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AN OVERVIEW OF A DREDGING DEMONSTRATION IN CONTAMINATED MATERIAL, JAMES RIVER, VIRGINIA

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ABSTRACT

The James River, Virginia is a tributary of the Chesapeake Bay polluted with the toxic pesticide Kepone. The Norfolk District of the Corps of Engineers accomplished maintenance dredging operations within the polluted portion of the James River channel during fiscal year 1982. As part of the channel maintenance, the District conducted a demonstration of a dredging method designed to contain and remove a polluted layer of sediment with a minimum of resuspension. The method involved modifying and fitting an existing dustpan suction head to a contractor's cutterhead dredge. The dredge was then operated using an anchoring and maneuvering wire arrangement that enabled precise positioning of the suction head within the specified layer of polluted sediment. Monitoring of operating parameters onboard the dredge, of resuspension at the suction head, and of water quality around the dredge and disposal area was accomplished with appropriate equipment. The dredge was also operated in the conventional cutterhead configuration for comparison with the dustpan arrangement. The data gathered during this demonstration project permitted evaluation of the dredging and disposal methods utilized, and will be useful in planning future projects in the James River and other sites involving polluted dredged material.

INTRODUCTION

The Norfolk District is located in Virginia, and includes the lower half of the Chesapeake Bay with its many tributaries, as well as a portion of the Atlantic Coast. In serving the nation, the maintenance of navigation channels and harbors is one of the most important missions. We have over 60 authorized navigation projects that are active, totaling over 700 miles (1100 km) of waterway. Depths in these channels vary from 4 feet (1.2 m) in the smallest, to 45 feet (13.7 m) in the largest harbor projects.

Our deepest projects serve the vital ports of the Hampton Roads area, where eventual deepening to 55 feet (16.8 m) is planned. Hampton Roads also provides deep-water access to the James River, one of our more important tributaries.

BACKGROUND

The James River (Figure 1) generally flows easterly, from the Allegheny Mountains of western Virginia, to its mouth at Hampton Roads and into the Chesapeake Bay. Between the City of Richmond and the mouth, a distance of 90 miles (145 km), the James is tidal and navigable. In this portion of the river, a navigation channel 25 feet (7.6 m) deep is maintained to serve the ports of Richmond and Hopewell, and the industries between these cities. These industries and port activities depend on the James River Channel for the economical transport of many commodities and raw materials. As is the case on many of the world's waterways, local industries have created pollution. In particular, the Allied Chemical Corporation, at plants in the vicinity of Hopewell, Virginia, was responsible for the release of Kepone into the James River system. Between 1967 and 1975 it is estimated that as much as 65,000 pounds (30,000 kg) of the highly toxic chemical was discharged into the James River basin.

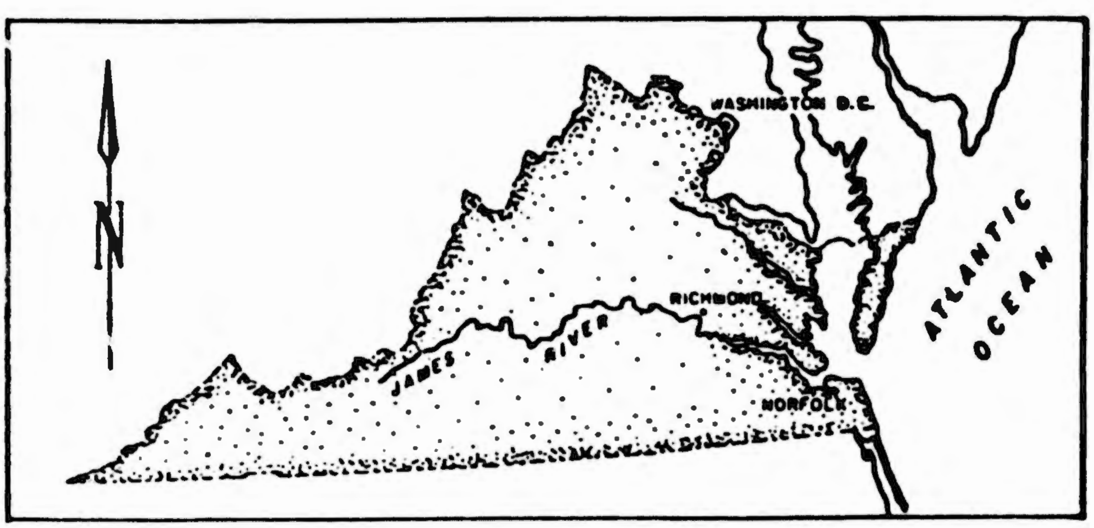

Figure 1. Location of James River, Virginia

Following discovery of the extent of Kepone pollution, and formation of State and Federal task forces, the U. S. Environmental Protection Agency (EPA) conducted the Kepone Mitigation Feasibility Study. As part of this effort, the Norfolk District was requested to evaluate alternatives for the removal of Kepone-contaminated sediments, and to investigate potential dredging technology and methods to control resuspension and secondary pollution. During this mitigation study, a delegation from EPA and the Norfolk District visited Japan to observe specialized methods of handling toxic sediments. The group was favorably impressed with the Oozer Dredge because of its alleged ability to achieve a high solids-to-water ratio and minimize resuspension. As a result of the Japan visit, the Norfolk District recommended that a demonstration project be conducted on the James River to evaluate the Oozer Dredge in comparison with a conventional cutter suction dredge. The basis for the recommendation was that there would be a need to know the best method of removing pollutant "hot spots," whether consisting of Kepone in the James River or toxics in other areas of the country, if the Corps were assigned a cleanup mission.

The recommendation to conduct a demonstration project was made to higher authority in early 1979, and resulted in much discussion among dredging experts both within and outside the Corps. Informally it was suggested that a dustpan dredge, appropriately modified, could perform as well as the Oozer Dredge in removing polluted sediments. It was further suggested that parts from retired Corps dustpan dredges, if available, could be adapted to cutterhead dredge plant. As a result of these discussions, an engineering consultant with Amalgamated Dredge Design, Incorporated, presented a proposal to the Corps. He recommended that an existing dustpan suction head and ladder, if available from a retired dredge in the St. Louis District, be modified and fitted to a contractor's cutter suction dredge. The effectiveness of this arrangement for dredging polluted sediment would then be tested and compared to the conventional cutterhead arrangement. The dredging would be accomplished as part of the maintenance of the James River Channel. This proposal was the basis for the dredging demonstration project in the James River.

DREDGING METHODS

Since most persons in the dredging business, and related activities and industries, are familiar with the various types of dredging equipment, detailed descriptions of the cutterhead and dustpan dredges and their operation will not be covered here. It is important, though, to show some of the differences between the two methods.

Cutter Suction Dredge

The James River has been economically maintained for decades by contractors with cutterhead plant. The conventional cutter suction dredge would appear to be well suited for removal of the contaminated material of the James.

The two stern spuds of the dredge, often termed the digging spud and walking spud, provide firm anchorage in the channel bottom. By rotating on the digging spud while making radial cuts across the channel, the dredge is able to move accurately over the specified dredging area. Dredging depth and output can also be accurately controlled. Furthermore, cutter suction dredges can discharge the material over long distances, which is a distinct advantage if polluted material is to be deposited in a distant containment site.

The cutterhead dredge does have apparent disadvantages for dredging the contaminated James River sediments. The rotating cutter can cause resuspension of material at the head, particularly in the silty-clay of the James. The action of the cutter also adds water to the material in excess of the in-place water content, increasing disposal area needs if a containment site were required. Because of the geometry of the cutterhead dredging pattern, overlap of the dredge cuts cannot be avoided. These overlaps result in additional, unwanted dilution water.

Dustpan Dredge

The dustpan type dredge was developed for use in maintaining the lower Missouri and Mississippi River channels, and can achieve high outputs in granular materials. While the dustpan is a hydraulic dredging method, as is the cutterhead, it differs in how it maneuvers and excavates.

While operating, the dustpan faces into the swift river current and is held on station by two crossing headwires, anchored well upstream. The wide but shallow opening of the dustpan suction head is advanced straight ahead into the shoal and makes long cuts by hauling in the two headwires. The advantage of this method in removing polluted material is the straight line advance, permitting a constant width of cut. The dustpan dredge can also accurately control the depth of dredging.

The dustpan dredge has disadvantages for working in the James River. The dustpan head has a number of water jets at the mouthpiece which fluidize the granular material of the Mississippi River bed, permitting flow into the suction head. These jets enable high outputs of granular material, but would cause unwanted resuspension and dilution of the fine-grained sediments of the James. This soft but more cohesive material may also cause choking in the dustpan head, and may possibly spill over and around the head. Finally, additional anchor lines would be needed in the James River, where currents change direction with the tide, versus the steady current of the Mississippi.

The Problem of Total Containment

To effectively remove a layer of contaminated sediment involves a concept our consultants termed "total containment." This is more than simply dredging the sediment. The specified layer should be removed at maximum density to lessen disposal problems. Resuspension should be minimized to lessen water quality problems and the amount of contamination left behind. Ideally, no more and no less than the desired volume of sediment would be removed. It is apparent that accurate placement of the dredging equipment in the material is a necessity.

In the James River estuary, the sediments forming shoals in the navigation channel are primarily silts and clays, with relatively low densities and high moisture contents. While this material is "easy digging" for a typical cutterhead dredge, it makes the problem of total containment more difficult.

Our consultants proposed, in essence, to combine some of the advantages of the cutterhead and dustpan methods of dredging, and eliminate some of their inherent drawbacks. The resulting dredge system would be further improved with an anchoring and maneuvering arrangement adapted from gold dredging techniques, and with advanced electronic positioning equipment.

MODIFICATION OF DUSTPAN SUCTION HEAD AND LADDER

Entry Design

The suction head on an existing Corps dustpan dredge was equipped with water jets along the top of the mouthpiece, and digging teeth on the bottom, to enhance the flow of granular material. These features are undesirable for dredging of contaminated silt, and removal of them was recommended.

Our consultants proposed fitting the dustpan (Figure 2) with a newly fabricated mouthpiece, to present a hydraulically "clean" opening to the material, without trash bars or grates. Still, the material had to overcome the entry losses of the flat rectangular mouthpiece. A rollover plate, shaped like a bulldozer blade, was recommended to accomplish this, by building up an artificial head of material at the top edge of the entrance.

The layer of material created above the head entrance would have a tendency to spill over the sides, leaving some of the specified material undredged. To prevent this, wing plates, attached to either side of the dustpan, and a splitter plate, attached in the center, were proposed. These plates were designed to provide some stability for the head as it advanced, and also to prevent the entry of dilution water at the sides.

Dredging Ladder

Modification to the existing dustpan ladder was advised for two reasons. First, the ladder required an extension to enable dredging at the greater depths of the James River. And second, this ladder needed to be modified to fit the well and trunnions of a contractor's cutter suction dredge.

ANCHORING AND MANEUVERING THE DREDGE

As well as mouthpiece design, total containment depends on the ability to accurately place and maneuver the suction head with the dredging area. This is dependent on the method chosen for wiring and anchoring the dredge.

The method proposed for the James River may appear unorthodox, but was based to some extent on mining dredging, where accurate movement and positioning is also needed. Under the proposed anchoring and maneuvering arrangement (Figure 3), the dredge would set up perpendicular to the channel center line, and make cuts across the channel between a head wire and a stern wire. The dredge would be held on station not by a spud, but by calibrated radial wires

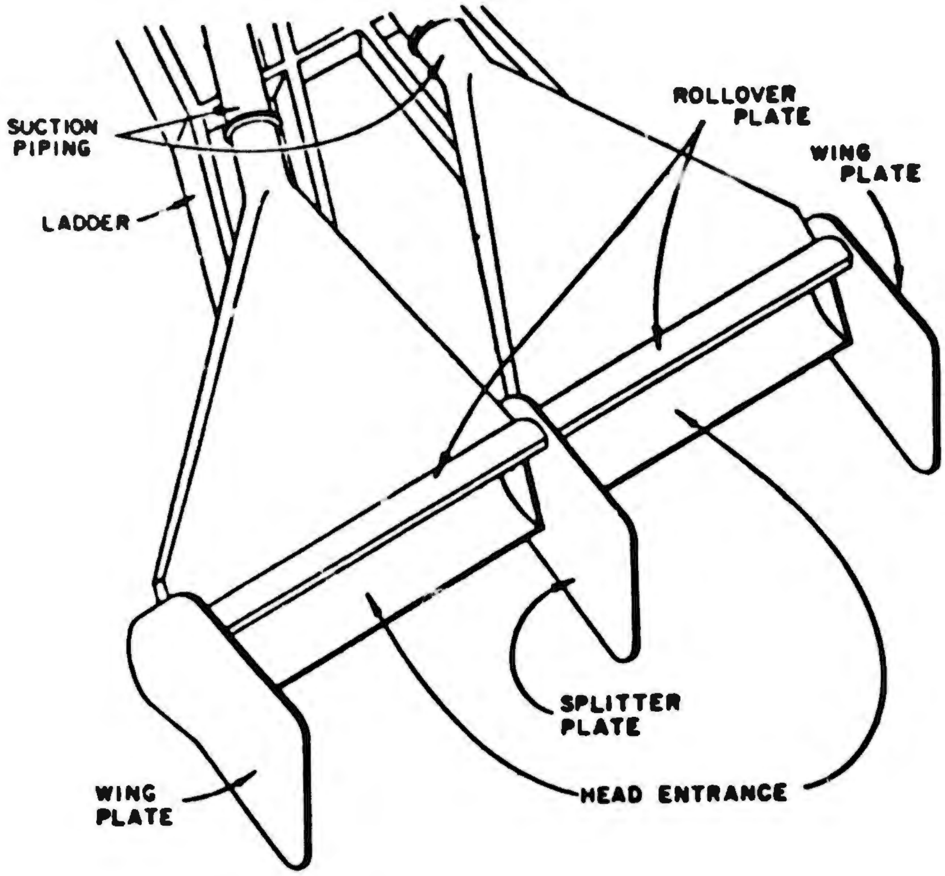

Figure 2. Modified Dustpan Head

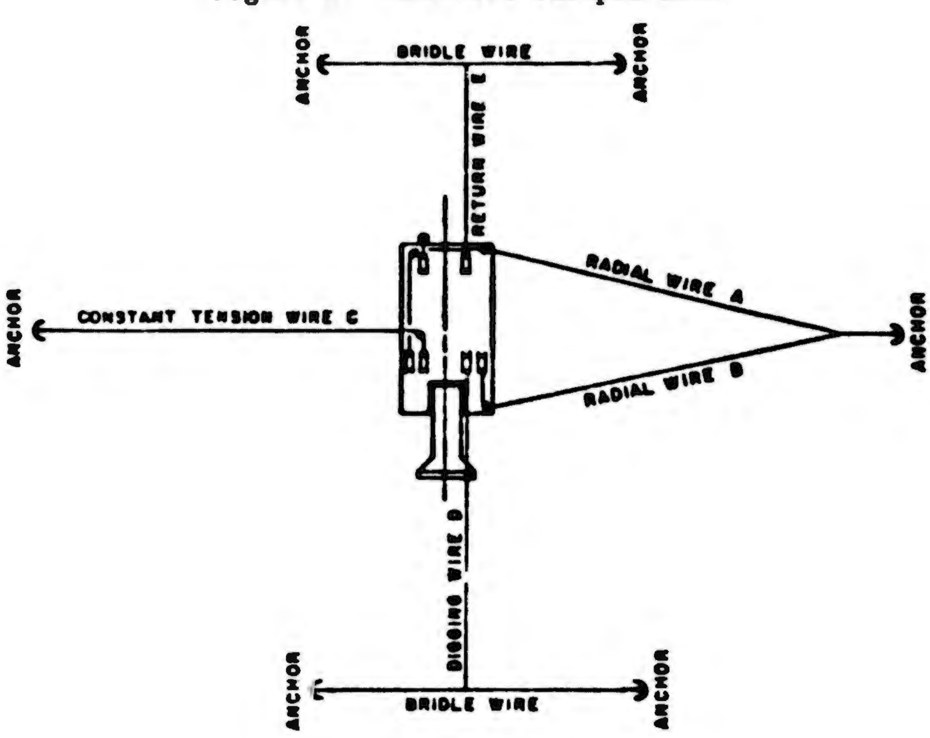

Figure 3. Wire Arrangement

anchored on the center line at a common point several hundred feet to the side. On the opposite side, our consultants recommended a wire anchored again on the channel center line, to keep the radial wires under constant tension and to enable smooth arcs across the channel.

To accurately move the dredge from one station to the next, the consultants proposed taking in an amount on the radial wires equivalent to the width of the dustpan head, and adjusting the tension wire. The resulting dredged pattern would be a series of smooth arcs across the channel. Overlap of the cuts would be minimal because of the length of the radius.

INSTRUMENTATION

The instrumentation recommended by our consultants fell into two broad categories: equipment for positioning and tracking the movement of the dredge head, and equipment for measuring and assessing the performance of the dredging system.

The first group included an electronic positioning system comprised of a three range navigation system, data processor, plotter, left/right indicator, and input/output terminal; and a ladder depth indicator with radio-transmitted tide correction. The navigation system would aid in accurate horizontal positioning and tracking of the dredge, while the ladder depth indicator would permit precise vertical placement of the dredge head.

The second group included transmitters and electronic indicators for pump vacuum and pressure and for discharge line velocity and density; a production calculator to measure output by integrating density and velocity; and a system for sampling and measuring turbidity around the dredge head. Our consultants also recommended the recording of other parameters that could be read on existing gauges, such as engine speed and engine temperature.

PROJECT IMPLEMENTATION

Environmental Coordination

Since discovery of the Kepone problem in 1975, all dredging projects within the lower James River basin have required special consideration. At first it was believed that disposal in upland containment areas would be the best disposition for Kepone-laden dredged material. State and Federal environmental agencies eventually adopted a policy that recommended open water disposal whenever feasible. Several reasons accounted for this change. Since historically the method of overboard disposal was used for most of the James River maintenance dredging, upland sites were generally not available near the Kepone contamination. Officials could not justify the tremendous expense of developing and using new upland sites for maintenance dredging requirements, which account for but a small percentage of the Kepone present in the river. Fears that Kepone deposited in upland sites would contaminate groundwater and be introduced to the upland food chain provided further impetus toward a policy of open water disposal.

During early 1981 the Corps presented the James River Dredging

Demonstration to State and Federal environmental officials. The project was proposed not as a "cleanup" effort, since open water disposal would be used, but rather as a demonstration of a potential cleanup technique. The agencies endorsed the project concept, some enthusiastically, and during the spring and summer of 1981, they met with the Corps to work out final details. Extensive water quality monitoring by both the State and the Corps was an important part of the plan.

Design Phase

A contract for architect-engineer services was awarded to Amalgamated Dredge Design, Incorporated, to prepare plans for the project and to act as chief consultants. The plans primarily involved design of modifications to the dustpan head and ladder, modifications to an existing cutter suction dredge, choice of onboard dredge instrumentation, and a program for carrying out the dredging tests.

Visits to the retired Corps Dredge KENNEDY were made to determine which dustpan parts could be made available for the project. The St. Louis District assisted by removing and delivering the specified parts to Norfolk, including the dustpan head and dredging ladder.

The designs could not be final until after it was known which cutter suction dredge would be used. The Corps received bids from four firms for lease of a dredge, and the low bidder, Norfolk Dredging Company, was awarded the dredging contract. The [illegible] inch (450-mm) cutter suction dredge ESSEX was designated.

During the design phase we also initiated procurement of the recommended instrumentation packages. For horizontal positioning, the contractor ordered a Tellurometer model MRD-1 three range navigation system and Digital Design & Development model PSS-1 data processing system. For vertical positioning of the dredge head, an Observator model MK-22 ladder depth indicator with tide correction was ordered. The dredge process instrumentation included IHC Holland transmitters and indicators for pressure, vacuum, velocity, and density, with a production calculator.

Maintenance Dredging

Restoration of the James River Channel would involve the removal of about a million cubic yards (756,000 cu m). We realized that the dredging demonstration effort could accomplish only a portion of this. Because of time limitations, the bulk of the dredging would need to be done conventionally. And conventional dredging could be accomplished before completion of plans for the demonstration and actual modification of the dredge, while waiting for delivery of essential instrumentation.

During November 1981 Norfolk Dredging Company removed 613,500 cubic yards (470,000 cu m) from the channel in the vicinity of Jamestown Island, using the ESSEX. The Corps and the State Water Control Board monitored water quality during this dredging, and found that Kepone levels remained within safe limits, both in the water and in shellfish. Dissolved Kepone did not exceed

9 parts per trillion, well within the water quality guideline of 15 parts per trillion.

Modification of Dredge

With final modification plans, Norfolk Dredging Company put the ESSEX into Colonna's Shipyard in February 1982 (Figure 4). The dustpan parts were reassembled, and the new mouthpiece installed. After extension of the ladder and modification of the suction piping, the dustpan was fitted in the well in place of the existing cutterhead ladder. Meanwhile, the anchor wire arrangement was altered to permit the new mode of operation.

A gantry on the dustpan head was installed to support turbidity sampling tubes. These tubes fed through a manifold to a pump for filling the turbidity test tank on the starboard deck. In the lever room, technicians began setting up instrumentation for positioning and output measurement.

Dustpan Dredging Tests

During April 1982, Colonna's Shipyard completed work on the ESSEX. We still lacked some of the instrumentation being shipped from Europe, but the decision was made to mobilize and start testing the dustpan configuration. The final items to complete the instrumentation package were the velocity and density transmitters, which were received, installed, then made operational during the first week of May by the suppliers service engineer. The dustpan dredging tests were conducted by Norfolk Dredging Company with the continuous support and advice of the engineers with Amalgamated Dredge Design, during the period April 13 through May 15, 1982. Approximately 69,000 cubic yards (53,000 cu m) was removed from the channel using the dustpan configuration and operating only during a 10-hour daylight period.

Cutterhead Dredging and Tests

Norfolk Dredging Company towed the ESSEX to their yard after completion of the dustpan tests, and replaced the dustpan head and ladder with the original cutterhead and ladder. The dredge wiring and anchor systems were also rearranged for cutterhead operation. Upon completion of this restoration work, the ESSEX was again mobilized to the James River, this time for testing of the cutterhead mode of operation and removal of the remaining shoals. Our consultants again took readings of turbidity around the head, and of vacuum, pressure, velocity, and density. The dredge contractor operated the ESSEX on a normal 24-hour day, with the exception of the 10-hour daylight period for testing and monitoring. Approximately 387,000 cubic yards (296,000 cu m) was removed between May 25 and June 15, 1982, with the dredge operating as a conventional cutterhead.

Water Quality Monitoring

During the periods of test dredging, both dustpan and cutterhead, we again conducted an extensive water quality monitoring program. Kepone and turbidity levels stayed within acceptable limits, and the effects of the disposal operation were confined to the open water disposal area. The dredging

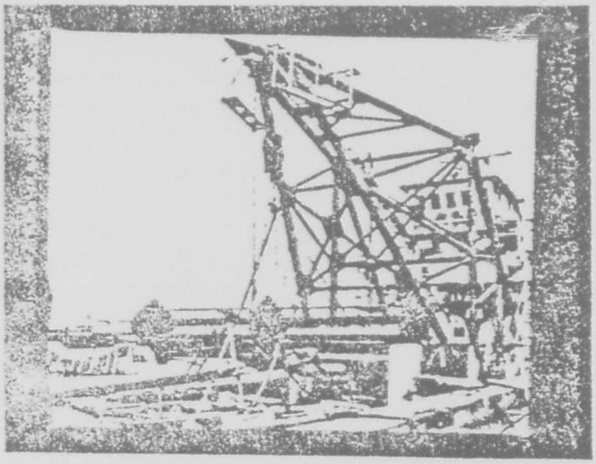

Figure 4. Dredge in Shipyard

tests provided an opportunity for the Waterways Experiment Station (WES) to conduct independent studies of the effects of the dustpan and cutterhead configurations on suspended solids levels. The State Water Control Board did not monitor during the dredging operations, but did sample to determine Kepone concentrations in the disposal areas after completion of dredging.

RESULTS OF DEMONSTRATION

Dustpan Tests

Norfolk Dredging Company's crew in cooperation with Amalgamated Dredge Design handled the setup and operation of the ESSEX in the dustpan mode efficiently and professionally. Crew training in this unfamiliar arrangement took place onsite during the first ten days and included maneuvering tests. The wiring and anchoring arrangement satisfactorily kept the dredge on station, once the crew became proficient and problems were worked out. These problems included anchor and winch brake slippage, and the stern wire catching on the pontoon line.

The success of the anchoring arrangement enabled accurate placement of the head from one cut across the channel to the next. This was desirable in trying to achieve "total containment" of polluted material. Our consultants believe the overlap between cuts was kept within acceptable limits of 3 feet (1 m) as compared to the width of the head of 28 feet (8.5 m).

Even with accurate pacement, the dustpan head was not able to contain the material as well as we had hoped. At the slowest speed of advance (7.7 feet or 2.3 m per minute) with a 9-inch-deep cut (23 cm) some material spilled over the head, creating turbidity. Our consultants believe this problem resulted from the poor hydraulic radius of the dustpan head and resistance to flow of the silty-clay. These conditions also contributed to occasional choking of the head. Average production was 300 cubic yards (230 cu m) per hour of operation.

Cutterhead Tests

With the ESSEX refitted to operate in the cutterhead mode, the contractor completed the dredging tests without significant problems.

Turbidity readings from sampling points at the suction head showed the cutter created significantly less resuspension than the dustpan. WES data confirmed this, showing a cutterhead plume in the channel averaging 10 mg per liter less than the dustpan plume. Density and output were more consistent and higher in the cutter mode than in the dustpan mode.

Throughout the final phase of cutterhead dredging, overall production was high, averaging more than 700 cubic yards (535 cu m) per hour. The contractor and consultant both attribute this to the relatively ideal conditions: soft material, good weather, and a pumping distance to the disposal area of only 2,000 feet (600 m). We believe this is also an indication of the "can-do" attitude of the contractor, and the dredging industry in general, as well as the efficiency of the conventional cutterhead dredge.

Comparison of Dustpan and Cutterhead

With any comparison of the two modes, we must keep in mind that the dustpan was modified in an attempt to contain polluted sediment, and that maximizing production during this phase was not a primary goal. This is in contrast to the cutterhead phase, where the dredge was operated efficiently and conventionally.

It was no surprise, then, that the cutterhead mode achieved higher production. During hours of operation (10 hours per day with dustpan, 24 hours with cutter) the cutter suction mode averaged more than double the production of the dustpan, on an hourly basis. Contrary to our anticipations, though, the dustpan also did not perform as well as the cutterhead in limiting resuspension at the head. Both our consultants and the Waterways Experiment Station observed higher levels of suspended material at the dustpan than at the cutterhead.

Water Quality Monitoring

The Norfolk District obtained valuable water quality data during each phase of the James River dredging. A team consisting of survey technicians, boat operator, scientists, and engineers sampled water for various parameters around both the dredge and the discharge point. The use of a survey vessel with electronic positioning enabled the samples to be taken at predetermined, known locations.

Our monitoring plan concentrated on Kepone and turbidity. Neither of these parameters increased significantly above background in the water column around the dredge head, for either dredging method. The situation differed at the disposal area. While levels of turbidity and suspended solids in this area were similar, but slightly higher during the cutter mode, the dissolved Kepone levels for the cutterhead averaged more than three times the levels during the dustpan mode (11.7 versus 3.2 parts per trillion). This is perhaps explained by the fact that the cutterhead moved more than five times the amount of material moved by the dustpan, during more or less equal periods on the calendar. At the disposal site, Kepone and turbidity levels remained within acceptable limits, and the elevation of these levels was short term and confined to the designated disposal area.

During the first phase of maintenance dredging in November 1981, the State Water Control Board conducted a study of Kepone levels in clams held within the disposal area. The Board's study concluded that Kepone in the shellfish rose slightly as a result of the disposal operation, but not enough to be of concern. Rather than test shellfish again during the dredging tests, the Water Board chose to sample surface sediments in the disposal areas. This study showed that sediment Kepone levels were higher after the cutterhead phase than the dustpan phase. This may be due again to the vast differences in quantities deposited during the two phases.

EFFECTIVENESS OF INSTRUMENTATION

Prior to this project we had no experience with the instrumentation used on the James River. The dredging demonstration has provided the opportunity to gain experience with and judge the effectiveness of the instrumentation packages.

Electronic Positioning System

The three-range electronic navigation system, coupled with data processing equipment and plotter, proved valuable in delineating the work area and the path of the dredge within accuracy of ± one meter. Dredge operators in the lever room could monitor the dredge head location with respect to the channel using either the plotter or a left/right indicator.

As well as providing accurate horizontal positioning of the suction head, the system could also indicate when the anchoring and maneuvering wire arrangement was functioning improperly. Slippage from the desired location would show up as a deviation on the plotter as it traced the dredge head path.

The electronic positioning system was not free of problems. Early in the testing program, our technicians determined that the system was malfunctioning, and a service engineer was called in for repair. We have learned that effective use of a sophisticated system such as this requires highly trained people for operation, monitoring, and routine maintenance of the equipment.

Dredging Ladder Depth Indicator

The ladder depth indicating system proved valuable to the dredge operator for accurate vertical positioning of the dredge head. The system measured the angle of the ladder, translated this into a depth, and corrected for the height of the tide. This freed dredge personnel from periodically reading the tide at a distant location and calculating the required depth.

One problem with the depth indicator surfaced shortly after start-up. The system was not properly correcting for the radio tide signal. The supplier's service engineer promptly adjusted the system, and for the remainder of the project no other problems occurred. Again, this indicates the need to have trained technical people available.

Dredge Production Instrumentation

Discharge pipeline velocity, density, and output readings were provided in the level room and were some of the more valuable data obtained during the project. To the dredge operator, this additional information was of little value, since he could operate as efficiently as possible using pressure, vacuum, and engine speed gauges. However, to our consultants, readings of velocity, density, and output were essential in evaluating the dustpan and cutter modes of dredging.

After calibration and start-up of the production instrumentation, the system proved steady and reliable. Our problems with this equipment were in procurement. For any instrumentation manufactured overseas, and particularly for the density transmitter with its nuclear source, we recommend long lead times to allow for procurement approval and licensing.

SUMMARY AND CONCLUSIONS

Our dredge contractor and engineering consultants did a commendable job in starting up and executing the dredging demonstration in the James River. In the dustpan mode the wiring and anchoring arrangement worked well and provided the needed accuracy. In terms of "total containment" the dustpan head did not perform as well as we hoped. Our consultants suggest that with the dustpan's wide flat opening and poor hydraulic radius, improvement may be obtained by some means of vibration or cutting action. This would reduce the resistance to flow which caused spilling over the top and sides of the head. The consultants also suggest that a different suction head design, such as a Fruehling type head, may be better in dredging contaminated silty-clay.

The selected instrumentation proved effective both in positioning accuracy and in evaluating dredge performance. Electronic equipment for horizontal and vertical positioning of the dredge head was more valuable to the dredge operators than was the production instrumentation. Management personnel of the dredging firm believe the package providing output, velocity, and density readings could be an effective tool for evaluating dredge performance problems. For sophisticated electronic equipment of any type, it is highly desirable to have well-trained technicians available, and contracts for service and maintenance are recommended.

The water quality studies conducted during the demonstration project showed that dredging in the James River does not create problems with Kepone resuspension or turbidity. The Corps and the State of Virginia have already used our documented monitoring results in evaluating and permitting other key dredging projects in the James that would otherwise have not been possible. The District is also using the information to develop a long-term disposal solution for a badly shoaled military port facility at Fort Eustis.

Overboard disposal proved to be economical and without serious environmental effects. The total project cost, including the additional costs for dredging tests and water quality monitoring, worked out to about $3.00 per cubic yard removed. Alternative plans such as upland disposal range as high as $5 to $10 per cubic yard. We believe that dredging managers, engineers, environmental scientists, and other individuals, who have a responsibility for channel dredging or removal of contaminated material, can benefit from the various findings of this project.

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