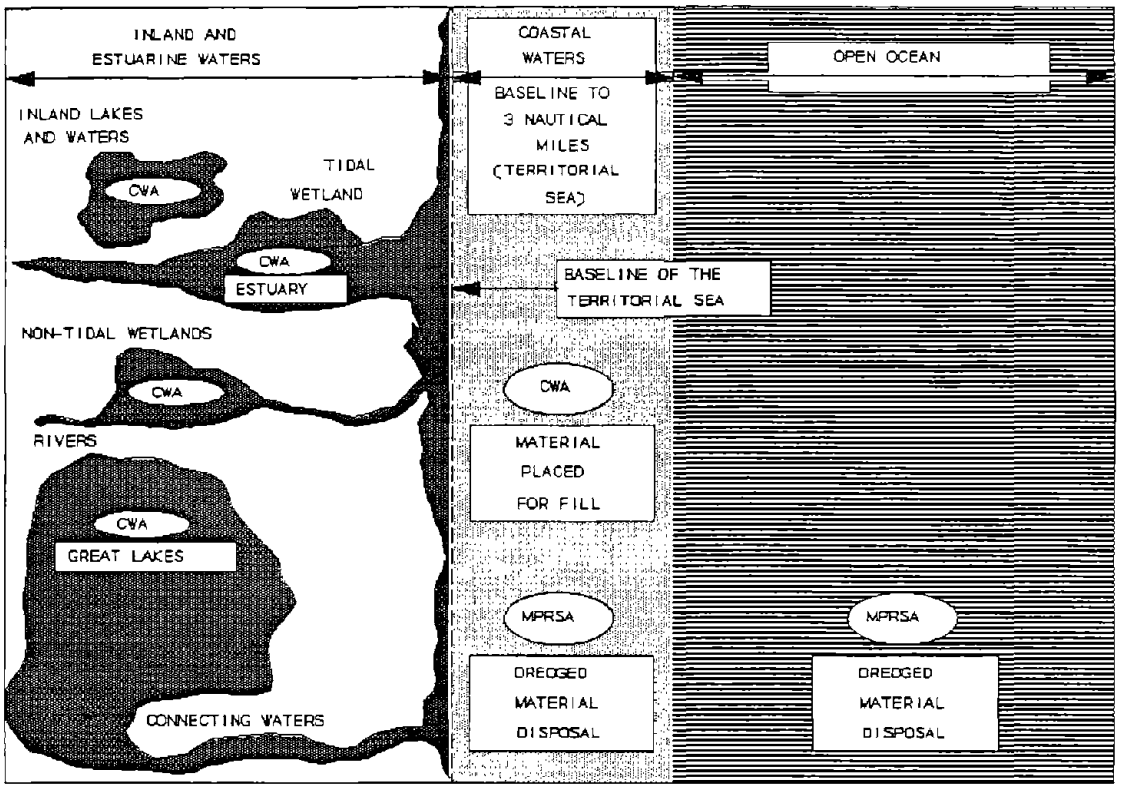

Figure 1. Geographical Jurisdiction of the Marine Protection, Research and Sanctuaries Act and the Clean Water Act. [Adapted from NACOA, 1981]

What Site Management is Not. Because of misconceptions encountered with other management frameworks, such as the USACE's Long-Term Management Strategy (LTMS; Mathis and Francingues, 1991), it is important to point out functions that site management is not intended to handle. Therefore, site management is not:

- A Long-Term Management Strategy for dredged material disposal from single or multiple navigation projects
- A formal institutionalized, new program with a major new authorization and appropriation
- An environmental habitat restoration program
- A contaminated sediment cleanup program

However, site management is an essential component of any of the above programs that include aquatic disposal of dredged material as an element.

The remainder of this paper discusses how each aspect of site management is integral to overall success of site management; the interrelationship of the site management elements is conceptually illustrated in Figure 2. The section on coordination describes how all

levels of the USEPA and the USACE work together to accomplish site management in an effective and efficient manner.

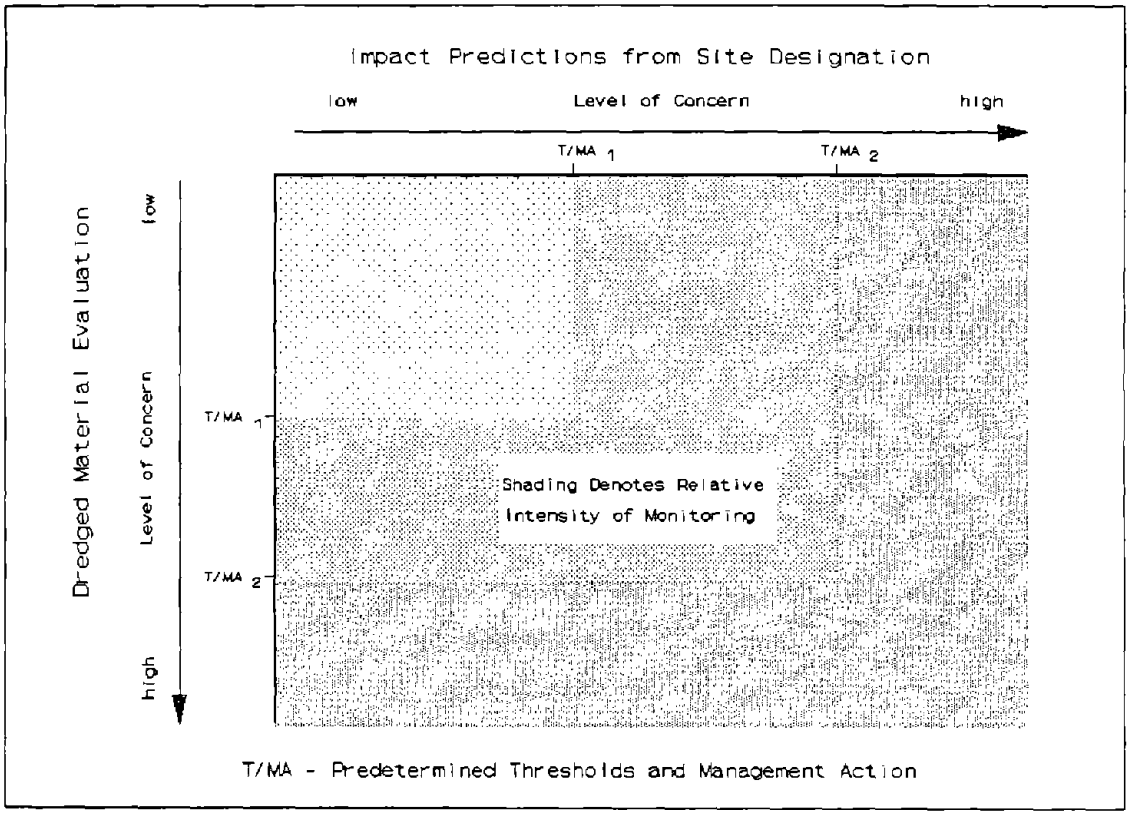

Figure 2. Interrelationship of Site Management Elements.

SITE DESIGNATION

Site designation may be the most important aspect of proper site management. Careful evaluation and designation of an aquatic site is one of the first management decisions which will ensure that disposal will not promote adverse operational or environmental effects. Appropriate site selection can also maximize the success of management actions that may be applied to disposal operations to facilitate the attainment of site management objectives.

While designating an appropriate site is important to site management, the findings of the site designation documentation may be even more critical. In most cases, there will be some identified potential impacts of the dredged material disposal at the selected site; however, for the site to be designated, these impacts can not be unacceptable (as determined by the Guidelines or Criteria, as appropriate). Future site management actions may be minimized when, of all the alternative site considered, disposal is authorized at the site

which would have the least adverse environmental and operational impacts. The site designation documentation must describe the assumptions that led to site designation, the impact predictions, and the operational limits on site use given the site characteristics. These factors become the basis for implementing, and assessing the effectiveness of, site management.

SITE MANAGEMENT PLANS

Site management plans have been recognized by USEPA and USACE as an indispensable tool for managing aquatic disposal sites (DA/USEPA, 1987). These plans are usually developed jointly by the USEPA Region and the USACE District at the time of site designation, and may be part of, or amended to, the site designation documentation. The findings of the site designation evaluation form the basis of the site management plan. Changed conditions and/or monitoring results may precipitate evolution of the management plan. Moreover, the existence of a site management plan will convey affirmatively to the public that the USEPA and the USACE have a system for monitoring and controlling unacceptable impacts to the aquatic environment.

A site-specific management plan for an aquatic disposal site can greatly facilitate management action by the USEPA and the USACE over the extended use of the disposal site. The management plan can clarify previous management decisions for present and future managers of a specific disposal site. The greatest advantage of a site management plan, however, is its ability to focus decision makers on the broad, overall management issues associated with aquatic disposal of dredged material at a given site and identify critical resources and site characteristics warranting further consideration or continuing evaluation.

PERMITTING SITE USE

The USACE is responsible for authorizing the disposal of dredged material at aquatic sites, if the disposal of such dredged material is determined to be in compliance with the Guidelines or Criteria, as appropriate, and other factors. Sediment evaluation guidance has been developed for the ocean dumping program to assist in determining if proposed dredged material meets the chemical- and biological-effects criteria and other requirements of the Criteria (USEPA/USACE, 1991). Complimentary guidance is under development for dredged material proposed to be disposed under the jurisdiction of the CWA. As stated earlier, the USEPA provides environmental oversight on USACE aquatic disposal decisions.

Dredged Material Evaluations

Dredged material evaluations play an important role in site management. While site management plans are designed around impact predictions based on known site conditions and potential dredged material characteristics, dredged material evaluations provide essential project-specific information for management decision-making. Information collected during dredged material evaluations and used in other elements of site management include the following:

- Volume and physical characteristics
- Identification of contaminants of concern

- Water column toxicity and mixing characteristics
- Sediment toxicity and bioaccumulation characteristics

Though each site management plan will be different, generally speaking, evaluations of these data will result in one of the following determinations:

- Disposal will not cause significant adverse effects and can proceed with minimal additional management actions
- Disposal will not cause significant adverse effects provided that additional, structured management actions are taken
- No management actions are available which will prevent the disposal from causing significant adverse effects.

Permit Conditions

Permit conditions[5] are legal means of implementing management actions which have to be carried out as part of the dredging and disposal operation. Permit conditions are developed to be understandable (i.e., unambiguous) and implementable by the permitee, and enforceable by the USEPA and the USACE. Typically, the USACE develops permit conditions by negotiating with commenters on a proposed project to resolves operational or environmental issues. A goal of proper site management is to predict a priori operational and environmental effects and reach agreement on appropriate site management actions. Therefore, as part of site management, standard permit conditions should be developed and agreed-upon beforehand by the USEPA and the USACE for all reasonably expected circumstances described in the management plan. However, as needs arise or circumstances change, new conditions would be developed and/or standard conditions revised or expunged.

SITE MONITORING

Crucial to site management, site monitoring provides important information about 1) the effectiveness of management actions, 2) unavoidable or unexpected impacts requiring additional management actions, and 3) changed site conditions requiring redirection or refocusing of the site management plan. Fredette and others (1990) and the NRC (1990) reviewed existing literature and provide a framework for developing useful monitoring programs. The following factors were identified in both publications as being necessary for the development of meaningful monitoring studies:

- Establish monitoring objectives
- Select variables, taking into account significance to monitoring objective, natural variability, and detectable levels of change
- Design sampling program capable of meeting objectives
- Convert data to useful information
- Make management decisions

Fredette and others (1990) describe a tiered framework for

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[5]"Permit Conditions" refer to conditions in actual USACE-issued permits as well as to contract conditions in USACE administered dredging projects.

developing monitoring programs. Under this approach, each tier would have its own predetermined operational and/or environmental threshold, hypothesis, sampling design, and management option(s) should the threshold be exceeded. When a threshold in one tier is exceeded, the next tier of monitoring and/or a predescribed management action would be triggered; conversely, when a threshold is not exceeded, additional monitoring or management actions would not be required. Fredette and others concluded that "this provides an 'early warning' system for detection of predetermined 'adverse effects'...(and) allows site managers to make modifications in (site) operations (e.g., capping a disposal site with clean sand) before an unacceptable impact occurs."

This approach to designing a monitoring program is recommended to be followed as part of proper site management. The monitoring objectives comport with the impact predictions (and adverse effects thresholds as described by Fredette and others (1990)) made during site designation and other management information required for decision making (e.g., enforcement). The results of monitoring have an important role in reevaluating the site impact predictions, revising the site management plan, and ultimately, in the continued viability of the site for dredged material disposal.

COORDINATION

Because the governing statutes have established site management as a shared responsibility between the USEPA and the USACE, the success of site management is directly contingent on the effective coordination and cooperation between these two agencies. The USEPA and the USACE have developed a number of means for agency coordination including the preparation of joint guidance documents, joint site designation documents, joint training, and a joint ocean dumping coordinating committee. While each of these coordination vehicles addresses all aspects of dredged material management, disposal site management is an increasingly important issue. As an example of this coordination, the USEPA and the USACE are currently developing joint guidance on the management of ocean disposal sites for dredged material.

To say that the realm of coordination is solely between the USEPA and the USACE would be incomplete. Within the USEPA, there is substantial coordination between the Section 404 program and the Ocean Dumping (i.e., MPRSA) program. Likewise, considerable coordination takes place between USEPA headquarters and EPA Regional field offices. All of this is done to ensure that dredged material aquatic disposal sites are managed in a consistent manner whether they are in the deep ocean, an estuary, or a river, or used by one project or many.

While this section discusses coordination within, and between, the USEPA and the USACE, it must be understood that other agencies and the public have important roles in site management decision-making. The role of guidance in the dredged material disposal program is to make decision-making processes more consistent and predictable for the regulated community and the public.

SUMMARY

There is little disagreement over the importance of effective dredged material disposal site management for the continued viability of of our Nation's waterborne transportation system. In this paper, we

described how the USEPA and the USACE use their various authorities under the MPRSA and the CWA to effectively manage aquatic dredged material disposal sites. Specifically, how site designations, dredged material evaluations, permit conditions, and disposal site monitoring are used in concert to achieve the goals of site management; and, how the operational- and environmental-impact predictions made during site designation are the single thread that runs through a properly designed and implemented site management program.

FINAL NOTE

The views expressed in this paper are those of the authors only, and do not necessarily represent the views of the USEPA.

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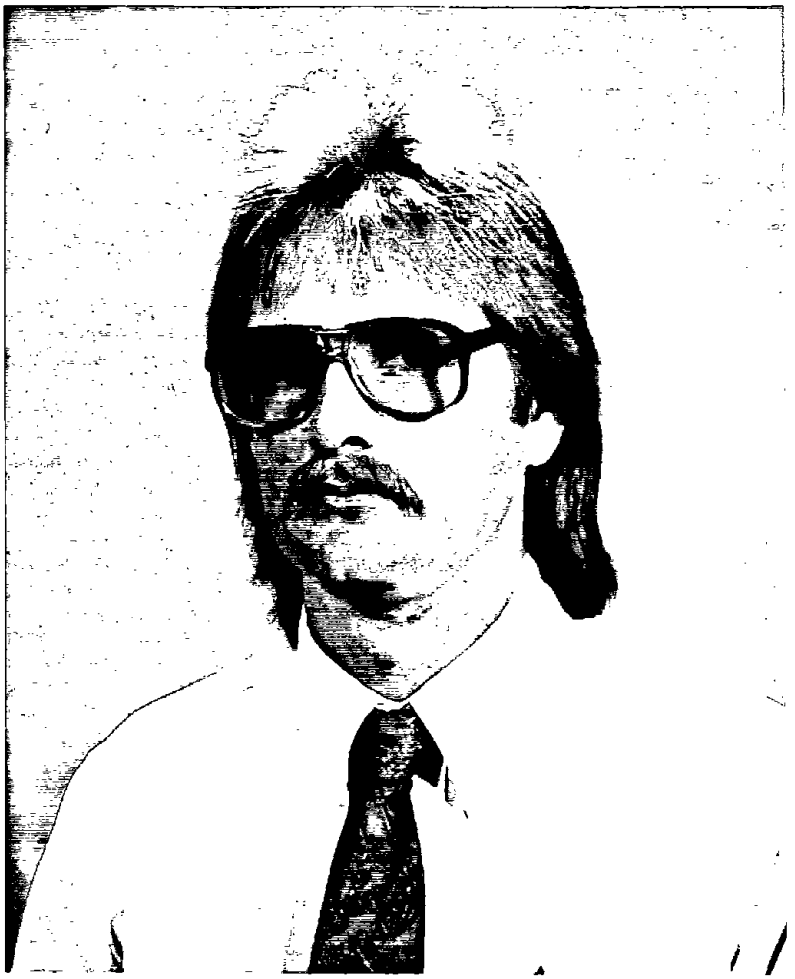
COTTON PRODUCTION ON YAZOO RIVER DREDGED MATERIAL

by

R.A. Price, P.R. Schroeder, L.E. Banks, J.G. Sanders and D.R. Johnson



R. A. Price

ABSTRACT

The use of Yazoo River dredged material for improving marginal farmland was considered as an alternative to thick-layer confined disposal facilities (CDF). Large, thin-layer CDF's can be placed on marginal farmland making it more suitable to cotton (*Gossypium hirsutum* L.) production. A study was conducted to demonstrate cotton production on Yazoo River dredged material. Dredged material was collected from an existing thick-layer CDF and cotton was grown in the greenhouse under various fertilizer treatments. Lint yields equivalent to 594 kg/ha ginned lint were obtained with an N rate of 168 kg/ha. After the greenhouse study, cotton was planted on the CDF using normal agricultural practices and N was applied at 78 kg/ha preplant and 78 kg/ha sidedress. The thick-layer CDF produced an average yield of 883 kg/ha of ginned lint. Sediment core samples collected from a 1.6 km stretch of river, scheduled for dredging, were mixed with soil from the proposed site of thick-layer CDF at 1:3 and 3:2 soil to sediment ratios. These sediment/soil mixes were subjected to the greenhouse test along with soil from a nearby productive cotton field. Fertilizer rates recommended by soil tests produced 319 kg/ha in the 1:3 mix, 178 kg/ha in the 3:2 mix and 244 kg/ha in the cotton field soil. Results of this study indicate that Yazoo River dredged material can produce cotton yields comparable to yields in area cotton fields.

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ABSTRACT

The use of Yazoo River dredged material for improving marginal farmland was considered as an alternative to thick-layer confined disposal facilities (CDF). Large, thin-layer CDF's can be placed on marginal farmland making it more suitable to cotton (*Gossypium hirsutum L.*) production. A study was conducted to demonstrate cotton production on Yazoo River dredged material. Dredged material was collected from an existing thick-layer CDF and cotton was grown in the greenhouse under various fertilizer treatments. Lint yields equivalent to 594 kg/ha ginned lint were obtained with an N rate of 168 kg/ha. After the greenhouse study, cotton was planted on the CDF using normal agricultural practices and N was applied at 78 kg/ha preplant and 78 kg/ha sidedress. The thick-layer CDF produced an average yield of 883 kg/ha of ginned lint. Sediment core samples collected from a 1.6 km stretch of river, scheduled for dredging, were mixed with soil from the proposed site of a thin-layer CDF at 1:3 and 3:2 soil to sediment ratios. These sediment/soil mixes were subjected to the greenhouse test along with soil from a nearby productive cotton field. Fertilizer rates recommended by soil tests produced 319 kg/ha in the 1:3 mix, 178 kg/ha in the 3:2 mix and 244 kg/ha in the cotton field soil. Results of this study indicate that Yazoo river dredged material can produce cotton yields comparable to yields in area cotton fields.

INTRODUCTION

The Upper Yazoo Project (UYP), for which construction began in the mid seventies, was designed to provide for flood control in the Delta area of western Mississippi. The project was conducted by the US Army Corps of Engineers, Vicksburg District and included channel enlargement and levee construction along 179 miles of the Yazoo, Tallahachie and Coldwater rivers. These rivers flow through some of the state's more productive farmland, especially for cotton. Channel enlargement was conducted by hydraulic dredging and the dredged material was placed in confined disposal facilities (CDF's) constructed on the adjacent farmland. Environmentally sensitive areas such as bottomland hardwoods and wetlands were avoided as CDF sites. In the late seventies, dredged material was disposed into CDF's in layers up to 20 feet deep. These thick-layer CDF's may take years to dry sufficiently to utilize the

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dredged material for agricultural purposes. Attempts by landowners to utilize the CDF's were largely unsuccessful resulting in the dredged material being characterized as spoil material, unsuitable for profitable agriculture. The purchase of easements from landowners to construct CDF's for dredged material placement became difficult. Landowners wanted to farm the land rather than lose it to thick-layer CDF placement. The Corps conducted research efforts to demonstrate to landowners that Yazoo river dredged material was a beneficial medium for cotton production and could be disposed in a manner allowing more rapid utilization.

METHODS AND MATERIALS

Phase I. A thick-layer CDF, constructed in 1978, was selected to evaluate the response of cotton when grown in the dredged material. The CDF was characterized by ponded water on the lower 1/4 and an assortment of weeds and small trees on the rest. After draining the ponded area and removing the trees and weeds, the CDF was divided into 30.5 x 30.5 m grids, rows A through Z, Figure 1. Each grid was sampled in 15 cm increments down to 46 cm using a 7 cm soil auger. Particle size distribution on the site was determined from these samples. The CDF was divided into three areas (A-H, I-M, and N-Z) based on particle size distribution. Two areas (I-M and N-Z) had physical characteristics suitable to cotton production. Dredged material was collected from each grid of the two areas and composited, by area, for the greenhouse test. Physical and chemical tests, including agricultural analyses, were conducted on the two composites. For the greenhouse test, a range of nitrogen, phosphorus and potassium fertilizers, based on agricultural analyses, were added to 13.2 kg of each composite in replicates of 4 (Table 1). The fertilizer amended composites were placed in 15.9-liter greenhouse pots and planted with 5 treated seeds of Delta Pine Land 50

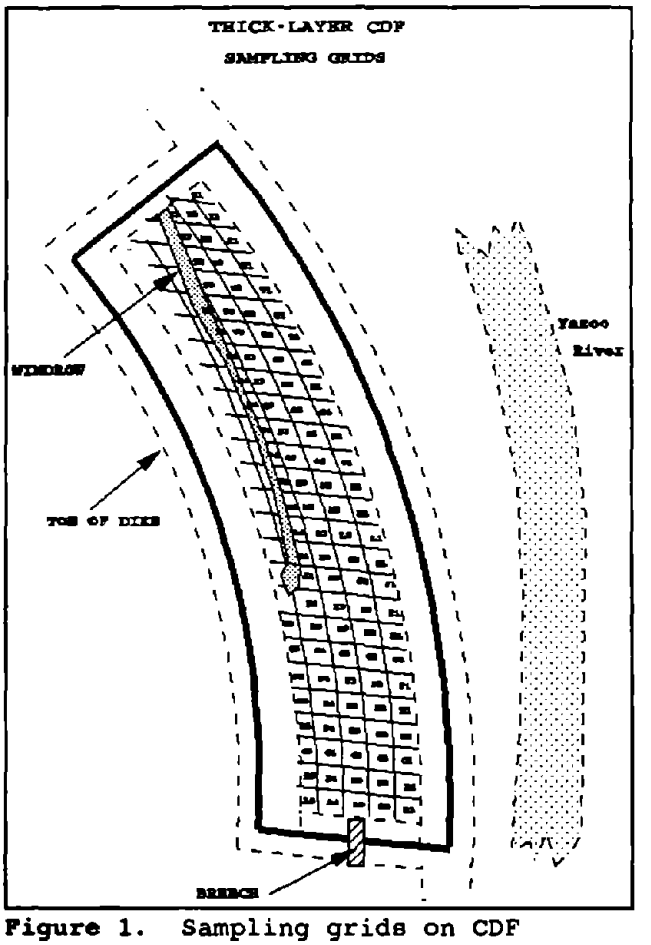

Figure 1. Sampling grids on CDF

(DPL 50) variety cotton. Seedlings were thinned to 2 individuals upon reaching a height of 15 cm. The cotton plants were grown in an environmentally controlled greenhouse having an artificially controlled day length of 16 hrs at a photosynthetic active radiation (PAR) of 1200 uEinsteins/m^2/sec. The temperature of the greenhouse was maintained at 32.2 $\pm$ 2° C maximum during the day and 21.1 $\pm$ 2° C minimum at night to simulate a summer environment. Relative humidity was maintained as close to 100% as possible, but never less than 50%. Moisture content of the dredged material was maintained between 30 and 60 MPa (field capacity is 30 MPa) by adding water as necessary. After 113 days, watering was discontinued to facilitate boll opening and the seed lint was harvested on day 132. The seed lint was oven dried at 70 degrees C and weighed to the nearest 0.001 gram to determine yields.

Table 1. Fertilizer Treatments in Phase I Greenhouse Test

TREATMENT	N (mg/kg)	P (mg/kg)	K (mg/kg)
CONTROL	0	0	0
N1P0K0	50	0	0
N2P0K0	75	0	0
N1P1K0	50	30	0
N2P1K0	75	30	0
N1P0K1[1]	50	0	30
N2P0K1	75	0	30
N1P1K1	50	30	30
N2P1K1	75	30	30
N3P2K2	150	60	60

[1] Recommended soil test fertilizer rate.

Using standard agricultural practices, the I-Z portions (approximately 4.047 hectares) of the CDF were prepared and planted with DPL 20 cotton on 10 May. The cotton was managed with normal practices including pre-plant, pre-emergence, and post-emergence herbicides with cultivation and insecticide applications for control of weeds and insects, respectively. Nitrogen was applied twice at the rate of 78 kg/ha side-dress for a total of 156 kg/ha. No other fertilizers were used and the cotton was not irrigated. Two strips, equivalent to 0.405 hectare (1 acre) were harvested by a mechanical picker in late October. The harvested seed lint was taken to a local cotton gin to determine the ginned lint yield.

PHASE II. In Phase II, sediment core samples were collected from a 1.6 Km section of the Yazoo River which was scheduled for dredging. Each core sample was individually air dried, ground to pass a 2 mm screen and subsampled for laboratory analysis. The samples (85 total) were combined and mixed to form one composite sample (CP-89). Soil material from a 24 hectare soybean field (SBF), the future site for thin-layer

CDF construction, was collected, dried and ground for mixing with the CP-89. Also, soil was collected from an adjacent cotton field (TCF), typical of cotton fields in the area, to use as a reference in the greenhouse test.

Engineering tests, which will not be discussed here, were conducted to determine possible scenarios by which dredged material could be disposed hydraulically into a large CDF and, upon drying, become mixed with a portion of the original underlying soil. Two scenarios were selected that would give mixing ratios of 1:3 SBF to CP-89 and 3:2 SBF to dredged sands (DS), respectively. These two mixes (1:3 mix and 3:2 mix) were prepared by mixing the soil and dredged materials by weight at the appropriate ratios. The DS is the sand portion of the CP-89 separated in one of the engineering tests. After preparing the mixes, samples were collected for additional laboratory analysis.

Table 2. Fertilizer Treatments in Phase II Greenhouse Test

1:3 and 3:2 Mix				TCF
NITROGEN/POTASSIUM (mg/kg)				
N0K0	N0K100	N0K200	N0K400	**N55K45**
N25K0	N25K100	N25K200	N25K400	
N50K0	N50K100	**N50K200**	N50K400	
N100K0	N100K100	N100K200	N100K400	

Treatments in bold are the soil test recommended rates.

Five DPL 50 cotton seeds were planted in 13.2 kg of the 1:3 mix, 3:2 mix and TCF placed in 15.9-liter greenhouse pots. Fertilizer treatments were added prior to planting and each treatment was replicated four times. Fertilizer treatment rates are presented in Table 2. The cotton plants were thinned to 2 individuals per pot and were grown in the greenhouse under the same controlled conditions as in the Phase I greenhouse test. After 150 days from planting the bolls were removed from the plants, the seed lint was harvested, and oven dry weight was determined.

RESULTS AND DISCUSSION

Phase I.

Dredged Material Characterization. Particle size analysis indicated high clay and low sand content, 60 and <5%, respectively, in the A-H grids. Since the most common restriction to cotton production is waterlogging (Monroe 1987), the A-H grids were eliminated from the

study. Mean particle size and chemical analysis of I-M and N-Z composites are presented in Table 3. The two composites were classified based on particle size analysis as a silty clay loam and loam for the I-M and N-Z composites, respectively. Fertility of the two composites was considered normal for agricultural purposes. However, concentrations of K, Ca and Mg were lower in the N-Z as compared to the I-M composite. Percent organic matter and cation exchange capacity (CEC) were also lower in the N-Z composite.

Greenhouse Cotton Growth and Yields. Seedling emergence and initial growth appeared normal in both the I-M and N-Z composites. Vegetative growth response to treatments varied between composites. Cotton did not respond well to the higher rates of N during initial stages of growth and higher vegetative yields were obtained with the N1 rates. Initial response of cotton, grown in the I-M composite, to increasing N was not

Table 3. Physical and Chemical Characteristics of Dredged Materials in Phase I

Parameter	GRIDS I-M	GRIDS N-Z
SAND (%)	5.5	51.3
SILT (%)	60.5	35.3
CLAY (%)	34.0	13.4
CLASSIFICATION	Silty Clay Loam	Loam
pH	5.8	6.0
PHOSPHORUS (mg/kg)	35	38
POTASSIUM (mg/kg)	124	97
MAGNESIUM (mg/kg)	579	300
CALCIUM (mg/kg)	2021	1106
ORGANIC MATTER (%)	0.72	0.37

significantly different, but final vegetative growth was greater with the higher N rates. Vegetative response to P and K additions were slight and variable. The cotton plants were observed daily for indications of disease, pests and nutrient deficiency. No diseases were noted however, symptoms of boron and sulfur deficiency were observed but not verified.

Yield of cotton lint, the most important measure of cotton production, was substantial for the I-M and N-Z composites. Total seed lint in grams is shown in Figure 2. Overall, I-M composite produced higher yields than N-Z for each treatment except N1P1K1. Yields increased in the I-M composite as N rate increased with the N3P2K2 treatment producing statistically higher yields than the other treatments. The affect of P and K on lint yield were variable in both

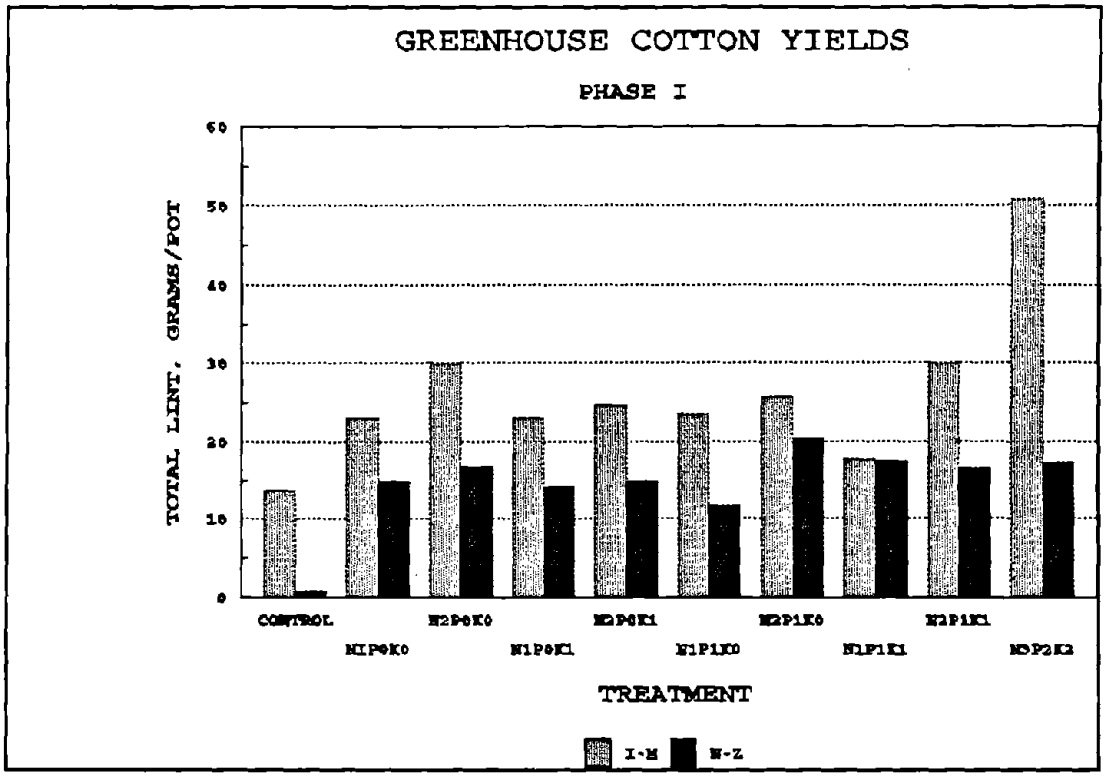

Figure 2. Seed Lint Yields in Phase I Greenhouse Test

Figure 3. Cotton Near Maximum Vegetative Growth on Thick-layer CDF

composites. The N rate had a variable affect on lint yield in the N-Z composite. Although the N2P1K0 treatment produced the highest yield, it was not statistically greater than the N1P1K1 and N3P2K3 treatments. This indicates that excessive N in the N-Z composite has no beneficial effect on lint yield. To estimate ginned lint yield on a kg/ha basis, grams seed lint/pot was multiplied by 25.8 (assuming 135,905 plants/ha). The average yield of the I-M and N-Z composites with a fertilizer rate of N2P0K0 was 594 kg/ha. Higher average yield from the CDF using the same fertilizer rate was expected.

Cotton Growth and Yield on the CDF. Cotton produced in the CDF did not require any special methods to produce healthy, vigorous plants throughout the growing season. A few low spots in the test area did remain waterlogged long enough after rainfall to have some adverse effects on growth. Cotton is shown at maximum vegetative growth on the I-M portion of the CDF in Figure 3. Although harvest occurred past the peak harvest period and some lint was already on the ground, the average yield was 883 kg/ha. This was considered a high yield for the area production year. Lint yield from the CDF, as expected, was higher than predicted from the greenhouse results. Splitting the N application in the greenhouse may have increased greenhouse yields.

Phase II

Sediment Cores and Soil Materials Characterization. Physical and chemical characteristics of the sediment cores composite, disposal site soil, cotton field soil, and composite/soil mixes are presented in Table 4. The CP-89 contains a little more sand (59.7%) than the Phase I N-Z composite and was improved by mixing with the SBF (1:3 Mix), reducing the sand content to 48.3%. Mixing 3 parts SBF to 2 parts DS (3:2 Mix) resulted in less sand and more silt and clay than in the 1:3 mix. The SBF was more suited to soybean production, since it was lower in elevation and has a higher clay content. Although typical of area cotton fields, the TCF it is not very different from the SBF in terms of particle size distribution. Fertility levels follow the clay content with higher clay content materials having higher fertility levels. Fertility levels were not determined on the 3:2 mix and DS materials; however, fertility in the 3:2 mix was estimated higher than the 1:3 mix due to the higher clay content. Although all levels shown were not optimum for cotton production, none were considered low except for potassium in the CP-89 and 1:3 mix.

Cotton Growth and Yield. Plant growth in the greenhouse appeared normal initially and declined with time in the lower N rate treatments. Generally, better vegetative growth was observed in the 1:3 mix than the 3:2 mix except in the N0 treatments and vegetative yield generally increased with increasing N. The 1:3 mix also produced higher lint yields compared to 3:2 mix except in the N0 rates, Figure 4. Lint yield was most dependent on N rates as evident in the N100K0 treatment which produced the highest yield in both mixes. Response to K additions was

Table 4. Physical and Chemical Characteristics of Soil Materials, Phase II

Parameter	Sediment Cores CP-89	Disposal Site SBF	Cotton Field TCF	CP-89 + SBF 1:3 Mix	DS + SBF 3:2 Mix	CP-89 Sands DS
Sand (%)	59.7	14.0	13.5	48.3	36.4	78.5
Silt (%)	27.7	49.6	57.4	34.6	39.6	14.0
Clay (%)	12.6	36.4	29.1	17.1	23.9	7.5
Soil Class	Sandy Loam	Silty Clay	Silty Clay Loam	Loam	Loam	Loamy Sand
pH	6.6	6.6	6.2	6.6	6.6	NA
P (mg/kg)	25	44	37	41	NA	NA
K (mg/kg)	60	187	131	74	NA	NA
Mg (mg/kg)	211	573	286	269	NA	NA
Ca (mg/kg)	943	2455	2198	1095	NA	NA
Org. Mat. (%)	0.77	0.93	0.96	0.75	NA	NA

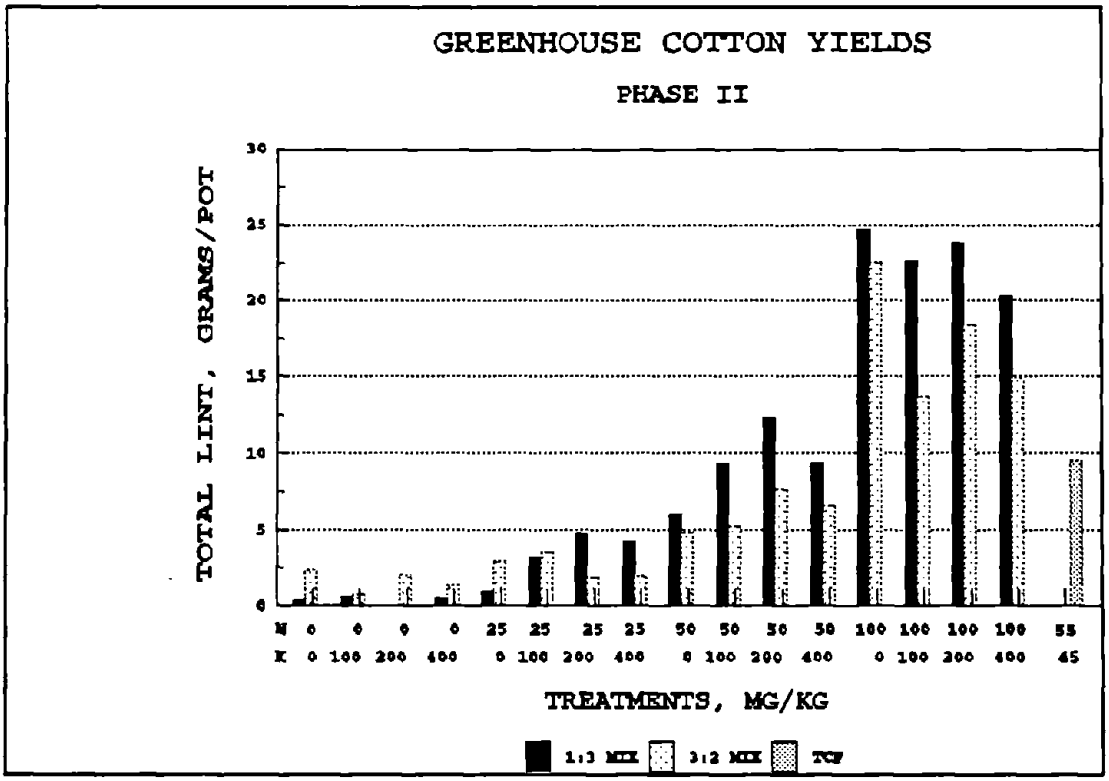

Figure 3. Seed Lint Yields in Phase II Greenhouse Test

evident in the 1:3 mix for N25 and N50 treatments and in the 3:2 mix for N50 treatment where highest yields were produced with the K200 rate. Response to K was variable in the N100 treatments for both the 1:3 and 3:2 mixes. The TCF fertilizer treatment of N55K45 was the recommended soil test rate as was the N50K200 for the 1:3 and 3:2 mixes. Lint yields equal to the TCF were produced in the 1:3 mix with N50K100 treatment while the recommended N50K200 rate yield exceeded the TCF yield. Yields for 3:2 N50 rates were below the TCF yields. Although the N100 treatments produced much higher yields, such high rates of N are uncommon in normal cotton production and were used in this test simply to observe response.

CONCLUSIONS

The Phase I portion of the study demonstrated that above average lint yields are possible on Yazoo River dredged material, even though the CDF was not designed for cotton production. The Phase II portion of the study indicated that yields comparable to yields in area cotton fields are possible in Yazoo River dredged material disposed in a thin-layer CDF design.

ACKNOWLEDGEMENTS

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INNER HARBOR NAVIGATION CANAL LOCK REPLACEMENT: A LOOK AT ENGINEERING, ENVIRONMENTAL AND ECONOMIC ASPECTS

Alan D. Schulz*

INTRODUCTION

The Corps of Engineers, New Orleans District is planning to replace the Inner Harbor Navigation Canal (IHNC) lock in New Orleans, Louisiana on the IHNC waterway. This waterway connects the Mississippi River with the Gulf Intracoastal Waterway (GIWW) and the Mississippi River Gulf Outlet (MRGO) in the Port of New Orleans (Figure 1).

The lock controls navigation traffic between the fluctuating water levels of the Mississippi River and the nearly static water levels of the IHNC/MRGO. The IHNC is located at River Mile 92.6 Above Head of Passes (AHP) and connects the Mississippi River with Lake Pontchartrain on the north and the Gulf of Mexico on the east. The MRGO waterway provides a shorter and more direct route to the Gulf of Mexico than the Mississippi River. The GIWW provides shallow-draft inland waterway transportation along the Gulf Coast from Texas to Florida. The IHNC is 5.3 miles long and is an average of 30 feet deep. The canal was opened to navigation in 1923.

The original lock was designed and constructed after World War I, and also opened to navigation in 1923. It has a usable length of 640 feet and a clear width of 75 feet with a depth of 31.5 feet over the sills. The lock was designed by engineer George Goethals, a retired Army Major General, who also designed the Panama Canal Locks. The present IHNC lock is still functioning but it is too small to handle today's navigation traffic. It will be replaced with a longer, wider and possibly deeper lock. The existing lock is located in a densely populated, urban area that has bridge crossings over important commuter routes, thus requiring extensive construction sequencing to maintain navigation and vehicular traffic throughout construction.

A site photograph (Figure 2) shows the Mississippi River in the foreground, the St. Claude Avenue Bridge (center), the existing lock, the Claiborne Avenue Bridge (top center) and the Florida Avenue Bridge (extreme top center).

ENGINEERING ASPECTS

The replacement lock and connecting channels are in the conceptual design stage. Plans are being developed for a 110-foot wide by 900-foot long lock chamber for a barge lock with a 22-foot depth, and for a ship lock with a 36-foot depth. Several alternate lock sites near the existing lock are being studied.

Two different construction methods are being studied. One method is an innovative, two-piece prefabricated steel lock that will be constructed off-site, floated-in to the site, connected, ballasted, and sunken into place on a prepared foundation. Another method is to construct the lock with concrete, cast-in-place, inside of a dewatered excavation. The excavation will be made by dredging, where possible, and/or land-based equipment. Cellular cofferdams will be constructed around the excavated

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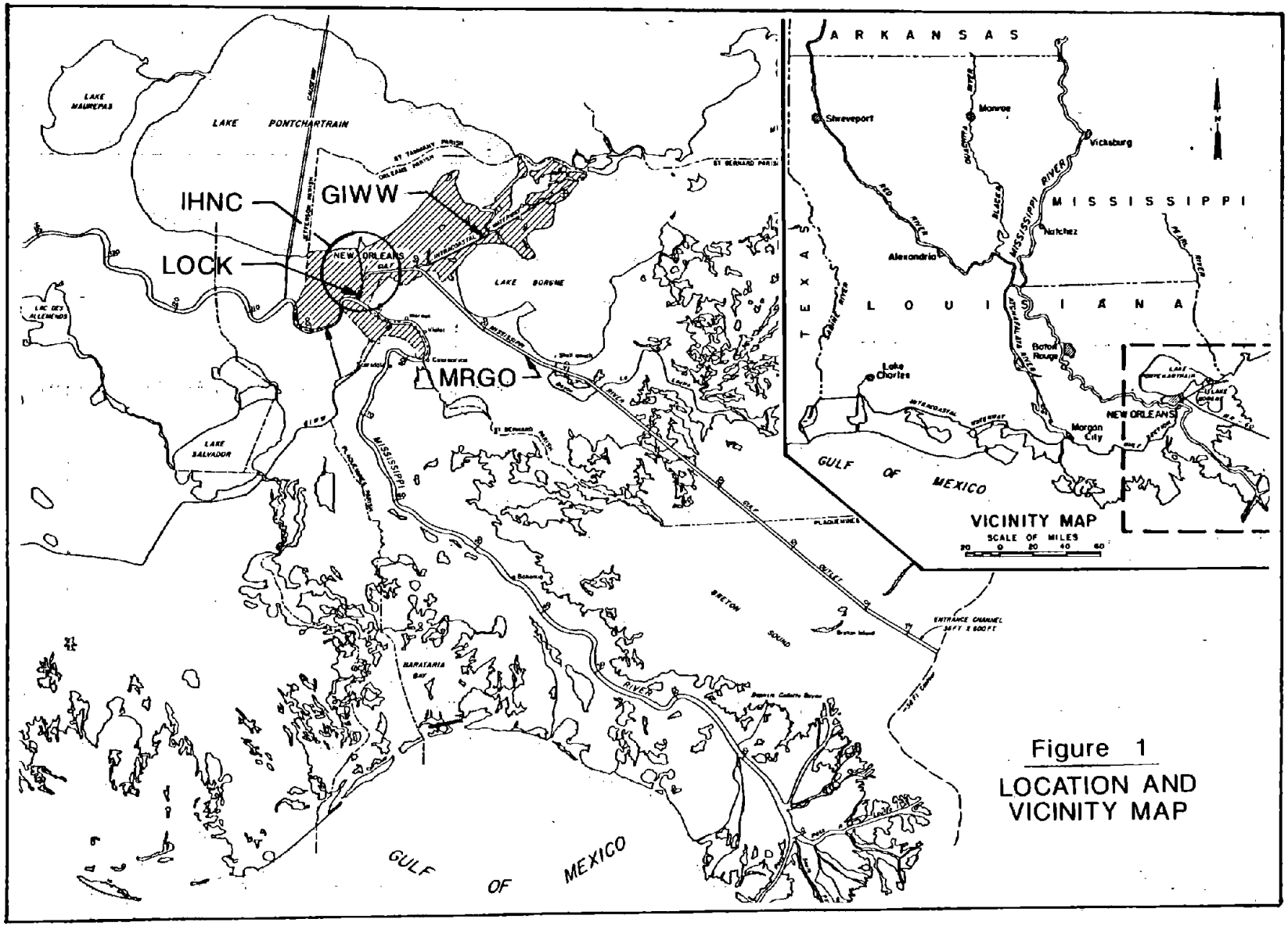
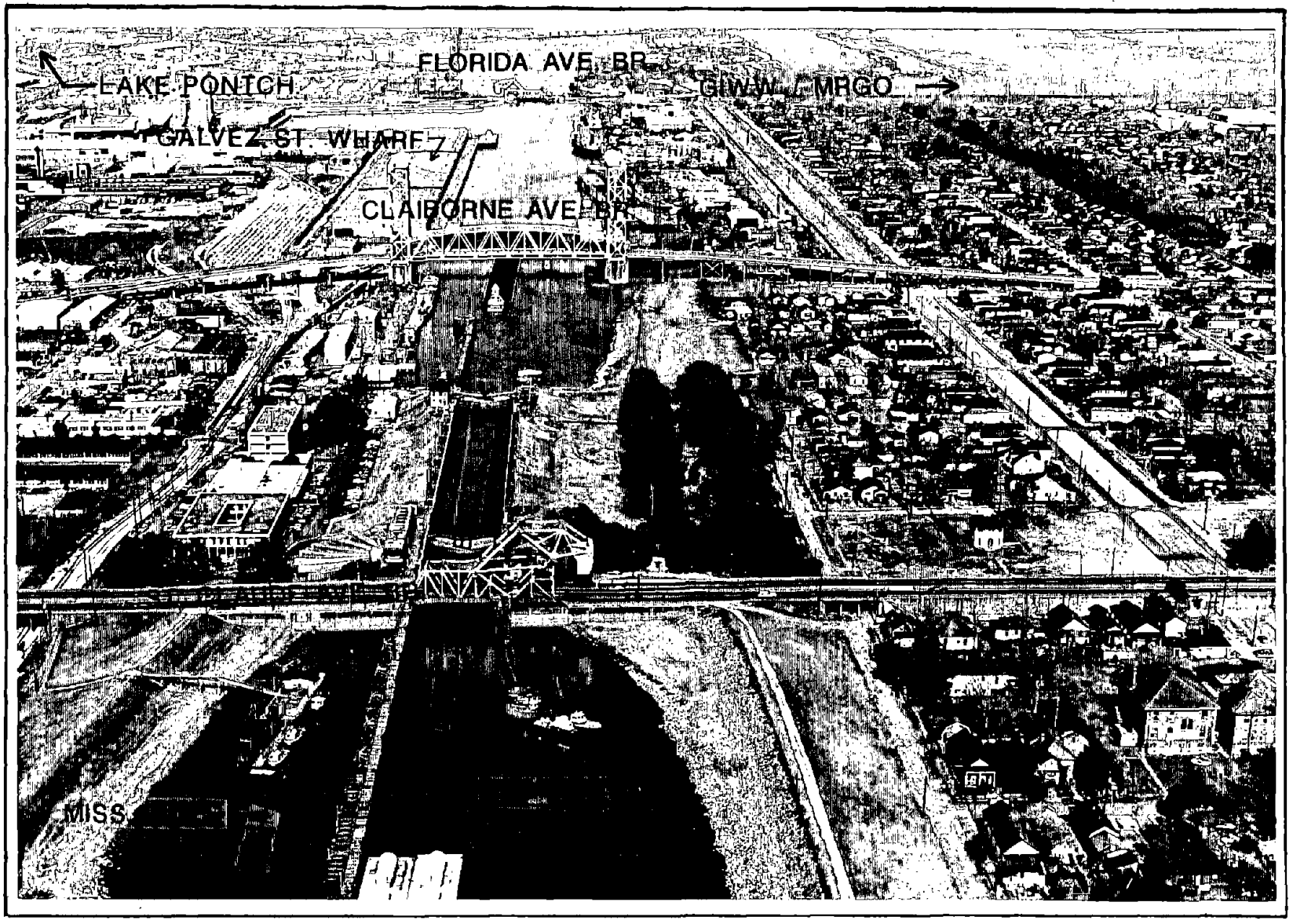


Figure 1
LOCATION AND VICINITY MAP


LAKE PONTCH
FLORIDA AVE. BR.
GIWW / MRGO
GALVEZ ST. WHARF
CLAIBORNE AVE. BR.
MISS

area prior to dewatering. Float-in construction reduces considerably the number of cellular cofferdams required to complete the lock replacement, and reduces on-site work and social impacts.

No final decision has been made by the Corps of Engineers to build the lock at the IHNC site. The Corps is working with local interests, including the Port of New Orleans, and community groups, among others, to develop a comprehensive plan using the "Open Planning Process". This process seeks to identify and reduce the social impacts of the project and to meet other project constraints. A total of ten plans were studied for determination of costs and merits.

A bypass channel is required in one lock construction plan. In this plan, the lock will be constructed approximately one-half mile north of the existing lock (Figure 3). A cross-section of the lock and bypass channel are shown (Figure 4). This site permits construction with continuous IHNC channel operation. Tug assistance is required to maintain continuous navigation during construction. Mississippi River levees will be extended to the entrance to the new lock. After completion of the new lock, the existing lock will be demolished and a replacement channel will be built in the former lock location.

Disposal areas for dredged material excavated for the lock structure may include a site northeast of the Florida Avenue Bridge in a marsh area if environmentally sound. Dredged material may also be placed in the Mississippi River downriver from the IHNC Lock. The channel cross section varies from an estimated maximum bottom width of 275 feet at the Mississippi River end to 200 feet in the replacement channel and to 110 feet at the lock entrance. Side slopes will be approximately one vertical on three horizontal where slope stability permits. If float-in construction is used, the excavated slopes generally can be steeper than in a fully dewatered excavation.

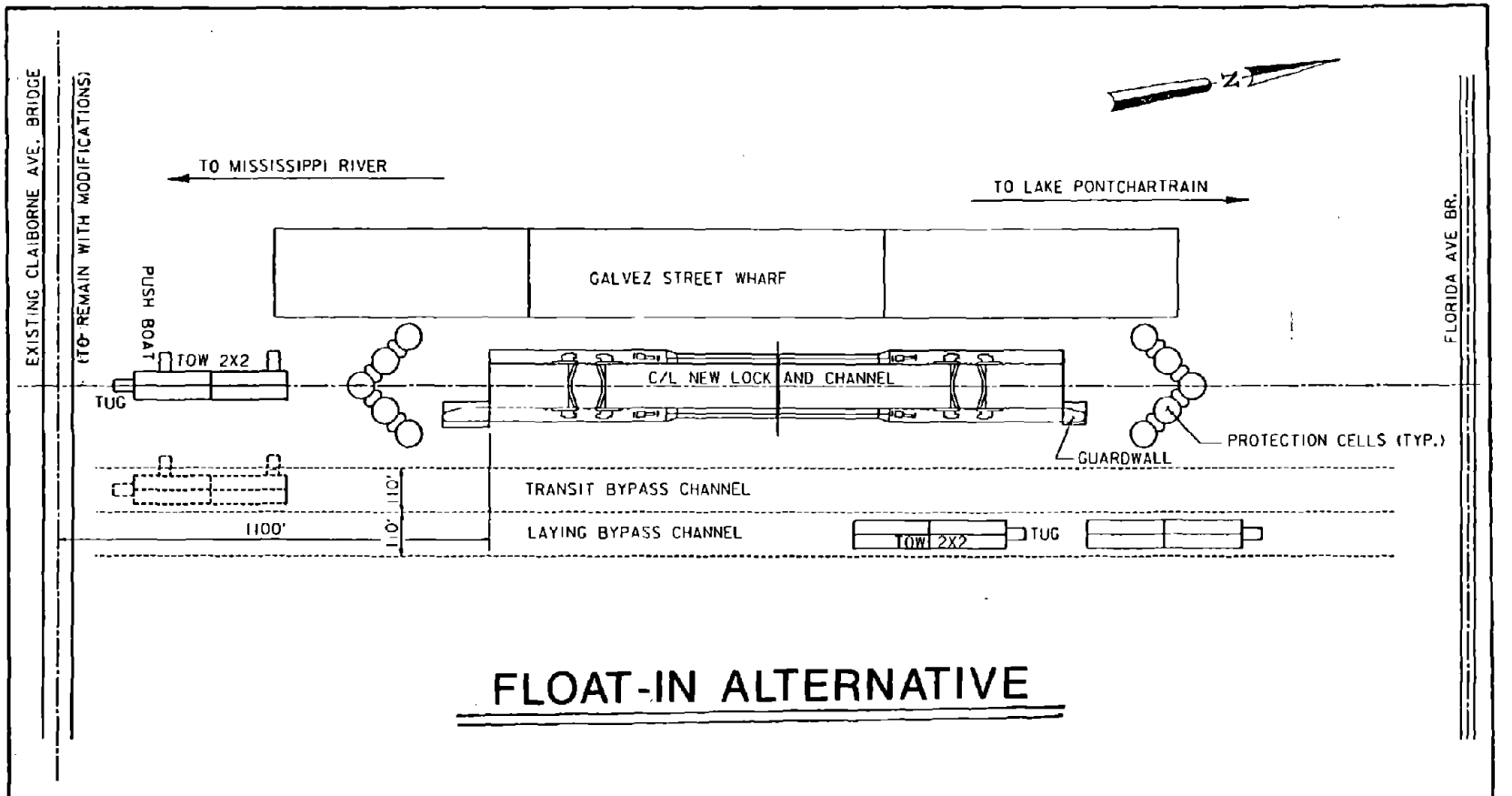
ENVIRONMENTAL ASPECTS

The Inner Harbor Navigation Canal has been in service for nearly 70 years and has passed vessels carrying cargo such as coal, fuel, grain, stone and gravel, among other cargoes. The banks of the canal are lined with industrial, government and commercial facilities.

The Corps of Engineers is considering environmental analyses appropriate for the planning and preliminary design stages of the lock replacement. Corps draft guidance for Civil Works projects (July 1990) calls for a preliminary assessment of the project area for potential HTRW sites. If the preliminary assessment indicates the potential for HTRW site, additional detailed investigations will be conducted during the feasibility phase of the project.

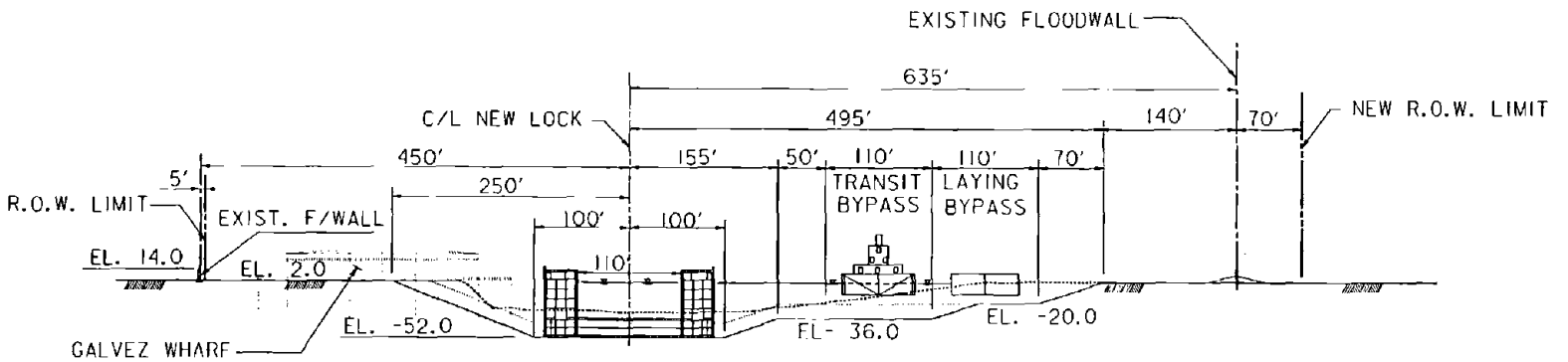
The preliminary assessment will include as a minimum the following:

a. engineering analysis of aerial photographs from historical and current files to determine past and present land use; and



FLOAT-IN ALTERNATIVE

Figure 3



TWO - WAY BYPASS
EAST SIDE CHANNEL

Figure 4

b. a site visit (walk-through); and

c. detailed investigations for historical land uses by Real Estate personnel for those areas deemed suspect by engineering analysis.

Testing may include analysis of sediments, surface water, soils, and possibly groundwater media. This is performed by Corps water quality (hydraulics) and geotechnical personnel.

The lock and channel cross-sections for the barge and the ship lock will be dredged using conventional dredging practices, where possible. The dredged channel material will be pumped to disposal areas near the site if environmentally suitable. Disposal in marsh areas may enhance the environment by marsh creation or by breakwaters created in part with dredged material. The quality and character of dredged material must be evaluated using Corps and industry guidance for hazardous and toxic wastes (HTRW). Any hazardous substance regulated under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 U.S.C. §9601, et seq, as amended, must be disposed of according to CERCLA provisions and other related Federal and state regulations. The scope and effect of these regulations is unclear at this time. Some basic definitions will be considered as listed in the Corps draft guidance.

Definitions of hazardous substances under Corps draft guidance parallel those under CERCLA and include:

a. "hazardous wastes" under the Resource Conservation and Recovery Act (RCRA);

b. "hazardous substances" identified under Section 311 of the Clear Air Act, 33 U.S.C. §1321;

c. "toxic pollutants" designated under Section 307 of the Clean Water Act, 33 U.S.C. §1317;

d. hazardous air pollutants designated under Section 112 of the Clean Air Act, 42 U.S.C. §7412; and

e. imminently hazardous chemical substances or mixtures that EPA has taken on under Section 7 of the Toxic Substance Control Act, 15 U.S.C. §2606. This does not include petroleum unless already included in the above categories, or natural gas. See 42 U.S.C. §9601 (14).

The Corps guidance is not final and is intended to provide information on how HTRW considerations may be factored into project planning and implementation. The Corps policy is to avoid HTRW contaminated areas for Civil Works projects where practicable by early identification. Where HTRW areas cannot be avoided, the local sponsor will likely be responsible for costs associated with removal of contaminated materials. State regulations also apply to any disposal of dredged materials.

Several innovative technologies are available for dredging contaminated sediments. The overarching goal for dredging of contaminated sediments is environmentally sound removal techniques. A 1991 report by Zappi and

Hayes of the Environmental Laboratory of the US Army Engineer Waterways Experiment Station in Vicksburg, MS considers the process for dredging contaminated sediments using 1) hydraulic, 2) pneumatic and 3) mechanical dredges. The report presents a synopsis of recent research efforts in this field.

The process for contaminant transport (per Zappi and Hayes (1991)) for dredged material is related to suspended sediment transport. Contaminant particles have an affinity for fine suspended sediment particles, and thus movement of suspended sediment particles acts as a convenient tracer for contaminant transport. The slow settling velocities of fine sediment particles increase the likelihood of contaminant transport away from the dredging site. The energy induced during dredging may cause loosely bound contaminants to be released into the environment. Most contaminants, however, are tightly bound and are unlikely to be separated from sediment particles. The potential for release depends on many factors such as sediment characteristics, contaminants present and local environmental conditions.

Thus the goal is to minimize sediment resuspension during dredging, and this requires careful selection of dredging equipment and methods. Note that Zappi and Hayes (1991) findings are not intended as a basis for in-depth comparisons between dredge types, but rather are to give information and insight on the innovative dredging equipment and techniques available to minimize the potential for sediment resuspension during dredging.

Several factors (Zappi and Hayes (1991)) should be considered when selecting a dredge to remove contaminated sediments:

a) the physical characteristics of the dredged area such as depth, sediment quantity and traffic;

b) the physical and chemical characteristics of the sediment;

c) disposal techniques;

d) equipment availability and

e) economics.

Further, a key factor in minimizing sediment resuspension is proper dredge operation. Innovative modifications to dredgeheads are available for hydraulic, pneumatic and mechanical dredges. Some features of the equipment innovations will be discussed.

First, hydraulic dredges are considered. These are generally efficient sediment movers, and are an economical means of transporting large volumes of contaminated sediment. Four common types of hydraulic dredges are the cutterhead, dustpan, bucket wheel and hopper dredges.

The key feature of the cutterhead dredge is a rotating cutter. The variables in the amount of resuspended sediment are:

a) dredge movement,

b) cutter penetration, and

c) cutter rotation speed.

Modification to conventional cutterhead dredges (Zappi and Hayes (1991)) that may reduce sediment resuspension include shielded cutters (covers), alternate cutterhead designs including some proprietary designs, and cutterless dredgeheads. Features such as intake grates, underwater TV cameras, gas collection systems and dredgehead positioning equipment are used to monitor and reduce sediment resuspension. Several proprietary cutterhead dredges are available to remove contaminated sediments (Zappi and Hayes (1991)).

The Corps of Engineers developed the dustpan dredge to remove free-flowing sediment from the Mississippi River (Zappi and Hayes (1991)). A modified dustpan dredgehead was developed and tested using curved inlet plates, wing plates for containment of sediment and trailing plates to increase suction efficiency.

Bucket wheel dredges may also be effective at minimizing sediment resuspension, but not much information is available in current literature (Zappi and Hayes (1991)). Hopper dredges are self-contained ships used mainly for maintenance dredging. These dredges are commonly used in a hopper overflow mode, but this should be avoided for contaminated sediments.

Second, pneumatic dredging equipment is considered. Pneumatic pumps use a positive displacement to pump slurry at high concentrations. The generally passive nature of this dredge makes it a candidate for removal of highly contaminated sediments (Zappi and Hayes (1991)). Several proprietary designs exist for pneumatic dredges.

Third, mechanical dredging equipment accomplishes sediment removal through entirely mechanical means. Clamshell or bucket, ladder and dipper dredges are the types of mechanical dredges available. Clamshell or bucket dredges are logical selections for sediment removal, but ladder and dipper dredges have generally high sediment resuspension rates, and thus are not as suitable for dredging contaminated sediments (Mitre Corporation (1983), reported in (Zappi and Hayes (1991)). Watertight buckets (proprietary) include covers, exterior pulleys and sealed joints. Turbidity barriers have also been used to restrict movement of sediment particles (Zappi and Hayes (1991)). Geotextile fabric is used to form the turbidity barrier.

ECONOMIC ASPECTS

The dredging plan for this project is still in the developmental stages. The main channel dredging and, if required, bypass channel dredging will be studied to determine an efficient dredging plan that considers the nature of dredged materials, distance to disposal areas and other significant cost items. Project features including bridges, utilities, the existing lock and other facilities must be considered in

the plan. Extensive construction sequencing is anticipated for the overall construction plan.

If hazardous materials are encountered, specialized removal techniques may be required and will include dredging where appropriate.

CONCLUSION

The IHNC lock replacement is anticipated to be a multi-phase, multi-year construction project. The channels for the barge or ship lock will be constructed using conventional dredging techniques to the extent practicable. Specialized dredging techniques will be used if hazardous materials are encountered in design studies. Innovative technologies for dredging contaminated sediments will be required to remove hazardous materials. Continual improvements in dredge methods will facilitate a time-efficient and cost effective solution for the IHNC lock replacement.

DEALING WITH REGULATION
or
(The Difference Between Men and Women;
Aristotelian Logic; and the Art of Zen in Government)

Thomas L. Elwell*

ABSTRACT

We live in a world of frequent interplay between the regulating and the regulated communities. Too frequently, this relationship is perceived by the participants as antagonistic, resulting in a net loss of potential benefits. This paper suggests an approach designed to promote a more symbiotic relationship aimed at a net gain in benefits for all parties. The central theme of the approach is an appreciation for the motivations of the individuals, and the group dynamics of the organizations, involved. The theoretical approach is explored and practical examples discussed.

INTRODUCTION

The following is not presented as the official opinion of the Washington Department of Ecology. Actually, by the time you hear or read this, it may no longer be my opinion. I'm reminded of the news items one sees on an otherwise slow day - interviews of people turning 100 or so. Somewhere in the interview many reporters seem compelled to ask: "If you had your life to live over, what would you change?" A common reply: "Nothing, I'd do the same things all over again." My reaction to this is to think that...."here is a person who has not been paying attention."

I don't pretend to have been paying perfect attention, and new experiences are sure to change my opinions; however, I do have many years of experience working the permitting end of major projects. I'd like to share some of my current thoughts with you in the hope that some of my perspectives will assist you through permitting experiences of your own.

The back cover of Tom and Ray Magliozzi's paperback book "Car Talk" advises the reader that the authors have acquired their expertise "....the professional way, by making mistakes on their customers' cars." - There is a parallel.

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Aristotelian "Logic"

Webster's Dictionary defines "Aristotelian" as "A person who tends to be empirical or practical in his thinking, rather than metaphysical or idealistic". "Aristotelian Logic" is defined as "Aristotle's method of deductive logic, characterized by the syllogism." "Syllogism" is "an argument or form of reasoning in which two statements or premises are made and a logical conclusion drawn from them .... deductive logic".

Our culture places a strong emphasis upon this form of logic. The sciences, including engineering, are built upon a foundation of deductive logic. We tend to strongly criticize decision-making which does not evidence a clear Aristotelian model. We tell each other, and often ourselves, that we humans are empirical, practical, "logical", thinkers.

I submit that, to a very large extent, this is a crock.

Intuitive "Logic"

Webster's contains a very interesting definition of the word "intuition": "the direct knowing or learning of something without the conscious use of reasoning; immediate apprehension or understanding". It seems particularly interesting that this definition does not preclude reasoning, only the "conscious use" of reasoning. Indeed, "intuitive logic" is very real. Most of us use it quite often, perhaps even more often than we use Aristotelian logic. Most of us even use intuitive logic to check our deductive conclusions.

For example, we design a structure, plan a budget, schedule a trip, or otherwise prepare for something. We may consult tables, do computations, look at precedents, consult others, and work out other things we conceive of as "logical" factors in our decision-making. However, having deduced the "logical" answer, we are uncomfortable unless the result "feels" right. Standing back and viewing the result, we use intuitive logic to do the final check. If the "feeling" is not right, we double-check our deductive logic until we either find and correct the problem or satisfy our intuition that there is no problem. Left unresolved, the issue may "bug" us throughout the project.

The opposite situation arises when our intuitive logic tells us to do something we can't support with deductive logic. Examples include a variety of purchasing decisions, such as a new car, fishing gear, hobby equipment, and expensive vacations. Using the new car example - it is very difficult to justify a new car using Aristotelian logic. No less authority than public radio's Tom & Ray Magliozzi (a.k.a. Click &

Clack, the Tappet Brothers) point out that deciding whether to keep a good older car or buy a new one takes no more deductive logic than deciding that $600 (average annual cost of maintaining older car) is less than $3600 (average annual payments for new car). Were everyone to use this logic, few new cars would be sold. However, there is no paradox; we simply don't use deductive logic when making these decisions. First we decide we want a new car, then (if necessary) we find some means (no matter how specious) to justify it. Clearly, we like our intuition better than our deductive logic - its more fun.

An interesting digression is to speculate about gender differences in the use of intuitive logic. In the 1950s, when I was growing up, there seemed to be a concept that it was much more acceptable for females to use intuitive logic (i.e. - women's intuition) than it was for males, who were expected to be "logical". It was sort of like the "men don't cry" concept; both sexes do it, men just get to feel guilty. Perhaps there are fewer of these society-imposed paradoxes today. I can't be sure, because my automatic first reactions tend to be those implanted in me during the 50s.

The point is that we all use intuitive logic; we may trust it more than deductive logic; and there is no reason to be embarrassed about it. Indeed, it is a perfectly valid form of logic. When I do it, I assume that it is simply my brain processing through all the experiences I have had, heard of, or read about; empirically finding the best fit for the present situation, and concluding how comfortable I feel.

"PRACTICAL" APPLICATION

So, why am I discussing this subject? How does it relate to anything useful? What does this have to do with the subject of governmental regulation?

I believe that it is crucial.

This belief does not come as a deduction from some grand theory of human behavior; it results from 18 years of experience managing the permitting of major new projects in the State of Washington. Thus, it is empirically-based intuitive logic.

A disclaimer is important. Like a lot of theories, mine tends to be much better at explaining selected past events than predicting the future. Use at your own risk.

Decision-making

We often seek to idealize decision-making into a mechanistic exercise in Aristotelian logic. Society establishes clear rules through laws; a proposed project is compared to these rules; and the decision is automatic. Building permits might provide an example. The city has adopted the Uniform Building Code; plans are submitted and compared to the UBC; if they conform, a permit is issued; and inspections verify that the "as-built" structure conforms. Simple. Everyone knows the rules; guesswork is eliminated; it is perfectly fair.

Some people act like all decision-making was once this way, but has become adulterated by "favoritism", "corruption", "politics", "liberalism", "conservatism", or whatever has motivated "them". I doubt it. I suspect that "unfairness" (defined as any exception to the normal rule, of which we are not the beneficiary) has been around since the first rules were created. A good argument can be made that our current decision-making process is about as open and fair as can be devised.

However, although we may not ignore our rules, those rules have become much less specific and more open to interpretation. Examples of such laws include National and state Environmental Policy Acts, the Clean Air Act, the Clean Water Act, the Fish and Wildlife Coordination Act, and the Coastal Zone Management Act, as well as Washington's Shoreline Management Act and noise regulations. Each of these laws requires that a governmental official exercise judgement in deciding how a specific proposal fits the rules. For example:

> The Clean Air Act requires the application of "Best Available Control Technology" (BACT) in many cases. BACT implies a tradeoff between energy, environment, and economics. Judgement plays an important role.
>
> NEPA and SEPA require decision-makers to weigh environmental considerations along with technical and economic ones. Adverse environmental impacts should be sufficiently mitigated such that a proper balance is achieved.
>
> The Clean Water Act requires the elimination of discharges deleterious to water quality. In practice, dilution zones and "short-term" modifications may be allowed if the public good is served.

Thus "Judgement" is a key component of modern decision-making. Of course the wisdom of any particular judgement decision is "in the eye of the beholder". Were we to find a "designated smart person" and all decide to trust his or her judgement, the system might work smoothly. However, another, somewhat new, factor also plays a major role. That

factor is public involvement.

Public Involvement

The term "Public Involvement" seems to have come into common usage in the latter 1980s, but the issue as a major factor seems to go back into the late 60s. There seems to have been a widespread disenchantment with government, the status quo, and the kind of judgement calls which were being made. Major complaints were that existing laws provided neither sufficient environmental protection nor adequate paths for the public to discover and correct errors in judgement.

Most of the laws noted above were enacted during this time. Extensive documentation and publicly available appeal procedures are common elements. Citizen-originated appeals became common in the permitting process. Thanks to man's penchant for paranoia, the effect of appeals became much more pervasive than actual appeals. Huge documents became the norm. This made sense since appeals are very expensive in both time and money; it is very tempting to just add another 200 pages to the EIS in hopes of averting one.

An awkward byproduct of extensive documentation is that decision-makers are exposed as having less than perfect Aristotelian logic upon which to base their decisions. There is a significant helping of intuitive logic (ie. "common sense") involved.

Many early environmental court cases resulted in the matter being remanded for further investigation. This was frustrating for all concerned; however, it could work in favor of the appellant in that the project proponent often just gave up.

The result was polarization and antipathy between "environmentalists" and "developers". Hyperbolic epitaphs were exchanged: "They" are money-grubbing developers ruining the environment" and "They" are namby-pamby pinko malcontent environmentalists ruining the economy and costing jobs.

Government, caught in the middle, reacted by creating more government -- more people, more reports, more lawyers, longer processes, etc.

It became increasingly clear that the problem was not so much a lack of facts as a lack of trust. Each side intuitively felt that the other side was wrong. Since intuitive logic plays such a major role in determining our conclusions, there seemed little hope of compromise.

A method we have used with considerable success is to attack this problem directly by forming a working group of proponents and agencies

and including citizens in that group. Meeting every other week throughout project development, and analysis, all parties become familiar with each other, as well as the basis for the deductive and intuitive logic involved. When people get to know each other "They" begin to be real human beings, not intuitive stereotypes. Cooperative planning can result in some degree of "ownership" in the result. Although everyone may not agree with the result, all parties understand those disagreements and (hopefully) respect each other's feelings. An example is probably useful:

> A Canadian company proposed to construct a new paper mill in a rural part of northeastern Washington. It would be the first new papermill in the state in 20 years - twenty years that had seen a tremendous change in procedures, laws, and expectations.
>
> Under our State Environmental Policy Act (SEPA), our agency was responsible for preparing an EIS as well as deciding most of the major permits. We first conducted a public "Scoping" meeting in the project area. The meeting was attended by about 200 citizens as well as representatives of the many agencies involved. We had a brief overview presentation from the company and opened it up to public comment. We wanted to know what people thought were the really important issues.
>
> We received many comments. Many persons and groups were quite excited about the prospect of new industry; others were alarmed that the quality of life they had sought in this rural area was threatened. All were concerned about air and water pollution.
>
> The project was not an "up or down" proposition such as might occur were the company to have a fully designed facility and be asking "Yes"?or "No"? The company had an option on some land, wanted to produce about 500 tons per day of newsprint, and hoped to make money doing it. Beyond that, they were flexible. This is the ideal situation; government and industry can work together to analyze effects and develop alternatives. It made a great deal of sense to include all involved state, local, and federal agencies in this process so that important factors were not overlooked. Why not include concerned citizens, too? We set up an interagency meeting in Spokane and asked several of the most concerned local citizens to join us.
>
> Based on the scoping process, we had prepared an outline of the EIS. The applicant had employed engineers as well as environmental consultants and sub-consultants. At the first meeting, we reviewed and discussed these plans and some of the preliminary work. Since several people were not familiar with papermaking, we arranged that, at the next meeting, we would tour a local mill. Meetings evolved into regular events over several

months. Reports evolved into concepts and alternatives. A draft EIS was published and a public hearing held. Concepts and alternatives evolved into a proposal. Finally, permits were issued and the mill constructed.

I could not begin to detail all the issues, directions, and new directions with which we dealt. However, at no time did we fail to discuss everything in open forum - good news, bad news, and puzzling news.

Not once did we suggest that people trust us. Finally, everyone came to understand that there were no dark secrets. Indeed, things were as they appeared. We all understood the level of Aristotelian logic involved, but more importantly we had similar information upon which to base our intuitive conclusions.

This is not a cookbook concept. There is no sure-fire recipe. Different situations require different approaches, and the right approach is not always obvious. However, there do seem to be some common elements.

People tend to be suspicious of government.

People won't trust you just because you tell them to do so. Trust takes time and experience. To trust someone is an intuitive decision.

Being absolutely open and honest is surprising to people whose intuition has preconditioned them to be suspicious. However, being open and honest is the best way to convince people that you are open and honest.

The most believable phrase in the English language is: "I don't know."

Find a forum in which citizens can play an important role in project development and analysis.

Caution is important. It is very important that this kind of "collaborative" public involvement not be perceive as disingenuous. Recently, laws and regulations have mandated a structured "public involvement process". Often specialists are employed to conduct public involvement. Words like "outreach" are used. This is fine, and is probably a natural result of government's tendency to structure everything, however; people have an intuitive fear of being manipulated. The more formal the process, the harder it will be to gain people's trust.

Human Motivation

A related subject is the motivation of the humans involved in a project. Once again, we tend to idealize human motivation (in a professional setting) as strictly Aristotelian. Once again, other factors, including intuitive logic, play major roles.

A very significant way in which this affects project management is the situation in which participants are intuitively unable to accept the basic premise of the project. Sometimes we joke about it by saying "my mind is made up, don't confuse me with facts." However, this is a very real phenomena, and one likely to lead to the greatest inefficiencies.

A good example may be the siting of sanitary landfills or hazardous waste disposal facilities. Government has spent years using the best deductive logic available to develop guidelines which "ensure" the safety of these facilities. Generalized standards have even approached "consensus". We recognize that zero risk is impossible so we require liners, leak detection systems, remediation plans, etc. to reduce the risks to "acceptable" levels. These risks, in which a most at risk person may be exposed to less than a one-in-a-million chance of additional health risk in a lifetime, are clearly far less than such everyday risks as the better than one-in-a-hundred chance of death attributable to drinking and driving. However, when general rules are translated into a specific proposal, prospective neighbors are outraged.

NIMBY (Not In My Back Yard) it is called. "Ah!" We say. "These are reasonable people. What we need here is public education." We set up our task forces and citizen groups. We carefully explain that this material was going to municipal landfills before it's importance was discovered. Our society has recognized the need to separate hazardous waste and treat it separately at carefully constructed and controlled facilities. Every reasonable precaution has been built into the design. The danger to society is much-much less than the old "take it to the landfill" option. "We are not satisfied." They say - so we design in a second and third liner, vadose zone monitoring, and police escorts for trucks. "Can you absolutely guarantee zero risk?" They ask. "There is no such thing as 'zero risk'." We reply. "However, this will be as close to zero risk as reasonably possible. Besides, all communities must accept some form of risk in this society. Some have prisons, some chemical plants, some rail terminals, some mental hospitals; the list goes on-and-on. This hazardous waste facility is much safer than those things. It is perfect Aristotelian logic that you should step forward to accept this facility as your civic duty." - Hopefully, you will see the tar-and-feathers coming in time to make your escape.

There are some things about which intuitive logic dominates, regardless. If your project is allowed to degenerate to this stage, you are in for a long rough road. I am aware of one Dangerous Waste facility in Washington which has been in the proposal/permitting stage for 15 years.

It is very important to avoid polarization. As proponents, you must absolutely resist the temptation to contribute to that polarization. If you feel that your project could have a polarizing influence, begin early. Work with government and community groups before controversy starts. Listen. Do not lecture. Accept the validity of people's feelings. Be willing to change. Communities often divide into pro-development and anti-development camps. Do not let this happen. Each camp feels that the other is composed of mindless lackeys. Do not let your supporters demonstrate the validity of this feeling. Remember, time, money, and heartache increase exponentially with polarization.

EXAMPLES

The Everett Homeport Example

Polarization came with this project proposal. Many persons felt that it was unwise for the Navy to build new "Homeports" at all, including at Everett, Washington. Nuclear weapons and nuclear powered ships added controversy, as did the idea of making Everett a "Navy town". Others, many who had lobbied hard to get the Homeport, felt that the Navy was just what this industrial town of disappearing industries needed to rejuvenate its economy.

Dredging provided a "field of honor" for many of these factions. The inner harbor was contaminated and needed remediation. In cooperation with Ecology, the Corps, and several other agencies, the Navy elected to dredge the whole harbor, using Confined Aquatic Disposal to isolate the contaminated fraction under a cap of clean material. Extensive technical work was done by WES to demonstrate that the technique would work. Three EISs were written. However, after permits were issued, a consortium of environmental groups appealed in both State and Federal courts. Although the State system supported the permits, the Navy settled the Federal action by agreeing to a "down-sized" Homeport with no dredging of the contaminated inner harbor sediments. The end result: The inner harbor sediments are still exposed to the environment and still need cleanup.

We were absolutely honest with everyone and did everything we could to keep the matter at an Aristotelian level; however, we were still viewed with suspicion. Perhaps there were too many issues providing polarization to ever have avoided it. What really bothers me is that I

don't know what I would do differently.

The Port of Seattle Example

In the Northwest, Port Districts have an historical image problem. They are often seen as insensitive to environmental issues. Some, like the Port of Seattle, are so big that to question their decisions has had a "David and Goliath" overtone.

But, times have changed. New land is not available. Recent attempts to more intensively use existing land have met strong community opposition. Rapid reaction to customer needs for new terminals is no longer possible. Long-range planning is essential. The Port is actively working with established and Ad Hoc citizen and community groups in order to head off confrontation. At the same time, the Port is proposing to clean up and redevelop a contaminated former shipyard. Dredging contaminated sediments would be involved, as might capping some contaminated material in place.

The traditional method would be to put the pedal-to-the-metal all ahead Bendix and roll over any opposition. However, the Port recognizes that this would not work. Endless studies and litigation would neither clean up contamination nor move containers. In addition, I believe that the personality of the Port has changed. There seems a genuine desire to conform to modern expectations.

The problem is how to convince the public, especially those members of the public whose intuitive logic is programmed to the way it was. The answer is to be genuine, honest, and give it lots of exposure and time. This the Port is doing. Many citizen and agency working groups have been formed and meetings will have been held for over a year before the first major planning documents are published. People have been listened to and their ideas have resulted in real project modifications. The Port has not told people to trust them, they have shown people that they are trustworthy.

So far, polarization has been avoided. I don't know how this will turn out, but the process promises the best chance for all parties to be winners.

CONCLUSION

I hope these ideas are useful to you. The basic concept is simple. Be open and honest; find forums to demonstrate this; listen to people; use their suggestions; give it time; avoid polarization and win/lose situations; understand that intuitive logic is real and valid. The

process gives the best chance for success. A useful byproduct is multiple occasions in project development when the proponent can assess whether to continue - a lot better than staking everything on an expensive win/lose court case at the end.

THE LONG-TERM ENVIRONMENTAL EFFECTS OF THIN-LAYER DISPOSAL ON A SALT MARSH, LAKE LANDING CANAL, NC

by

Pace Wilber[1], Joseph J.Luczkovich[2] and David B. Knowles[2]

ABSTRACT

Finding areas acceptable for the disposal of dredged material is becoming more difficult, particularly for projects surrounded by wetlands. Placing dredged material in relatively thin, uniform layers may reduce environmental impacts associated with dredged material placement enough to make disposal in some areas environmentally acceptable. Although such proposals have been made for at least 10 years, there are few quantitative studies of the long-term environmental effects of thin-layer disposal. In 1982, the Lake Landing Canal, Hyde County, NC, was maintenance dredged with a high-pressure hydraulic unit that sprayed material in a thin layer onto the adjacent *Juncus/Distichlis/Spartina* marsh. Throughout most of the disposal area, dredged material was placed adjacent to the canal at thicknesses that ranged from 1 cm to over 10 cm, but was most commonly about 5 cm thick. In a small portion of the project area, dredged material was placed on an island at the mouth of the canal at thicknesses that ranged from 1 cm to over 20 cm, but was generally about 10 cm thick. Disposal (Canal and Island) and two reference areas were sampled during 1991 to examine the long-term effects of these disposal operations.

Several characteristics of the Island site, relative to reference sites, were consistent with the relatively thick amount of dredged material placed there, including: a higher mean elevation (10-13 cm, difference relative to reference areas), lower total aboveground vegetation biomass (614 g-dry-wt m^{-2} *vs* 1652 and 2437 dry g m^{-2}) and shoot or leaf density (700 m^{-2} *vs* 1207 and 1226 m^{-2}), a higher sediment bulk density (1.1 g-dry-wt cm^{-3} *vs* 0.27 and 0.41 g-dry-wt cm^{-3}), and a lower sediment organic content (22.5% *vs* 58 and 70%). Some characteristics of the Canal site also differed from reference areas in ways consistent with the deposition of dredged material, including: a slightly higher mean elevation (3 cm), lower vegetation biomass (1297 g-dry-wt m^{-2}) and shoot or leaf density (901 m^{-2}) for all plant species, and a slightly

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lower sediment organic content (53%). Abundance of infaunal organisms differed between all four sites (range 146-2002 m^{-2}), however, disposal areas did not have lower abundances than reference areas. Although there were several statistically significant differences between disposal and reference areas for vegetation and soil parameters, values of these parameters were not atypical of North Carolina oligohaline marshes.

INTRODUCTION

Each year, navigation interests must find several thousand acres of new disposal sites for dredged material (Hatch 1987). This task is becoming more difficult for projects surrounded by wetlands because dredged material can impair the functions of these habitats. To help alleviate this situation, several US Army Corps of Engineer Districts and members of the dredging industry have proposed that placing dredged material in relatively thin, uniform layers will reduce environmental impacts associated with dredged material placement enough to make disposal in certain areas environmentally acceptable. These proposals reflect recognition that long-term impairments to marsh functions are primarily caused by raising ground elevations and by altering soil characteristics to levels that do not support marsh vegetation. Additional support for these proposals comes from work that shows impacts to biota are correlated with overburden thickness (*e.g.*, Maurer *et al.* 1986) and observations that some environmental impacts from placing dredged material in marshes are qualitatively similar to impacts caused by storms (Zaremba and Leatherman 1984, Bertness and Ellison 1987, Knowles 1989).

Although thin-layer disposal (*i.e.*, the planned placement of dredged material at thicknesses believed to reduce immediate impacts to biota or hasten recruitment of biota to the material without transforming a habitat's function) potentially can reduce the environmental impacts of marsh disposal, there have been few quantitative examinations of the effects of this disposal technique on marsh habitat (Cahoon and Cowan 1988). Such studies are needed to determine if impacts from thin-layer disposal of dredged material in marshes are sufficiently minor to make such practices acceptable. This report presents results from an examination of a marsh in Gull Rock, NC, approximately 10 years after the marsh was used for thin-layer disposal.

METHODS

Our study area was an oligohaline marsh that borders the Lake Landing Canal (also known as Gray Ditch), Hyde County, North Carolina (Figure 1). The canal connects Lake Mattamuskeet to Wysocking Bay. Marshes that border Wysocking Bay are similar to marshes described by Adams (1963), Cooper and Waits (1973), Copeland *et al.* (1984), and Brinson (in press). The more common types of vegetation at the site

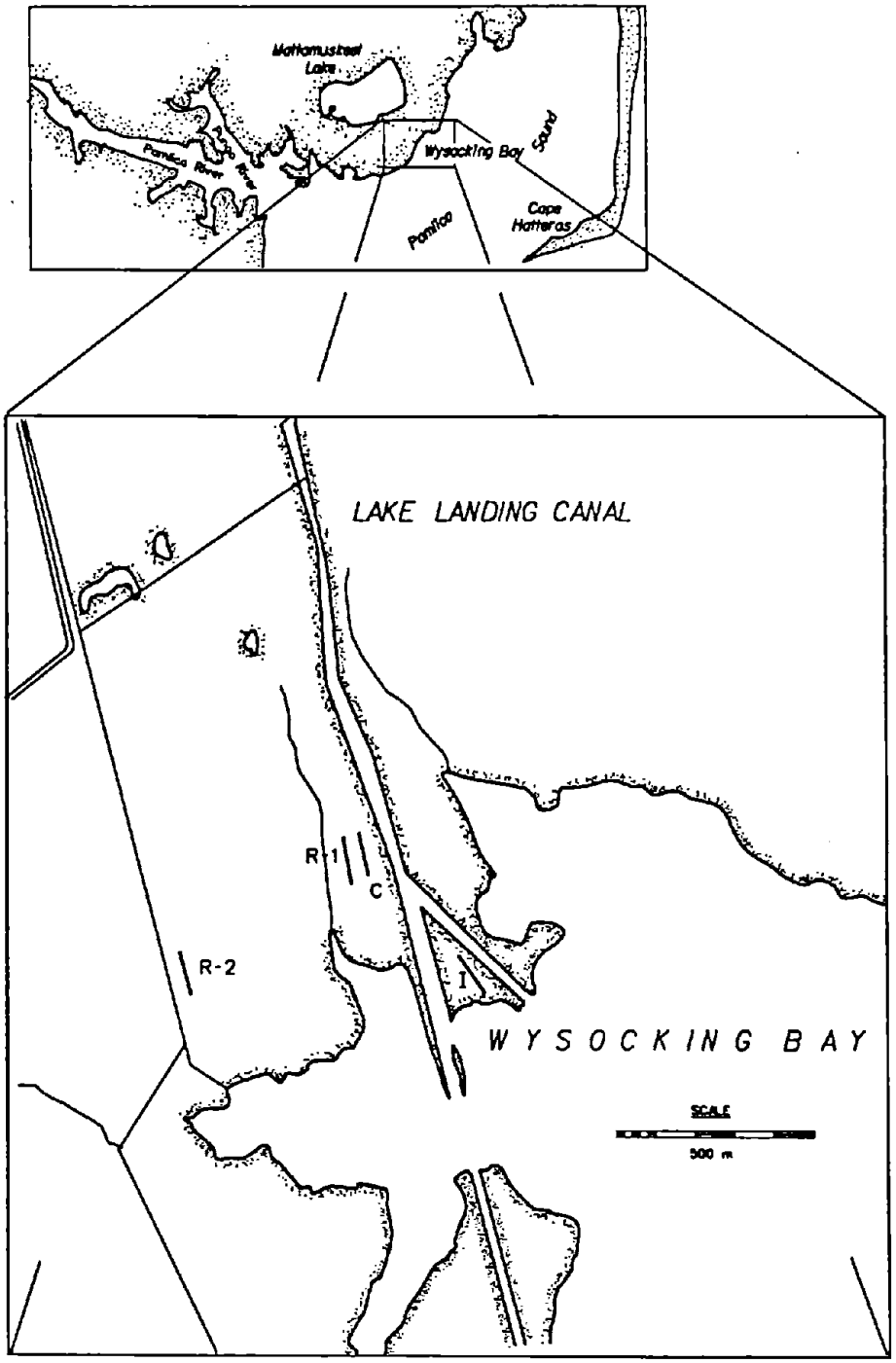

Figure 1. Study sites along the Lake Landing Canal, Gull Rock, NC. Disposal sites were Canal (C) and Island (I), reference sites were Reference 1 (R-1) and Reference 2 (R-2).

are *Juncus roemerianus* (black needle rush), *Distichlis spicata* (saltgrass), *Spartina alterniflora* (smooth cordgrass) and *S. patens* (saltmeadow cordgrass). Water levels are strongly influenced by winds and do not vary according to typical tidal periods. Natural elevations within the marsh are approximately 0.3-0.6 m MSL. The Lake Landing Canal and several of its tributaries are navigable in small boats. During construction of the canals approximately a century ago, most of the dredged material was placed along the canal banks forming narrow berms. The more common types of vegetation on these berms are *Cladium jamaicense* (sawgrass), *Myrica cerifera* (wax myrtle), *Quercus virginiana* (live oak), and *Rhus radicans* (poison ivy).

During February-March 1982, the Hyde County Board of Commissioners maintenance dredged 1830 m of channel within the Lake Landing and Boundary Canals to an approximate depth of -2.25 m MSL and a width of 9.15 m. In addition to this work, a 120-meter access channel to the Lake Landing Canal (9.15 m wide and -2.25 m MSL) was constructed in Wysocking Bay. The approximate volume of material excavated was 8000-12,000 m^3 and consisted predominantly of clay, silt and fine sand. Within the canals, dredged material was excavated with a barge-mounted, high-pressure hydraulic dredge that slurried material before spraying it onto marsh along both sides of the canals. The approximate range of the spray was 45 m and the thicknesses of dredged material accumulated measured from 1 to over 10 cm, but were most commonly about 5 cm (D. Gossett and T. Moore, unpublished report). Material removed to create the access channel also was excavated with a high-pressure hydraulic dredge that slurried material before spraying it onto the marsh of an island at the mouth of the Lake Landing Canal; however, the system used to place dredged material in this area differed from that used along the canals. At the island disposal area, the thicknesses of accumulated dredged material measured from 1 to over 20 cm, but was generally about 10 cm (D. Gossett and T. Moore, unpublished report).

During October-November 1991, two areas that received dredged material were examined to determine if any long-term effects from the disposal operations were discernable. The Canal site was approximately 10 m west of the edge of the Lake Landing Canal and clearly within the disposal area used for the 1982 dredging. In this area, the bank of the canal is relatively free of trees that could have blocked the spray of dredged material from reaching the marsh. The other disposal area examined (Island) was the island at the mouth of the Lake Landing Canal. In addition to these disposal areas, two reference areas were examined. Reference 1 was parallel to the Canal site and approximately 70 m from the edge of the canal. Reference 2 was approximately 10 m from the eastern edge of a nearby canal. Given local topography, hydrology, shoreline orientation, and depositional pattern of dredged material, we expected the reference areas to serve as adequate bases of comparison for any changes that may have occurred at the Canal site. Because of its insular nature, the Island site

may have been very different from the reference areas before dredging; however, no area within the immediate vicinity of the island appeared to be a more adequate reference.

Vegetation Parameters: Three vegetation parameters were examined: aboveground biomass, shoot or leaf density, and amount of senescence among *Juncus roemerianus* leaves. These parameters were measured by establishing a 100-meter transect parallel to the canal at each site. At five randomly selected locations along each transect, all vegetation within a 0.25 m^2 quadrat was clipped at the sediment surface, sorted by species, shoots enumerated (leaves for *Juncus roemerianus*), and weighed after being placed in an oven at 85°C for 24 hours. Because samples were collected late in the growing season, live and dead material of *Spartina patens* and *Distichlis spicata* could not be differentiated reliably. To estimate the amount of senescence occurring in *J. roemerianus* leaves, photosynthetically active (i.e., green) and total leaf lengths were measured for up to 50 leaves from each quadrat before drying (broken leaves were not included in this analysis).

Sediment parameters: The sediment parameters measured were: bulk density (g-dry-wt cm^{-3}), approximate organic content (as % weight loss on ignition), and relative elevation. Along each transect used to estimate plant biomass and density, bulk density and approximate organic content of surface soils were determined by removing five 3.8-cm diameter by 10-cm plugs of material and weighing them after they had been in an 85°C oven for 48 hours; this yielded bulk density. Samples were then heated to 500°C for 4 hours and reweighed to yield the approximate organic content. Surface elevations were determined using a Tokyo Optical Company Model AT-F2 automatic transit with a 40X telescope and a target staff calibrated to 1 mm. Since no USGS benchmarks were nearby, a benchmark that corresponded to the water level within the canal on November 17 was established, and all elevations reported are relative to this benchmark. Using techniques described in Whyte (1976), elevations were measured at 10-meter intervals along each 100-meter transect used to sample vegetation.

Faunal parameters: The density of infaunal organisms was measured by taking three 7.6-cm diameter cores to a depth of 10-15 cm at each of five randomly selected locations along each of the four transects used for the vegetation sampling. The samples were then preserved in 10% formalin and stained with Rose Bengal in the field. In the laboratory, organisms that were in the top 5 cm of each core and could not pass through a 0.5-mm mesh screen were picked from the material and identified to the lowest practical taxonomic unit. Due to the low number of organisms found in each core, statistical analyses were done after combining the three replicates from each station and grouping species into high-order taxonomic units. Cursory surveys of

marsh use by fishes and mobile macroinvertebrates were made with unbaited traps. Pitfall traps were 4.5-liter buckets placed in the ground so their rim was flush with the soil surface. One pitfall trap was placed at each end of the transect at each site and harvested four weeks later. Willson traps essentially are pitfall traps with a coarse-screen opening and are similar to traps used by Breeder (1960) and Harrington and Harrington (1961, 1985). Four Willson traps were placed at randomly selected locations at each site and harvested a few hours later.

Statistical Analyses: In general, statistical analyses were done according to procedures described in Sokal and Rohlf (1981) and (Manly 1986). Because multiple parameters were measured per quadrat and many of these parameters are known to covary, multiple univariate ANOVAs could lead to unacceptably large type I errors. This potential problem was controlled by using MANOVAs when significant correlations among individual parameters of a group existed. Statistical significance of the MANOVAs was judged using the approximate F-statistic based on the Hotelling-Lawley Trace. Because of tendencies toward non-normal distributions, vegetation biomass, shoot or leaf density, and infaunal densities were transformed prior to final statistical analyses (ln [X+1]). All statistical tests were done on raw or log-transformed data, however, in the subsequent discussions, data are presented as m^{-2}.

RESULTS

Vegetation: Reference 1 had the highest mean total aboveground biomass of the sites examined (2437 g-dry-wt m^{-2}), the Island site had the lowest (614 g-dry-wt m^{-2}; Table 1). In terms of aboveground biomass, *Juncus roemerianus* was the most common species at the Canal, Reference 1 and Reference 2 sites (Figure 2). At these sites, the mean total (live plus dead) *J. roemerianus* biomasses were 1139, 2372 and 1185 g-dry-wt m^{-2}, respectively. Approximately 30-40% of the *J. roemerianus* material exhibited at least some green coloration. At the Island site, *Spartina alterniflora* exhibited the highest mean aboveground biomass (278 g-dry-wt m^{-2}). When viewed by species, several statistically significant correlations existed among species (Table 2A), therefore MANOVA was used to contrast the sites. MANOVA showed there were significant overall differences among the four sites ($F = 1.99$, $p=0.048$). Inspection of Figure 2 and univariate ANOVAs for each species (Table 2B) showed the major contributors to the significant overall difference were *J. roemerianus* and *S. alterniflora*.

Reference 2 had the highest total mean shoot/leaf density (1226 shoots or leaves m^{-2}); the Island site had the lowest (700 shoots or leaves m^{-2}; Table 1). In terms of shoot and leaf densities, *Juncus roemerianus* was the most common species at the Canal and Reference 1 sites (mean leaf densities were 532 and 886 leaves m^{-2}, respectively),

Table 1. Summary of total vegetation biomass (g-dry-wt m^{-2}), total vegetation density (shoots or leaves m^{-2}), *Juncus roemerianus* leaf length (cm), soil bulk density (g-dry-wt cm^{-3}), and soil organic content (%). Mean leaf lengths were determined by weighting all observations from a transect equally. Numbers listed are means, numbers in parentheses are standard deviations. Contrasts are based on ANOVAs with $p<0.10$; I=Island, C=Canal, R1=Reference 1, and R2= Reference 2. The total number of fish and *Uca minax* caught in pitfall (2 traps per site) and Willson (4 traps per site) traps also are given. NA = Contrasts were not applicable (see text for further discussion).

Parameter	Island	Canal	Reference 1	Reference 2	Contrasts
Vegetation:					
Biomass	614	1297	2437	1652	I<C=R2<R1
	(578)	(907)	(607)	(600)	
Density	700	901	1207	1226	I=C<R2=R1
	(620)	(337)	(324)	(413)	
Leaf Length	82.8	87.1	93.1	83.7	NA
Soil:					
Bulk Density	1.10	0.38	0.27	0.41	R1<C=R2<I
	(0.32)	(0.05)	(0.03)	(0.06)	
% Organic	22.5	52.7	69.8	58.4	I<C<R2<R1
	(9.7)	(3.3)	(3.1)	(4.2)	
Fauna:					
Pitfall Traps					
Uca minax	10	30	12	4	NA
Fish	9	3	10	0	NA
Willson Traps					
Fish	2	31	50	52	NA

and *Distichlis spicata* was the most common species at the Island and Reference 2 sites (mean shoot densities were 222 and 492 shoots m^{-2}, respectively; Figure 3). Because the densities of *J. roemerianus* and *Spartina alterniflora* were correlated ($r=-0.664$, $p<0.001$), MANOVA was used to contrast the sites even though this was the only significant correlation among the density data. MANOVA showed there were significant overall differences among the four sites ($F = 2.096$, $p=0.050$). Inspection of Figure 3 and univariate ANOVAs for each species (Table 2B) showed the major

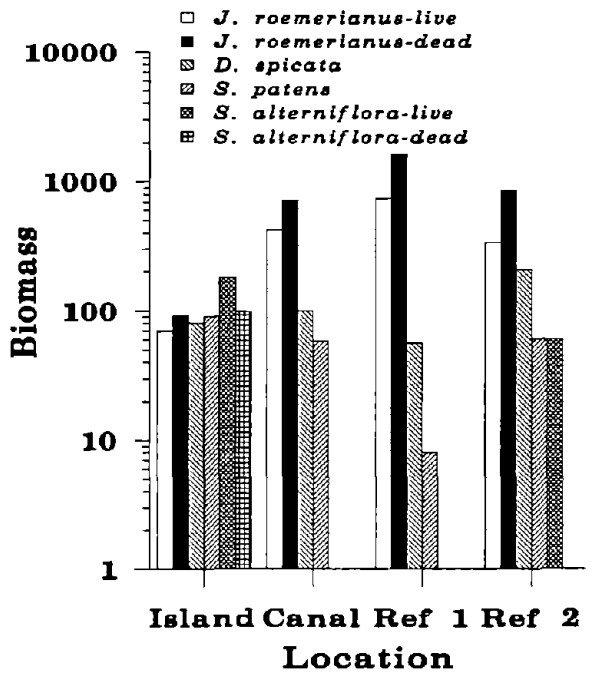

Figure 2. Biomass (g-dry-wt m^{-2}) of live and dead *Juncus roemerianus* and *Spartina alterniflora*, and all *Distichlis spicata* and *S. patens* at disposal sites (Island and Canal) and reference sites.

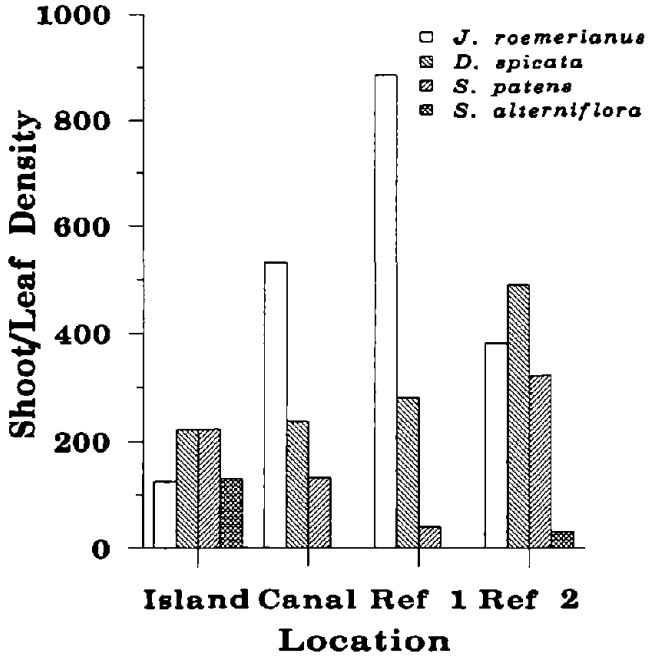

Figure 3. Shoot density (m^{-2}) for *Spartina alterniflora*, *S. patens* and *Distichlis spicata* and leaf density for *Juncus roemerianus* (m^{-2}) at disposal sites and reference sites.

Table 2. A. Pearson correlation matrix for vegetation parameters for all transects. All data were transformed (ln[X + 1]) before analysis. Dead *Juncus roemerianus* and *Spartina alterniflora* were not counted when determining shoot/leaf density. **B.** Univariate ANOVAs comparing vegetation parameters at the Island, Canal, Reference 1 and Reference 2 sites for each species. *Jr*-l = Live *J. roemerianus*, *Jr*-d = Standing dead *J. roemerianus*, *Ds* = *Distichlis spicata*, *Sp* = *S. patens*, *Sa*-l = live *S. alterniflora*, Sa-d = Standing dead *S. alterniflora*, NA = Contrast not applicable (see text for discussion)

A. Biomass

Species	*Jr*-l	*Jr*-d	*Ds*	*Sp*	*Sa*-l
J. roemerianus-dead	0.964[c]				
D. spicata	-0.499[a]	-0.531[a]			
S. patens	-0.200	-0.312	0.486[a]		
S. alterniflora-live	-0.676[c]	-0.647[b]	0.138	0.086	
S. alterniflora-dead	-0.145	-0.188	-0.113	0.218	0.438[a]

a = $p \leq 0.05$; b = $p \leq 0.01$; c = $p \leq 0.001$

B. Univariate Contrasts

	Biomass		Shoot/Leaf Density	
Species	F-Statistic	P-Value	F-Statistic	P-Value
J. roemerianus-dead	5.304	0.010	NA	NA
J. roemerianus-live	4.314	0.021	4.83	0.014
D. spicata	1.007	0.415	0.36	0.781
S. patens	1.126	0.368	1.37	0.287
S. alterniflora-live	5.269	0.010	5.57	0.008
S. alterniflora-dead	2.616	0.087	NA	NA

contributors to this significant overall difference were *J. roemerianus* and *Spartina alterniflora*.

Juncus roemerianus leaves were tallest at Reference 1 (mean length = 93.1 cm) and shortest at the Island site (mean length = 82.8 cm; Table 1). The greatest source of variation was among quadrats within sites (Table 3). By site, the percentage of individual *J. roemerianus* leaves not undergoing senescence was lowest at Reference 2 (74%) and highest at Reference 1 (81%). Rigorous statistical comparisons of the percentages of *J. roemerianus* leaves undergoing senescence were difficult because this

percentage was correlated with leaf length ($r = -0.364$, $p < 0.001$) and over 30% of the observations were 100% (which greatly skewed the overall distribution away from normality). However, inspection of Figure 4 indicates the most important aspect of the relationship: between-quadrat variability exceeded between-site variability.

Table 3. Nested ANOVA for leaf lengths of *Juncus roemerianus*. Because the mean square error for quadrats nested within sites is larger than that of sites, relatively more variation occurs between quadrats. DF = Degrees of freedom

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-Value
Site	8848	3	2949	0.33	>0.500
Quadrat(Site)	98478	11	8953	10.74	<0.001
Error	509237	611	833		

Soil Parameters: Relative to the benchmark established on November 17, 1991, the mean elevations of the Island, Canal, Reference 1 and Reference 2 sites were 25.1, 15.0, 11.9 and 17.8 cm, respectively. Differences between these means were statistically significant (ANOVA $F=61.68$, $p<0.001$). More importantly, mean elevations of the Canal and adjacent Reference 1 sites also differed significantly (ANOVA $F=15.28$, $p=0.001$), reflecting an average difference in elevation of 3.1 cm at the Canal site. Overall the bulk densities of the soil were low and organic contents high (Table 1). The Island site had the highest bulk density and lowest organic content of the soils examined, Reference 1 had the lowest bulk density and highest organic content. The between-site differences in these parameters were statistically significant (ANOVA $F=26.77$, $p<0.001$, and $F=61.21$, $p<0.001$, respectively).

Faunal Parameters: Peracarid crustaceans, oligochaetes and polychaetes were the more common infaunal organisms at the sites (Figure 5). Reference 2 had the highest density of infaunal organisms (2002 m^{-2}), mostly reflecting a relatively high density of peracarid crustaceans; Reference 1 had the lowest density (146 m^{-2}). The abundance of peracarid crustaceans was correlated with the abundance of polychaetes ($r=0.487$, $p=0.030$) and insects ($r=-0.451$, $p=0.046$), therefore MANOVA was used to contrast the infaunal densities between sites. MANOVA showed there were significant overall differences among the four sites ($F = 5.124$, $p<0.001$). Inspection of Figure 5 and univariate ANOVAs for each species showed all major taxa except insects contributed to this significant overall difference.

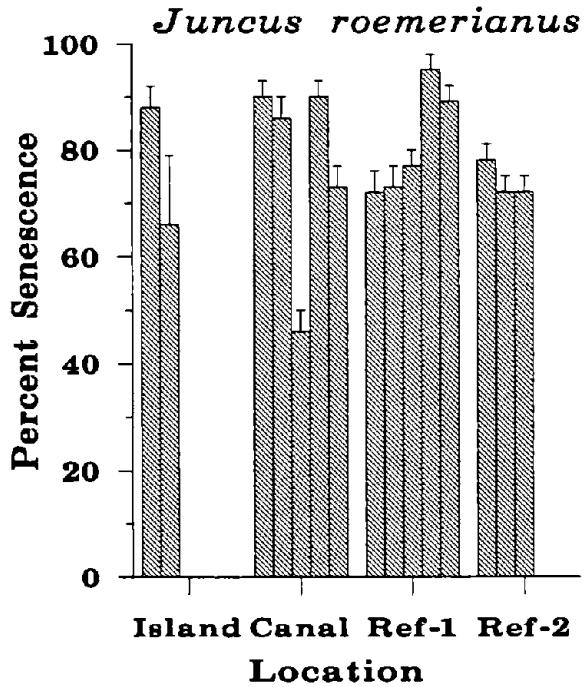

Figure 4. Proportion of *Juncus roemerianus* leaves undergoing senescence at disposal sites (Island and Canal) and reference sites. Error bars represent one standard error. Some quadrats had no *J. roemerianus*, consequently some means are zero.

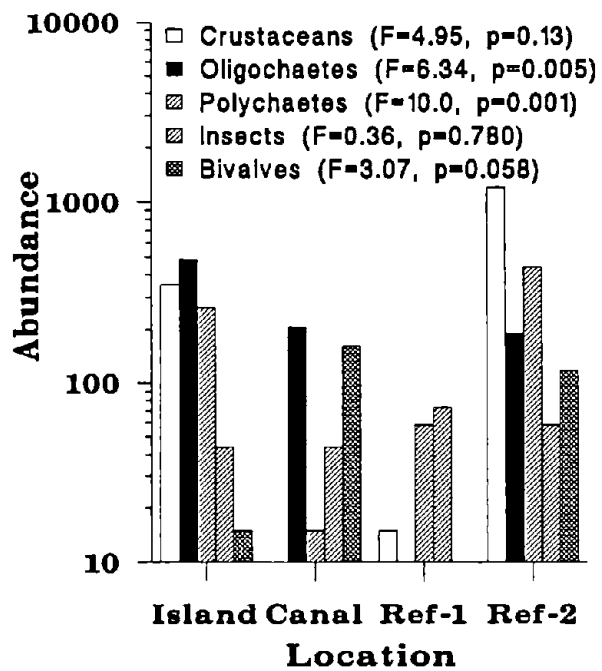

Figure 5. Mean abundance (m^{-2}) of infauna from disposal sites (Island and Canal) and reference sites (Ref-1 and Ref-2); results of univariate ANOVAs also are given.

The fiddler crab *Uca minax* and minnows *Fundulus heteroclitus* and *F. confluentus* were the most common organisms in the pitfall traps (Table 1). Of all the organisms captured in these traps, most were caught at the Canal site (42%) and the least were caught at Reference 2 (5%). The minnow *Gambusia holbrooki* was the most common organism in the Willson traps (74%). Of the organisms caught in these traps, relatively more were caught at Reference 1 (37%) and Reference 2 (39%), the least were caught at the Island site (1%).

DISCUSSION

The more common impacts of placing dredged material in wetlands include: habitat alteration created by raising elevations and changing soil characteristics, isolation of viable wetlands by creating berms, and direct destruction of vegetation via smothering (Cahoon and Cowan 1988). Thin-layer disposal apparently reduced or eliminated these impacts within the portions of the Lake Landing Canal marshes examined for this study. Undoubtedly, these results are related to the amount elevations were increased relative to the height of natural water fluctuations. Similar results may not have occurred if elevations in the Lake Landing marshes were closer to upland elevations.

Elevational-based habitat alteration is probably the most severe impact from placing dredged material in marshes. The disposal areas we examined had higher mean elevations than reference areas, reflecting a difference of approximately 10 cm for the Island site and 3 cm for the Canal site. The pre-disposal elevation of the Island site is unknown. Given this site's insular nature and relatively distant location, it is not appropriate to infer that the higher elevations observed there were solely the result of dredged material deposition. Cursory explorations of the Island with soil-recovery probes suggested a horizon of light-colored material 5-8 cm below the surface. Such a horizon is consistent with deposition of the relatively sandy dredged material, but also is consistent with storm-related deposition of subtidal material. The absence of pre-disposal information from the Canal site also precludes a definitive conclusion regarding the higher elevations observed at that site. However, the proximity of the Canal and Reference 1 sites strongly suggests that the difference was caused by dredged material, even though cursory explorations with soil-recovery probes did not indicate a dredged-material horizon. Whatever the cause of the elevational differences between the disposal and reference areas, it was apparent that these differences did not transform the marsh into upland habitat. It is not clear why *Spartina alterniflora,* rather than *Jouncus roemerianus,* was dominant at the Island site. Possibilities include relatively higher salinities at the mouth of the canal favoring the more salt-tolerant species and the dredged material introducing *S. alterniflora* seeds to the area.

Although soils at the disposal areas exhibited bulk densities and organic contents similar to those reported for other marshes (Nixon and Oviatt 1973, Buresh 1978, LaSalle *et al.* 1991), differences between disposal and reference areas were consistent with the deposition of relatively sandy dredged material. Soils at the Island site had the highest bulk densities and lowest organic contents of the sites examined, which is consistent with the relatively large amounts of dredged material placed there and that the material placed there probably had a higher sand content due to its open-water source. Soils at the Canal site were similar to those at Reference 2, but differed slightly from soils at Reference 1 in ways consistent with dredged material disposal.

In many cases, disposal of dredged material in wetlands has altered the hydrology of wetlands outside the immediate disposal site. If this occurred at Lake Landing Canal, the effects were small from the disposal event relative to changes resulting from construction of the canal. The Canal site was between the Lake Landing Canal and Reference 1, hence, deposition at the Canal site potentially could affect inundation frequencies at Reference 1. The cursory samples for fish and fiddler crabs showed the relative abundance of these organisms was high at Reference 1, suggesting that any alterations to surface hydrology from the disposal of dredged material did not block access to the canal.

Some smothering of vegetation occurred during disposal operations, mostly due to the large volumes of water involved in the spraying operations (D. Gossett and T. Moore, unpublished report). Our data show the disposal areas now support robust stands of marsh vegetation when compared to vegetation densities in other southeastern marshes (*e.g.*, Williams and Murdoch 1972, Gallagher *et al.* 1980, Gross *et al.* 1991, LaSalle *et al.* 1991). The time required for this recovery to take place is unknown, but probably was no more than a few growing seasons. However, there were minor differences between disposal and reference areas consistent with the disposal of dredged material. In terms of aboveground biomass, the Canal site had 45% less total standing vegetation than the adjacent Reference 1 site and 20% less than Reference 2. If these differences were caused by thin-layer disposal, the data indicate more than 10 years is required for full recovery.

Infaunal densities observed at all sites were relatively low compared to densities at other marshes in North Carolina (Cammen 1976, Rader 1984, Wenner and Beatty 1988). Although each site supported a different infaunal community, no relationship between these differences and the deposition of dredged material was discerned.

In conclusion, although disposal and reference areas at Lake Landing Canal differed in ways consistent with the disposal of dredged material, the more severe impacts from placing dredged material in the marsh were reduced or avoided due to use

of thin-layer disposal. Detailed studies of the economics of thin-layer disposal in marshes have not been done, however, preliminary evidence suggests costs of this practice may exceed costs of bucket dredging by a factor of 2-14 (Cahoon and Cowan 1988). Additional studies are underway at the Corps of Engineers to describe the environmental effects of thin-layer disposal and the types of equipment needed to implement thin-layer disposal in various types of habitat.

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MONITORING DREDGED MATERIAL PLUMES FROM A SINGLE POINT DISCHARGE IN THE JAMES RIVER, VIRGINIA

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ABSTRACT

Research is being conducted by the Dredging Research Program (DRP) of the U.S. Army Corps of Engineers to provide a turn-key system of acoustic instrumentation, in situ sampling, and procedures called the PLUmes MEasurement System (PLUMES). The purpose of PLUMES is to monitor the movement of dredged material placed in open water for management of dredged material placement sites. In the Fall of 1991, the DRP conducted a field data collection project at Tylers Beach, located on the James River, Virginia, to monitor the movement of dredged material vertically placed by a single-point pipeline discharge. The specific objective of the study was to determine the potential for dredged material to migrate onto an oyster seeding ground called Point of Shoals, located adjacent to the dredged material placement site. The study area was monitored for 2 days prior to dredging operations, and for 3 days during dredging and placement operations. Two teams monitored the area; one team conducted acoustic surveys in the placement site and took wide-area profiles of Conductivity, Temperature, and Depth (CTD), and samples of suspended material and bottom sediment; the second team monitored fixed stations in the channel and on Point of Shoals, taking CTD and transmissivity profiles and suspended sediment samples. Twelve acoustic surveys were conducted during the study, together with extensive collection of in situ samples and profiles. This paper provides an overview of the instrumentation and procedures used during the Tylers Beach study and discusses the results from subsequent data analyses. It was found that no dredged material reached Point of Shoals, and suspended material concentration at the site is dominated by the tide and wind.

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INTRODUCTION

An objective of the U.S. Army Corps of Engineers Dredging Research Program (DRP) Technical Area 1 (TA1), entitled "Analysis of Dredged Material Placed in Open Water" is to provide information for managing existing dredged material placement sites. The PLUmes MEasurement System (PLUMES) has been developed by the DRP TA1 to achieve that objective (Kraus and Thevenot 1992). The PLUMES employs newly developed, remote-sensing acoustic instrumentation together with standard sampling equipment and procedures to measure suspended material flux synoptically, and it has been successfully used in monitoring the movement of dredged material plumes formed at placement sites offshore of Mobile Bay, Alabama (Kraus et al. 1991) and offshore of Miami Beach, Florida (Prickett and Kraus 1991).

In the fall of 1991, two work units of the DRP TA1, "Measurement of Entrainment and Transport" and "Cohesive Sediment Processes," conducted a field study supported by the U.S. Army Engineer District, Norfolk, to monitor the movement of dredged material during placement operations in the James River, off Tylers Beach, Virginia. The dredged material placement site is located adjacent to Point of Shoals, a large oyster seeding ground unique to the region and a significant environmental and economic resource for residents living along the James River. The main objective of the study was to collect wide-area measurements of the current, and suspended material prior to and during maintenance dredging operations at Tylers Beach to determine the potential for dredged material to reach Point of Shoals when placed at the site by pipeline at a vertical, single point discharge. A second objective was to continue development of PLUMES equipment and procedures to monitor dredged material movement during a variety of placement operations and under diverse conditions.

The Tylers Beach project, conducted during the period 29 September through 3 October 1991, included 2 days of monitoring background conditions at the site prior to dredging and 3 days of monitoring during dredging and placement operations. This study is the first application of the PLUMES in a riverine and very shallow-water site (5 to 27 ft), which, in this case, is also part of the Chesapeake Bay estuary. This paper provides an overview of the equipment and procedures used during the Tylers Beach monitoring project and presents selected results. A description of the project, including equipment, procedures, and results, is contained in a comprehensive data report (Prickett et al. 1992). A narrated color video documenting the Tylers Beach Project is also available (Prickett 1992).

BACKGROUND

Tylers Beach is located approximately 13 mi upstream of Chesapeake Bay in an embayment known as Burwell Bay on the southeast shore of the James River in Virginia. The James River is approximately 5 mi wide at the Tylers Beach area, and Point of Shoals is located approximately 1 mi offshore of Tylers Beach to the east (Figure 1). The dredged material placement site is a depression with a maximum depth of approximately 27 ft and is located in a natural river channel which curves to the west (by Tylers Beach) around Point of Shoals. The natural channel became relict at the turn of the century, after the Corps of Engineers created a straight, self-maintaining channel directly through Point of Shoals. The placement site has an area of approximately 50 acres and is bounded by Point of Shoals to the east.

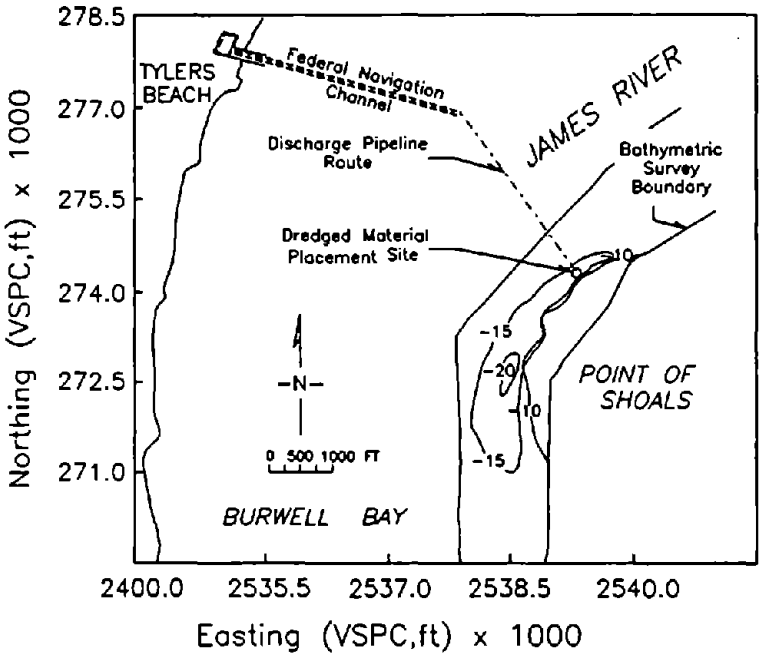

Figure 1. Location map of Tylers Beach study site

During the period 1 - 5 October 1991, dredging operations were conducted at the Tylers Beach Federal Navigation Project, comprised of a small harbor and navigation channel. Approximately 18,000 cu yd of material were removed during 24-hr operations by a hydraulic cutterhead dredge with approximately 4500 to 7500 ft of 12-inch diameter pipeline attached. At the end of the pipe, a 90-deg elbow was placed, and additional pipe was attached to form a vertical section extending approximately 15 ft below the water surface. A conical diffuser was affixed to the

end of the vertical section with an angle of 15 deg from the vertical to provide greater accuracy in depositing the dredged material at the placement site.

EQUIPMENT

Two monitoring teams were formed to conduct the Tylers Beach study and were comprised of investigators from the DRP, personnel from the Norfolk District, and private contractors. Team 1 monitored the discharge point location and surrounding area with PLUMES acoustic instruments, and took in situ measurements of Conductivity, Temperature, and Depth (CTD), and samples of suspended material and bottom sediment.

Team 1 worked onboard the *Lynnhaven*, a 45-ft hydrographic survey vessel provided and operated by the Norfolk District. Equipment onboard the *Lynnhaven* included a 4-beam, 2.4-MHz Broad-Band Acoustic Doppler Current Profiler (BBADCP) which took 3-dimensional current profiles in the water column and backscatter intensity measurements. The BBADCP was specifically selected to obtain the fine vertical resolution needed in the shallow-water operations. A second acoustic system with one beam and operating on a 600-kHz frequency obtained backscatter intensity data. The different frequencies of the acoustic instruments, which are preferentially sensitive to various particle sizes, allows for future comparison of acoustic measurements with the potential to provide additional information on suspended materials.

The two acoustic systems were mounted side-by side, on a 4-inch steel pipe and secured amidship to the port side of the *Lynnhaven*. Both systems were connected to computers in the cabin of the *Lynnhaven* to record data and to view the acoustic and current information during the study period. A schematic showing the acoustic instruments mounted on the *Lynnhaven* and their beam configuration is shown in Figure 2.

Vertical CTD profiles through the water column were obtained with a submersible data logger, which was manually lowered over the side of the *Lynnhaven*, taking readings at 15-sec intervals. A cable from the sensor was run to the cabin of the *Lynnhaven* to a computer system for data logging. Suspended material samples corresponding to the CTD profiles were taken using a peristaltic pump powered by a 12-Vdc battery with plastic tubing attached. The tubing was affixed to the CTD sensor, and suspended material samples, collected in 8-oz plastic bottles, were obtained at depths approximately 1 ft from the bottom, mid-water column, and 1 ft from the water surface. Bottom sediment samples were obtained with a clamshell grab sampler which was lowered off the stern of the vessel.

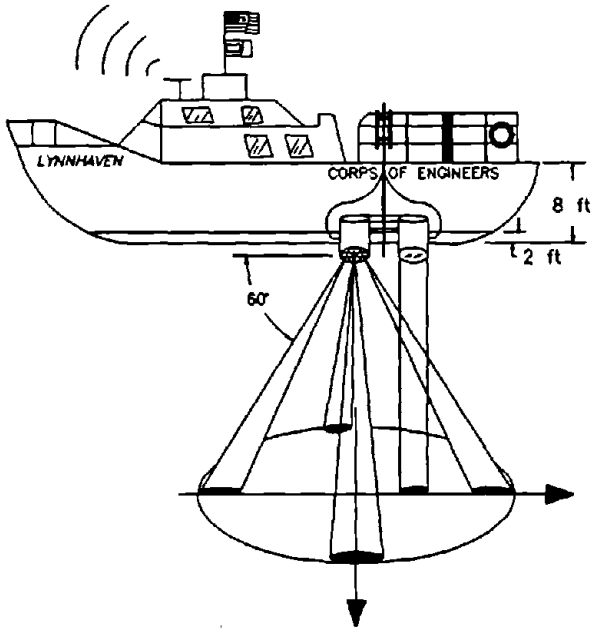

Figure 2. Configuration of acoustic instruments deployed aboard the *Lynnhaven*

Team 2 established and monitored two stations located in the placement site (one upstream and one downstream of the discharge point) and two stations on Point of Shoals from a 25-ft vessel, the *Mr. Dave*. Team 2 also obtained in situ suspended material samples with a pump and sampling tube assembly similar to that used by Team 1, which was attached to a current velocity and directional indicator assembly lowered off the side of the boat. Vertical profiles of transmissivity were obtained with a CTD unit outfitted with a 10-cm beam transmissometer. Salinity values were recorded with a portable salinity meter.

Team 2 also deployed two automatic water samplers equipped with an internal computer to take composite samples of suspended material throughout the night after major data collection activities were completed to obtain a complete set of samples through the tidal cycle. The automatic samplers contained 24 1-ℓ bottles and were programmed to take four 200-mℓ samples per bottle during a 6-hr time period. Samples were taken approximately 1.5 ft above the site bottom. One automatic sampler was overturned on 30 September, but was re-deployed on 2 October and programmed to take discrete samples at 30-min intervals. Both samplers were removed on 2 October due to forecast of bad weather.

MONITORING PROCEDURES

The site was monitored on 29 and 30 September 1991 to record background conditions. Team 1 acoustically monitored the project site in three 8000-ft transects running approximately north and south of the discharge point (the central reference point). The location of the westernmost transect was determined by bathymetric surveys made prior to the study period; the central transect ran directly through the dredged material placement site, the location of the discharge point, and the deepest part of the channel. The easternmost transect marked the topographic boundary between the relict channel and Point of Shoals. During acoustic monitoring, CTD profiles, bottom grab samples, and suspended material samples were taken from 35 stations along each transect in approximately 500-ft intervals for about 2,000 ft north and south of the discharge point and 1,000-ft intervals further away from the discharge point. Following this sampling procedure, the three transects were monitored without interruption with the acoustic instruments, and then the previous sampling procedure was repeated to obtain baseline acoustic data and samples during all phases of the tide (flood, ebb, and slack). At periods of ebb tide, the shallow water in the area of Point of Shoals along the easternmost transect would not permit access by the *Lynnhaven*. Team 2 sampled the four fixed stations on an hourly basis.

Dredging and placement operations began on 1 October, and Team 1 initially monitored the project site acoustically to detect the location of the dredged material plume (which was not visible on the water surface) by running a transect through the center of the channel following the natural course. This procedure allowed determination of the direction and extent of the dredged material plume. Team 1 then ran 1,500-ft long acoustic surveys across the channel in approximately 200-ft intervals in a tight "S" pattern running approximately east to west then west to east. This type of monitoring provided cross-sectional acoustic profiles of the shore, the placement site, and Point of Shoals. Figure 3 is a schematic showing both the background transects and the plume monitoring transects.

Once the range of dredged material movement in the placement site was ascertained and acoustic profiles completed, selected in situ sampling stations that had been monitored during background at and around the discharge point were occupied again where dredged material was detected. As the tide reversed, the cross-surveys and sampling procedure was repeated to obtain data during different phases of the tidal cycle. This procedure was repeated on 2 October.

Weather forecasts on 2 October predicted a storm coming out of the northeast would arrive at the project area by evening. Intensive collection of acoustic data, suspended material samples, and bottom grab samples was conducted under the assumption the weather would make conditions too rough to take measurements and

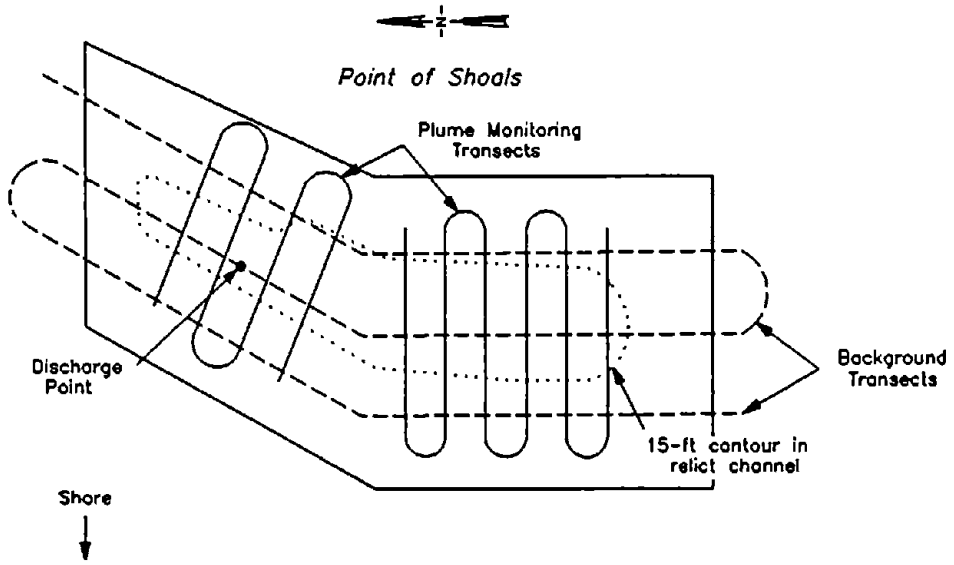

Figure 3. Schematic of monitoring procedures

samples on 3 October, the last scheduled day of the monitoring project. The storm did move through during the night, and, on the morning of 3 October, wind speed was high at the beginning of the 1-hr transit to the project site, but steadily dropped. By the time the *Lynnhaven* reached the project site, the river was sufficiently calm to continue monitoring operations.

Field calibration samples for the acoustic systems were obtained on 3 October. The transmissometer from Team 2 was taken aboard the *Lynnhaven*, and the suspended material sampling tube was attached. The *Lynnhaven* acoustically monitored the project site to find zones of relatively uniform sediment concentration. Once such a zone was found relative to a specific color (indicating acoustic backscatter intensity) appearing on the computer monitor, transmissometer readings were taken together with samples of suspended material to provide a semi-controlled field calibration of the acoustic systems. The sediment concentration determined from backscatter intensity depends on transmission frequency, particle size distribution, suspended material type, and total concentration. A laboratory tank calibration of the acoustic systems was conducted following the project. Both the field and laboratory calibrations provided curves from which concentrations of suspended material from acoustic backscattering intensity can be calculated.

Following the field monitoring, suspended material and bottom bed samples were analyzed in the laboratory for salinity, concentration, and grain size. Laboratory

settling tests were performed on the bed samples to gage the depositional characteristics of the material. The transmissometer was also calibrated using field samples and in the laboratory to obtain relative concentration values from transmissivity measurements taken at Tylers Beach.

RESULTS

In Situ Samples

Current direction measured during the project by both the 2.4-MHz acoustic system and the mechanical current meter showed that the current typically flowed to the northeast during flood tide and to the southwest during ebb tide. Current speed ranged from zero in periods of reversal, or slack water, increasing to speeds up to 2.0 ft/sec during periods of peak ebb or flood. Small vertical shears were detected at moderate to peak tidal current, particularly at stations located in the relict channel. The data indicate conditions typical of an estuarine site. The surface currents in the James River are ebb dominated, whereas the bottom currents are somewhat flood dominated, and the depth-averaged flow is seaward, as expected for a river.

Salinity values also reflected the nature of tidal flow in the the James River and ranged from 10 to 14 ppt, fluctuating with the tidal cycle. No significant change in salinity was observed as a result of dredging and placement operations.

During background monitoring (29 and 30 September), samples taken by Team 1 at stations in the relict channel indicate a wide range of suspended material concentration, particularly near the bottom of the channel. The variation in concentration at all depths closely follows the tidal cycle, with minimum concentration found during periods of slack water. Concentration was observed to increase with current speed. Suspended material concentration in the surface and mid-water column of the channel ranged from 8 mg/ℓ during slack water to 60 mg/ℓ during moderate to high current speed (0.6 to 1.1 ft/sec). Near-bottom concentration of suspended material showed greater variability, ranging from a minimum of 14 mg/ℓ to a maximum concentration of 115 mg/ℓ. Samples with higher concentrations (>60 mg/ℓ) were taken during peak flood tide with current speeds of 1.0 to 1.2 ft/sec.

Suspended material samples from the four stations monitored by Team 2 showed an increase in concentration at all stations late in the afternoon of 30 September during a period of high wind speed (approximately 10 to 12 mph) and peak flood current. This increase was noted in one station in particular, located in the relict channel approximately 250 ft north of the discharge point, where samples yielded concentrations ranging from 85 to 102 mg/ℓ. As the wind speed diminished, concentrations at that station decreased to an average of 48 mg/ℓ. The two stations

located on Point of Shoals, and the station located upstream of the discharge point position, yielded a background range of 17 to 62 mg/ℓ.

During dredging and placement operations on 1 and 2 October, surface and mid-water column samples taken by Team 1 ranged from 9 to 57 mg/ℓ, similar to concentrations from background samples. The maximum ambient suspended material concentration was 115 mg/ℓ, and measurements less than this value were considered representative of normal fair-weather conditions. Six near-bottom samples yielded concentrations above the assumed background limit. On 1 October, two near-bottom samples taken within a 5-min time period at the discharge point during dredged material discharge yielded concentrations of 15,702 and 4,168 mg/ℓ and were taken during ebb tide with an average current speed of 1.1 ft/sec. Surface and mid-column samples at that location had much lower concentrations of 21 and 30 mg/ℓ, respectively. Two near-bottom samples taken at a station downstream of the discharge point and located on the relict channel/Point of Shoals boundary, had concentrations of 11,071 mg/ℓ during ebb tide (23-ft depth), and 4,846 mg/ℓ during flood tide (26-ft depth). Surface and mid-column concentrations for both samples profiles ranged from 14 to 29 mg/ℓ, similar to concentrations taken at the same station during background monitoring. Two other near-bottom samples had concentrations above background; the first sample, with a concentration of 273 mg/ℓ, was obtained from a station located approximately 250 ft downstream of the discharge point during ebb tide (current speed 0.9 ft/sec); the second sample was taken during a period when the dredge had temporarily ceased operation and yielded a concentration of 173 mg/ℓ. This sample station was located approximately 750 ft northwest of the discharge point.

All of the suspended material concentration values discussed in the preceding paragraph were taken at stations located at or relatively close to the discharge point during periods of moderate to high current speed (0.7 to 1.1 ft/sec). Those samples probably represent true concentrations of suspended dredged material near the bottom of the placement site. However, Team 1, in attempting to lower the sampling instrument to within 1 ft of the bottom, suspension of bottom material may have occurred, making the high concentration values suspect. Samples taken on 2 October by Team 1 had concentrations similar to background levels.

Samples taken by Team 2 showed no increase in concentration at the stations located on Point of Shoals and south of the discharge point. However, bottom samples obtained from the station located north of the discharge point yielded higher concentrations (68 to 108 mg/ℓ) than found during background that were apparently due to the dredged material placement. The higher concentrations generally occurred during flood tide and at moderate current speed.

Composite samples from one automatic water sampler located on Point of Shoals and east of the discharge point had concentrations ranging from 12 to 29 mg/ℓ, with maximum concentrations taken on 30 September during background monitoring. The second sampler (which took discrete samples on 2 October), located approximately 50 ft west of the discharge point, yielded concentrations ranging from 34 mg/ℓ to a maximum of 160 mg/ℓ which was taken at the end of the day.

Bed sediments and dredged material samples were generally found to be predominantly fine-grained. Because the size gradation difference between the dredged material and bottom sediment from near the discharge point was slight and the number of samples relatively small, size gradation could not be used to distinguish discharged dredged material from other material existing in and transported through the placement site.

Measurements from Acoustic Instruments

During the Tylers Beach surveys the 2.4-MHz and 600-kHz acoustic systems provided depth profiles of acoustic backscatter intensity. Simultaneous measurements of the 3-dimensional current field were also made by the 2.4-MHz device. Each signal or ping from the acoustic systems produces an individual vertical backscatter profile; sequential pings give a cross-section of the area traversed by the survey vessel. Also during the surveys, the track of the *Lynnhaven* was recorded by the vessel's navigation system and later combined with acoustic and current measurements to provide greater accuracy in profile positions and to verify BBADCP bottom tracking data to verify BBADCP bottom-tracking capability. The backscatter intensity data were converted to concentration values using calibration curves discussed above; therefore, and the data will be referred to below in concentration (mg/ℓ).

Background acoustic measurements showed a wide range in concentration during the tidal cycle. During ebb tide, low concentrations of 10 to 20 mg/ℓ were observed in the northern section of the channel, even in periods of moderate current speed (0.8 ft/sec). At the southern end of the channel, concentrations moderately increased to about 30 mg/ℓ, with highest concentrations occurring near the bottom of the channel. When the current was weak, or at slack tide, less than 20 mg/ℓ suspended material was observed through the water column in the channel. Concentrations of suspended material were significantly greater during flood tide as bottom material was re-suspended by increased current speed. Patches of suspended material with concentrations up to 70 mg/ℓ were observed near the surface, both in the channel and on Point of Shoals. Concentrations exceeding 100 mg/ℓ were observed along the bottom of the channel, particularly in the deeper areas, and in the dredged material placement site. Figure 4 is a profile of acoustic data taken during background monitoring that runs through the center of the channel. The lighter shades represent

low concentrations of material, and higher concentrations are indicated by darker shades.

During dredging and placement operations on 1 - 3 October, nine acoustic surveys were conducted during all tidal phases. It is important to note that natural water turbidity prevented the dredged material plume from being observed on the water surface; therefore, the PLUMES acoustic instruments were the key to locating the dredged material plume. The acoustic data taken during these plume surveys showed the dynamics of the dredged material from the discharge plume were primarily determined by the tides. During periods of strong ebb current, the majority of dredged material descended directly into the placement site (Figure 5) and spread several hundred feet along the bottom of the channel south of the discharge point. In Figure 5, Tylers Beach is located to the left side of the profile (west) and Point of Shoals is located to the right (east). South of the discharge point, the dredged material was pushed against the foot of the Point of Shoals wall by the current, but did not extend upward or over onto Point of Shoals. Other than the well-defined plume and some clouds of dredged material located directly above the bottom, little suspended material, approximately 10 to 20 mg/ℓ, was detected in the channel.

During slack water, acoustic monitoring close to the discharge point showed the dredged material discharge formed a narrow, vertical plume that settled directly into the placement site. A thin layer of unsettled material was seen on the bottom. Except at the vicinity of the discharge point and near the accumulated material at the bottom of the site, concentrations less than 20 mg/ℓ were observed in the water column. One survey was conducted during slack water when the dredge was not operating for approximately 40 min. Again, suspended material concentrations less than 20 mg/ℓ were observed in the water column, indicating that the majority of dredged material had settled at the bottom of the placement site.

Higher concentrations of suspended material were observed in acoustic profiles taken during periods of peak flood current. At the discharge point, the vertical plume of dredged material detected during ebb current and slack water was quickly dispersed to the north by the strong flood current. A bottom layer of unsettled dredged material was observed at the discharge point and to the north, in the direction of current flow. This layer was observed to spread and move out of the channel towards the shore. Clouds of suspended sediment with concentrations up to 100 mg/ℓ were observed immediately above this layer and were advected by the flood current toward shore. On Point of Shoals, suspended material concentrations ranged from 40 to 60 mg/ℓ through the water column but, because of the current direction, appeared to be a result sediment resuspension.

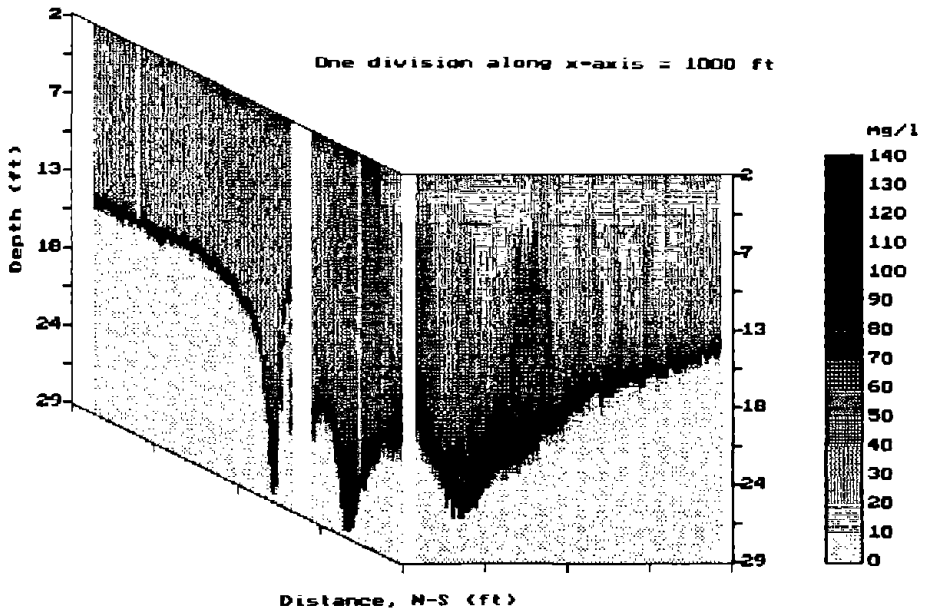

Figure 4. Background acoustic data during peak flood tide and high current velocity

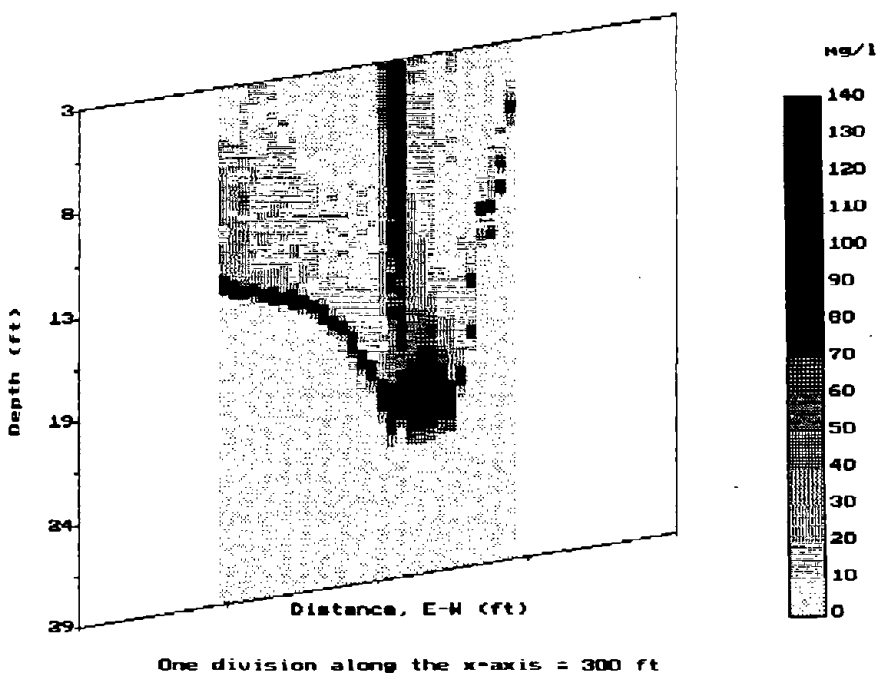

Figure 5. Acoustic profile of dredged material at discharge point during ebb tide

DISCUSSION AND CONCLUSIONS

Field studies to detect dredged material plumes using acoustic instrumentation such as commercially available fathometers and transmissometers were conducted in the mid-1970's (e.g., Proni et al. 1976, Bokuniewicz et al. 1978). More recently, field studies in the Chesapeake Bay area monitored dredged material plumes from hopper dredge overflows (Nichols, Diaz, and Schaffner 1990) using acoustic instruments to determine the plume development and characteristics. Pipeline-discharged dredged material plumes have also been monitored (Panageotou and Halka 1990) in Chesapeake Bay using acoustic instrumentation from which concentration was qualitatively related to acoustic data. To date, no direct calibration of the acoustic instrumentation appears to have been made in any other dredged material study, except that determined in an earlier PLUMES proof of concept study at Mobile, Alabama (Kraus 1991).

Measurements from both acoustic and in situ sampling instruments showed water and sediment movement in the James River at the Tylers Beach study area is dominated by tide and wind-generated waves. Currents move to the northeast during flood tide and to the southwest during ebb tide. During peak periods of flood and ebb, current speed reached 2.0 ft/sec. Salinity also varied with the tide from 10 to 14 ppt. Water column measurements of salinity and temperature were generally uniform, showing no significant stratification.

Background concentrations of suspended material also followed the tidal cycle, with minimum concentrations (10 to 30 mg/ℓ) found during slack water. Concentrations of suspended material significantly increased as flood and ebb currents reached peak velocities, and concentrations of 60 to 70 mg/ℓ were found throughout the water column in the channel and on Point of Shoals. Suspended material concentrations greater than 100 mg/ℓ were observed near the bottom of the channel.

Concentrations from both the suspended material samples and acoustic surveys during dredging and placement operations were similar to background conditions, except at the bottom in the immediate vicinity and down current of the discharge point, where concentrations reached above 15,000 mg/ℓ. Clouds of suspended material that were observed in the shallow water on Point of Shoals during flood tide appeared to have been formed from bottom material suspended by increased current and/or wind speed.

During flood tide, dredged material was observed to move north along the bottom several hundred feet from the discharge point in the direction of current flow. During ebb tide, the dredged material moved several hundred feet south of the discharge point along the bottom and was pushed against the foot of the steep Point

of Shoals wall by the current. At slack water, when the dredged material was most likely to disperse onto Point of the Shoals, the material settled to the bottom of the site within the vicinity of the discharge point.

From data obtained during the Tylers Beach study, it is apparent that the dredged material discharged into the placement site was mainly confined by the natural topographic boundaries of the site. During periods of peak flood current some dredged material was advected from the bottom of the channel in a northwest direction towards the shore and away from Point of Shoals. No increase in naturally occurring concentration of suspended material from the dredged material discharge was observed on Point of Shoals.

Objectives of the Tylers Beach study were met, and the PLUMES acoustic instruments and tracking procedures were refined and utilized in combination with in situ sampling procedures to obtain an extensive and qualitative data set. The Norfolk District, other Corps of Engineers field offices, and the dredging research community will benefit from the information provided by the Tylers Beach project for future plume monitoring studies and management of dredged material placement sites.

ACKNOWLEDGEMENTS

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ENVIRONMENTAL LAW AND THE DREDGING INDUSTRY

by

Michael H. Payne

ENVIRONMENTAL LAW AND THE DREDGING INDUSTRY

by

Michael H. Payne[1]

The last twenty years has seen an increased sensitivity to the critical condition of the global environment and, as a result, a tremendous growth in the number of environmental laws and regulations. Local, state, and federal agencies have all become involved in the enactment and enforcement of legislation designed to preserve the quality of the air, water and land. The resulting environmental regulations may be best described as an overlay of local, state, and federal laws with concurrent, and sometimes conflicting, jurisdictional basis. Serious penalties have been prescribed for those who "harm" the environment and fail to abide by the requirements of this myriad of laws and regulations.

The dredging industry, as well as the construction industry generally, has felt the impact of the environmental movement. Virtually every project requires some form of environmental permit, and the cost of compliance with environmental policies is an integral part of any dredging estimate. In view of the rapidly developing regulations, and the controversy which frequently surrounds the implementation of environmental policies, dredging contractors should be certain that they are up-to-date on environmental rules and that environmental requirements are not neglected.

The importance and complexity of environmental laws and regulations have, unavoidably, led to considerable litigation and have generated a new area of specialization within the legal profession. A recent article in the American Bar association Journal reported that "Since its inception little more than twenty years ago, environmental law has become part of our popular culture." A number of law schools now offer concentrations in environmental law and we have arrived at a point where environmental advocacy groups, private law firms, corporations, and government agencies employ cadres of lawyers expert in the intricacies of the growing number of environmental laws and regulations.

The decade of the seventies was a time of indoctrination for the dredging industry into the "new world" of emerging environmental policies. Although, the U.S. Army Corps of Engineers had been involved in the regulation of activities in the nation's waters since 1890, prior to the enactment of the Clean Water Act of 1977 (33 U.S.C. 1251 et seq.) the thrust of the Corps' regulatory program had been the protection of navigation. In keeping with Justice Holmes' pronouncement that "a river is more than an amenity, it is a treasure," the Corps enforced Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 401 et seq.), which prohibited the obstruction or alteration of any navigable water of the United States, the excavation from or depositing of material in such waters, or the accomplishment of any other work affecting the course, location, condition, or capacity of such waters unless the work had been recommended by the Chief of Engineers and authorized by the Secretary of

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the Army. The instrument of the authorization was a "Section 10" permit.

The Clean Water Act of 1977 provided two additional federal permit programs. First, Section 402 provided for the National Pollutant Discharge Elimination System (NPDES) to regulate the discharge of pollutants, in general, into water. The term "discharge of a pollutant" was defined as "any addition of any pollutant to navigable waters from any point source . . . " (33 U.S.C. 1362[12]). A "point source" was defined as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." (33 U.S.C. 1362[14]). The Act defined "pollutant" to mean "dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, cellar dirt and industrial, municipal, and agricultural waste discharged into water." (33 U.S.C. 1362 [6]).

Second, Section 404 of the Clean Water Act established a federal permit program, administered by the Corps of Engineers, to regulate the discharge of dredged or fill material into water. In addition, Section 401 of the Act required applicants for federal permits for discharge of dredged or fill materials to obtain a state water quality certificate. In those states where Section 404 responsibility had been transferred, by the Environmental Protection Agency, to the states, the Corps of Engineers was required to obtain a permit from the state for the discharge of dredged or fill materials in connection with federal projects managed by the Corps, unless exempted under Section 404(r).

Concern for the protection of wetlands has been particularly emphasized. EPA guidance provides that dredged or fill material shall not be discharged into the "aquatic ecosystem," unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact on the environment. Although the Corps of Engineers administers the federal permit process, the EPA maintains a veto power. Since the primary mission of the Corps frequently involves the construction of a project, including new work and maintenance dredging, the Corps and EPA do not always agree on the implementation of environmental policies. Nevertheless, the Corps, and the dredging industry, are obligated to follow the guidance issued by the EPA.

The Corps of Engineers has adapted to the requirements imposed by environmental laws and regulations and coordinates its efforts with the EPA, the U.S. Fish and Wildlife Service, as well as other federal and state agencies. Corps of Engineers dredging contracts provide that contractors shall not pollute streams, lakes, bays, estuaries, or other ocean or fresh water with fuels, oils, bitumens, calcium chloride, acids or harmful materials. The Corps further imposes the responsibility on the contractor to investigate and comply with all applicable federal, state, county, and municipal laws concerning water pollution. A

standard clause in all federal dredging contracts, "Clean Air and Water (APR 1984)," FAR 52.223-0002, mandates compliance with clean water standards, and all requirements of the Clean Water Act.

Dredging techniques are also of concern to the Corps of Engineers and dredging specifications warn dredging contractors that "dredging in project waters shall be performed with minimum damage to the environment." In this regard, contractors are instructed to confine the discharge of dredged material to areas designated by the Contracting Officer; to limit the depth of cut in a single swing of the dredge to that depth which precludes the collapse of facing material; to control the cutterhead speed to obtain reasonable progress without producing excessive turbidity; and, to control air release devices in the discharge piping to minimize the spilling of dredged material into the waters outside of the disposal areas. Above all, dredging contractors are required to take special measures to prevent the spilling of chemicals, fuels, oils, and greases into area waters.

A dredging contractor who overlooks, or ignores, environmental requirements risks the imposition of criminal and civil penalties, as well as debarment. Even if the contractor's management complies with environmental rules and regulations, however, a contractor cannot relax and must nevertheless be concerned about the actions of its employees. A member of a dredge crew who intentionally, or recklessly, permits a discharge of a pollutant into the project waters may implicate the company's management, even though management did everything possible to prevent such conduct. Although the employees who engage in an illegal discharge may be criminally prosecuted in their individual capacities, the company (or corporation) may also be subject to criminal, civil and administrative penalties.

It is not widely known, but the EPA has the power, and indeed the responsibility, to debar a dredging contractor if the contractor is criminally convicted for violating the Clean Water Act. This debarment is accomplished by the <u>automatic</u> listing of the convicted contractor's "facility" on the "EPA List of Violating Facilities" which is part of the GSA List of "Suspended and Debarred Contractors." Although, pursuant to 40 CFR 15.4, a "facility" is defined as "any building, plant, installation, structure, mine, <u>vessel or other floating craft</u> . . . to be used in the performance of a contract...." (emphasis added), the EPA has used this list to name a company's home office as the "facility" and thereby bring about a debarment of the corporation, rather than the mere exclusion of a single vessel. The EPA has argued that the definition of "facility" at 40 C.F.R. 15.4 "allows for interpretation" of the term to "mean the operational headquarters of a company whose crime is the result of a management decision, not an equipment failure." While the EPA's interpretation of "facility" may be subject to question, a contractor faced with placement on the "List of Violating Facilities" faces a considerable uphill battle.

Unlike debarment actions taken by the Department of the Army, which provide for an administrative hearing within thirty days, a

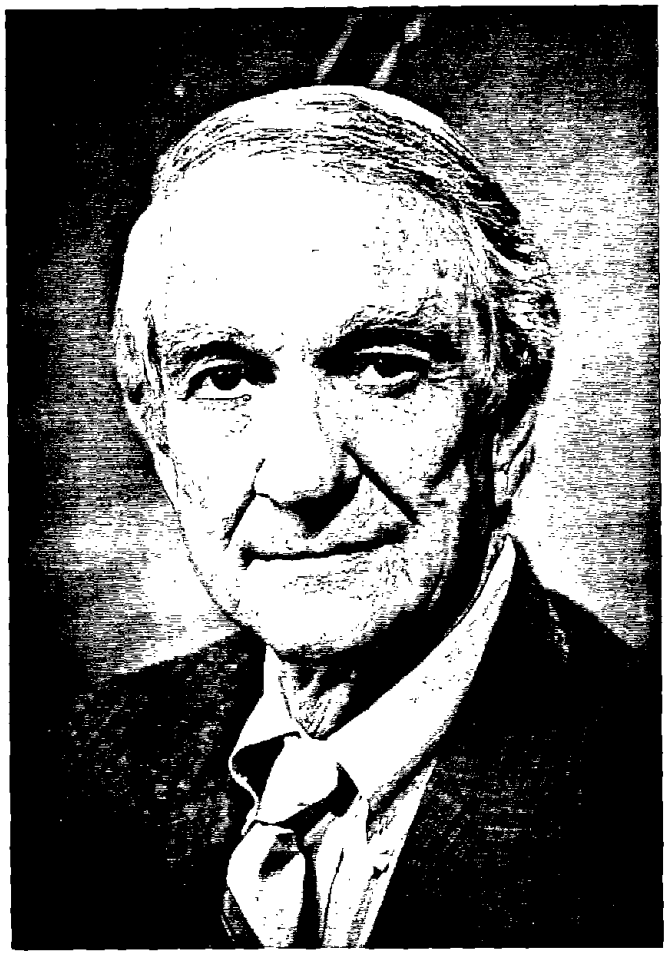
contractor "listed" by the EPA must file an application for removal from the list (or "de-listing"). The contractor is only entitled to an administrative hearing if the application for removal from the list is denied. It is important to note, however, that the EPA is not required to act on the application within any particular time and, consequently, a contractor may be debarred for months without any opportunity for a hearing on the merits.

It is imperative, therefore, that dredging contractors educate their employees as to the consequences of violating environmental laws and regulations. The Corps of Engineers, the EPA, and the courts are unsympathetic to those who harm the environment and stiff penalties have been imposed on those who wittingly, or unwittingly, violate the rules. Environmental compliance is yet another facet of the criminalization of the federal procurement process which, unfortunately, mandates extreme diligence even by those who are law-abiding and who would not intentionally violate the law.

POTENTIALS OF LIABILITY FOR REMOVAL AND/OR DECONTAMINATION OF TOXIC POLLUTANTS IN DREDGED MATERIALS

by

Alexander W. Dann, Jr.



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POTENTIALS OF LIABILITY FOR REMOVAL AND/OR DECONTAMINATION OF TOXIC POLLUTANTS IN DREDGED MATERIALS

by

Alexander W. Dann, Jr.[1]

INTRODUCTION

Since the late 1960s, the United States Congress has reflected a growing popular concern for the environment by enacting a broad spectrum of legislation regulating activities which affect our land, air, and water resources. Chief among these federal laws are the Acts designed to regulate the handling and disposal of hazardous and toxic substances. The purposes of these Acts can be summarized this way:

(1) They provide for the nation-wide clean-up and decontamination of existing hazardous waste sites;
(2) They regulate the on-going generation, transportation, and disposal of hazardous substances to prevent the introduction of further contamination into the environment; and
(3) They impose the costs of mandatory hazardous waste clean-up and handling on private individuals and corporations whose property ownership or use, or other activities have brought them into contact at any time, or at the present time with the contaminants.

Congress has declared that such laws must be construed liberally to achieve their purposes. The federal district courts have been quick to impose liability for clean-up, treatment and disposal costs when called upon to do so by the federal agencies. Defenses are severely restricted. Collective liabilities of all defendants who have had any connection with toxic contaminated soils approach the level of strict liability, where there are no defenses.

In the face of the growing aggressive atmosphere in governmental agencies charged with enforcement of environmental laws, the dredging industry is going to need to protect its dredging operations and its treasure from random encounters during contract performance with hazardous substances concealed in streambed sediments.

This paper discusses some of the consequences of dredging activities under three of the principal federal environmental statutes which have clear impact on the industry. They are: The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Title 42 U.S.C. §9601 et seq., as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA); the Resource Conservation and Recovery Act of 1976 (RCRA) Title 42 U.S.C. §6901 et seq.; and the Clean Water Act (CWA) Title 33

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U.S.C. §1251 et seq. with particular emphasis upon §1317 of the Act.

This paper will discuss what you can expect to encounter as the practical risks of dredging the sludges and sediments of industrial wastes. Finally, the paper will suggest short and long-term solutions and it will support possible ideas by which practical accommodations by the industry and the federal and state agencies of each other's problems under environmental laws can be put to work before enforcement activities heat up.

First, we should examine the Acts.

(A) THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980 (Title 42 U.S.C. §9601 et seq.)

(1) History and Purposes

The Comprehensive Environmental Response, Compensation, and Liability Act known by friends and foes alike as "CERCLA" was enacted by Congress in 1980 in response to publicity by the media regarding serious threats of mass poisonings which seeped from chemical dumps of industrial wastes and polluted waters famous for seafoods and shellfish. Each month new stories were published about dioxin-soaked roadside ditches or massive, noxious landfills. Congress tailored CERCLA to provide a system for compulsory private funding coupled with enforcement authority, to pay for cleaning up the nation's existing hazardous waste sites. In the Act the funding is called "response costs" to make the idea more digestible. Congress hoped to achieve the clean-up by imposing funding liabilities from private sources on virtually every person or company identified as having had any involvement, at any time, with the land contaminated by hazardous waste.

(2) Potentially Responsible Parties

Parties which may be charged with liability for fines and clean-up costs under CERCLA are called "potentially responsible parties" under the Act. This is one of many understatements contained in the Act.

(a) Heading the list are business entities or individuals who were owners of the land at the time such land received the deposits of hazardous waste. Such owners have been labelled "covered persons" under Section 107(a)(3) of CERCLA (42 U.S.C. §9607(a)(3). (See) Jersey City Development Authority vs. PPG Industries, (D.N.J. 1987) 655 F. Supp. 1257, 1260.

(b) Second on the list are business entities, or individuals, who are the owners of the land when the land is reported to contain hazardous waste. These people are "present owners", obviously, and "covered persons", even though they may have lacked either actual or imputed knowledge of the existence

of the hazardous waste. Lack of knowledge might, perhaps, be the basis for an affirmative defense if buttressed by evidences of innocence and unfairness. All of those things would be matters of proof in court, of course, with accompanying legal costs, of course.

(c) Then, on the List are the companies or individuals which generate hazardous wastes in the course of their daily operations. These are the "Generators". Generators have a bad name. But it is true that the agitation of dormant toxic sludge in the course of the dredging process could be viewed as generation of hazardous waste. So, our point is that instead of enjoying remote involvement, dredgers may find themselves on the front lines.

(d) Companies, or individuals, which transport hazardous wastes to a site of their choosing are "covered persons" which the Act labels as "Transporters". The pumping of hazardous material into a contract-designated disposal area would induct the unlucky dredger into the growing circle of parties charged with sharing massive clean-up costs on the fact of it.

These four classes of entities: past owners, present owners, generators, and transporters are what the environmentalists call "Potentially Responsible Parties". The label does not promise hope of exoneration.

(3) Exposures Under CERCLA For Dredgers

(a) Illustration:

Assume that an hypothetical company named Clearwater Dredging Company is hired by a local municipality to perform maintenance dredging within a municipal harbor facility on the Tennessee River. Dredge spoil is to be discharged in designated areas along the river bank. Clearwater Dredging Company is not required by its contract to perform, and did not perform, soil tests of the river sediments. Such tests had not been required for previous maintenance dredging done twelve years before. Unbeknown to Clearwater Dredging Company, the river sediments had been contaminated in the intervening years by industrial discharges of paint pigments containing chromium and other materials from a paint factory upstream after which the paint factory had gone out of business and its owners had disappeared. Clearwater Dredging Company dredged the contaminated material still unaware of its character and pumped it onto an onshore dredge disposal area. Two years later, long after acceptance of the work and final payment, the dredged spoil is found to be contaminated.

The work of Clearwater Dredging Company which stirred up the contaminated spoil and the act of pumping the spoil to a disposal area would put the Company at risk as a "generator" or "transporter" of hazardous waste under CERCLA.

The situation is serious under CERCLA. Even though the dredging contractor in the example did nothing wrong or illegal, "strict liability" could be imposed under the broad and arbitrary prohibitions of the Act. As a potentially responsible party, Clearwater Dredging Company could be required, legally, to bear the response costs of the clean-up and decontamination of the disposal area. The liability could be joint and several, involving the dredging contractor as a contributor only to response costs if there are other defendants, or involving it as the sole "covered person" if the municipality, the landowner of the dredge disposal area or the dissolved paint factory end up removing themselves from liability through statutory defenses.

(b) Goals of CERCLA Beyond Clean-Up of Hazardous Waste Sites

At the outset of efforts to enforce identification, analysis and clean-up of the country's waste sites, industry was stunned by Federal court decisions which held that individuals' and firms' defense that they exercised due care regarding waste disposal would be stricken in actions to recover response costs incurred in cleaning up landfills because CERCLA imposes strict liability upon defendants for the categories of costs and damages listed in 42 U.S.C. §9607(a)(4).
The Act provides as follows:

> "any person who accepts or accepted any hazardous substances for transport to disposal or treatment facilities, incineration vessels or sites selected by such person from which there is a release, or a threatened release which causes the incurrence of response costs, of a hazardous substance, shall be liable for - -
>
> (A) all costs of removal or remedial action incurred by the United States Government or a State or an Indian tribe not inconsistent with the national contingency plan;
> (B) any other necessary costs of response incurred by any other person consistent with the national contingency plan;
> (C) damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction or loss resulting from such a release, and
> (D) the costs of any health assessment or health effects study carried out under section 104 (i) [42 U.S.C. §9604(i)]."

Strict liability under the foregoing section was held to be

subject only to limited defenses enumerated in the Act. (See United States v. Dickerson (D.C. Md. 1986) 640 F. Supp. 448)

Section 9607(a)(4), on the face of it, resonates with menace for hard pressed dredging contractors whose bids must be competitive. CERCLA was drafted and passed to address the massive wastes left in vacant fields and abandoned pits in the wake of American industry. Section 9607(a) was drafted with apparent intent to address the tank car and tank truck transporters of wastes to landfills. It is doubtful that in 1980, many members of Congress reflected upon the impact of the Section on the dredging process of the transport of solids in slurry form to dredge disposal sites.

The statutory defenses allowed by the Act in 42 U.S.C. §9607(b) are too limited to give comfort. The text of the section on defenses states the following:

> "(b) Defenses. There shall be no liability under subsection (a) of this section for a person otherwise liable who can establish by a preponderance of the evidence that the release or threat of release of a hazardous substance and the damages resulting therefrom were caused solely by ---
>
> (1) an act of God
>
> (2) an act of war
>
> (3) an act or omission of a third party other than an employee or agent of the defendant, or than one whose act or omission occurs in connection with a contractual relationship, existing directly or indirectly, with the defendant (except where the sole contractual arrangement arises from a published tariff and acceptance for carriage by a common carrier by rail) if the defendant establishes by a preponderance of the evidence that (a) he exercised due care with respect to the hazardous substance concerned, taking into consideration the characteristics of such hazardous substance, in the light of all relevant facts and circumstances, and (b) he took precautions against foreseeable acts or omissions of any such third party and the consequences that could foreseeably result from acts or omissions; or (4) any combination of the foregoing paragraphs."

Some authorities suggest that withholding of material information regarding known presence of hazardous substances in shoaled material by a governmental contracting agency could be asserted as an affirmative defense by a defendant contractor under the third party provision of Section 9607(b)(3). Case decisions have settled that state and federal governmental agencies fall within the definition of third parties as the term is used in the Act.

We believe that ultimately, the severity of the Act will prompt a judicial softening of the rulings presently prevailing in current cases. We believe CERCLA has room in its wording to argue for relief of dredging contractors under long standing judicial precedents in contract disputes when they rely without notice to the contrary on the information contained in their contract documents. Such relief would come, if at all, in the form of a shift of the strict liability burden to the governmental contracting agency through contract dispute provisions. Such a shift might be more difficult for dealings with State and Local governments.

If the issue of strict liability should arise out of an encounter with contaminated materials during performance of a state or municipal dredging contract, there would seldom be local funds to carry the clean-up costs of the encounter even if contract provisions recognize claims which might permit treatment of the encounter as a differing site condition.

The second statute to be examined is the Resource Conservation and Recovery Act. The Act is regulatory in character, designed to attend to the details of on-going production of hazardous materials.

(B) THE RESOURCE CONSERVATION AND RECOVERY ACT
(Title 42 U.S.C. §6901 et seq.)

(1) History and Purposes

The Act (RCRA) became law in 1976. We have seen the comment that ultimately, RCRA will provide "cradle to grave" regulation of the nation's hazardous wastes. RCRA differs from CERCLA in that, while CERCLA deals with the clean-up of areas which have accumulated hazardous wastes over the years in the past, RCRA regulates the management of the same things for today, tomorrow and in future years. It focuses on the handling. Regulation is accomplished through the use by the Government of a Manifest System which requires that a document describing the nature of the waste and its ultimate destination must accompany it at all times. The Manifest System is designed to apply best to the management of industrial wastes. However, the Regulations under the Act fit the generation of wastes by construction equipment where a Manifest System would be impossible to apply.

(2) A close relationship exists between the enforcement provisions of CERCLA, RCRA and RCRA's clean water counter-part, section 1317 of the Clean Water Act (CWA) [33 U.S.C §1317]. The three statutes focus on prohibiting the discharge of toxic and hazardous wastes on land under provisions of CERCLA and RCRA, and into water under Section 1317 of the Clean Water Act, unless such discharges can be carried out as under permits which mandate and control treatment and decontamination of the wastes.

(3) Under EPA's "Mixture Rule", soil and sediments contaminated with hazardous wastes are, themselves, considered to be hazardous wastes. This could bring the total material of a work area excavation within the prohibitions and mandates of the statutes. For discharges on both land and in water now RCRA has added the punch of the mandatory injunctions.

By injunctive order, in a civil action authorized under RCRA in 42 U.S.C. §6972(a)(1)(B) (1988) any person may be restrained from prohibited activity and may be compelled to comply with clean-up programs and technologies demanded under authority of the Act. This would include any past or present generator, any past or present transporter, or past or present treatment, transportation or disposal of any solid or hazardous waste. Any such injunctive process could also include an order as generalized and costly as to take "any such action as may be necessary". (See: Tanglewood East Homeowners et al. v. Charles-Thomas, Inc. (CA-5 1988) 849 F.2d 1568, 1575-76)

Mixtures of toxics with uncontaminated material obviously amplify the scope and dollars of response costs when "actions as may be necessary" are imposed on covered parties by a court's injunctive order. We have not seen indications that appellate courts will reverse such orders by lower courts on grounds of vagueness. "Necessary action" would be viewed to be defined by the Regulations under RCRA.

(4) EPA's Mixture Rule is equally applicable to under-water sediments contaminated by concentrations of hazardous wastes. Strictly applied, the rule could change an otherwise routine maintenance dredging project into a SuperFund problem. A dredging contractor pumping dredge spoil contaminated under the Mixture Rule could find itself exposed to RCRA restrictions of its work. Restrictions could include duties far beyond the scope of the original maintenance dredging contract of the contractor.

(5) Regulations adopted to implement the RCRA require that when hazardous waste is encountered in the course of a site excavation, the material must (a) be treated with "Best Demonstrated Available Technology" to render it non-hazardous, or (b) in the alternative, it must be transported to a licensed RCRA treatment, storage and disposal facility.

The drafters of the regulation may have overlooked the limitations and peculiarities of the dredging method of removal and transportation of solids in water when setting up the remedies of applied technology or transport to a facility. An acceptable method of getting at the toxified materials to apply a "Best Demonstrated Available Technology" for effective decontamination, might be to pump the material to a disposal area specially designated and prepared for the purpose. Once there, the material could be processed, or it could be dried out carefully to prevent escape of toxics and then processed, using best demonstrated available technology.

(6) As suggested, dredging contractors which encounter sediments contaminated by toxic wastes may find that they are charged as generators and transporters under RCRA Regulations. The problems which pile up for such contractors may trace back to the fact that their own otherwise thorough prebid site examinations were not performed to include laboratory testing of shoal sediments for toxic materials. Because of the absence of such test there would have been no warnings from test results to alert the contractor's estimators.

(7) The term "Best Demonstrated Available Technology" as it is used in the Resource Conservation and Recovery Act has been investigated by the EPA. The Agency published the identities of nine general categories of treatment technologies which it is willing to recognize as "available" and "demonstrated" for contaminated soil. (Federal Register Vol. 56, No. 206 Thursday, October 24, 1991 p. 55173)

The nine categories are "(1) Biological treatment, (2) chemical extraction, (3) soil washing, (4) dechlorination, (5) low-temperature distillation, (6) high-temperature distillation, (7) thermal destruction, (8) stabilization, and (9) vitrification."

At this writing, the record is still open on the effectiveness in any given situation of any of the nine categories of treatment. EPA has been hampered in its investigations by such things as inadequate quality assurance and/or quality control information, incomplete analysis for all contaminated soil constituents; and inconsistencies in the field in the use of analytical test methods, to mention a few.

Further, EPA does not appear to have treatment data on "demonstrated" and "available" technologies for soils of varying clay, silt, and, sand content, or mixtures of organics and inorganics, to determine the effects of such mixtures on the treatability of contaminated soils. The picture of "Best Demonstrated Available Technology" is like muddy water for the dredging industry on every aspect of decontamination of toxic pollutants found while dredging stream bed sediments except one thing. The process will be expensive.

(8) The similar term, "Best Available Technology" is used in a like context in Section 1317 of the Clean Water Act (33 U.S.C. §1317) to describe the procedure required to treat the sources of toxic effluents, and to render such effluents non-toxic before re-entry of the same into waters of the United States from sources on land.

The provisions in the RCRA and Section 1317 of the Clean Water Act which compel generators, transporters, site operators and owners to detoxify and decontaminate materials encountered in the course of activities such as dredging, using Best Available Technology, are closely interrelated. The point can be illustrated by an example: Having unwittingly stirred up an accumulation of mercury contaminated stream bed sediments, without knowing that it had excavated toxic wastes, a dredging contractor normally would pump the dredge spoil either to spots in shallow waters beyond the channel, or to a contract-designated dredge disposal area on the land. If the contractor should be required to discharge the dredged solids into the shallows of a river without a permit issued under Section 1317 of the Clean Water Act, the contractor would be in technical violation of the Clean Water Act and subject to its sanctions for "transporting" (and possibly "originating") the entirety of the mixture and reintroducing it as a hazardous waste "into waters of the United States".

If, on the other hand, (a) the dredging contract required the discharge of the dredged spoil into a controlled dredge disposal area; (b) the contractor failed to discover the mercury contaminant and did not attempt to treat the material to detoxify it; and (c) government samples of the run-off from the disposal area showed unacceptable levels of mercury, then, the contractor would be in technical violation of both the RCRA and Section 1317 of the Clean Water Act, and subject to the sanctions imposed by each Act, at the election of the enforcing agency, and the U. S. Department of Justice.

(C) SECTION 1317 OF THE CLEAN WATER ACT (33 U.S.C. §1317)

(1) In general terms, the Clean Water Act was assembled by Congress in 1972 to restore and maintain the physical, chemical and biological integrity of "the waters of the United States". Most discharges into the waters of the United States are regulated pursuant to Section 1342 of the Act which establishes the National Pollutant Discharge Elimination System (NPDES). The section is currently prominent in the regulatory efforts of the E.P.A. to establish storm water discharge permits for construction projects.

Discharges of dredged material are regulated by Section 1344 of the Act under conditions involving normal materials. Discharges of Dredged material contaminated by toxic substances are specifically subject to the provisions of Section 1317 of the Act.

(2) Section 1317 is captioned Toxic and Pretreatment Effluent Standards. The Section is the "toxic effluent" prohibition provision of the Clean Water Act. To illustrate, at present, technically, any unpermitted discharge of dredged material containing "toxic pollutants", as defined under federal law and listed on the EPA Administrator's published list as such, is unlawful. Under a literal reading of the Sections, discharges of toxic pollutants in minute concentrations of threshold parts per million still may require a permit if discharges in those concentrations enter "waters of the United States".

Any toxic effluent from contaminated slurry would trigger application of §1317. As with the Resource Conservation and Recovery Act, toxic effluent under §1317 of the Clean Water Act must be treated with the "Best Available Technology" until rendered non-toxic, and before such effluent can be allowed to re-enter the river or bay waters from which it was dredged at the outset.

Our study of the Act and cases on point has indicated to us that discharges of permit authorized toxic effluents into the shallows of dredged waters and into regulated and EPA approved dredge disposal areas on shore would impose no liability on the dredger who is aware of the statutes and regulations, and because of it could comply with restrictions and circumstances imposed as conditions to issuance of an authoritative permit.

(D) THE POTENTIAL EFFECTS OF PERMITS AND RESPONSIBILITIES CLAUSES IN FEDERAL DREDGING CONSTRUCTION AND MAINTENANCE DREDGING CONTRACTS

This brings this paper to a consideration of the ways in which a dredging contractor can be exposed to the environmental enforcement statutes by its own contract provisions which contain a standard Permits and Responsibilities Clause.

(1) Under the provisions of the Permits and Responsibilities Clause which appear in federal maintenance dredging contracts pursuant to FAR 52.236-7, there is no doubt that the Government would be expected to argue that the permit requirements and provisions of the Resource Conservation and Recovery Act and the Clean Water Act apply to dredging contract activities. The Clause states as follows:

> "The Contractor shall, without additional expense to the Government, be responsible for obtaining any necessary licenses and permits, and for complying with any Federal, State, and municipal laws, codes, and regulations applicable to the performance of the work."

(2) If you are the dredging contractor or its consultant, you will know that you will not be able to count on the original hazardous waste generators of the toxic pollutants

which have been turned up to come forward voluntarily with an open checkbook to foot the bill for the costs of applying the "Best Demonstrated Available Technology" to detoxification of the sediments and comply with permit requirements.

(3) In the light of the language of the Permits and Responsibilities Clause of the Contract, it is equally unlikely that a contracting federal government agency would willingly absorb the detoxification and response costs or costs associated with permits needed to proceed.

(4) In times of tight budgets and constricted appropriations, a contracting government agency would find no cause for joy on being confronted with the problem of funding an awkward and costly job of detoxifying stream bed sediments. Although the contractor might well have a claim under the Differing Site Conditions Clause or under the defective specifications provisions of the Changes Clause of its Contract, it should expect to have to shoulder the expense of response costs and detoxification technology expense for a protracted period of delays and costly litigation to convince the agency to reimburse it.

(5) Based on attitudes which appear to prevail at policy levels of the Federal agencies regarding the scope of the standard Permits and Responsibilities Clause required for dredging contracts by FAR 52.236-7 we suggest the following:

(a) Under the Clause it appears that it will be made the primary responsibility of the dredging contractor to seek and obtain any permit required under either the RCRA or Section 1317 of the Clean Water Act, if the existence of contaminated sediments is suspected or established in the materials to be dredged.

(b) It will be quite possible that standards for proper site examinations will be stiffened to burden bidders with representative sampling and testing of stream bed materials to be dredged, as an expected part of site examination. Failure to sample and lab-test materials will be the same as failure to inspect properly the site of the work, and grounds for judicial denial of claims for differing site conditions when toxics turn up and the contractor seeks equitable adjustment of its costs of proceeding with clean-up using Best Demonstrated Available Technology. (See: Stuyvesant Dredging Co. v. U.S. (Ct. Cl. 1987) 11 Ct. Cl. 853 aff'd 834 F2d. 1576 for site examination implications of harbor channel-bottom test data in specifications.)

(c) Failure by a bidding dredge contractor to procure a permit and an accompanying failure to file for approval of a plan for available technology in case of suspectable toxics which it would be prudent to anticipate as cost factors may be viewed in future months after the fact as both a breach of contractor obligations under the Permits and Responsibilities Clause and the Site Inspection Clause of a given dredging contract. In either event, a claim for clean-up costs imposed on

the contractor by CERCLA, RCRA or Section 1317 of the Clean Water Act should be expected to be denied out of hand because of Government policies which would be expected to deny liability in such situations, based on current U.S. Army and Navy releases.

(E) PENALTIES UNDER CERCLA, RCRA AND THE CLEAN WATER ACT

Violations of CERCLA, RCRA, or the Clean Water Act can bring harsh results. Under CERCLA, a dredging contractor found to be a "Potentially Responsible Party" could, in theory, be held financially liable for the entire cost of cleaning up the contaminated disposal area. Depending on the site, clean-up costs can often range from approximately One Hundred Thousand Dollars to unspeakable sums. Although it is unlikely that the entire cost would be thrust upon the contractor, it is probable that a financial liability would be imposed upon him which would be a resented unmanageable amount.

Violations of RCRA and Section 1317 of the Clean Water Act also can precipitate substantial penalties which would be expected to be strictly enforced. Both Statutes provide for civil fines of up to $25,000 for each day of violation. Such fines require aggravations normally. In cases where a contractor knowingly violates the law, criminal fines of up to $50,000 per day, and possibly imprisonment would be authorized by law.

(F) EVALUATION OF RISK FOR DREDGING CONTRACTORS UNDER CERCLA, RCRA, AND SECTION 1317 OF THE CLEAN WATER ACT

One question that is asked continually is, "How can environmental statutes be applied to dredging contractors who have not contributed to the generation of the hazardous waste and its subsequent accumulation in river and stream sediments?" On this question, several points need to be made:

(1) It is not fair to hold a dredging contractor liable in situations where he innocently dredges and disposes of contaminated waste. Fairness is not a prerequisite of justice. We have said through our forty years in the business of working government contract disputes through the process that justice for most clients is impossible. All we have grown to expect is mercy, and there is very little of it.

(2) It is apparent that Congress did not anticipate and therefore, did not consider the fairness or unfairness of the situation which Congress intended to address when debating the passage of the statutes. The Acts have the fault of arbitrary unfairness.

(3) Nevertheless, as things now stand, dredging activities, involving the discharge of contaminated material, appear to be within the ambit of the statutes. A dredging contractor can lawfully be charged with the results, and still do its work strictly according to contract.

(4) In work situations which share elements in common with excavation or construction of embankments by dredge, lawsuits have been brought against excavation contractors who unknowingly hauled contaminated dirt.

(5) There are numerous cases where innocent parties have been held liable under the statutes.

(6) Given the remedial nature of the statutes, and the courts' propensity to liberally construe them, their potential application to dredging activities cannot be ignored.

(G) SUGGESTIONS

We suggest the following:

(1) (a) Get acquainted with the Resource Conservation and Recovery Act and ask your legal counsel to analyze your various operations to evaluate areas where you may be at risk. (b) Develop a file of technical experts to whom you can refer future laboratory work and problems when they are needed and who have experience and knowledge which you do not have on what you can do.

(2) Examine Invitations on which the Company intends to bid to sort out potential contamination problems. Aside from the obvious things, this would include inquiries to local municipal authorities for information on past incidents or practices of polluted wastewater discharges of industrial plants in the vicinity of the work, or news stories in past issues of the local press regarding such incidents. Build a file on the area.

(3) Check with EPA, or the appropriate State agency, in addition to local municipal authorities, for information regarding histories of Clean Water Act or Resource Conservation and Recovery Act citations in the areas upstream of the proposed work site.

(4) If, in your investigation, you compile positive indications and data of the possibility of toxic materials deposited in the sediments to be dredged, then it is suggested that the sediments to be dredged should be sampled and analyzed by a well recognized laboratory to develop what you need to know and cover in your estimate. Then to protect your price enough before Bid Opening Date, you should put the Contracting Officer on formal notice of what you have discovered about toxic conditions. If the Contracting Officer follows regulations, your toxic data and information and its inflationary cost consequences must go out to all other competitive bidders. This is a point on which you should insist on compliance. It would be the thing to do to check to be sure that the contracting officer does follow through. If your site samples show no risk of toxics the Government would not expect to hear from you and the thing to do

would be to double check your data and file the results in your own data files.

(5) It would be a good thing if bidding information available to all bidders should contain the laboratory test results of enough samples taken by the government contracting agency to fairly represent the character of materials to be dredged or excavated. This would relieve bidders of costs of independent tests, and encourage competition among more bidders. But more importantly, if contamination should be found, the open-end costs of treating and/or removing the material to a Certified Disposal Facility could be included in the bids. This way, long run costs could be controlled by the Government to the level of the price contained in the lowest and best responsive bid.

(6) There are other ways in which a dredging contractor might attempt to hedge its exposure under CERCLA, RCRA, and the Clean Water Act.

(a) Indemnification Agreements. The federal government is prohibited by law from entering into indemnification agreements with its contractors, since such an agreement could result in the expenditure of sums not authorized or appropriated by Congress. (See the Anti-Deficiency Act 31 U.S.C. §134 and prohibitions stated in FAR 28.311-2 under fixed price and cost reimbursement contracts.)

However, such agreements can be beneficial to dredging contractors contracting with non-government entities. Indemnification agreements will not immunize a contractor from liability; instead, they serve to deflect liability from the contractor indemnitee to the indemnitor. The contractor, although legally liable, could be indemnified for any monies spent in complying with the law. One obvious point about indemnification agreements is that they are only as good as the solvency of the indemnitor. Still, when contracting with private entities, dredging contractors should press for such a clause in their contracts.

Finally, there might be a way to cover the risks of clean-up costs with insurance.

(b) Environmental Impairment Liability Insurance. Environmental Impairment insurance policies, broadly speaking, protect the contractor from liabilities arising from environmental problems which may be incurred in the course of the contractor's work. Originally, such policies were fiercely expensive. Recently, however, such insurance has become much more affordable. The contractual language has become correspondingly more avoidable. Many dredging contractors will find it difficult to justify such an expense or commitment.

CONCLUSION

As a final thought, contractors which engage in federal dredging programs for maintenance and improvement of this nation's coastal waters, rivers and harbors are required to manage high levels of risk in the national public interest as a given of the nature of the business. However, the risks of being burdened with unexpected great costs of cleaning-up someone else's toxic leavings are gravely unfair when the only connection between such contaminations and a dredging contractor is an unfortuitous encounter in the course of dredging a project strictly according to specifications. We believe that where the circumstances show nothing to indicate that the contractor should have been on notice, the contracting agency should assume the costs of clean-up using the best demonstrated available technology.

Biographical Sketch

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Dredging and Environmentally Sustainable Development

Hugh A. McClellan[1]

Introduction

Environmental Management has four primary elements: 1) Compliance 2) Mitigation for Unavoidable Impacts, 3) Restoration and Enhancement and 4) Environmental Sustainable Development that includes the components of Prevention and Conservation. Compliance, as meeting the letter of the law, is the nuts and bolts of the program while prevention, mitigation, restoration, conservation and enhancement lead toward environmental sustainability. The Mobile District, U. S. Army Corps of Engineers, has successfully integrated these concepts (McClure, 1991). The national dredging industry contributed greatly to our journey toward sustainability. The industry developed and implemented many technical innovations to reduce or eliminate adverse impacts of dredging and modified placement techniques to better accommodate beneficial use of the dredged material.

Beneficial use can be a large component of sustainable development. This paper stresses the partnerships that are necessary to implement the concept.

It is appropriate that WEDA chose Mobile for this Thirteenth Annual Meeting and Technical Conference. Slightly over 16 years ago the American Society of Civil Engineers (ASCE) sponsored a Conference on Dredging and Its Environmental Effects at Mobile (Krenkel, *et.al.* 1976). This was just three years into the Dredged Material Research Program (DMRP) and the ASCE material along with the many studies that flowed from the DMRP, is the core from which we can today approach environmentally sustainable development in projects involving dredging.

Background

Man, like any other organism, modifies his environment. An organism normally modifys the environment to its own benefit and with increasing frequency we are finding that man and environment can coexist. This is not a new insight. We have just forgotten it at times. It has only been four decades since Aldo Leopold observed that the environment, particularly wildlife, could benefit from man's chance purtabations. Leopold correctly

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believed that environmental benefits resulting from chance could be greatly magnified through prudent habitat manipulation. This concept is the foundation of most game management programs. For non-game species, the literature is replete with dredged material islands and bird habitat. One early example is Davids (1978). In many of these projects habitat was an unplanned ancillary to the "real" project. Then in 1986 and 1987 the Water Resources Support Center and the U.S. Army Corps of Engineers hosted two workshops on beneficial uses of dredged material (Landin and Smith, 1987, and Landin, 1988). The workshops provide numerous examples of proactive planning for dredged material placement that also demonstrate the benefits accrued by meeting both navigational and environmental needs.

Environmentally sustainable development depends on environmental interests, planners, constructors, builders, and operators working together. But first my version of how we have gotten to our present state.

Our relationship with the land frequently depends more on our instant need that the thought of any long term result. We have seen in our past: (1) man's domination over nature, (2) environmental preservation instead of use, and (3) approaches frequently called multiple use. We are now at a time when our clear choice is sustainable development. Nations around the world have long struggled with the issue of a sustainable economy along with a measure of population control. The United Nations played an important role in the effort. Often in the third world countries the United Nations underwrote programs that focused either on the economy or the population. Many failed. It was not until 1987 that a special world commission focused on the environment along with development (Anonymous, 1987). Environmentally sustainable development means meeting our present needs without compromising the ability of future generations to meet their own needs. Our actions must preserve a range of choice for the future.

The Council on Environmental Quality (1990) describes the last 20 years as a new reality of combined economic growth and environmental protection. We made great improvements in the areas of water and air quality while increasing our overall economic output 75 percent. However, the CEQ report recognizes that our progress in coastal areas and wetlands was painfully slow. The U.S. dredging industry, however, made significant contributions in coastal and wetland establishment during this period. This is most remarkable because the dredging industry's contributions occurred in an era of rapidly escalating Federal, State, and local laws and regulations. At times it seemed that the regulatory maze could forestall any project.

The following projects celebrate the industry's contributions. Sound planning, excellent engineering and design, and sensitive construction techniques yielded these environmentally sustainable projects. However, none would have been possible without risktaking and innovation.

The Projects

Tennessee-Tombigbee Waterway. Excellent summaries of the environmental challenges in this project are found in Auerbach *et.al.* (1985) and McClure (1985). A unique approach of this project was to make it environmentally better during construction. A Board of Environmental Consultants contributed much as did the willingness of the design engineers to accept change. One major change was from the perched canal concept to a chain of lakes in the canal section. The design for dredged material placement areas in the river section also received emphasis. Major firms completing hydraulic dredging in the river reaches included Hendry, Williams-McWilliams, B.F. Diamond, Weeks, Roger Au, T.L. James, Bean, and Folke Construction. Upland placement sites in the divide section now serve as agricultural sites and game plots. Riverine dredged material placement areas have primary and secondary zones. Although the secondary zones are needed in the future, some are presently functioning as green tree areas and are used by waterfowl (Hartley, 1988). Another unique feature involved material placement for gravel bars downstream of Columbus Lock and Dam. Although these riffle areas were designed primarily for mussel habitat, a full range of macroinvertebrate benthos is present (Miller, *et.al.* 1988). N. D. (Skeeter) McClure IV has been the constant environmental champion on this project. Mr. McClure's efforts established a program to fully mitigate the project's adverse effects on fish and wildlife in 1990. The mitigation element provides an unusual degree of partnership and cooperation among the agencies involved (U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the game and fish agencies of Mississippi and Alabama).

Two-Mile Channel and Breakwater. This project in 1976 was our first coastal attempt at planned beneficial use. Sudden squalls regularly damaged or destroyed the oyster fleet at the small fishing village, Two Mile, in Aplachicola Bay, Florida. The oyster fishermen needed some type of breakwater and a reliable channel. Both problems were eventually solved. Our design personnel thought that a dredged material breakwater could be developed from the channel material. However, a dike was required in the open waters of Apalachicola Bay to protect adjacent wetlands and nearby oyster reefs during the work to build the breakwater. Diking contingencies, nearby oyster reefs and wetlands yielded a bid in excess of the maximum fiscal cap for small navigation projects. The Area Engineer, Mr. Alton Colvin, was much more confident and constructed the project through a rental contract. The sandy material was distributed along the breakwater alignment by pocket pipe and the dikes constructed with bay bottom material contained the fines to a 5 acre area within the dikes. Natural oyster reefs and wetlands were protected. The Waterways Experiment Station's, Dr. Luthur Holliway, planted various marsh species in the fine grained material and Drake Wilson Island was born. The project now functions in every way as a natural coastal dune-wetland ecosystem.

Theodore Channel and Gaillard Island. Theodore channel was completed in 1981 by Bean Dredging. The enormous uncertainty about our ability to construct Gaillard Island is well documented in Blakeney (1987). Although the project was our second planned beneficial use of coastal dredged material, many staff members did not believe an island was possible due to the extraordinarily poor foundation conditions and the characteristics of the material to be dredged. Mr. Harvey Blakeney believed otherwise and wrote the specifications for the contract. Gaillard Island was constructed with channel material under the diligent oversight of Mr. Paul Warren, Mobile Area Engineer. The site provides long-term containment of project maintenance material. The island's design also maintains existing salinity and circulation patterns within Mobile Bay. It combines vegetative shoreline stabilization with more traditional riprap as dictated by erosional forces around the island. Mr. Paul Bradley, Mobile District, was the environmental champion for the wetlands and birds. Both wetlands and birds have been dramatically successful on the island. Birds, especially brown pelicans, have been the major beneficiary. A four agency (Alabama State Docks, U.S. Fish and Wildlife Service, Alabama Department of Conservation, and U.S. Army Corps of Engineers) Bird Management Plan established use zones for some portions of the island. For example, pipeline corridors are available even during peak nesting periods. The birds, wetlands, and continued dredged material placement will coexist long into a sustainable future.

Offshore and Feeder Berms at Mobile. One would think that these prior successes would provide incentive toward beneficial use. However, in 1987 we found ourselves in a posture "of getting rid of" instead "of doing with". The Water Resources Development Act of 1986 authorized the deepening of Mobile Harbor to 55 feet. The Phase I deepening to 45 feet would yield over 18 million cubic years (MCY) with the deepened increments to be implemented in later years. Although we had analyzed the suitability of the material for beneficial use several times, we concluded that nothing could be built with it. However, Mr. Bill Murdin of the Water Resources Support Center asked that we reexamine our thinking to consider an Atlantic coast fine grained material success in berm construction. We realized that we had fallen into our past error of judging the performance of dredged material in the 0.5 kilogram lump and the 6-inch core. We began to realize that the material behaved very differently in 50 cubic yard (CY) buckets and 6,000 CY hopper barges. Mr. Patrick Langan caught the spirit within the Mobile District and a national demonstration project proposed two berms. We constructed one with 600,000 CY maintenance material from the Mobile bar and the other from new work harbor dredging. Langan (1986) and McLellan and Imsand (1989) documented the nearshore and offshore berms at Mobile. Gulf Coast Trailing built the nearshore berm and Great Lakes constructed the offshore structure. Both are very successful and appear to be environmentally sustainable.

Fowl River and Gulfport Harbor Distributive Placement Demonstrations. Although the literature and Federal and State agency

opinion are frequently divergent, the overall literature suggests that open water placement of dredged material can be a suitable environmental option. In shallow riverine driven estuaries many studies have shown that the benthos normally recovers from open water dredged material placement within a 6-9 month period. Distributive placement is an attempt to shorten this recovery time by limiting the placement thickness. This allows some benthic fauna to move up through the new material. Colonization is thus facilitated. Dr. Susan Rees and Mr. Douglas Nester championed this technique within the Mobile District. Initial work at Fowl River by River Products, Inc., with maintenance material displayed promise and more detailed work at Gulfport by Mike Hooks using maintenance material emphasized benefits of the technique (Nester, 1986, Rees and Nester, 1987 and Nester and Rees, 1988). Additional work is presently underway at Gulfport Harbor to apply this technique to both new work and maintenance material in a national demonstration project. Partners in the study include EPA, FWS and NMFS. It is a potential environmentally sustainable technique for coastal channels.

Conclusions

We constructed these projects through multidisciplinary effort of planners, engineers, designers, and constructors. Essential team members in every project are the innovators and the risk takers who were willing to try unproven techniques. These projects only scratch the surface of the possibilities of the present. U.S. Army Corps of Engineers authorities were greatly expanded by the last three Water Resources Development Acts. We can now restore environmental resources to historic levels and we can consider environmental protection as a coequal partner among other more traditional authorities. In addition, many programs are emerging which share responsibilites with other Federal agencies. These include: Coastal America {Corps of Engineers, Fish and Wildlife Service (FWS), Environmental Protection Agency, and National Marine Fisheries Service (NMFS)}; Gulf of Mexico Program (EPA); National Waterfowl Initiative (FWS); National Estuary Studies (EPA); and the joint Corps/NMFS Fish Habitat Agreement. The best is yet to come and we may find ourselves in the future dredging just to get material for habitat restoration.

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TWENTY-FIFTH ANNUAL DREDGING SEMINAR

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