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DREDGED MATERIAL RESEARCH: NOTES, NEWS, REVIEWS, ETC. VOLUME D---ETC(U)
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DREDGED MATERIAL RESEARCH: 12

Notes, News, Reviews etc. Volume D-77-1

U. S. ARMY CORPS OF ENGINEERS
INFORMATION EXCHANGE BULLETIN

Vol D-77-1
11 Jan 1977
12 16p.

NOTES • NEWS • REVIEWS etc

PUBLIC LAW 94-587—OCT. 22, 1976

Coulee Dam for the purpose of identifying navigational hazards and preparing maps of the river channel at an estimated cost of $500,000, and providing information necessary for establishment of aids to navigation.

SEC. 148. The Secretary of the Army, acting through the Chief of Engineers, shall utilize and encourage the utilization of such management practices as he determines appropriate to extend the capacity and useful life of dredged material disposal areas such that the need for new dredged material disposal areas is kept to a minimum. Management practices authorized by this section shall include, but not be limited to, the construction of dikes, consolidation and dewatering of dredged material, and construction of drainage and outflow facilities. *33 USC 419a.*

SEC. 149. The Secretary of the Army, acting through the Chief of Engineers, is hereby authorized and directed to remove Shooters' Island located north of Staten Island, New York, at the mouth of Arthur Kill and to utilize such removed material for fill and widening of Arthur Kill. *Shooters' Island, N.Y., removal.*

SEC. 150. The Secretary of the Army, acting through the Chief of Engineers, is authorized to plan and establish wetland areas as part of an authorized water resources development project under his jurisdiction. Establishment of any wetland area in connection with the dredging required for such a water resources development project may be undertaken in any case where the Chief of Engineers in his judgment finds that— *Wetland areas. 42 USC 1962d-5e.*

(1) environmental, economic, and social benefits of the wetland area justifies the increased cost thereof above the cost required for alternative methods of disposing of dredged material for such project; and

(2) the increased cost of such wetland area will not exceed $400,000; and

(3) there is reasonable evidence that the wetland area to be established will not be substantially altered or destroyed by natural or man-made causes.

(b) Whenever the Secretary of the Army, acting through the Chief of Engineers, submits to Congress a report on a water resources development project after the date of enactment of this section, such report shall include, where appropriate, consideration of the establishment of wetland areas. *Report to Congress.*

(c) In the computation of benefits and cost of any water resources development project the benefits of establishing of any wetland area shall be deemed to be at least equal to the cost of establishing such area. All costs of establishing a wetland area shall be borne by the United States. *Costs.*

SEC. 151. The project for the Chief Joseph Dam authorized by the Act of July 2, 1946 (Public Law 525, 79th Congress) is modified to ... the Secretary of the Army, acting through the Chief of ... such temporary school facilities as he may deem ... of dependents of persons engaged in the ... power facilities at Chief ... determines it to be ... Engi- *Chief Joseph Dam, Wash., project modification. 60 Stat. 634. Cooperative arrangements.*

SPECIAL EDITION—*Planning for Secs. 148 and 150 of* PL 94-587

SECTIONS 148 AND 150 AND THE DMRP

On 22 October 1976, the President of the United States signed into law the Water Resource Development Act of 1976 (PL 94-587). Two sections of this law, Sections 148 and 150, are of particular interest and significance to those concerned with the environmental effects of dredging and dredged material disposal and alternative disposal methods. The first of these sections (as can be seen from the full text contained on the cover of this bulletin) is concerned with the utilization of management practices to extend the useful life of disposal areas, and the second with establishing wetland areas as part of authorized water resource development projects. While there is no apparent direct link between this enabling legislation and the activities and results of the Dredged Material Research Program (DMRP) from the standpoint of origin of the concepts and impetus, the legislation does open the door to the application of DMRP-generated technology on a major scale. In fact, it is not unreasonable to conclude that effective implementation of the requirements of either of these sections of the law is not possible without reference to or use of the results of DMRP research.

To assist Corps operating elements in planning for implementation of Sections 148 and 150, the DMRP staff has carefully reviewed the entire program specifically from the view of identifying all completed or active studies that are relevant to the new legislation. Of a current total of 220 work units in the DMRP, 82 are considered sufficiently applicable to warrant discussion.

Since many of the applicable work units are still active, there is a minimal amount of results in final and/or synthesized form that can be conveyed at this time. Even though minimal, that which is available is too voluminous to be summarized in usable form in a document as brief as this bulletin. Consequently, the mode of presentation selected for use herein is designed to serve basically as a reference or key to existing and expected DMRP information rather than a presentation of information per se. The vehicle selected to serve as the base for the key is a form of logic diagram or decision matrix reflecting the sequence of steps and considerations that a Corps operational element will apply to any given project. Although not readily apparent, the matrices included herein (one for each section of the law) reflect a large amount of knowledge and experience gained by the DMRP staff through its involvement in conceptual, laboratory, and field investigations. The individual factors or considerations listed are those that have been proven, through experience and trial-and-error, to be critical to the success of both disposal site management and wetlands development.

This issue of the bulletin was prepared by the staffs of the Disposal Operations (DOP) and Habitat Development (HDP) Projects of the DMRP under the direct supervision of Mr. C. C. Calhoun, Jr., and Dr. H. K. "Bo" Smith, Managers, respectively, of the DOP and the HDP. Coordination, review, and general supervision were provided by Dr. R. T. Saucier, Special Assistant for Dredged Material Research, Environmental Effects Laboratory of the Waterways Experiment Station (WES).

SECTION 148—DISPOSAL AREA MANAGEMENT TECHNIQUES

To date, there have been few cases of the application of planned management practices to confined dredged material disposal areas. With few exceptions, material is placed in an area and left unattended until the time approaches to place additional material at the site again. Consequently, dredged material that characteristically is fine grained (silt and clay) is retained in the containment area at very high water contents. It is not unusual to find water-to-sediment ratios of two or more parts water for every part of solid sediment in the area. Therefore, the retention dikes serve essentially as dams, holding back large quantities of water and relatively small quantities of solids. Through the application of proper design and management techniques, much of the water can be removed from a disposal area, thereby increasing its effective storage capacity.

Although the primary purpose of removing water is to obtain additional capacity, the physical and engineering properties of the material are also improved, thus the material is much easier to rehandle and to be put to some productive use. If the material is removed from the site, the site can then be reused as a containment area. The goal of these management techniques is to extend the service life of containment areas, which, of course, means requirements for additional sites are reduced. A reduction in the number of sites required to contain dredged material yields obvious economic and environmental benefits.

In the initial planning stages of the DMRP, a need to develop management techniques for increasing the service life of containment areas based on sound engineering and scientific principles was identified and given high priority. A major part of the work within the DMRP DOP has been aimed at developing management guidelines for confined disposal areas. Significant contributions have also been made by the Environmental Impacts and Criteria Development (EICDP) and Productive Uses Projects (PUP). The results of this work have prompted a rapidly developing state-of-the-art and knowledge that has coincided fortuitously with the passage of this enabling legislation.

MANAGEMENT GUIDELINES

It has been the consistent philosophy of the DOP that integrated disposal area management must be considered from the earliest planning stages of a project. Consequently, the planning, design, construction, and management phases of containment areas should be considered as a whole with none of the phases standing alone. The simplified decision network shown in Figure 1 has been developed to indicate how and where the management guidelines being developed may be applied. Figure 1 is not intended to be a complete decisionmaking network but can be used to identify critical areas where management decisions should be considered. Since environmental considerations may dictate the location of a new site or govern the continued use of an existing site, an evaluation of these considerations must be made in developing the overall management scheme and hence are included in Figure 1.

Work units or specific efforts within the DMRP that are directly applicable to the development of these guidelines are shown in Table 1 with the numerical designations that they carry under the DMRP and that will be used in this discussion. It is difficult, however, to determine how the numerous work units fit into the overall management scheme from inspection of Table 1. The following discussion, keyed to Figure 1, is intended to clarify the work unit/management scheme relationships.

The reader should also keep in mind that more detailed guidance is being prepared in many areas and will be available in separate report form from the DMRP within the next year or so. Where guidance is being developed in a particular area, the specific work unit is cited throughout the text for further reference. It should be emphasized that information from all work units will be synthesized into a condensed, more usable form as one end product of the DMRP.

PRELIMINARY PLANNING

After a dredging project has been authorized, all disposal alternatives are candidates for consideration as shown in Figure 1; however, only the logic that applies when *confined disposal* [1]* is being considered or has been selected is pursued in this figure.

The *in situ volume of sediment* to be dredged over the design life of the containment area must first be determined [2]. This involves more than simply determining from surveys the amount of material to be removed, for a determination of the type and density of material must be made (4A16A, 5A19).** Once this essential information has been acquired, the *containment area volume* required (considering no management techniques) is determined [3] (4A16A, 5A19). This provides the worst or "do-nothing" case (most volume required) to which the benefits of the management techniques may be related.

Effluent water-quality and other environmental protection requirements (such as leachate control) must be established [4] (2D01, 2D02, 2D04, 2D05, 6B05). Other *potential environmental problems* (such as odors, noise, and mosquitoes) should not be overlooked [5] (2C06, 2C11, 2C12).

From the previously determined information [1]-[5], a *preliminary plan* for containing the material should be developed [6]. This plan should consider the maximum volume of containment area required, the environmental protection measures needed, and a consideration of all available potential sites (4A16A, 2C06).

DISPOSAL SITE SELECTION

At this point, two basic alternatives are generally available. Either a containment area may be built at a new site or an existing area may be reused.

* Refers to similarly numbered boxes in Figure 1.
** Refers to similarly numbered work units in Table 1.

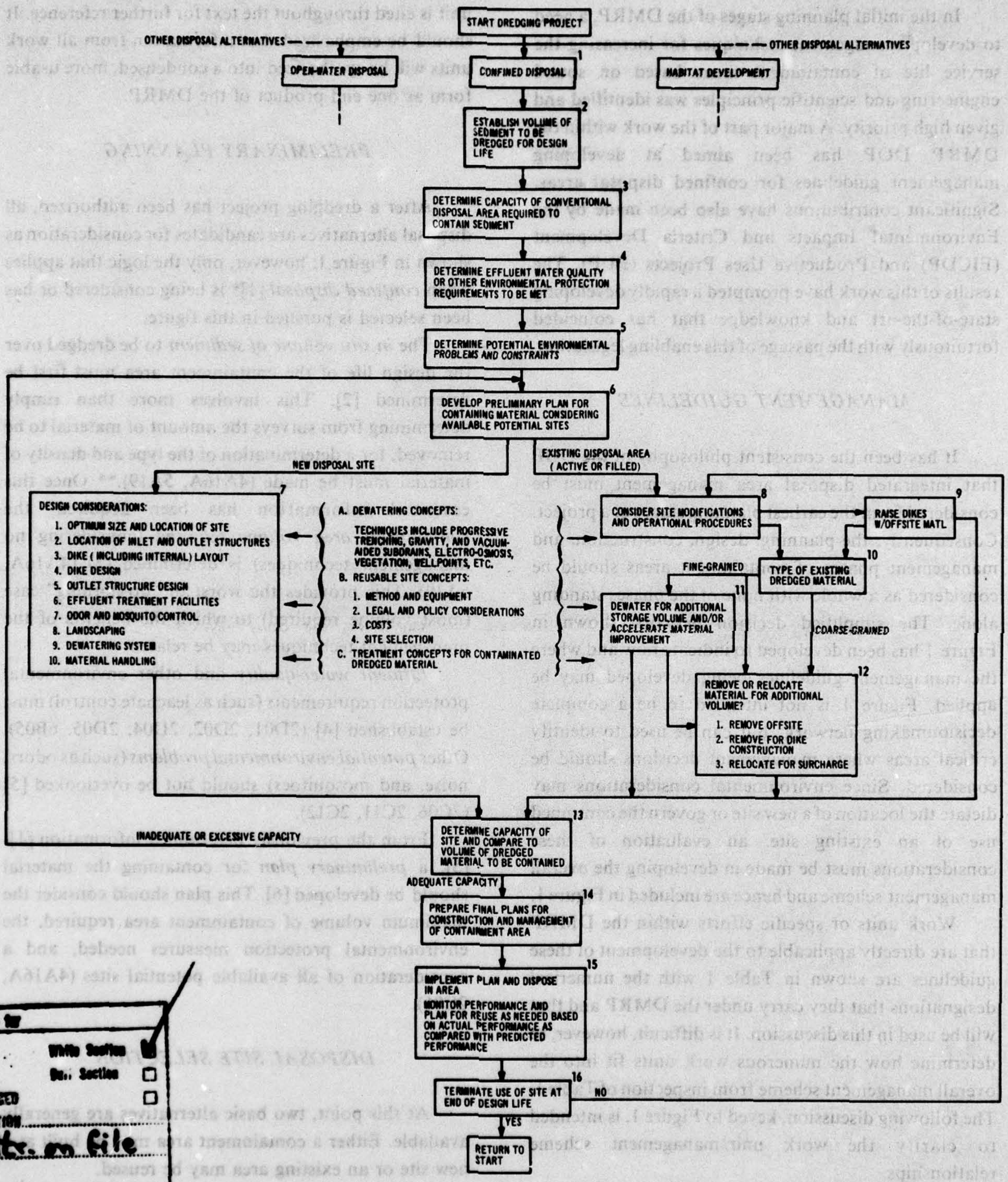


Figure 1. Dredged material disposal—management decision network

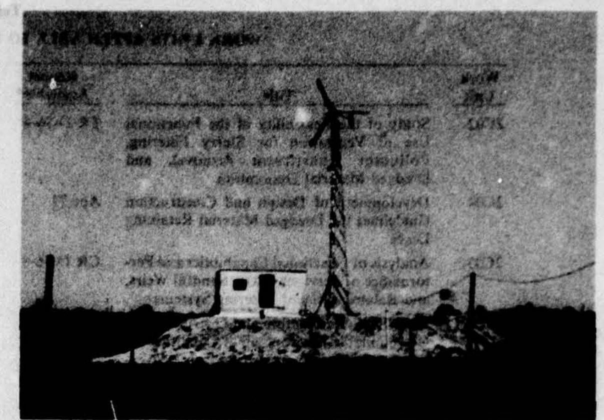
Table 1

WORK UNITS APPLICABLE TO DISPOSAL AREA MANAGEMENT

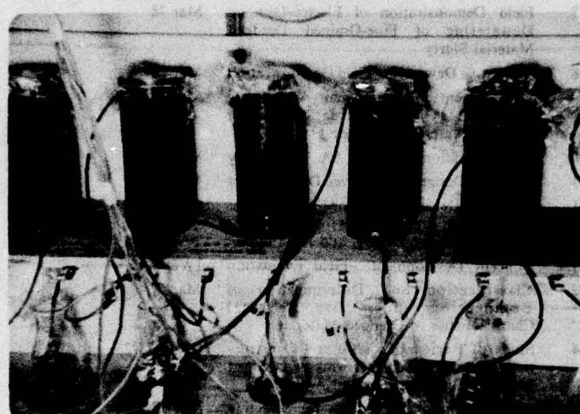
Work Unit	Title	Report Available*
2C02	Study of the Feasibility of the Functional Use of Vegetation for Slurry Filtering, Pollutant Constituent Removal, and Dredged Material Desiccation	TR D-76-4
2C04	Development of Design and Construction Guidelines for Dredged Material Retaining Dikes	Apr 77
2C05	Analysis of Functional Capabilities and Performance of Pervious Dikes, Sandfill Weirs, and Related Effluent Filtering Systems	CR D-76-8
2C06	Identification of Nature and Distribution of Objectionable Environmental Conditions in Confined Disposal Areas	CR D-74-4
2C09A	Development of Concepts Using Low-Ground-Pressure Construction Equipment for Containment Area Operation and Maintenance (Equipment Inventory)	Jul 77
2C09B	Development of Concepts Using Low-Ground-Pressure Construction Equipment for Containment Area Operation and Maintenance (Development of Field Evaluation Investigations)	Jul 77
2C09C	Procedures and Practices Used in Construction, Maintenance, and Management of Dredged Material Containment Areas	Jul 77
2C10	Demonstration of Dredged Material Drying by Use of Vegetation	Aug 77
2C11	Investigation of Physical, Chemical, and/or Biological Treatment for Odor Control in Dredged Material Disposal Areas	CR D-76-9
2C12	Investigation of Physical, Chemical, and/or Biological Control of Mosquitos in Dredged Material Disposal Areas	Dec 77
2C14	European Dredging and Disposal Practices	May 77
2C15	Field Investigation of the Functional Use of Vegetation to Filter and Remove Contaminants from Existing Dredged Material Disposal Areas	Input to 2D01
2C16	Containment Area Design to Maximize Effectiveness of Confined Disposal Areas	Oct 77
2C17	Public Information Brochure Regarding Land Planning Principles and Landscape Design Concepts for Confined Dredged Material Disposal Facilities	Jan 77
5E01	Landscaping Concept Development for Confined Dredged Material Disposal Site	CR D-75-5
4A16A	Performance of Containment Areas Filled with Dredged Material	Aug 77
2D01-2D03	Physical and Chemical Characterization of Contaminated Dredged Material Influents, Effluents, and Sediments in Confined Upland Disposal Areas	Jul 77
2D02	A Study of Leachate from Dredged Material in Upland Disposal Sites and/or in Productive Uses	Apr 78
2D04	Characterization of Confined Disposal Area Influent and Effluent Particulate and Petroleum Fractions	Oct 77
2D05	Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas	Apr 78
5A02	Laboratory Study of Dredged Material Slurry Water Loss Due to Mechanical Agitation	Jan 76**
5A03	State-of-the-Art Survey and Evaluation of Current Physical, Mechanical, and Chemical Dewatering and Densification Techniques	Jul 77
5A04	A Laboratory Study to Determine the Variables that Influence the Electro-Osmotic Dewatering of Dredged Material	IWD†
5A05	A Laboratory Study of Aeration as a Feasible Technique for Dewatering Fine-Grained Dredged Material	CR D-76-10
5A06	Feasibility Study of General Crust Management as a Technique for Increasing Capacities of Dredged Material Containment Areas	Jul 77
5A07	Feasibility of Frost Action for Densification of Dredged Material	Jul 77
5A08	Mobile (Alabama) Field Study	Mar 78
5A09	Feasibility Study of Consolidating Fine-Grained Dredged Material with Windmill-Powered Vacuum Wellpoints	Mar 78
5A10	Development of Capillary Enhancement Devices for Dewatering Fine-Grained Dredged Material	Mar 78
5A11	Feasibility of Injecting Fine-Grained Sand Slurry into Dredged Material	IWD
5A13	Containment Area Management as a Means of Promoting Densification of Fine-Grained Dredged Material	May 77
5A14	Mechanical Stabilization of Fine-Grained Dredged Material by Periodic Mixing in of Dried Surface Crust	IWD**
5A15	Field Evaluation of Slurry Densification by Underdrainage Techniques	Mar 78
5A16	Development of Dewatering Alternatives Manual for the Mobile District	Mar 78
5A17	Field Demonstration of Electro-Osmotic Dewatering of Fine-Grained Dredged Material Slurry	Mar 78
5A18	Vegetative Dewatering Field Demonstration	Mar 78
5A19	Development of Containment Area Sizing Methodology Considering Effects of Dredged Material Dewatering	Mar 78
5A20	Implementation of Task 5A Technology	Mar 78
5A21	Task 5A Design Alternatives Development	Mar 78
5C01	Concept Development for Appurtenant Containment Area Facilities for Dredged Material Separation, Drying, and Rehandling	CR D-74-6
5C01A	Concept Development...-Field Evaluation	IWD
5C02	Classification and Determination of Engineering and Other Physical Characteristics of Dredged Material	Mar 77
5C04	Study of Regional Landfill and Construction Material Needs in Terms of Dredged Material Characteristics and Availability	CR D-74-2
5C05	Development of Procedures for Selecting and Designing Reuseable Dredged Material Disposal Sites	Nov 77
5C06	Investigation of Legal, Policy, and Institutional Constraints Associated with Dredged Material Marketing and Land Enhancement	CR D-74-7
5C07	Feasibility Study of Vacuum Filtration Systems for Dewatering Dredged Material	Aug 77
5C08	Identification of Alternative Power Sources for Dredged Material Disposal Operations	Jun 77
5C09	Survey of Districts for Needs and Areas of Potential Application for Disposal Area Reuse	Mar 78
5C11	Development of Methodology for Designing Fine-Grained Dredged Material Sedimentation Basins	Mar 78
6B01	Assessment of Chemical, Physical, and Biological Processes for Treatment of Dredged Material	IWD
6B02	Laboratory Treatability Studies of Polluted Dredged Material	TR D-76-2
6B05	An Evaluation of Oil and Grease Contamination Associated with Dredged Material	May 77
6B07	Flocculation as a Means for Water-Quality Improvement from Disposal of Dredged Material in Confined Areas	Oct 77
6B08	Development and Application of Design and Operational Procedures for Coagulation of Dredged Material Slurries and Diked Area Effluents	Nov 77
6B09	Field Verification of the Functional Use of Vegetation to Remove Contaminating Constituents of Effluents from Dredged Material Disposal Areas	Apr 77

* CR—Contract Report; TR—Technical Report; IWD—Internal Working Document.
** To be combined with Work Unit 5A20.
† To be combined with Work Unit 5A17.

Equipment used in large-scale controlled laboratory experiment to investigate the effect of surface agitation on the drying rate of dredged material slurry (Work Unit 5A02)

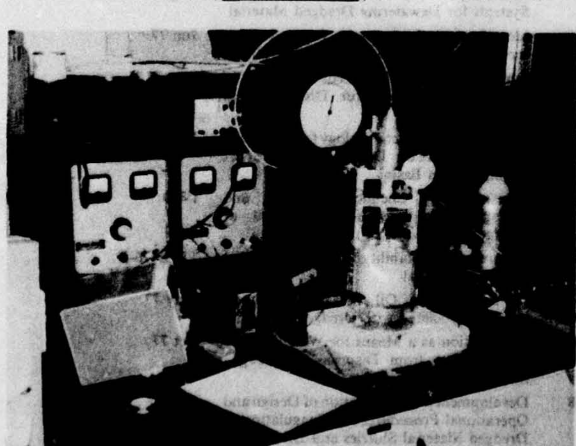


Windmill located on perimeter dike powers vacuum and water pumps (Work Unit 5A09)



Electro-osmotic drying of fine-grained dredged material, indicated by the light-colored portion of the samples, being carried out in the laboratory of KMA Research Institute, Mesa, Arizona (Work Unit 5A04)

Mixing sand slurry grout for pressure injection into dredged material to create drainage layer (Work Unit 5A11)



Special apparatus developed to determine the consolidation caused by successive freeze-thaw cycles in fine-grained dredged material (Work Unit 5A07)

One of four 24 × 24 m test pits with different underdrain configurations used to evaluate the effectiveness of underdrains to dewater fine-grained dredged material (Work Unit 5A15)

Figure 2. Laboratory and field investigations of dewatering techniques

New Disposal Sites

In Figure 1 consideration of a new area is shown on the left. Numerous factors must be considered in the *design* of a new containment area, some of which are listed in Figure 1 [7]. The actual design selected will usually depend upon the management system adopted. Two major management concepts that may be considered are shown in Figure 1 as {A} and {B} along with guidance on developing, if required, treatment systems for contaminated material {C}.

If the sediment to be dredged is fine grained, *dewatering* {A} the dredged material may provide significant additional effective volume in the containment area. The feasibility of various dewatering techniques has been or is being investigated by the DMRP in the laboratory and/or field (Figure 2). Concepts include progressive trenching (5A08), gravity and vacuum-aided subdrains (5A03, 5A11, 5A15), low voltage gradient electro-osmosis (5A04, 5A17), vegetation (2C02, 2C10, 5A18), vacuum wellpoints (5A09), aeration (5A05), capillary wicks (5A10), mechanical stabilization (5A14), natural frost action (5A07), and general operations and desiccation crust management (5A02, 5A06, 5A13, 5A16). All initial feasibility studies have been completed, and field studies are under way and will be completed in mid-1977. All major field studies are being conducted at the Upper Polecat Bay Disposal Area on the Mobile River (Figures 3 and 4). The field studies are being coordinated through and assistance is being obtained from the Mobile District. Much unpublished information is presently available on the feasibility of the concepts, operational problems, time and rates of dewatering, and costs and will be incorporated in the final reports and synthesis documents.

The second major management scheme {B} involves *reuse concepts*, i.e., reuse as a disposal area. The basic idea is to use the containment area essentially

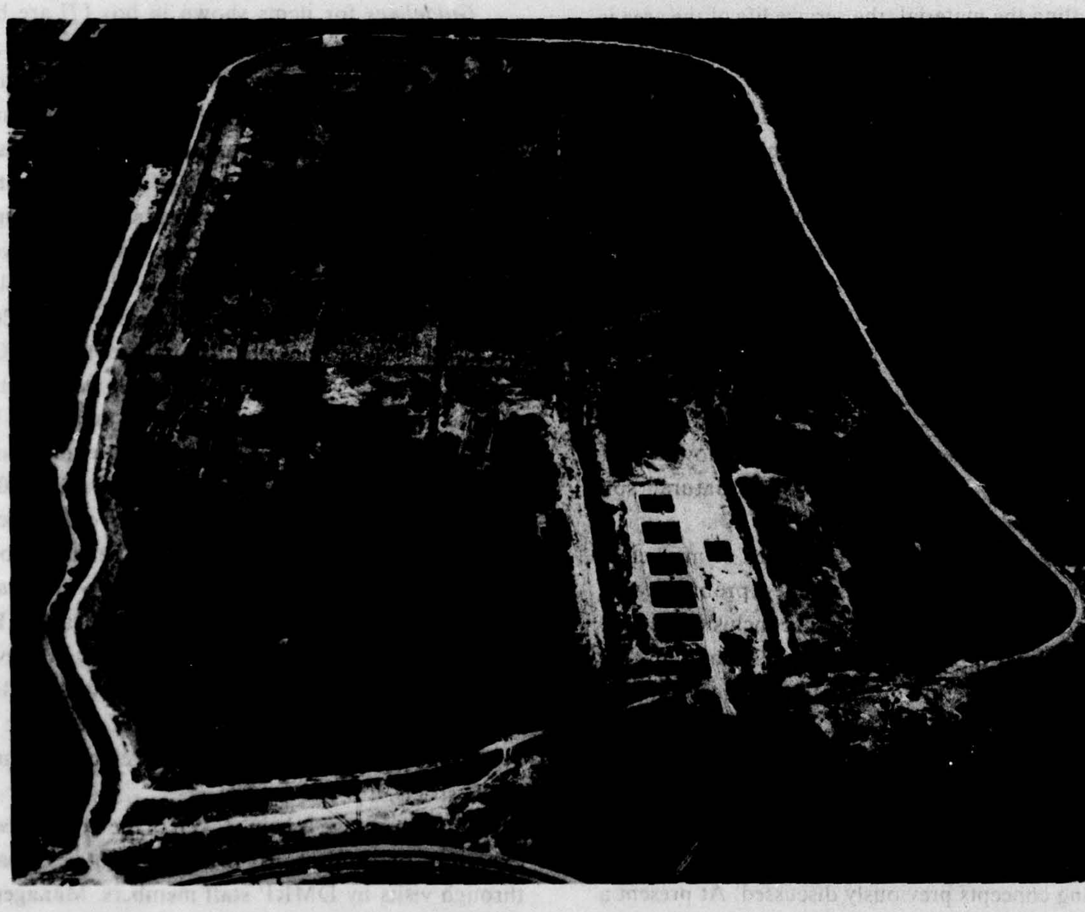


Figure 3. Test site and field demonstrations at the Upper Polecat Bay Disposal Area, Mobile, Alabama

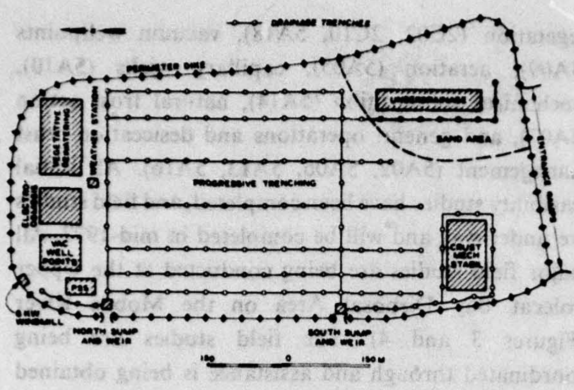


Figure 4. Layout of dredged material dewatering field demonstration areas, Upper Polecat Bay disposal site, Mobile, Alabama

as a rehandling basin. Ideally all material placed in the area would be removed and put to a productive use. Realistically, it is doubtful that an ideal case will occur; consequently, in DMRP terminology, reusable disposal site concepts include areas where, through management or rehandling the material, the service life of the area is significantly extended rather than prolonged indefinitely. Initial DMRP studies dealt with development of techniques for separating, drying, and rehandling of dredged material to promote removal for productive use (5C01, 5C01A). Later studies have been aimed at refining the concepts (5C07, 5C08, 5C11).

A study has been completed to determine the potential use of dredged material as landfill or construction material (5C04). It was found that numerous potential needs exist for the material. A companion study (5C02) was designed to dispel the rather widespread public opinion that dredged material is always undesirable gunk. This study showed that dredged material basically consists of natural soil materials that may be used as such.

If dredged material is to be donated or marketed, legal or policy problems may arise. These problems were investigated (5C06) with the general conclusion that, in most cases, legal processes are available that allow for removing and marketing or donating the material.

An overall strategy for developing reusable disposal sites (5C05) is being developed which will provide guidelines with respect to site selection, design, management, and costs. It is obvious that in many cases the reusable site concepts are dependent on the dewatering concepts previously discussed. At present a DMRP team is visiting District offices (5C09) to outline reusable containment area concepts and obtain feedback on their operational feasibility and practicality.

Although not a management technique for directly increasing the capacity of a containment area, guidelines are being developed for *treatment technology* {C} for the cases where effluent from a containment area must be treated. First, significant physicochemical interactions within a containment area that influence effluent quality are being identified (6B05, 2D01, 2D02, 2D05) for a better understanding of processes and the development of a predictive capability. Treatment of the material either chemically or biologically was next considered in general (6B01, 6B02) as an operational alternative; presently, specific treatment techniques using chemicals (6B07, 6B08), vegetation (6B09, 2C15), and filtering (2C05) are being refined.

Although few reports have been published to date on studies relating to the three general concepts previously discussed, {A, B, C}, DMRP staff members can discuss and provide interim results.

Guidelines for items shown in box [7] are being developed. A study of the disposal site area needed to ensure that effluent quality will be met is currently under way (5C11). This relates closely with guidance on site configuration, including the need for interior dikes and optimizing the locations of inflow and outflow structures (2C16). Of major importance is the design of dikes and outlet structures to ensure that a stable system will exist (2C04). Guidance will also be available on odor and mosquito abatement strategies (2C11, 2C12) and overall landscaping of a disposal area (5E01, 2C17).

An inventory of *specialized equipment* that can operate in and around containment areas has been developed (2C09A), and promising equipment is presently being evaluated in the field (2C09B, 2C09C). The most promising and in fact the only piece of equipment found that can operate and perform work in most containment areas containing fine-grained dredged material is the Riverine Utility Craft or RUC (Figure 5). The RUC has been described in previous DMRP Information Bulletins, and there is a backlog of requests by Corps Districts for its use. Steps are now being taken to obtain more of these vehicles for use by the Districts.

Full advantage is being taken of the *experience and expertise* of Europeans (2C14) and the Japanese through visits by DMRP staff members. Management techniques used in these countries are in some respects

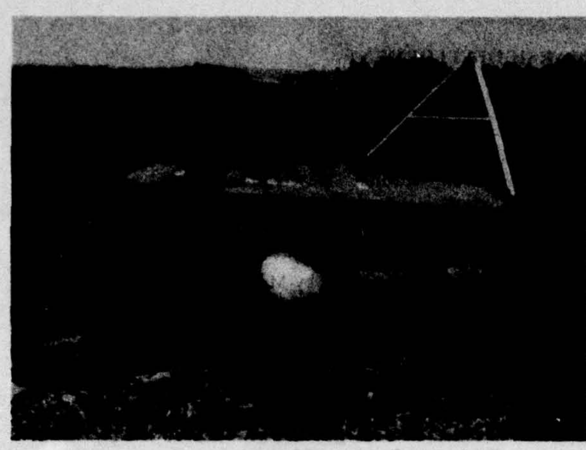


Figure 5. The RUC, pictured above, can operate in extremely soft soils in dredged material disposal areas to perform management tasks

far superior to those in the United States and will be reported so as to broaden the base of options to be considered.

Existing Disposal Areas

If *existing disposal areas* are available and have potential for reuse, management of these areas should be considered. The site may have to be modified and operational changes made [8] to make the most efficient use of the site. Included would be most of the design considerations shown in box [7] and the application of the techniques shown as {A, B, C}.

Probably the first consideration would be to *raise the dikes*. The method often used would be to raise the dikes with offsite material [9], and guidance is being developed on the design of such dikes (2C04). However, consideration should be given to the material existing in the site [10].

If the material is fine grained and saturated, *dewatering* would provide needed additional site volume [11] and might be useful in improving the material so it can be used to raise existing dikes or implement reusable disposal site concepts [12]. If the material is coarse grained, raising the dikes or implementing the reusable site plan will be simplified since dewatering will not be necessary.

SITE CAPACITY

After steps [1] through [12] have been considered, the next step is to determine the *final capacity* of the site [13]. Guidelines are being developed to enable the designer to predict the volume gained [3] by implementing dewatering and/or reuse concepts (5A19, 5A20, 5A21, 5C11). If the capacity of the site is inadequate or is excessive, redesign will be necessary as indicated in Figure 1. If the capacity of the managed site is adequate, *final plans* should be prepared [14]. The detailed plans may be developed by applying most of the technology previously discussed.

SITE PERFORMANCE

Once a plan is chosen and implemented, the *performance* of the site should be monitored and documented [15]. As with any plan, changes may be needed after actual performance is observed and assessed. Guidance will be given in the final reports of the DMRP concerning recommended monitoring and documentation procedures. For the interim, when concepts are being considered for implementation by a District, the staff of the DOP are available to provide guidance and assistance and consider that the greater their involvement with Districts in the evaluation of the concepts, the greater will be the opportunity to perfect the concepts based on broader feedback from the field.

At the end of the design life, a decision must be made to either terminate use of the site or apply other management techniques [16]. As shown in Figure 1, if future use is desired, return to [8] and redesign as needed. If for various reasons use of the site is to be terminated, it will be necessary to go back through the entire procedure.

The preceding discussion is a key to DMRP results based on a very general description of the strategies required for design of containment areas when including new or improved technical concepts and developing an overall management scheme. By the end of the DMRP in March 1978, it is believed that practically all of the as-yet unanswered questions encountered when following the procedure (Figure 1) will be addressed and proper guidance will be available to make sound engineering and scientific judgments.

SECTION 150—WETLAND HABITAT DEVELOPMENT

Habitat development on dredged material has been shown to be a proven disposal alternative. Four distinct types of biological communities are suited for

Table 2

WORK UNITS APPLICABLE TO MARSH DEVELOPMENT

Work Unit	Title	Report Available*
2A05	Marsh-Estuarine Nutrient and Heavy Metal Cycling	Mar 77
2A07	Effect of Dredged Material Deposition on Short Form *Spartina alterniflora* Marsh	Dec 77
4A01	Study of Identification of Relevant Criteria and Survey of Potential Application Sites for Artificial Habitat Creation	CR D-76-2
4A03	State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques	CR D-74-9
4A04A	Productivity of Minor Marsh Grass Species and Their Substrate Selective Properties (Atlantic Coastal Area)	Apr 77
4A04B	Productivity of Minor Marsh Grass Species (Gulf Coast Area)	Apr 77
4A05	Modeling of Ecological Succession and Production in Estuarine Marshes	Mar 77
4A06	Physiological Response of Marsh Plants to Environmental Stress	Apr 77
4A07	Concept Development and Economic and Environmental Compatibility Analyses of Underwater and/or Floating Dredged Material Retaining and Protective Structures	Sep 77
4A08	Development of Guidelines for Material Placement in Marsh Creation	CR D-75-2
4A10J	Branford Harbor (Connecticut) Marsh Habitat Development: Site Report	Oct 77
4A11M	Windmill Point (Virginia) Marsh Habitat Development: Site Report	Mar 78
4A12C	Buttermilk Sound (Georgia) Marsh Habitat Development: Site Report	Jan 78
4A13K	Bolivar Peninsula (Texas) Upland and Marsh Habitat Development: Site Report	Mar 78
4A14D	Rennie Island (Washington) Marsh Habitat Development: Site Report	Jun 77
4A15	Heavy Metal Uptake by Marsh Grasses (Phase I)	TR D-76-5
4A16	Prediction of a Stable Elevation for Marshes Created from Dredged Material	May 77
4A17	Dyke Marsh Demonstration Area (Virginia). Feasibility Study	TR D-76-6
4A17A	Detailed Design—Dyke Marsh Demonstration Area (Virginia)	May 77
4A18	Pond Three Marsh Demonstration, San Francisco, California	Dec 77
4A19	Marsh Development, Apalachicola Bay, Florida	Dec 77
4A20	Productivity of Marsh Plants, Pacific Coast	Nov 77
4A22	Productivity and Succession on Dredged Material: A Synthesis	Planned
4A23	Engineering Considerations and Cost Effectiveness of Habitat Development on Dredged Material: A Synthesis	Planned
4A24	Marsh Plant Establishment on Dredged Material: A Synthesis	Planned
4B05M	Miller Sands (Oregon) Upland and Marsh Habitat Development: Site Report	Planned
4B06	Establishment of Marsh Grasses on Dredged Material	Feb 77
4E02	Grassbed Development, St. Joseph Bay, Florida	Dec 77

* CR—Contract Report; TR—Technical Report.

establishment on dredged material: marsh, terrestrial, island, and aquatic habitats. The HDP of the DMRP has concentrated the most attention on marsh development. Both completed and planned activities of the DMRP related to marsh creation are keyed to a flow diagram for the selection and design of wetland habitats (Figure 6).

The principal elements of the diagram have been italicized in the following discussion, and, where appropriate, specific elements of research conducted by the HDP are identified. The basis of much of the discussion is derived from detailed field verification studies complete or now in progress in Connecticut, Virginia (2 sites), Georgia, Florida (2 sites), Texas, California, Oregon, and Washington. Summary reports for these field sites containing a detailed analysis of the engineering, environmental, social, and economic factors which influenced habitat development at each site, will be published under Work Units 4A10J, 4A11M, 4A12C, 4A13K, 4A14D, 4A17A, 4A18, 4A19, 4B05M, and 4E02.* A complete list of DMRP research activities related to marsh development is presented in Table 2 above.

DETERMINATION OF FEASIBILITY

Habitat development [1],** one of several general dredged material disposal alternatives, presents a series of alternatives ranging from establishment of upland terrestrial communities to the development of seagrass meadows. *Marsh habitat* [2] is a generic term that, as

* Refers to similarly numbered work units in Table 2.
** Refers to similarly numbered boxes in Figure 2.

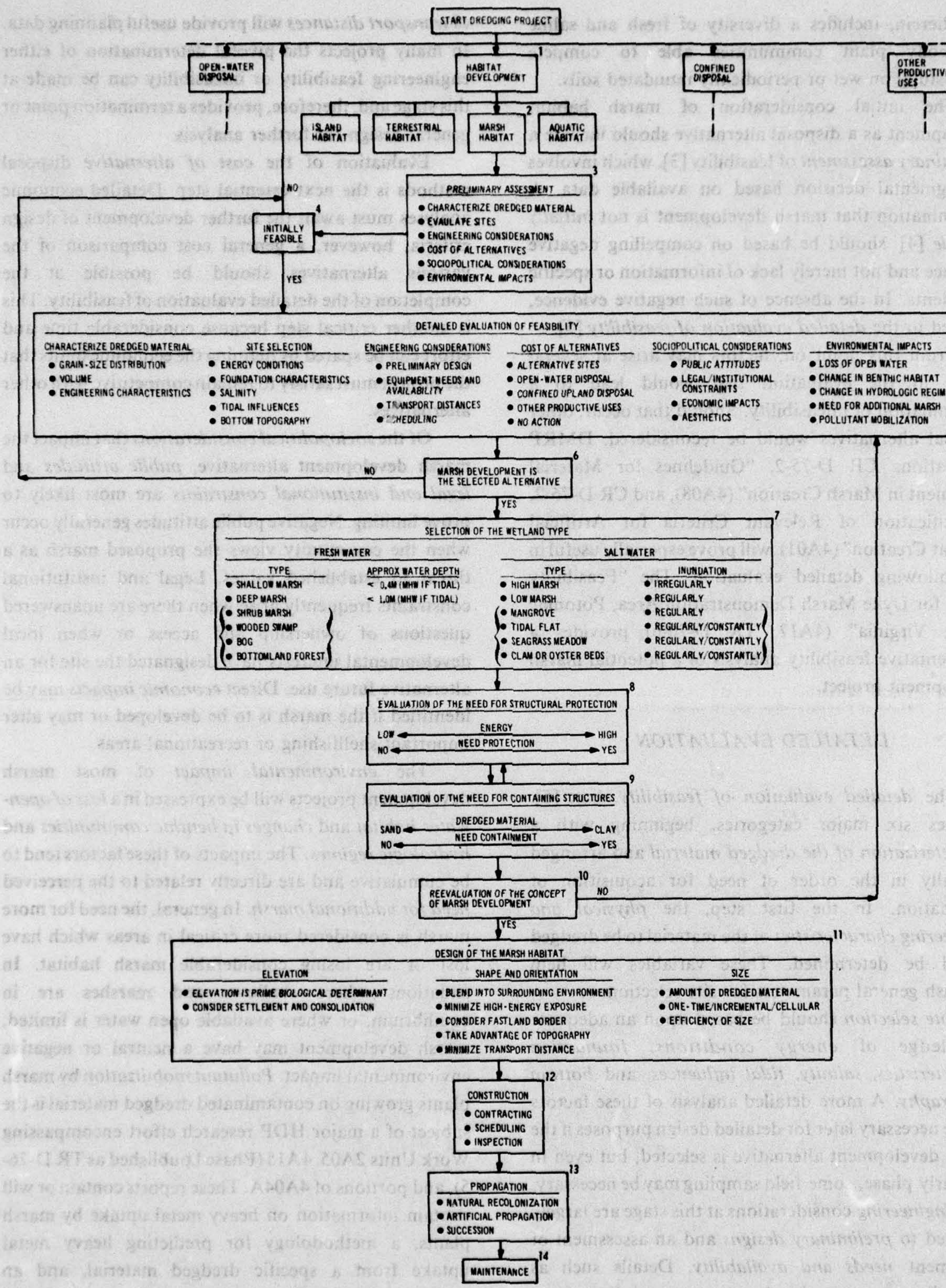


Figure 6. Selection and design of wetland habitats

used herein, includes a diversity of fresh and saline nonwoody plant communities able to compete successfully on wet or periodically inundated soils.

The initial consideration of marsh habitat development as a disposal alternative should include a *preliminary assessment* of feasibility [3], which involves a judgmental decision based on available data. A determination that marsh development is not *initially feasible* [4] should be based on compelling negative evidence and not merely lack of information or specific precedents. In the absence of such negative evidence, proceed to the *detailed evaluation of feasibility* [5].

From this point on, factors may arise at several stages in the evaluation that would lead to a determination of infeasibility. Should that occur, other disposal alternatives would be reconsidered. DMRP publications CR D-75-2, "Guidelines for Material Placement in Marsh Creation" (4A08), and CR D-76-2, "Identification of Relevant Criteria for Artificial Habitat Creation" (4A01), will prove especially useful in the following detailed evaluation. The "Feasibility Study for Dyke Marsh Demonstration Area, Potomac River, Virginia" (4A17, TR D-76-6), provides a representative feasibility analysis of a potential marsh development project.

DETAILED EVALUATION

The *detailed evaluation of feasibility*, box [5], includes six major categories, beginning with a *characterization of the dredged material* and arranged generally in the order of need for acquisition of information. In the first step, the *physical and engineering characteristics* of the material to be dredged should be determined. These variables will help establish general parameters for site selection.

Site selection should be based upon an adequate knowledge of *energy conditions, foundation characteristics, salinity, tidal influences,* and *bottom topography*. A more detailed analysis of these factors will be necessary later for detailed design purposes if the marsh development alternative is selected, but even in this early phase, some field sampling may be necessary.

Engineering considerations at this stage are largely confined to *preliminary designs* and an assessment of equipment *needs and availability*. Details such as *scheduling* to meet critical environmental dates (e.g., spring or summer planting times) and the identification of *transport distances* will provide useful planning data. In many projects the pivotal determination of either engineering feasibility or infeasibility can be made at this stage and, therefore, provides a termination point or general design for further analysis.

Evaluation of the *cost of alternative* disposal methods is the next essential step. Detailed economic analyses must await the further development of design criteria; however, a general cost comparison of the various alternatives should be possible at the completion of the detailed evaluation of feasibility. This is another critical step because considerable time and effort can be spared by defining the economic limits that the project must satisfy to remain competitive with other alternatives.

Of the *sociopolitical considerations* that impact the marsh development alternative, *public attitudes* and *legal and institutional constraints* are most likely to prove limiting. Negative public attitudes generally occur when the community views the proposed marsh as a threat to established values. Legal and institutional constraints frequently arise when there are unanswered questions of ownership and access or when local developmental interests have designated the site for an alternative future use. Direct *economic impacts* may be identified if the marsh is to be developed or may alter important shellfishing or recreational areas.

The *environmental impact* of most marsh development projects will be expressed in a *loss of open-water habitat* and *changes in benthic communities* and *hydrologic regimes*. The impacts of these factors tend to be cumulative and are directly related to the perceived *need for additional marsh*. In general, the need for more marsh is considered more critical in areas which have lost or are losing considerable marsh habitat. In situations where shallows and marshes are in equilibrium, or where available open water is limited, marsh development may have a neutral or negative environmental impact. *Pollutant mobilization* by marsh plants growing on contaminated dredged material is the subject of a major HDP research effort encompassing Work Units 2A05, 4A15 (Phase I published as TR D-76-5), and portions of 4A04A. These reports contain or will contain information on heavy metal uptake by marsh plants, a methodology for predicting heavy metal uptake from a specific dredged material, and an evaluation of the effects of Eh and pH on contaminant availability.

SELECTION OF WETLAND TYPE

Upon completion of the evaluation of feasibility, a determination can be made to advance to detailed planning or consider other alternatives. If *marsh development is the selected alternative* [6], it is necessary to *select the wetland type* [7]. A rich diversity of wetland types exists, and these types are often defined by rather subtle differences. Also, note that several nonmarsh wetland alternatives merit consideration. In most situations, the selection of a wetland type will be largely predetermined by overriding environmental parameters such as tidal range and salinity. Most marsh development projects, simply because of the nature of material disposal and the formation of drainage patterns, inherently will contain elements of shallow and deep marsh (fresh water) or high and low marsh (salt water).

EVALUATION OF STRUCTURAL REQUIREMENTS

A careful *evaluation of the need for structural protection* [8] and *for containing or confining structures* [9] is a critical element in the implementation of the marsh development alternative. High hydrologic energies (waves, currents) may prevent the formation of a stable substrate and the establishment of vegetation. Therefore, various forms of protective structures or mechanisms are required if high energy conditions are present. Correspondingly, less protection is required under conditions of lower hydrologic energy.

Another major consideration in the protection/containment equation is the grain-size distribution of the dredged material. Fine-grained material generally requires containment. Containment usually becomes less critical when coarser grained material is placed.

Site energy and dredged material grain-size distribution are closely interrelated in the determination of the need for protection and containment. Hydraulically placed clay will almost always require containment, regardless of wave or current conditions. Silt under very low energy conditions may require no containment or protection. Sand that would require containment under high energy situations may require some protection under moderate wave energy. Obviously a wide range and combination of conditions exist.

Structural solutions will depend on the needs of a specific site and may involve floating energy-dissipating devices, bulkheads, cellular cofferdams, crib walls, gabions, or dikes. Figures 7-9 depict several techniques

Figure 7. A portion of a 1000-m dike used in marsh development in the James River, Virginia. The dike, built from sandy dredged material, provides containment for fine-textured dredged material and protection for a freshwater marsh established at this high-energy riverine site

Figure 8. This 500-m sandbag dike provides protection for a salt marsh established on sandy dredged material along the south shore of Galveston Bay, Texas. This site, subject to very high wave energies, would not support marsh without such a breakwater

Figure 9. Dredged material was placed adjacent to an existing island to form an 80-hectare protected cove in the Columbia River, Oregon. The quiet waters of the cove provide an ideal site for marsh habitat development

used to solve the containment/protection problem. A state-of-the-art survey will be conducted in 1977 to provide current information on the design and cost of energy dissipating and containing structures applicable to habitat development (4A07).

REEVALUATION

At this point *reevaluation of the concept of marsh development* is in order [10]. Designation of the wetland type and determination of the need for containment and protection will have been made and this information should be input to the cost and engineering aspects of the *detailed evaluation of feasibility* [5]. Before proceeding, site location must be finally determined and a detailed analysis of energy conditions, foundations, tidal influences, bottom topography, and availability of equipment and construction material (if necessary) should be completed.

DESIGN OF MARSH

Detailed *design of the marsh habitat* [11] is separated into three basic determinants: *elevation, shape and orientation, and size*. The design should maintain the goals of disposal of dredged material through the development of a desirable biological community, using the most cost-efficient method and causing a minimum of environmental perturbation.

Final *elevation* of the marsh substrate is largely determined by *consolidation and settlement* and is the most critical of the operational considerations as it dictates both the amount of material disposed and the biological productivity of the habitat established. A methodology has been developed as part of Work Unit 4A16 to predict the stable elevation of a given volume of dredged material placed in a confined intertidal situation. Salt marshes are most productive within the upper half of the tidal range, and freshwater marshes should generally be between 0.1 and 1.0 m deep. Variation in topography will produce habitat diversity and should be encouraged, provided that the majority of the area is within the desired intertidal elevations. If the possibility of not being able to achieve a desired elevation appears likely, slight overfilling is preferable if it is operationally feasible to rework the surface to the desired elevation at a later date. HDP Work Units 4A04A, 4A06, 4A20, and 4B06 will present a detailed evaluation of the relationships between marsh substrate, elevation, and productivity. A succession and productivity model for salt marshes has been designed under Work Unit 4A05. Final reports on this research will be available by spring of 1977. A synthesis report (4A22), incorporating the field site data, regarding the productivity and succession on dredged material sites will be prepared in 1978.

The *shape and orientation* of the new marsh will largely determine its total cost, its efficiency as a disposal site, and its effectiveness as a biological addition to the natural scene. The shape should minimize impact on drainage or current patterns in the existing environs and, insofar as possible, present a scene that appears natural and *blends into the surrounding environment*. If high-energy forces are anticipated, the marsh should be shaped to *minimize high-energy exposure*. Such design will reduce the threat of failure and reduce the cost involved with providing protection from hydrologic energies. If available, a *fast land border*, such as a cove, island, or breakwater, can serve as low cost protection and minimize the length of otherwise necessary and costly containing or protective structures. An effort should be made to take advantage of *bottom topography* during the design of the new marsh. Disposal sites are often not uniform in depth, and, if possible, protective structures should be located in shallow water and the fill area in deep water to maximize the containment efficiency. If dikes are built from local material, it may be possible to deepen the disposal area by locating borrow within the diked area. The distance from the dredging site to the disposal site may be a critical economic or operational problem, and therefore the new marsh should be located as close as possible to the dredging operation. In this regard, shapes that parallel the dredging area tend to minimize the transport distance.

The *size* of the disposal area will be a function of the in situ volume of the material to be dredged and the volume of the disposal area. There are several filling options that might affect size, including one-time, incremental, and cellular filling. *One-time* filling implies that a site will be filled and marsh established within a discrete operation and that the area will not be used again for disposal. In *incremental* filling it is recognized that the site will be used during the course of more than one dredging operation or season and that the disposal area will be considered full when a predetermined marsh elevation is attained. In *cellular* filling a compartment of a prescribed disposal area is filled during each disposal project. Both incremental and cellular filling offer the efficiency of establishing a large disposal site and utilizing it over a period of years, thus avoiding repetitive construction, design, and testing operations. A major difference between these two methods is that the cellular method provides a marsh substrate at the end of each season, whereas many years may be required before incremental filling attains this goal. Both cellular and incremental filling benefit from an *efficiency of size*. That is, for most disposal area configurations, an increase in the length of the dike provides proportionally more disposal area. Cellular or incremental disposal sites would generally be larger than one-time disposal sites, and this increase in size may offer a more cost-effective disposal site.

The engineering considerations and cost effectiveness of habitat development on dredged material will be the subject of a synthesis report (4A23). This report, now scheduled for early 1978, will contain an evaluation of all available information on marsh development, using field site verification as its technical base.

MARSH CONSTRUCTION

Having completed the detailed design, *construction* [12] can proceed. *Contracting* procedures in marsh development may prove difficult because, in most instances, the contractors will have had no previous experience in this type of disposal operation. Pre-bid conferences to explain the intricacies of the project and carefully detailed contract specifications are strongly advised. The dredging *schedule* can prove to be particularly important. In order to obtain maximum vegetative cover within the first year, it is necessary to have the dredged material in place, with a relatively stable surface elevation, by the beginning of the growing season. Delays will affect the initial success of the project and may result in replanting costs, adverse public reaction, and unwanted erosion at the site. Careful *inspection* of the disposal operation is essential as the attainment of the prescribed elevation is critical, an aspect that may not be appreciated by the dredging crew.

PLANT PROPAGATION

Propagation [13] of marsh plants can be attained by natural invasion or planting (see Figures 10 and 11). If the environmental requirements for a marsh community, including a source of propagules, are present at a site, then natural invasion and establishment can be expected. In some cases natural invasion will vegetate a site within a few months, in others many years may be required for natural establishment. The process of marsh establishment may be accelerated in many instances by seeding or sprigging. The advantage of propagation by natural invasion is low cost, and this may be a pivotal consideration in borderline projects. The advantages in sprigging or seeding are more rapid surface stabilization and an immediate vegetation. Marsh propagation is the subject of a variety of HDP studies, and an integral

Figure 10. Natural vegetation occurred within a few months after dredged material disposal at this freshwater marsh site in the James River, Virginia

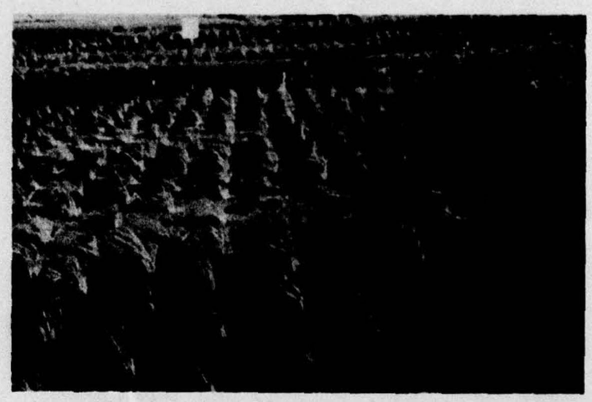


Figure 11. Although this intertidal disposal site in the Columbia River, Oregon, would have eventually revegetated naturally, the process was advanced many years by sprigging

portion of all of the field sites. An available report, "State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques" (4A03, CR D-74-9) contains an excellent summary of marsh propagation information up to 1974. Updated information will be provided by a recently completed study entitled "Establishment of Marsh Grasses on Dredged Material" (4B06) and a synthesis report (4A24) on marsh plant establishment that will be completed in 1978.

MARSH MAINTENANCE

Dredged material marshes should be designed to be relatively *maintenance* [14] free. The degree of maintenance will largely depend on the energy conditions of an area, and this is a factor that should be included in the cost analysis of the project. No maintenance may be required to protect the new marsh in low-energy situations. In areas of somewhat higher energy conditions, protection may be required only until the marsh has had a chance to mature; in those areas, protective structures may be designed for a relatively short life, with no additional maintenance required. In high-energy situations, perpetuation of the marsh may require planned periodic maintenance of protective structures.

This bulletin is published in accordance with AR 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Effects Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Dredged Material Research Program (DMRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions of notes, news, reviews, or any other types of information are solicited from all sources and will be considered for publication as long as they are relevant to the theme of the DMRP, i.e., to provide—through research—definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Effects Laboratory, ATTN: R. T. Saucier, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call AC 601, 636-3111, Ext. 3233.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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