International Conference on Case Histories in Geotechnical Engineering

(1998) - Fourth International Conference on Case Histories in Geotechnical Engineering

12 Mar 1998, 1:00 pm - 2:30 pm

Design of Contaminated Dredged Fills Utilizing Geosynthetics

Ronald C. Chaney
Humboldt State University, Arcata, California

Kenneth Demars
University of Connecticut, Storrs, Connecticut

Gregory N. Richardson
G. N. Richardson and Associates, Raleigh, North Carolina

Recommended Citation

Chaney, Ronald C.; Demars, Kenneth; and Richardson, Gregory N., "Design of Contaminated Dredged Fills Utilizing Geosynthetics" (1998). *International Conference on Case Histories in Geotechnical Engineering*. 4.
https://scholarsmine.mst.edu/icchge/4icchge/4icchge-session10/4

Proceedings: Fourth International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, March 9–12, 1998.

DESIGN OF CONTAMINATED DREDGED FILLS UTILIZING GEOSYNTHETICS

Ronald C. Chaney
Humboldt State University
Arcata, California-USA-95570

Kenneth Demars
University of Connecticut
Storrs, Connecticut-USA-

Gregory N. Richardson
G.N. Richardson and Associates
Raleigh, North Carolina-USA-

Paper No. 10.04

ABSTRACT

Throughout the Great Lakes, about four million cubic yards of sediments are dredged annually to maintain navigation in channels and harbors for commercial, military and recreational users, and as part of environmental projects. CDF design criteria based on contaminant level and partitioning potential of sediments is presented. CDF designs reflect the level of isolation which the sediments under consideration warrant. In this paper the application of geosynthetic components for limiting contaminant pathways in the CDF containment basin and final closure are discussed.

KEYWORDS

contaminant, dredged materials, CDF, geosynthetics, design, sediment

INTRODUCTION

Throughout the Great Lakes, about four million cubic yards of sediments are dredged annually to maintain navigation in channels and harbors for commercial, military and recreational users, and as part of environmental projects. Sediment is primarily composed of clay, silt, and sand particles, organic matter, shells, and can include varying quantities of residuals from industrial discharges polluted by synthetic organic compounds and heavy metals. About one-half of the total amount of sediments dredged (approximately 2 million cubic yards) are sufficiently contaminated to preclude their unconfined release to the environment.

The United States Army Corps of Engineers (USACE) uses confined disposal facilities (CDF's) to contain contaminated sediments which cannot be released without control to the environment and to facilitate settling and disposal of clean sediments. CDFs can be located at both upland and in-lake sites (shoreline and island). CDF designs reflect the level of isolation which the sediments under consideration warrant. In this paper the application of geosynthetic components for limiting contaminant pathways in the CDF containment basin and final closure will be discussed (Demars et al., 1994).

REGULATORY REQUIREMENTS

The Clean Water Act (CWA) governs the discharge of dredged material into "waters of the United States." As shown in Table 1, no discharge of dredged material into US waters is permitted under CWA Section 404 if it causes violations of any applicable State Water Quality Standards (WQS). Dredged materials which can not meet the CWA standards for open water disposal or beneficial use, are considered problematic dredged materials, and must be segregated from the environment to some extent. Sediments which cannot be released to the environment in an unrestrictive manner are labeled problematic dredged material in Table 1 (Richardson et al., 1996). The disposal of problematic dredged materials is the focus of this paper.

The regulatory requirements for the disposal of dredged material are determined by both the type and level of the contaminants associated with the dredged material, as well as the extent to which the contaminants could potentially be released from the sediments to proximal air, ground water or surface water. To date, regulatory concern with most contaminated dredged material disposal projects have been focused primarily on containment of release routes to water. This is reflected in Table 1, which presents a conceptual plan for containment which considers the level of sediment contamination, the degree of contaminant partitioning to the water associated with the sediments, in conjunction with three categories under which sediment disposal can occur and the significant disposal regulations. As depicted on Table 1, these three conceptual approaches to dredged material disposal are labeled "beneficial use or open water disposal," "solids retention" and "hydraulic isolation."

The USACE uses confined disposal facilities (CDFs) to contain contaminated sediments which may not be released without control to the environment and to facilitate settling and disposal of clean sediments. CDF designs reflect the level of isolation which the sediments under consideration warrant. CDF designs can be grouped under two headings; CDFs which isolate the sediments and any derived effluent from the adjacent environment (hydraulic isolation).

Dredged materials contain large amounts of water. Depending upon the method used to excavate the materials, dredged materials are typically composed of 50 to 95% water by weight. The disposal of large quantities of material with high percentages of both solids and water presents both technical and regulatory challenges unique to dredged materials. Generally, the disposal of wastes which have a high percentage of water is regulated by the CWA while the disposal of waste high in solids is regulated under RCRA. Given large quantities of water and solids, CDFs commonly incorporate considerations from both regulatory program requirements into their designs.

Most contaminants are tightly bound (sorbed) to the solids which compose the sediments. Consequently, a principal criterion of CDF designs has been the retention of as high a percentage of the dredged material solids as practical. CDFs which retain the contaminated dredged material also retain and isolate most of the contamination from the environment. CDF designs premised upon this approach are included under the portion of Table 1 labeled "solids retention". Increasing levels of contaminant concentrations would be reflected in CDFs with an increasing degree of sediment isolation. This is generally reflected in more elaborate CDF designs aimed at the removal of lower concentrations of suspended solids from the water entrained with the sediments during the dredging process. In the absence of significant partitioning of contaminants to the associated free water phase, and given the removal and retention by the CDF of the sediment solids, this approach has been environmentally acceptable. Satisfactory design, performance, and monitoring of CDFs requires the evaluation of all potential pathways and a clear understanding of the partitioning of the contaminant between the dredged material particles and the impacted waters.

CDF BASIN DESIGN

The containment basin of a CDF is formed by perimeter dikes and the subgrade of the site. Water can potentially leave the basin as a non-point source by either seepage through the perimeter dikes or by leaching into the underlying subgrade. The control of either pathway is therefore dependent upon limiting hydraulic gradients and/or the design of a barrier to limit advective transport of contaminants, or design of a filter to attenuate the flow of the dredged material itself.

Water carried by the dredged sediments must be removed from the CDF to provide space for additional sediments and to develop a stable base for construction of the final cover over the dredged material. Effluent can leave the CDF by seeping through perimeter filter dikes or through a weir point discharge system. The latter is particularly attractive if the effluent must be processed to remove or attenuate contaminants. Monitoring of effluent release through conventional CDF dikes (Schroeder, 1983) indicates that point discharges from porous zones in the dikes occur rather than physically isolate the sediment solids from the adjacent environment (solids retention) and CDFs which hydraulically uniform seepage along the entire dike structure. Effluent seepage through the dikes can be limited by controlling the level of effluent within the CDF or by designing a impermeable barrier layer into the dike as shown on Table 2 and Fig 1 (Richardson et al., 1996).

Integration of barrier systems into CDF dike sections must (1) not impair the stability of the dike, (2) allow construction of the barrier using conventional technology, and (3) key into a lower permeable layer to minimize effluent discharge beneath the dike.

STABILITY OF THE DIKE

The importance of barrier element stability within a dike has been demonstrated at the Chicago CDF. The design dike section, shown on Fig. 2a, incorporates an impervious membrane beneath the armor stone on the disposal side of the dike. Placed on the 3H:2V slope (33.8^{0} slope angle), the membrane creates a sliding failure plane due to its surface smoothness. Typical interface friction angles for various membranes range from as low as 8 degrees for a smooth sheet to as much as 28 degrees for a textured sheet. A prior knowledge of the low interface friction values for such membranes would have alerted the designer to the eventual sliding failure that developed. The membrane stability problem at the Chicago CDF could have been eliminated by using a barrier system that has a higher interface friction angle, by reducing the slope angle of the membrane, or by increasing the thickness of the disposal side armor stone such that it would have been self buttressing. Barrier systems offering higher interface friction angles include a non-woven geotextile or graded soil filters. Such systems can be designed to be clogged by the effluent. Alternatively, the layers of "B" and "C" stone on the disposal side could have been replaced with a grout filled fabriform barrier that provides both erosion control and a low permeability barrier, see Fig. 2b.

SUMMARY AND CONCLUSIONS

Containment and isolation are important components in the regulation of contaminated sediment disposal in the U.S.A. The basic design considerations are to control all potential contaminant migration pathways. The applicable regulations covering the disposal of contaminated sediments is shown to be a function of both the concentration of contaminant and the partitioning coefficient for the contaminant in water. Those sediments that have very low levels of contamination or are contaminated with constituents having a very low solubility in water, e.g. having a low partitioning coefficient can be controlled by designing the CDF for solids retention. For higher concentrations of contaminants or for contaminants having high partitioning, the CDF must be designed based on hydraulic isolation of the waters released by the sediments.

Uncontaminated Sediments

Highly Contaminated Sediments

CWA 404 Guidance

Partitionong > State WQS or not Meeting CWA 404

Significant Partitioning

	PROBLEMATIC SEDIMENTS			
Minor Sediment Contamination Minimal Partitioning	Minor Partitioning	Moderate Partitioning	Extensive Partitioning	RCRA/TSCA Sediments
Beneficial Use or Open Water Disposal Passes 404 Evaluation for Open Water Disposal CWA 401 Certification for Dredged Material Discharge	Solids Retention Approach Increasing Degree of Sediment Isolation Filter Intake CDFs CWA 401 Certification for Discharge	Hybrid Approach Hydraulic Isolation During Sediment Disposal Only CWA 401 Certification for Point or Diffuse Discharge	Hydraulic Isolation Approach Increasing Degree of Hydraulic Isolation CWA 401 Certification for Point Discharge	Hydraulic Isolation CDF MTG Design (Appendix E) CWA 401 Certification for Point Discharge CWA 402 Permit for a Point Discharge TSCA "Third Alternative" Design, 40 CFR 761.60(a)(5) Conformance with RCRA-C Minimum Technology Guidance

←— 87 USACE CDF DESIGN MANUAL —→

←— SHORELINE AND IN-LAKE CDF DESIGNS —→

←— UPLAND CDF DESIGNS —→

←— REGION 5 CDF GUIDANCE DESIGNS —→

←— CWA SECTION 404 AND EPA/USACE FRAMEWORK —→

— INCREASING DEGREE OF SEDIMENT CONTAMINATION —→

Table 1 Summary of Regulations

	Barrier System	Barrier Location*	COE Usage	In-Lake CDF	Shoreline CDF	Upland CDF
Impermeable	Compacted Clay Liner (CCL)	C		N/A	N/A	●
	Geomembrane Liner (GML)	C	X	○	○	●
	Geosynthetic Clay Liner (GCL)	C		N/A	○	●
	Geomembrane Cut-off Wall	A		●	●	●
	Bentonite Slurry Cut-off Wall	A	X	●	●	●
	Fabric Form w/ Grout	C		●	●	●
Low permeable						
	Clean 'Fine' Sediments	C		●	●	●
	Clogged Geotextile	C	X	○	●	N/A
	Graded Soil Filter	B	X	○	●	●
	Fabric Form w/Sand	C		●	●	N/A
	N/A NOT APPLICABLE ● Good Application ○ Maybe Difficult to Construct					

* Barrier Locations

Table 2. Dike Barrier System Application in CDF's

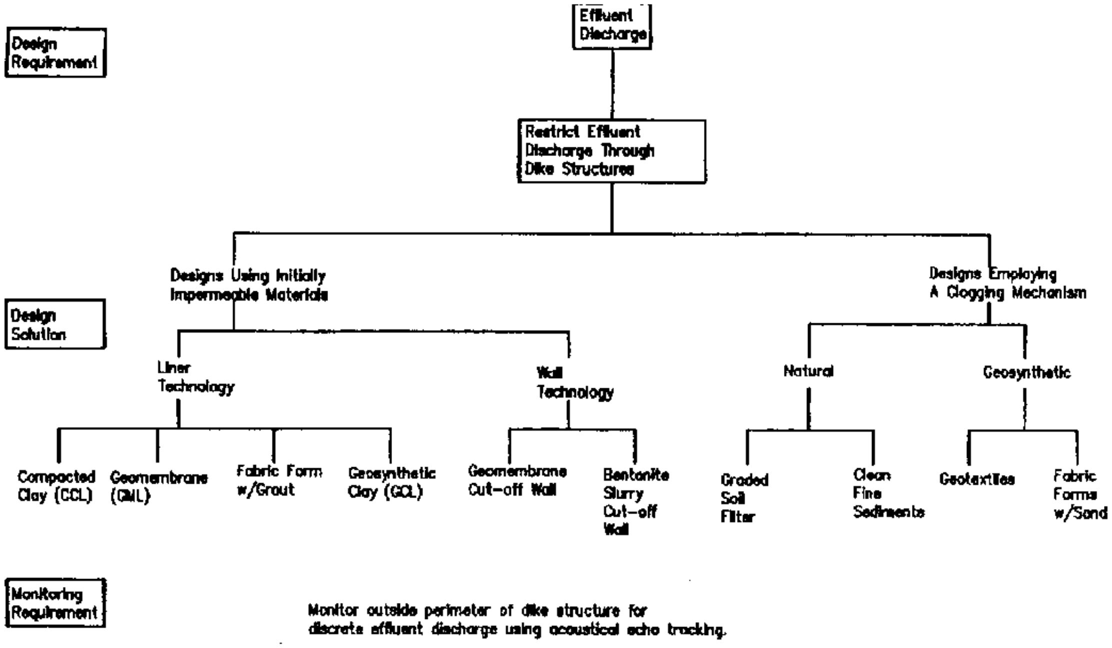


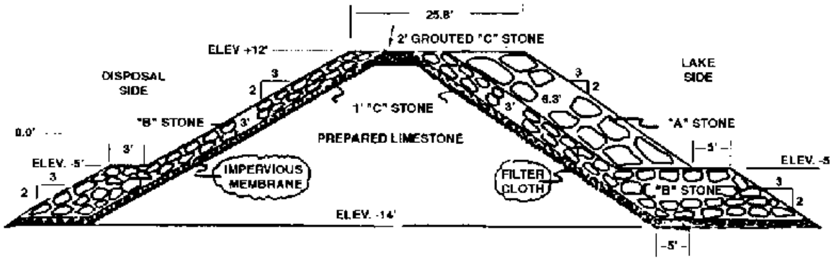
Fig. 1 Effluent Dike Discharge Control

REFERENCES

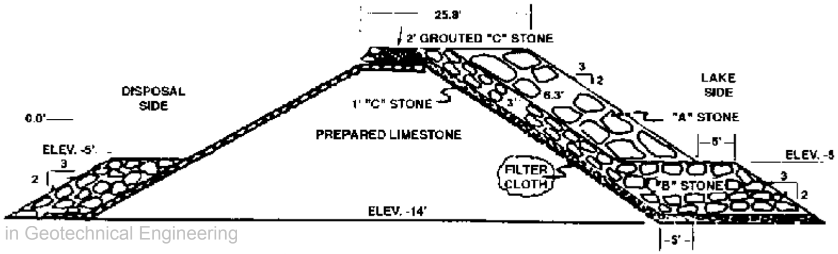
Demars, K. R., Richardson, G.N., Yong, R.N., and Chaney, R.C. editors (1994). "*Dredging, Remediation and Containment of Contaminated Sediments*", STP 1293, American Society for Testing and Materials, Philadelphia.

Richardson, G.N., Chaney, R.C., and Demars, K. R. (1996) "*Design, Performance, and Monitoring of Dredged Material, Confined Disposal Facilities in Region 5: Guidance Document*," U.S. Environmental Protection Agency, Chicago, Illinois. EPA 905-B-96-003

Schroeder, P.R. (1983). Chemical Clarification Methods for Confined Dredged Material Disposal, Technical Report D-83-2, Department of Army, Waterways Experiment Station, Vicksburg, MS.



A. Chicago CDF Dike Section



B. Grout Filled Fabric Form Barrier

Fig. 2 Chicago CDF Dike Section