20000822 140

EEDP-01-32
July 1993

Environmental Effects of Dredging Technical Notes

Managing Dredged Material Via Thin-Layer Disposal in Coastal Marshes

Purpose

This technical note describes how dredged material can be successfully managed in an environmentally sound manner in marshes by placing it in layers of 5 to 15 cm. (Unless otherwise indicated, all layer thicknesses indicated in this report refer to material that has undergone postdisposal consolidation.) Environmental studies of this process and of the regulatory history of thin-layer disposal in marshes are summarized. General planning and monitoring considerations are described, including descriptions of the types of equipment used to place dredged material in thin layers in marshes.

This note complements *Environmental Effects of Dredging* Information Exchange Bulletins, Volumes D-92-1, D-92-3, and D-92-5, which describe case histories of thin-layer disposal, and an upcoming *Environmental Effects of Dredging* technical note, which will provide additional detail on engineering aspects of managing dredged material by thin-layer disposal. Together, these documents provide guidance for the planning, execution, and monitoring of thin-layer disposal in marshes.

Background

Channels that pass through marshes can be difficult to dredge, because dredged material cannot be readily placed in marshes without impairing wetland functions. Hence, effort is spent finding scarce upland sites, or additional costs are incurred transporting material to other areas. To help alleviate this situation, several groups have proposed that thin-layer disposal (hydraulically

US Army Engineer Waterways Experiment Station

placing dredged material in single layers of 5 to 15 cm) will reduce environmental impacts sufficiently that disposal in some marshes may become acceptable. If true, maintaining channels that pass through wetlands, especially those in remote areas, may be facilitated.

Although thin-layer disposal potentially can reduce environmental impacts in several types of habitat, few reviews have been conducted of the environmental effects of this disposal technique. This note and the earlier information bulletins provide additional reviews needed to determine when thin-layer disposal in marshes is an effective disposal option for dredged material.

Additional Information

Contact the author, Dr. Pace Wilber, (601) 634-4258, or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624.

Regulatory History

Anecdotal accounts indicate that thin-layer disposal in marshes has been used intermittently as a management technique since the 1930s for channels that pass through marshes, although this practice reflected engineering constraints more than efforts to minimize environmental impacts. Early bucket dredges often could not place material far enough away from a canal to prevent it from slumping back into the canal (Williams 1944, McGhee and Hoot 1963). To remedy this situation, relatively low-pressure hydraulic dredges were used to spray material into marsh away from the canal bank. By the 1950s, bucket dredging technology had improved, and by the 1960s it was generally more cost effective than hydraulically dredging these canals.

During the 1970s and early 1980s, opposition to placing dredged material in marshes mounted, as the value of these habitats to fisheries and water quality became more clear (Davis 1973, Nixon 1980) and it was realized that wetlands outside disposal areas were also affected by these practices (Scaife, Turner, and Costanza 1983, Swenson and Turner 1987). In response to these concerns, relatively high-pressure spray technology was developed for placing dredged material in the late 1970s, but this practice has not been used widely.

Thin-layer disposal has been required (via Section 404 permits or analogous state approvals) for managing dredged material in marshes for only a few projects in Georgia, Louisiana, North Carolina and, possibly, Florida. (Thin-layer disposal has been done several times in Florida, but it is unclear whether this method was mandated by regulatory agencies or was simply the choice of construction managers.)

Thin-layer disposal in marshes as a technique for managing dredged material has received wide discussion only in Louisiana, where thousands of hectares of remote marsh are crisscrossed by oil-rig access canals. For 10 to 20 of these projects during the mid-1980s, several regulatory agencies, most notably the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, suggested that Section 404 permits and analogous state approvals require that thin-layer disposal be used to minimize environmental impacts in and around disposal areas (Cahoon and Cowan 1988). However, cost considerations resulted in issuance of relatively few (5 to 10) permits with such stipulations (LaSalle 1992). At that time in Louisiana, hydraulic thin-layer disposal was 2 to 14 times more expensive than conventional bucket dredging (Cahoon and Cowan 1988). Further, dredging many of the access canals also involved constructing a dock or platform for drilling machinery, work that could be done using a bucket dredge's derrick. Thus, a bucket dredge resulted in less mobilization/demobilization cost for the overall project. In several cases, applicants for permits modified projects to make them acceptable to review agencies without having to resort to thin-layer disposal to minimize impacts (LaSalle 1992).

Environmental Effects

Case Studies

Instances of thin-layer disposal of dredged material in marshes or uplands were identified in Florida, Texas, Georgia, North Carolina, and Louisiana; however, only four formal studies of environmental effects of this management practice were found. Reimold, Hardisky, and Adams (1978) used 0.6-m^2 plots along St. Simons Sound, Georgia, to examine the effects of thin-layer disposal on *Spartina alterniflora* (cordgrass). Corrugated metal pipe was driven 122 cm into the ground to create each enclosure. Six layer thicknesses (8, 15, 23, 30, 61, and 91 cm), three dredged material types (sand, silty sand, and silt), and three discharge times (late winter, summer, and fall) were examined for up to 21 months (two growing seasons) after disposal. The layer thicknesses indicated above were prior to postdisposal consolidation and were achieved by shoveling material into the rings.

Layer thickness was the most important factor. Placement of material smothered most stems. Recovery of the vegetation occurred by either new shoots arising from rhizomes or by seeds germinating at the surface of the dredged material, the latter process being much slower than the former. Recovery from the 8- to 23-cm layers was generally from new shoots penetrating the dredged material, with seedlings accounting for the limited recovery of the 61- and 91-cm layers. More shoots emerged from the sandy and silty-sand material than from the silty material. However, shoots emerging from the silty material tended to have a higher biomass, perhaps reflecting the higher nutrient content of the material or reduced competition for nutrients from other shoots.

At the end of the experiment, there was little variation in vegetation abundance due to discharge time, and differences that were present partly reflected differences in length of the postdisposal monitoring (21, 16, and 11 months for the late-winter, summer, and fall discharges, respectively). It was unclear if, at the end of the experiment, complete recovery had occurred from the 8- to

23-cm layers. Biomass in these plots was considerably lower than in nearby reference marshes, but approximated levels seen in plot controls (enclosures that received no dredged material). Hence, the pipe used to create the enclosures may have introduced artifacts (for example, shading and reduced groundwater movement) that prevented full recovery of the vegetation to background levels.

Cahoon and Cowan (1988) semiquantitatively examined two brackish marshes in Louisiana up to 11 and 17 months after disposal of material excavated for small new-work channels and barge slips. At Dog Lake, about 14,400 m^3 of silty-clay material was placed in a layer 10 to 15 cm thick up to 70 m from the canal edge. At Lake Coquille, about 8,000 m^3 of silty-clay material was placed in a layer 18 to 38 cm thick up to 80 m from the edge.

At both sites, placement of dredged material smothered most of the aboveground vegetation. Eight to 14 months later (about one growing season), limited recolonization by *S. alterniflora*, *Salicornia* spp. (glassworts), and *Distichlis spicata* (saltgrass) was evident, presumably via new shoots emerging from old rhizomes. Three months later (midway through the second postdisposal growing season), vegetation cover had increased but had not yet reached the presumed predisposal levels. Only the Lake Coquille site had wetland area converted to upland habitat by dredged material, but the extent of this alteration was limited to less than 100 m^2 (0.025 acre). No obvious obstructions to water flow were created by the dredged material at either site.

In addition to Dog Lake and Lake Coquille, Cahoon and Cowan visited two floating roseau cane (*Phragmites australis*) marshes soon after approximately 15,000 m^3 of material was placed upon each. At both sites, no accumulation of dredged material was apparent because the material sank into the extremely soft substrate. However, at both sites, much of the standing vegetation had been crushed.

LaSalle (1992) returned to Cahoon and Cowan's Dog Lake and Lake Coquille sites in 1992, about 6 years after disposal. Both marshes had healthy stands of vegetation (Figure 1, upper panel). Species distributions and abundances in the Lake Coquille disposal area were similar to nearby reference areas. However, the Dog Lake disposal and reference areas differed in several ways. The disposal area consisted predominantly of *S. alterniflora* and *Salicornia* spp., whereas *D. spicata*, *Juncus roemerianus* (needle rush), and *S. alterniflora* dominated reference areas. Further, shoot density was about 20 percent less in the disposal area. In both areas, sediment cores exhibited a layered structure (Figure 2). The top few centimeters consisted of roots and rhizomes from the existing marsh. Below this was 10 to 20 cm of compact silt/clay material that appeared to be dredged material. Below this was another few centimeters of roots and rhizomes, which presumably represented the predisposal marsh. In contrast to Cahoon and Cowan's earlier observations, the apparent dredged material layer was thinner at Lake Coquille (10 to 15 cm) than at Dog Lake (15 to 20 cm).

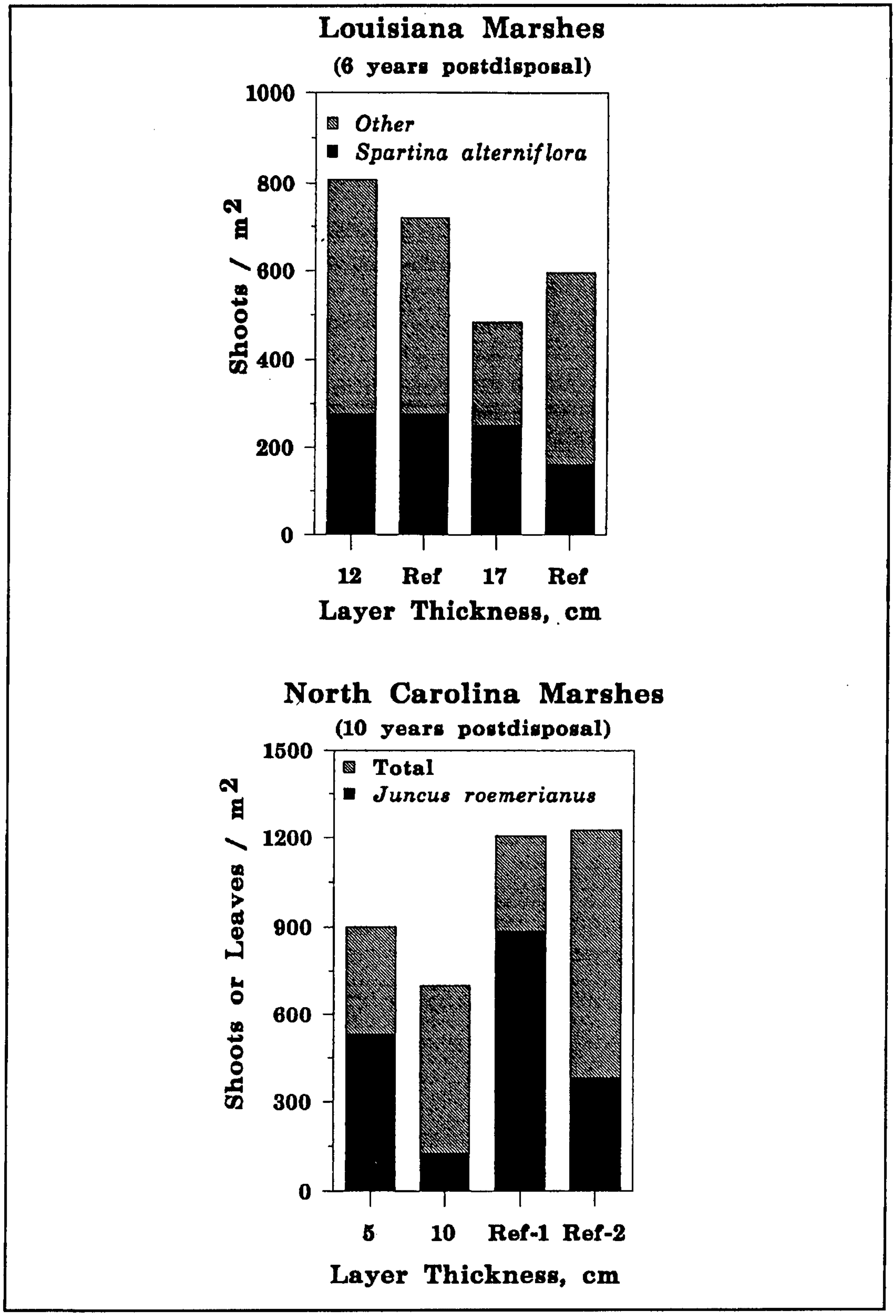

Figure 1. Vegetation densities in disposal areas of marshes used for thin-layer disposal. (For comparison, densities at reference sites are also given)

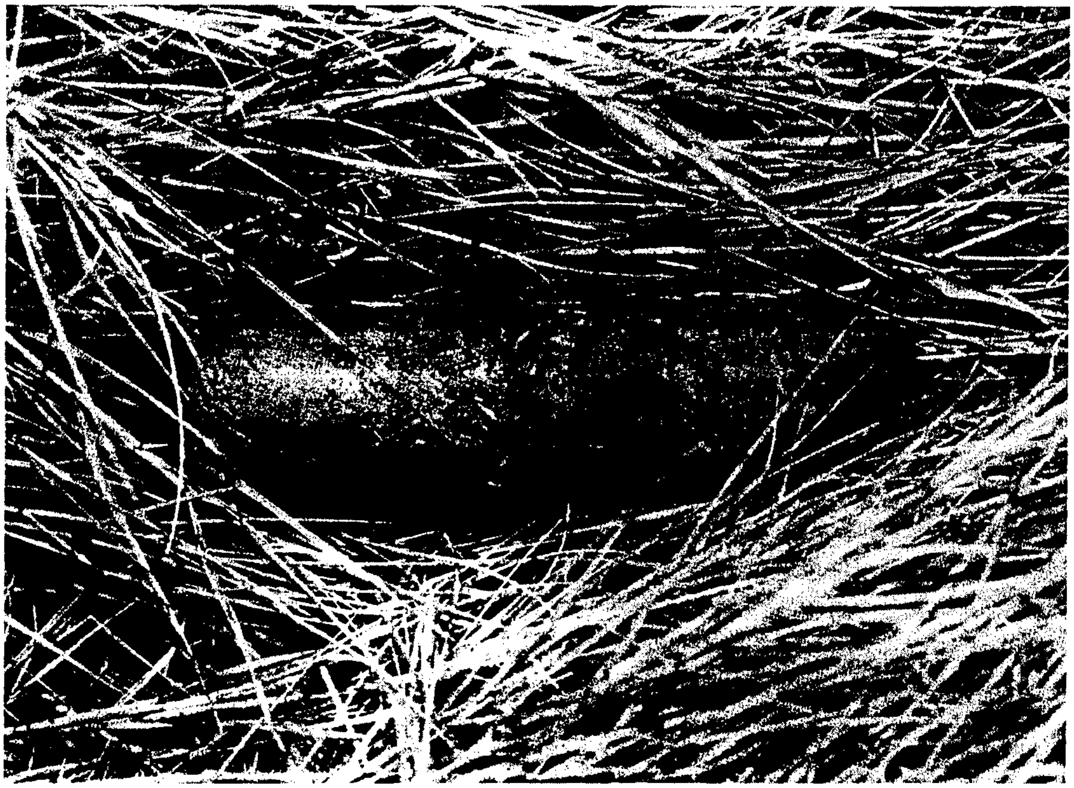

Figure 2. Sediment core from Lake Coquille, Louisiana, 6 years after thin-layer disposal

Wilber, Luczkovich, and Knowles (1992) examined an oligohaline marsh in Gull Rock, North Carolina, approximately 10 years after it had been used for thin-layer disposal of 8,000 to 12,000 m^3 of mostly silty maintenance material. The two disposal areas examined had healthy stands of vegetation, but nonetheless, some differences were apparent when compared to reference areas (Figure 1, lower panel). An area where the disposal layer was about 5 cm thick had slightly less *J. roemerianus* than an adjacent reference area, and shoot density was 25 percent lower. An area where the disposal layer was about 10 cm thick was dominated by *D. spicata* and *S. alterniflora*, whereas the reference areas were dominated by *J. roemerianus* and *D. spicata*. Shoot density at this site was 40 percent lower than at reference areas. Although there were small differences in the plant community, estimates of infauna abundance and use by fiddler crabs and larval fish were similar to reference areas.

Several other groups are currently examining environmental effects of thin-layer disposal. During January-March 1993, the city of Savannah, GA, placed about 30,000 m^3 of sandy material in a 10- to 20-cm layer of a tidal-freshwater forested wetland. The city will monitor disposal areas for 3 years. Plaquemines Parish, LA, is examining effects of thin-layer disposal projects at West Pointe-a-la-Hache and La Reussite. However, the Louisiana projects involve diverting fresh water to a brackish marsh, an intentional habitat change that limits the scope of inferences that can be drawn from the Plaquemines Parish studies.

Related Studies

Two common types of natural disturbance, dune overwash and wrack deposition, are qualitatively similar to thin-layer disposal of dredged material and provide some insight about the long-term effects of this management technique. Severe storms and hurricanes transport large mats (500 to 1,500 m^2) of dead vegetation into the upper region of marshes; the thickness of the wrack layer can be 20 to 30 cm. The wrack has the immediate effect of smothering existing vegetation. The area then recovers as wrack decomposes or is relocated by subsequent storms. Reidenbaugh and Banta (1980), Bertness and Ellison (1987), and Hartman (1988) examined wrack accumulation in *Spartina* marshes and concluded that almost complete recovery occurs in two growing seasons if roots and rhizomes are not killed. Knowles (1989) examined this process in a *Juncus* marsh and found that recolonization can occur at a similar rate, but species composition may change.

Marsh vegetation commonly occurs on the lee side of sand dunes along the eastern coast of the United States. When hurricanes and other storms overwash these dunes, sandy material often smothers this vegetation. Zaremba and Leatherman (1984) found that recovery from these disturbances via new shoots arising from roots and rhizomes varies with species, initial cover, and elevation. *Spartina patens* was able to penetrate up to 33 cm of material, and *S. alterniflora* was able to penetrate up to 24 cm of material. Less quantitative data are available demonstrating recovery by other marsh grasses and shrubs.

Other information indicates potential problems from thin-layer disposal in marshes. Mendelssohn, McKee, and Patrick (1981), King and others (1982), and DeLaune, Pezeshki, and Patrick (1987) discuss the effects of water-logged soils and high sulfide concentrations on marsh vegetation. In poorly drained soils, decomposition of organic material can lead to hypoxic conditions inconducive to plant growth. Since dredged material is placed hydraulically in a thin-layer operation and water volume can exceed material volume 10-fold, significant alteration of soils could occur. Finally, numerous studies of wetland creation (Broome 1989, Lewis 1989) show that elevation changes as small as 5 cm can significantly alter vegetation patterns.

A General Model for Marsh Recovery

The above studies can be synthesized into a conceptual model of how marshes respond to a thin-layer disposal event (Figure 3). Dredged material is hydraulically placed onto the marsh with some type of spray device. The distance of the spray and the texture of material within it depend upon equipment and operation. Placement of material will smother standing vegetation, although the cause may be the large amounts of water used in placement rather than dredged material itself. Rate of recovery depends upon layer thickness and the extent to which soil characteristics are altered. If a substantial number of roots and rhizomes survive the hypoxia and high sulfide conditions that often result from water-logged soil and decomposing vegetation, new shoots will arise. If enough new shoots penetrate the dredged material, new

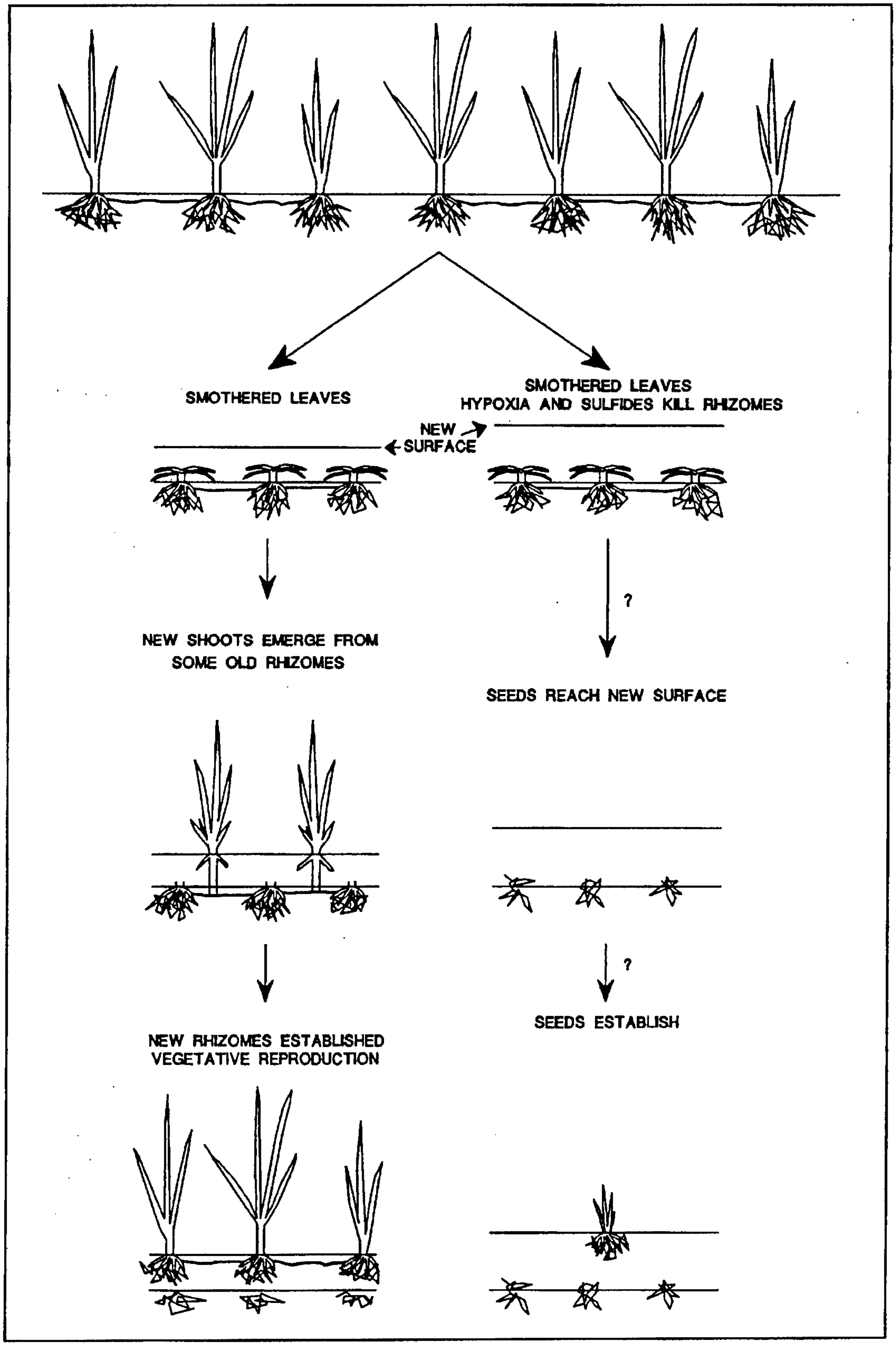

Figure 3. Illustration of conceptual model for marsh recovery after thin-layer disposal

adventitious roots and rhizomes will occur at the newly appropriate soil depth; old roots and rhizomes will be abandoned. Areas where new shoots did not arise will be subsequently colonized via vegetative growth.

This process generally requires two growing seasons to reach vegetation densities commonly found in marshes, but may require longer to reach predisposal levels. Marsh plants differ in their ability to withstand this type of stress and reproduce vegetatively. Hence, species composition of the new marsh may differ from the old marsh. However, if the new elevations remain within the marsh range (which varies with tidal range but can be crudely approximated by mean low water to mean higher high water), the new community will still be a marsh rather than an upland.

If too many roots and rhizomes are killed by altered soil conditions or if too few shoots penetrate the dredged material, the bulk of recolonization will be by seedlings, assuming marsh elevations are preserved. This method of recolonization will require considerably longer than two growing seasons to establish typical marsh vegetation patterns and may allow erosive forces to prevent recovery from occurring at all. Thus, the key to successfully managing dredged material in marshes with thin-layer disposal is placing material in a manner such that severe hypoxia and sulfide levels do not result and new shoots can penetrate the dredged material. Studies of thin-layer disposal in Louisiana and North Carolina show this goal can be reliably achieved with layers of 5 to 15 cm.

Project Planning and Monitoring

General Planning Considerations

Although detailed engineering analyses of thin-layer disposal in marshes have not been done, determining appropriate layer thickness and estimating a marsh's disposal capacity are the most important steps. Before exploring these steps, it is necessary to understand various aspects of dredged material solids concentration or volume, and the changes that occur during dredging, disposal, and postdisposal. Initially, the volume of sediment and its concentration are known in situ, yielding the total mass of solids to be dredged and disposed. During hydraulic dredging, water is mixed into the sediment to create a slurry that can be pumped; therefore, the volume of dredged material is 4 to 7 times as large as the in situ volume, particularly for new-work dredging of fine-grained material (Headquarters, U.S. Army Corps of Engineers 1987).

During disposal, the dredged material slurry undergoes sedimentation, and supernatant water runs offsite. The volume of dredged material continues to decrease as the material undergoes compression settling. Immediately following disposal, the material volume may still be 2 to 4 times larger than before dredging.

During postdisposal, the dredged material continues to densify by self-weight consolidation and desiccation. The rate of densification for thin-layer disposal will be fast since the drainage length for the water to escape from the material is small. Complete densification should occur in less than a year, with the actual rate a function of soil permeability, location of the water table, evaporation, and other climatic factors. Final volume may be somewhat less than in situ volume (0.7 to 1.1 times) for maintenance dredging and somewhat more than in situ (1.3 to 2 times) for new-work dredging.

Studies of thin-layer disposal in Louisiana and North Carolina show healthy stands of marsh vegetation atop 5- to 15-cm layers of dredged material. Since the thicknesses of these layers were measured months to years after disposal, these can be considered postconsolidation thicknesses. The question then arises, What were the immediate postplacement thicknesses? Reimold, Hardisky, and Adams (1978) found that 8- to 91-cm layers of dredged material shrink 10 to 40 percent in thickness by 10 days after placement, and the shrinkage rate was inversely related to initial layer thickness and did not differ between dredged material types. Using these results and assuming no other processes were involved, the immediate postplacement thickness of dredged material in the above studies would have been approximately 8 to 22 cm. Standard engineering analyses indicate that the immediate postplacement thickness depends on grain size, and could have been as much as 15 to 45 cm.

Elevation data from nearby wetlands should be used to determine which part of the postconsolidation range should be targeted. If similar marshes occur at elevations 10 to 15 cm higher than the ambient predisposal marsh, the upper portion of the range may be appropriate. Otherwise, a postconsolidation change of 5 to 10 cm should be targeted, unless this range would bring the marsh to upland elevations, in which case thin-layer disposal should not be attempted.

In practice, wetland thin-layer disposal sites have been sized by estimating the volume of material to be excavated per meter of channel length and then calculating how wide the disposal area needs to be to reduce that volume to a given thickness (personal communication, January 1993, R. Hallman and J. Sawyer, City of Savannah, Savannah, GA).

Figure 4 illustrates such calculations for a range of layer thicknesses. It should be noted that the disposal area width shown in Figure 4 is for the *total disposal area.* Thus, if material is placed on both sides of a channel, the two widths (one from each side of the channel) are summed to yield total disposal area width. In making these calculations for a specific project, certain special circumstances should be considered. If the channel makes a severe bend, disposal swaths may overlap, locally reducing disposal capacity. One advantage of thin-layer disposal is that placement of dredged material in creeks, sloughs, and other sensitive areas can be readily avoided by redirecting the discharge. However, the cost for such avoidance is reduced disposal capacity, which should be considered when planning a project.

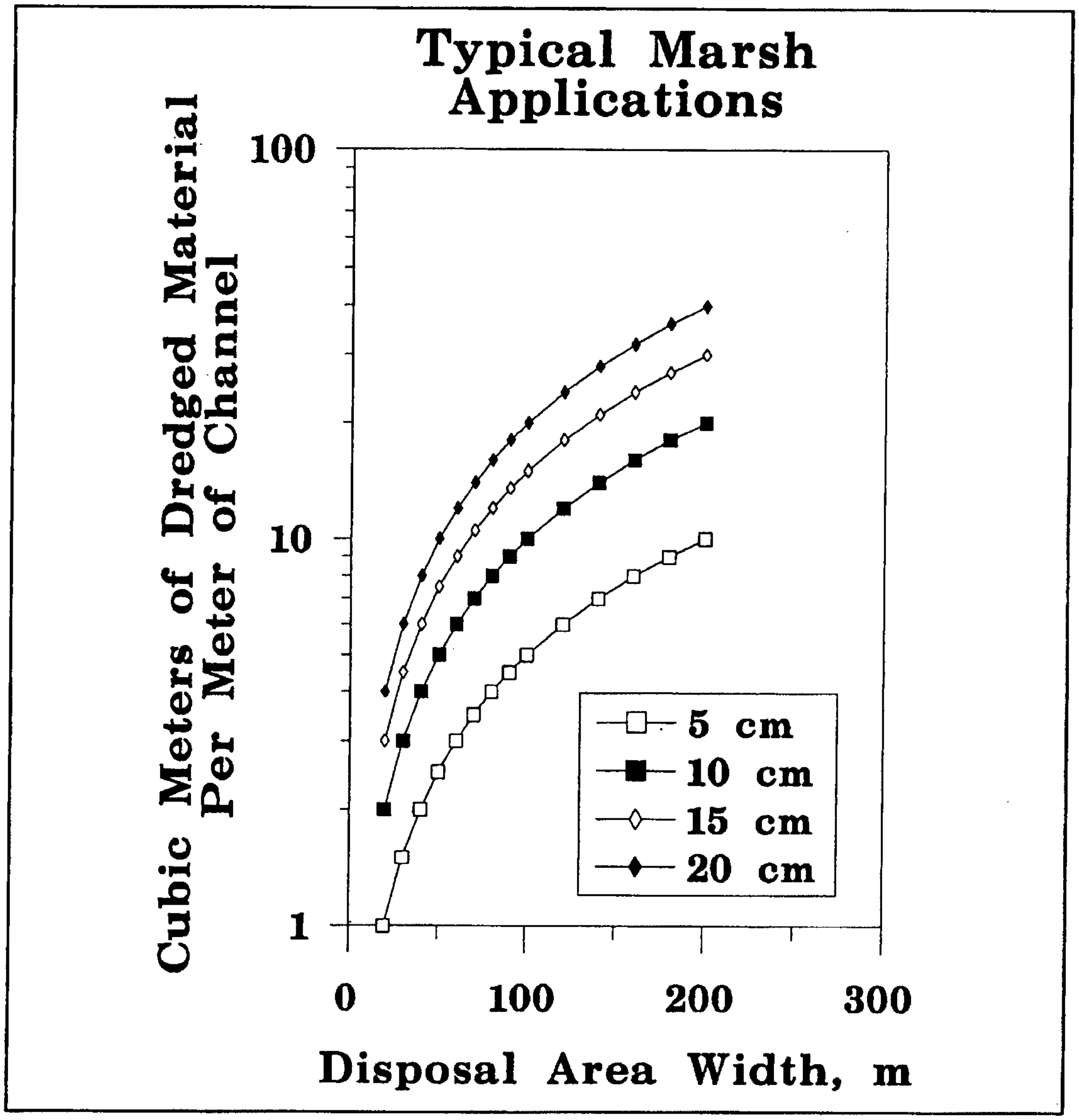

Figure 4. Nomogram that indicates relationship between total disposal area width and volume of dredged material per meter of channel for selected layer thicknesses

Equipment and Monitoring

At present, thin-layer disposal in marshes is accomplished by slurrying dredged material and spraying it onto nearby marshes. In almost all cases, the cutterhead, pump, and spray device occur on the same vessel; in a few cases, the pump and spray device were connected by a few hundred meters of pipe.

The type of cutterhead chosen is determined by the nature of the material to be dredged. Horizontal auger cutterheads have been used for fine material, and radial cutterheads for sandy material. In either case, the goal is to turn material into a fine slurry. Both high- and low-pressure hydraulic dredges can be used, although high-pressure dredges can spray material farther, which potentially increases disposal capacity. A high-pressure system that includes cutting blades in the pump impeller has been patented under the name JET-SPRAY, but other equipment can be used in these operations.

Since it is relatively easy to control the direction of the spray device, a thin-layer disposal operation can avoid marsh creeks, sloughs, and other sensitive areas within a disposal site. Although control at this level is relatively easy, precisely controlling the thickness of the dredged material layer has proven difficult. No thin-layer disposal site has been thoroughly examined to determine how close actual layer thicknesses were to target thicknesses. The limited available data indicate layer thickness will vary by at least 10 cm.

The variability in layer thickness probably results from several factors. First, there is a lack of real-time feedback from the disposal area to the dredge operator. Because of the large amounts of water involved in slurrying the material and because the marshes suitable for thin-layer disposal have little slope, water can accumulate in the disposal area and hide the dredged material layer from view, making it difficult to monitor. To deal with this situation, arrays of large buckets with bottom drain holes are often placed in the disposal area to catch dredged material. However, turbulence from the raining material may keep material in the bucket partially suspended if drains are not working properly. Second, trees and wind deflect the spray from its intended target. Third, although spray ranges can be 80 m, fallout along that range is not even leading to uneven accumulations. However, placing a deflector plate a few centimeters from the spray nozzle reduces this problem (personal communication, January 1993, J. Sawyer, Savannah, GA). Since the only way to deal with layers thicker than planned is to stop dredging, it is extremely important to accurately determine material volumes and disposal site capacity.

Other Uses of Thin-Layer Disposal Technology

Thin-layer disposal, as discussed here and in the previous Information Exchange Bulletins, is defined narrowly to focus on how the practice minimizes environmental impacts from dredged material disposal. However, thin-layer disposal technology has other applications suited to beneficial uses of dredged material. Eustacy and subsidence are increasing the submergence of many marshes in Louisiana, causing the marshes to deteriorate and disappear. Wilsey, McKee, and Mendelssohn (1992) have shown that *S. alterniflora* transplanted to these dieback areas is more likely to become established if elevations are raised 30 cm. Access to deteriorating interior marshes is a problem that requires technological innovation, but the basic principles of thin-layer disposal should still apply. Thin-layer disposal technology may also be useful in habitat creation projects where small changes in elevation are needed (for example, transforming shallow subtidal areas into intertidal marshes).

References

Bertness, M. D., and Ellison, A. M. 1987. "Determinants of Pattern in a New England Salt Marsh Plant Community," *Ecology*, Vol 57, pp 129-147.

Broome, S. W. 1989. "Creation and Restoration of Tidal Wetlands in the Southeastern United States," *Wetland Creation and Restoration: The Status of the Science*, Vol I, Regional Reviews, J. A. Kusler and M. E. Kentula, eds., pp 37-72.

Cahoon, D. R., Jr., and Cowan, J. H., Jr. 1988. "Environmental Impacts and Regulatory Policy Implications of Spray Disposal of Dredged Material in Louisiana Wetlands," *Coastal Management*, Vol 16, pp 341-362.

Davis, D. W. 1973. "Louisiana Canals and Their Influence on Wetland Development," Ph.D. dissertation, Louisiana State University, Baton Rouge, LA.

DeLaune, R. D., Pezeshki, S. R., and Patrick, W. H., Jr. 1987. "Response of Coastal Plants to Increase in Submergence and Salinity," *Journal of Coastal Research*, Vol 3, pp 535-546.

Hartman, J. M. 1988. "Recolonization of Small Disturbance Patches in a New England Salt Marsh," *American Journal of Botany*, Vol 75, pp 1625-1631.

Headquarters, U.S. Army Corps of Engineers. 1987. "Confined Disposal of Dredged Material," Engineer Manual 1110-2-5027, Washington, DC.

King, G. M., Klug, M. J., Weigert, R. G., and Chalmers, A. G. 1982. "Relation of Soil Movement and Sulfide Concentration to *Spartina alterniflora* Production in a Georgia Salt Marsh," *Science*, Vol 218, pp 61-63.

Knowles, D. 1989. "Vegetation Patterns and Wrack-Initiated Disturbance in a Nontidal Brackish Marsh in North Carolina," M.S. thesis, East Carolina University, Greenville, NC.

LaSalle, M. W. 1992. "Effects of Thin-Layer Disposal of Dredged Material in Louisiana Coastal Marshes," report to U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lewis, R. R. 1989. "Creation and Restoration of Coastal Plain Wetlands in Florida," *Wetland Creation and Restoration: The Status of the Science*, Vol I, Regional Reviews, J. A. Kusler and M. E. Kentula, eds., pp 73-101.

McGhee, E., and Hoot, C. 1963. "Mighty Dredger—Little Known Work Horses of Coastal Drilling, Producing, Pipelining—Now 25 Years Old," *Oil and Gas Journal*, Vol 61, pp 150-152.

Mendelssohn, I. A., McKee, K. L., and Patrick, W. H., Jr. 1981. "Oxygen Deficiency in *Spartina alterniflora* Roots: Metabolic Adaptation to Anoxia," *Science*, Vol 214, pp 439-441.

Nixon, S. W. 1980. "Between Coastal Marshes and Coastal Waters—A Review of 20 Years of Speculation and Research on the Role of Salt Marshes in Estuarine Productivity and Water Chemistry," *Estuarine and Wetland Processes*, P. Hamilton and K. MacDonald, eds., Plenum Press, New York, pp 437-525.

Reidenbaugh, T. G., and Banta, W. C. 1980. "Origin and Effects of *Spartina* Wrack in a Virginia Salt Marsh," *Gulf Research Reports*, Vol 6, pp 393-401.

Reimold, R. R., Hardisky, M. A., and Adams, P. C. 1978. "The Effects of Smothering a *Spartina alterniflora* Salt Marsh with Dredged Material," Technical Report D-78-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Scaife, W., Turner, R. E., and Costanza, R. 1983. "Coastal Louisiana Recent Land Loss and Canal Impacts," *Environmental Management*, Vol 7, pp 433-442.

Swenson, E. M., and Turner, R. E. 1987. "Spoil Banks: Effects on a Coastal Marsh Water Level Regime," *Estuarine and Coastal Shelf Science*, Vol 24, pp 599-609.

Wilber, P., Luczkovich, J., and Knowles, D. 1992. "The Long-Term Environmental Effects of Thin-Layer Disposal on a Salt Marsh, Lake Landing Canal, North Carolina," *Proceedings of the 13th Meeting of the Western Dredging Association*, pp 170-185.

Williams, N. 1944. "Dredging Canals for Servicing Field in Marsh and Swamp Districts of Louisiana," *Oil and Gas Journal*, Vol 43, pp 95-96.

Wilsey, B. J., McKee, K. L., and Mendelssohn, I. A. 1992. "Effects of Increased Elevation and Macro- and Micronutrient Additions on *Spartina alterniflora* Transplant Success in Salt-Marsh Dieback Areas in Louisiana," *Environmental Management*, Vol 16, pp 505-511.

Zaremba, R., and Leatherman, S. 1984. "Overwash Processes and Foredune Ecology, Nauset Spit, Massachusetts," Miscellaneous Paper EL-84-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: MANAGING DREDGED MATERIAL VIA THIN-LAYER DISPOSAL IN COASTAL MARSHES

B. DATE Report Downloaded From the Internet: 08/15/00

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #):

US Army Engineer Waterways Experiment Station
Environmental Laboratory
PO Box 631
Vicksburg, Mississippi 39181-0631

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __LF__ **Preparation Date 08/21/00**

The foregoing information should exactly correspond to the Title, Report Number, and the Date on the accompanying report document. If there are mismatches, or other questions, contact the above OCA Representative for resolution.