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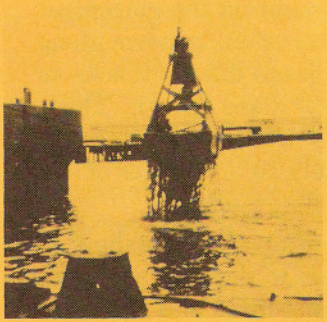

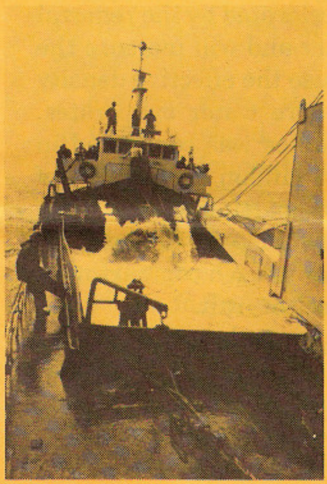

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Environmental Effects of Dredging

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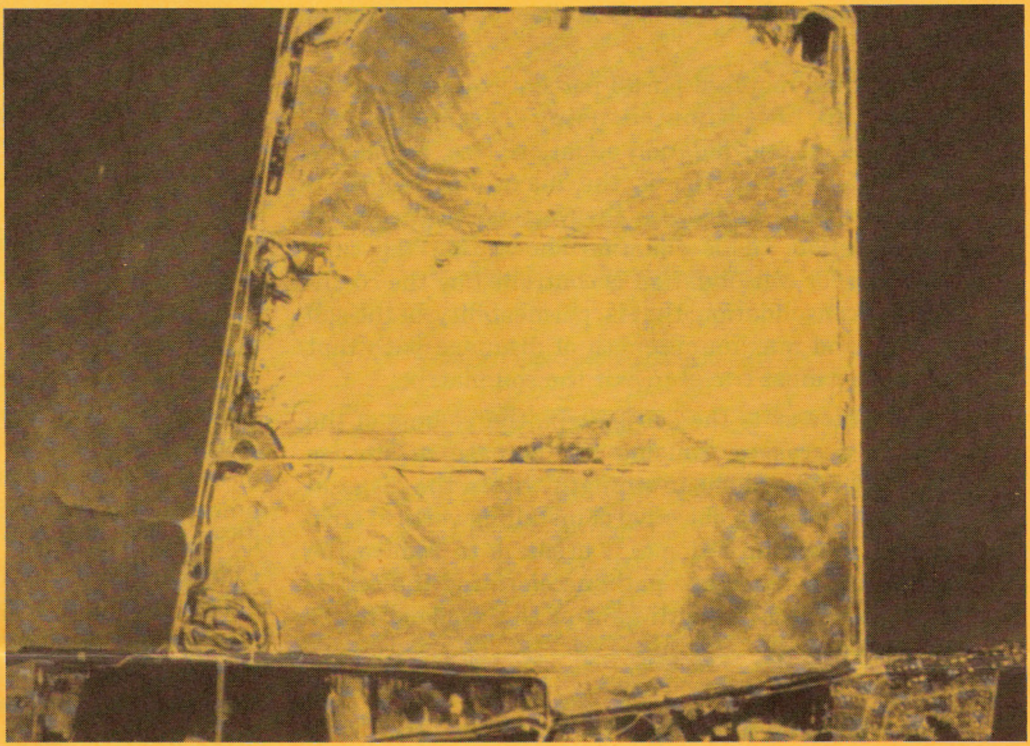

Craney Island Disposal Area

Using Vertical Strip Drains to Increase the Storage Capacity of Confined Disposal Areas

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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, $t_{90\%} = (0.848$ ö $H_{dr}2)/(C_v)$, 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 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 Disposal Area

The Craney Island disposal 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 dike or large dike setbacks to ensure stability of the perimeter dikes or both. These setbacks were approximately 200 feet (Figure 1), which resulted 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 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 US Army Engineer Waterways Experiment Station conducted an extensive consolidation and desiccation analysis to predict the life expectancy of

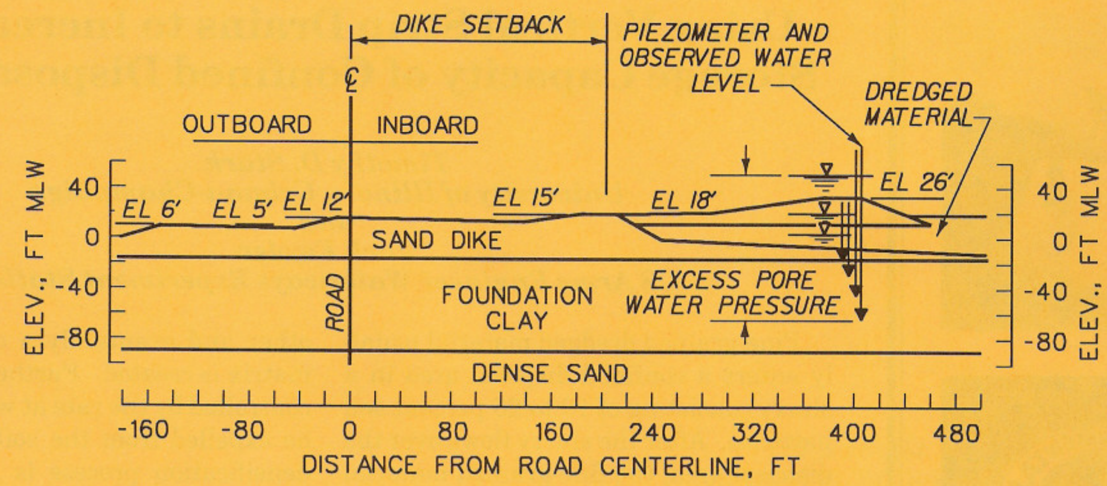


Figure 1. Typical profile of perimeter dikes at Craney Island

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 1 shows that the excess pore-water pressures in the foundation clay presently exceed the ground surface by about 25 feet. 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 given 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 2 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 3, 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, that is, 3 feet, instead of one-half of the compressible layer thickness, that is, 55 feet. 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. If Craney Island were not underlain by a permeable material, however, the compressible layer would be singly drained and the maximum drainage path would be 110 feet.

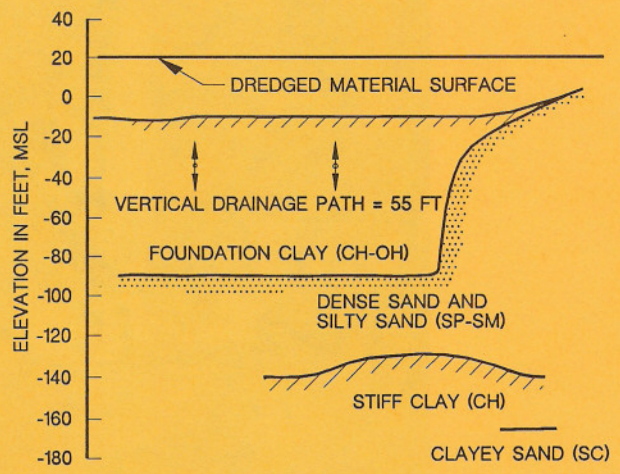


Figure 2. Generalized subsurface profile (Note: Soil classifications in this figure are by the Unified Soil Classification System.)

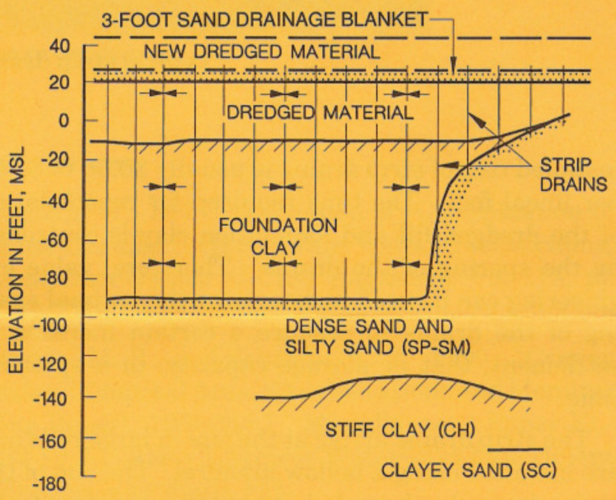


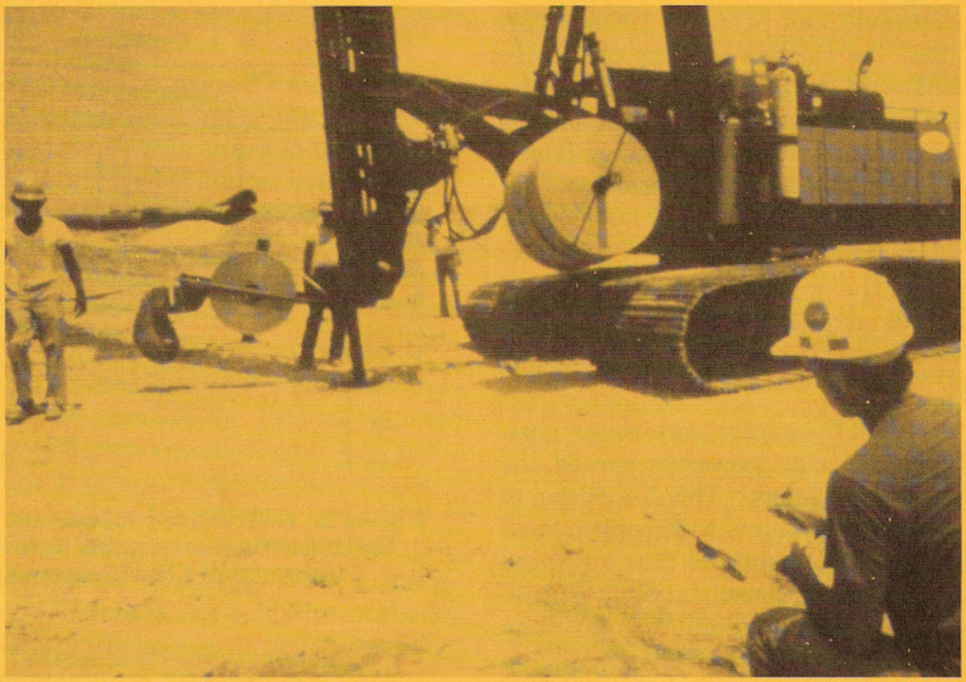
Figure 3. Radial drainage pattern using vertical strip drains (Note: Soil classifications in this figure are by the Unified Soil Classification System.)

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 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, including the recent expansion of the Port of Los Angeles, the Seagirt project in Baltimore Harbor, and the construction of dredged material containment areas in the Delaware River near Wilmington, Delaware, and the New Bedford Superfund site, New Bedford, Massachusetts, to accelerate consolidation of soft cohesive soils.

Vertical strip drains are easily installed using equipment that exerts a ground pressure as low as 2 to 3 pounds per square inch. A well-developed desiccated crust can support the required equipment. The



Typical strip drain installation equipment

installed cost of 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. 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. 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 be installed in one of three compartments. The remaining two compartments have sufficient capacity to receive dredged material for several years if needed. 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 or gravel, will probably 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.

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

Benefits of Vertical Strip Drains

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

Strip drain installation procedure

area. The installed strip drains and sand drainage blanket also will accelerate consolidation of existing dredged fill and foundation clay as new dredged material and perimeter dikes are placed.

For additional information, contact Jack Fowler at (601) 634-2703.

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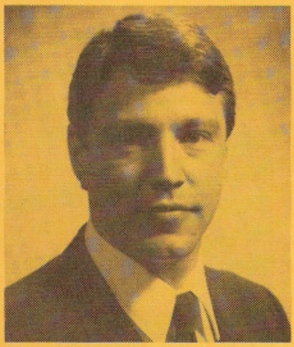

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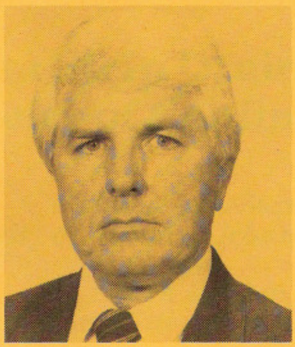

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The Craney Island disposal area was originally designed for a capacity of 100 million cubic yards and a 20-year design life. Dredged material has now been placed in the disposal area almost continuously since 1957. The capacity of Craney Island has been increased through three major dike raising efforts. The Virginia State Legislature has ruled that the disposal area cannot be expanded or replaced, requiring the development of new techniques for increasing its storage capacity. The use of vertical strip drains to decrease the drainage path and accelerate consolidation of the dredged material is reported on in this issue.

ENVIRONMENTAL EFFECTS OF DREDGING

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the Waterways Experiment Station. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program managed by the Environmental Effects of Dredging Programs. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Contributions of pertinent information are solicited from all sources and will be considered for publication. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Communciations are welcomed and should be addressed to the Environmental Laboratory, ATTN: Dr. Robert M. Engler, U.S. Army Engineer Waterways Experiment Station (CEWES-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call AC 601/634-3624.

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