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Environmental Effects of Dredging Technical Notes

ACOUSTIC TOOLS AND TECHNIQUES FOR PHYSICAL MONITORING OF AQUATIC DREDGED MATERIAL DISPOSAL SITES

PURPOSE: This article provides interim guidance on the use of acoustic tools and techniques for physical monitoring of aquatic (open-water) dredged material disposal sites. The information presented is taken from the "Guidelines for Biological and Physical Monitoring of Aquatic Dredged Material Disposal Sites" (Fredette et al., in preparation).

BACKGROUND: Increased coastal and marine dredging, limited upland disposal sites, and a drive to reduce dredging costs combine to increase the need for open-water disposal of dredged material relatively close to shore. Effective monitoring of disposal activities is necessary to prevent adverse physical and biological impacts resulting from such disposal operations. Lack of guidance on monitoring was identified as a problem at the Long-Term Management Strategy Workshop in August 1985 (US Army Engineer Waterways Experiment Station, in preparation), leading to a Dredging Operations Technical Support (DOTS) management task to provide needed guidelines to the Corps field offices.

The focus of the guidelines and of this article is on dredged material that has complied with the guidelines of the Clean Water Act (Section 404) and the Ocean Dumping Act (Section 103), i.e. material that is acceptable for open-water disposal. Consequently, chemical concerns associated with contaminated sediments are not addressed.

These guidelines were developed under the DOTS Program, and the tools and techniques recommended are being further evaluated under DOTS and through cooperative studies with Corps of Engineer District Offices.

A series of articles on monitoring aquatic dredged material disposal sites is planned for the Environmental Effects of Dredging Technical Note Series. Future topics include biological monitoring, a sediment profiling camera, sampling tools, measurement of engineering properties of disposed sediments, dredged material consolidation, and other topics as information becomes available.

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Introduction

Monitoring programs should provide information the site manager needs to make decisions concerning continued disposal operations. Potentially adverse physical and biological impacts resulting from disposal should be defined before initiating a monitoring program. This will allow the design of a monitoring program to address those factors that will provide the site manager with information needed to modify the disposal operation prior to creating any substantial adverse effect. The size and cost of the monitoring program should be based on the size and cost of the project. These objectives can be met with a tiered monitoring program based on predetermined trigger levels. Exceeding a predetermined monitoring trigger level provides the manager with an early warning and calls the next higher (more detailed) tier of monitoring.

In some cases, concern is limited to physical impacts such as increased shoaling that may create a navigation hazard. In cases where biological resources are of concern, the impact may stem from physical processes such as burial or change in grain size of the substrate. Because physical impacts drive the biological changes, and because physical impacts are more easily measured, the first tier of any monitoring program should include basic physical measurements.

A physical monitoring strategy combines remote techniques covering broad areas (bathymetry, side-scan sonar, subbottom profiles) with direct measurements (cores, grab samples, sediment profiling camera) at chosen locations to verify the information provided by the broad-area techniques. Direct and indirect measurements of sediment transport are also used, including current meters, sediment traps, reference rods, and near-bottom current drogues (seabed drifters). Other physical monitoring methods include remote sensing applications and measurement of engineering properties of disposal sediments. Navigation and positioning systems must be chosen with care to ensure that the monitoring data collected have sufficient accuracy.

This technical note discusses the broad-area acoustic tools and techniques of bathymetry, side-scan sonar, and subbottom profilers. These tools complement each other in monitoring activities. Bathymetry provides topographic measurements of the disposal area, side-scan sonar gives qualitative surface topography and distinguishes between sediment types, and subbottom profilers show subsurface layers.

Acoustic Monitoring Tools and Techniques

Bathymetry

Probably the most fundamental measurement of a disposal site is bathymetry. For most applications, bathymetric surveys are the primary tool for determining where the material has been placed and how much remains on-site. Bathymetric surveys usually require microwave positioning accuracy (National Oceanic and Atmospheric Administration 1976, Hart and Downing 1977). Standard quality control measures and equipment include precision depth sounders (200 kHz or higher, narrow beam), tide and squat corrections, and a bar check (speed of sound correction). Even with all these accuracy-improving techniques, Morton, Stewart, and Germano (1984) reported an estimated repeatability of ±0.7 ft. The accuracy of an individual depth sounder measurement is estimated at 0.1 ft under ideal conditions, with more typical accuracies of 0.3 to 0.7 ft (Clausner, Birkemeier, and Clark 1986).

Some sources of error vary rapidly during the survey. Waves, signal ambiguities, and some components of positioning contribute randomly changing errors that are both positive and negative. These random variations tend to "average out" in volume change calculations. Hands (1976) showed that 80 percent of the sounding errors canceled out over 1,000-m profiles. Morton, Stewart, and Germano (1984) provide an additional discussion of percent errors in volume change.

Other critical items to consider in bathymetric survey planning are the density, pattern, and extent of the survey grid. The complexity of the survey effort should depend on the intent of the monitoring program. If the bathymetric survey is being conducted to verify the formation of significant mounds, or other changes in bathymetry, a minimal density survey plan may be adequate. Conversely, if the survey's purpose is to make an accurate measurement of the volume of material contained in a mound, closely spaced survey lines (i.e. 100- to 200-ft spacing) may be necessary. One or two crossed lines can be used to verify survey accuracy. Appropriately spaced parallel survey lines are preferred over a grid pattern due to the reduced ship time required. The survey pattern should be at right angles to the anticipated bathymetric slope or contour lines. Spacing will be a function of the size of the area, and a trade-off between accuracy and cost. When attempting to estimate volume of contaminated material, or the thickness of a sand cap over contaminated material, distances between survey lines of 50 to 80 ft may be required and cross surveys are a must.

Bathymetric surveys should extend beyond the area of interest to include areas "not affected" by the disposal operation. Initially, the survey boundaries should be 100 to 200 percent longer than the disposal site. For large sites (greater than 2 miles on a side) this figure may be reduced to 50 to 100 percent. As time passes and no changes occur, the area surveyed may be reduced, or expanded in the direction of material movement. Controlled disposal at precise coordinates or at marker buoys may reduce the required survey area to only a fraction of the total permitted disposal site.

Several new computer-integrated sounding systems have potential applications for monitoring disposal sites. (See Fredette et al., in preparation, for detailed information.)

Bathymetric surveys are often an expensive portion of a monitoring study. Proper scheduling to coincide with other monitoring activities may be cost-effective.

Side-scan sonar

Surface characteristics of the seafloor can be mapped using side-scan sonar. This tool uses acoustic energy projected laterally from a pair of transducers housed in a towed "fish." The received signal is transmitted through the tow cable to the shipboard receiver, which processes the signal and prints the record. The resulting image of the bottom is roughly similar to a continuous, oblique aerial photograph. However, the interpretation of side-scan sonar records requires some training and experience. Side-scan sonars for disposal site monitoring should usually be operated at a frequency of 100 or 500 kHz. The lower frequency has a greater range, but provides less detail than the higher frequency.

A survey run at 500 kHz distinguishes differences in bottom texture that can be used to map suspected variations in grain size. For example, moderately graded 0.25- and 0.13-mm sands may be identified (Figure 1). Spacing and orientation of sand ripples recorded on the sonograph can be used to interpret grain-size variations and direction and magnitude of sediment movement. Because ripples form more readily in sands than silts, and are usually larger for a coarser sand size, discrimination between placed and in-situ sediments may be further enhanced.

If bed-form or grain-size differences are substantial, a 100-kHz survey

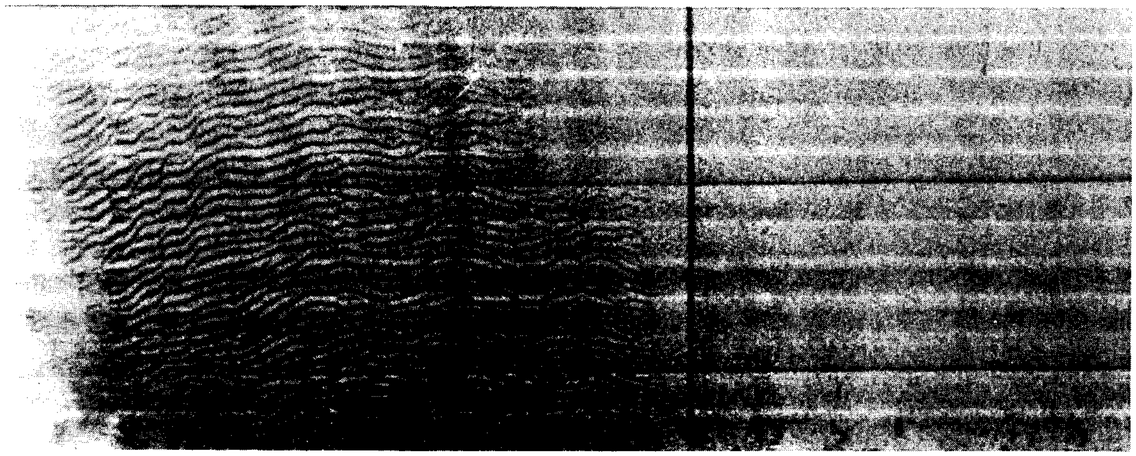

Figure 1. Side-scan sonar record of Dam Neck Disposal Site showing the difference between the native sand bottom (left) and disposal sediments (right)

may be preferred for its wider coverage in spite of poorer resolution. The lower frequency system may cover 200 to 400 m of bottom (depending on water depth) in a single scan as compared with 100 m for the 500-kHz system. Trial surveys with both frequencies are recommended when surveying unfamiliar areas. The grid spacing and overlap between the tracks, if any, will be a function of the purpose of the survey and the positioning system used. Complete coverage with 30- to 50-percent overlap should be required only for contaminated material, or to check coverage of capping operations. Relatively few tracks with no overlap may be appropriate for determining whether or not a stable deposit has begun to spread. A discrete track spacing of three times the swath width is recommended.

Overlapping coverage obtained with closely spaced survey lines, as in Figure 2a, allows precise and continuous mapping of the edges of disposal deposits. Side-scan surveys delineate the edge of disposal deposits more accurately than bathymetric surveys, provided the released and native sediments have distinctive backscatter characteristics. Definitive backscatter is likely, as the two materials frequently have different grain-size characteristics. Even if the grain sizes and reflection characteristics of the native

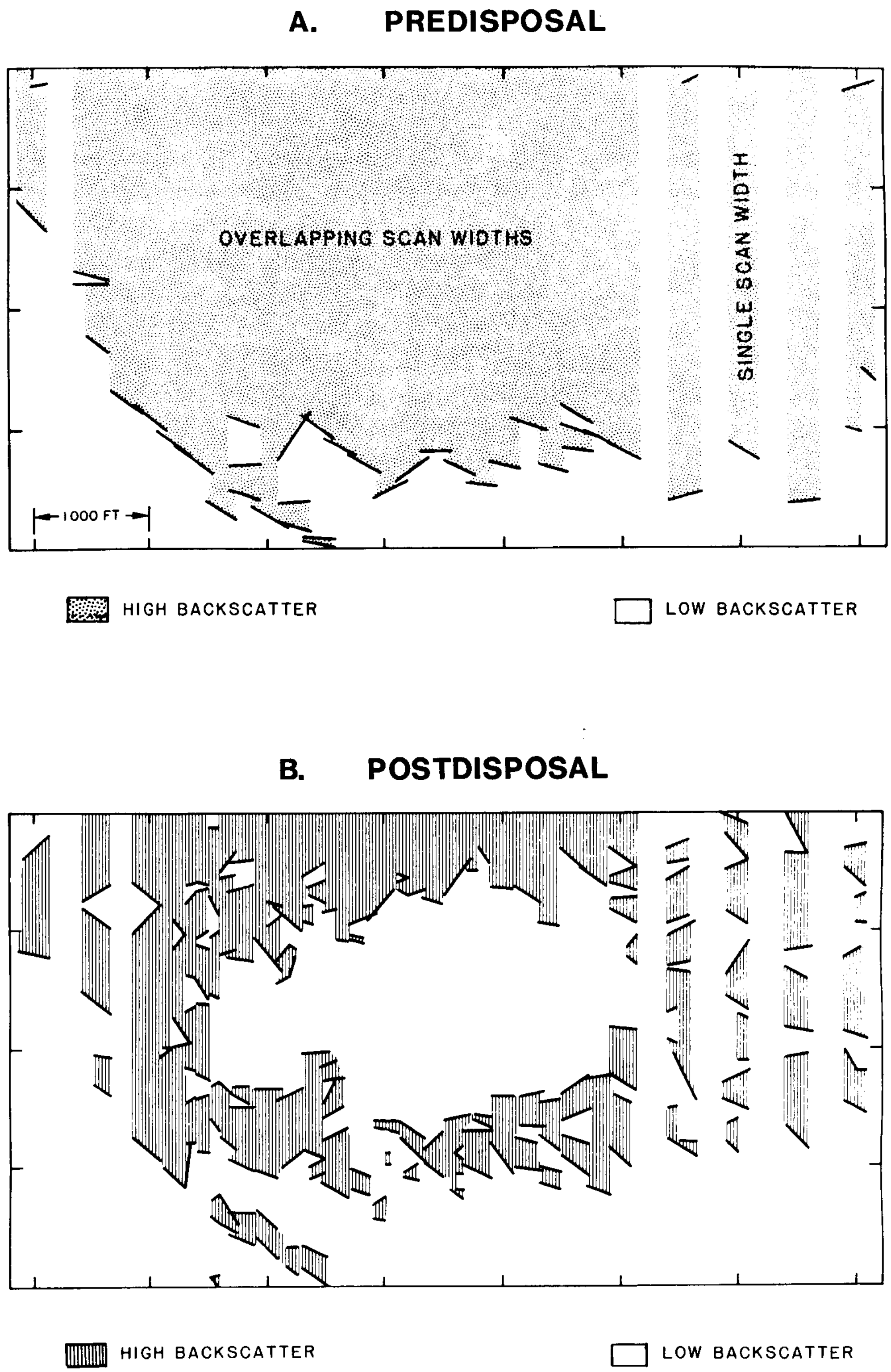

Figure 2. Predisposal and postdisposal maps of the Dam Neck Disposal Site produced from side-scan sonar records. In map B, the large low-backscatter area in the center represents the footprint of the disposal mound. Smaller areas scattered farther afield represent thin deposits of the finer grained material

and disposed material are similar, differences in bed forms can still be observed on a side-scan sonar record. To increase the probability of observing bed-form differences between native and disposal sediments, side-scan sonar surveys should be conducted as soon as possible after disposal. Deep water and less active driving forces may increase the allowable time between disposal and survey.

Individual side-scan sonar strips may be combined to observe a large area at one time. Heavy lines on each scan in Figure 2a indicate distinct contacts between high- and low-backscatter regions in the predisposal, native sediment population. Note that these contacts, which were identified on each scan separately, often match longitudinally when composed in the map view.

The low-backscatter region along the base of the predisposal survey indicates a silty bottom. The same low-backscatter region can be seen in the postdisposal survey 5 months later (Figure 2b). Reappearance of the same boundary on both surveys and the close match from one scan to the next within each survey establish position control accuracy.

The new low-backscatter area at the center of the postdisposal survey delineates the major deposit. Outlying low-backscatter patches represent many shallow depressions which now contain the finest disposal material that eroded from the central deposit.

At the edge of the major deposit and in outlying patches, the disposed material thins to a surface film. Bathymetry should be run in conjunction with side-scan surveys to determine where deposits are thick enough to warrant attention. These areal techniques extend and strengthen one another.

Subbottom profilers

The principles of subbottom acoustical profiling are fundamentally the same as those in acoustic depth sounding; however, subbottom acoustical systems employ a lower frequency, higher power signal to penetrate the shallow sediments of the seafloor. The signal is reflected from interfaces between sediment strata of different acoustic impedance. Subbottom technology was originally developed to search for deep petroleum traps. In contrast, the interest in disposal site monitoring is on high-precision, shallow penetration, to detect stratification within and just below deposits. Medium-power, high-resolution subbottom equipment on the order of 25 to 50 joules and 3.5 to 14 kHz best suits this type of application. The configuration of sediment layers within the disposed deposit can indicate characteristics such as degrees and uniformity of compaction, while the shape of the predisposal bottom may indicate subsidence of the underlying seafloor. Such settling, if unidentified, could be mistakenly interpreted as a loss of dredged material from the disposal site.

Geophysical surveys are now frequently conducted during archaeological (cultural resource) evaluation of potential disposal sites in the United States. Follow-up subbottom surveys, sediment cores, and geotechnical measurements may be needed to confirm the extent to which compaction and subsidence contribute to apparent losses of material from disposal mounds. Since subbottom surveys are usually performed in conjunction with bathymetric and/or side-scan sonar surveys, spacing and grid dimensions are usually related to those used for the other surveys. A significant thickness (at least 2 ft) of disposed material that is acoustically distinct from the predisposal seafloor will be necessary to obtain beneficial information from subbottom records. Under these restrictions, subbottom information may be used to check the thickness of a protective cap, but this information should be verified with core results.

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