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A NEW CONCEPT FOR DREDGED MATERIAL DISPOSAL

Michael R. Palermo, et al

February 1976

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A NEW CONCEPT FOR DREDGED MATERIAL DISPOSAL

by

Michael R. Palermo, Raymond L. Montgomery

Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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Final Report

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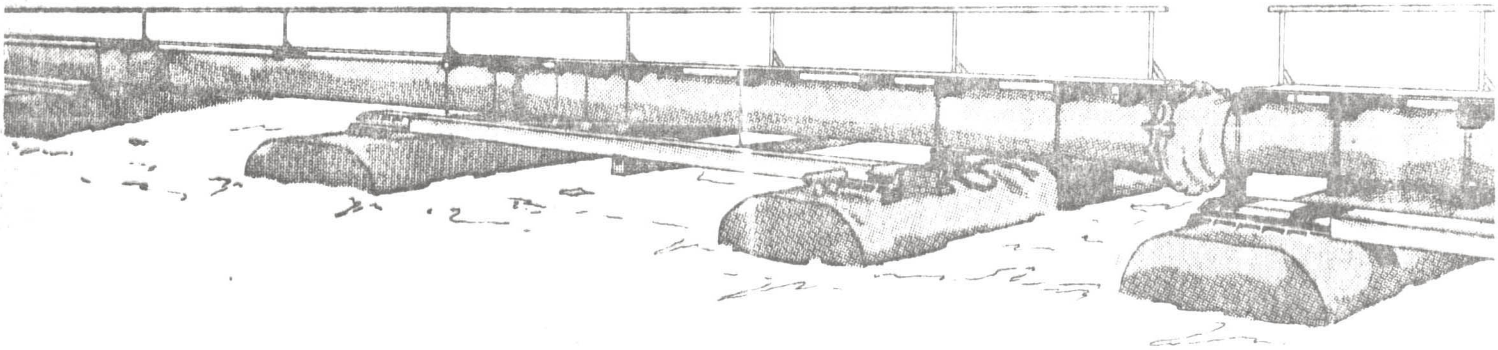

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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For site reuse to be successful, the material must be in a usable condition, potential uses must be identified, and site management must be tailored to meet requirements for continued reuse. Research completed to date has identified methods of separating, drying, and rehandling dredged material, legal and policy constraints regarding marketing and disposition of the material, and potential use of dredged material for landfill and construction purposes. The feasibility of site reuse as established through completed and ongoing research must be established by field studies which are currently being initiated. Ultimate widespread use of reusable disposal areas will depend upon future constraints placed on conventional disposal methods and upon economic and environmental considerations.

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Preface

This paper was prepared for and presented at the Eighth Dredging Seminar in Houston, Texas, on 7 November 1975. The seminar was sponsored by the Center for Dredging Studies, Sea Grant Office, Texas A&M University.

The work described herein was conducted under the Dredged Material Research Program (DRMP), Environmental Effects Laboratory (EEL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

The paper was prepared by Mr. Michael R. Palermo, Design and Concept Development Branch, and Mr. Raymond L. Montgomery, Chief, Design and Concept Development Branch. The paper was presented by Mr. Palermo in Houston.

The report was prepared under the general supervision of Dr. John Harrison, Chief, EEL, and Mr. Andrew J. Green, Chief, Environmental Engineering Division, EEL.

Director of WES during the preparation and publication of the paper was COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

Contents

Conversion Factors, U. S. Customary to Metric (SI) Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1609.344	metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres

A NEW CONCEPT FOR DREDGED MATERIAL DISPOSAL

Introduction

1. Millions of cubic yards of sediment must be dredged annually to maintain navigation channel depths because of the effects of shoaling. The maintenance dredging data shown in Figure 1 provide an indication of the annual quantities of material dredged and the relative importance of the common disposal methods (open water, confined, and unconfined) in the various geographical regions. The term "undifferentiated" has been used to cover projects where both confined and open-water disposal are practiced and no breakdown of the total quantity was available. As shown in Figure 1, a large percentage of dredged material must be confined in land disposal areas, and each year large amounts of new land are required to accommodate these disposal needs. Because most dredging projects are located in the estuarine zone where there is already excessive and often conflicting land-use requirements, it is doubtful if land use for a form of waste disposal can continue at the present rate.

2. Virtually without exception, the dredged material disposal problem foremost in the minds of the Corps District and Division office personnel contacted during the first phase of the Dredged Material Research Program (DMRP) conducted by the U. S. Army Engineer Waterways Experiment Station (WES) was that of finding available sites for land disposal of dredged material.[1,2] In a number of Corps Districts, important dredging has been delayed because land disposal sites were not available. In other Districts, historical disposal sites are being filled and no new land is available for new containment facilities.

3. Under the DMRP a new dredged material disposal concept--the reusable disposal area--is being investigated. The purposes of this paper are to present this disposal concept and to discuss its current status.

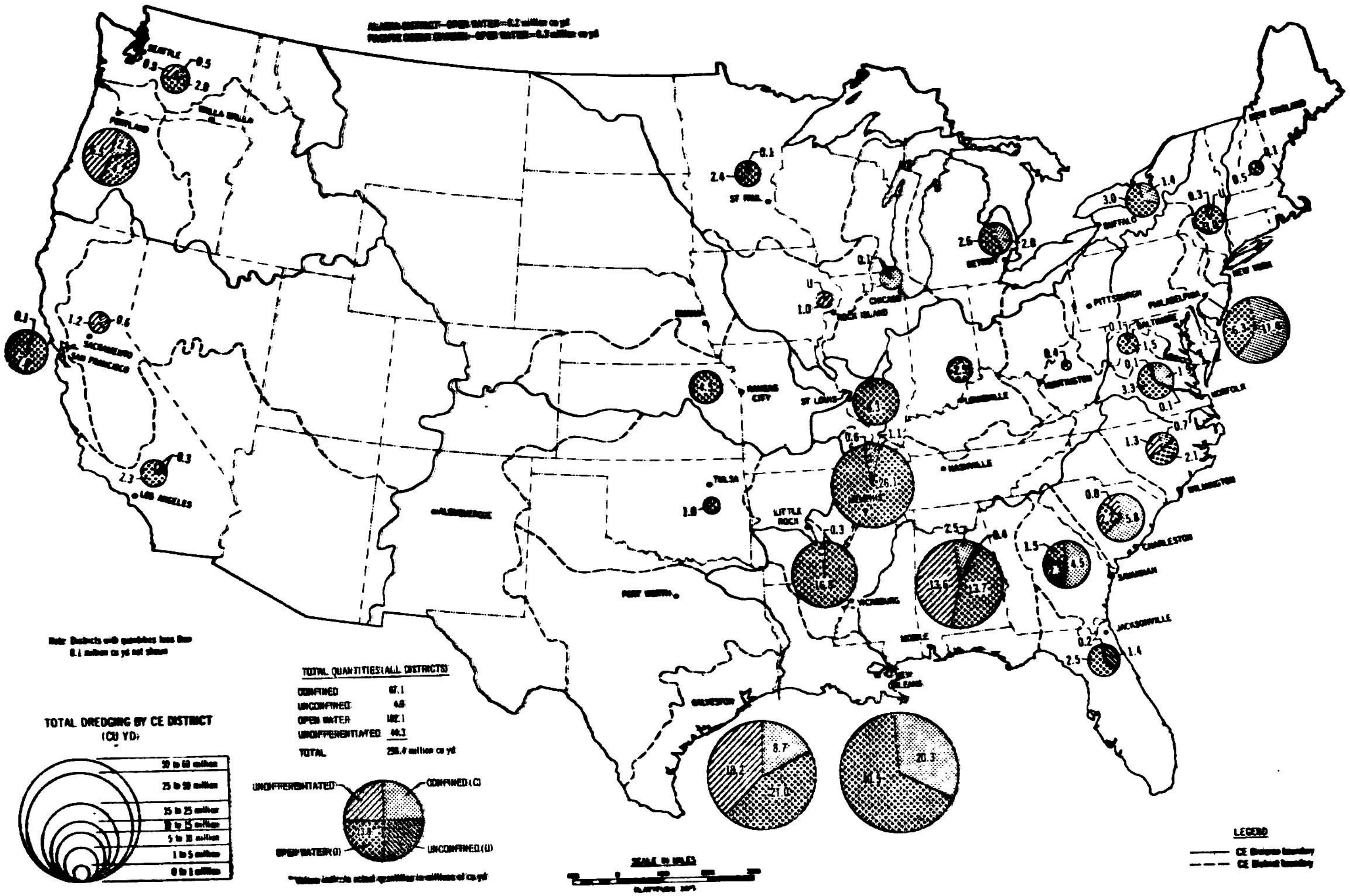


Figure 1. Disposition of dredged material generated in maintenance dredging operations and average annual quantities of material disposed by area by District (1972)

Disposal Area Reuse Concept

4. The reusable dredged material disposal area would be a collection and processing site where valuable portions of the dredged material would be made available for productive use while unusable material would be treated, if necessary, and disposed of. Methods and procedures would provide for continuous or periodic removal of dredged material for use or storage elsewhere in order to increase the life expectancy of the facility. It might be more appropriate to call the reusable disposal facility a dredged material transfer station where dredged material would be collected, processed, and prepared for transportation to other areas for productive use or disposal.

5. In one sense this concept is not entirely new to Corps dredging activities. A form of the concept has been used to transfer dredged material from transporting vessels (scow or hopper dredge) into a land transporting system to move the dredged material to land containment facilities. In this case the object was simply to transfer the dredged material from one mode of transportation to another for disposal on land. However, the reusable disposal area concept now being developed in conjunction with the DMRP has broader objectives. The major ones are to minimize the dredged material disposal area land requirements while maintaining environmentally compatible land disposal operations.

6. The advantages of a site that can be reused indefinitely are as follows: (a) permanent sites could be provided convenient to maintenance dredging areas; (b) the expense of and objection to providing new lands for disposal sites are eliminated; (c) construction and landfill materials are made available for productive use; and (d) a reasonable alternative is provided for solving land disposal problems and reducing the excessive use of valuable lands. From these listed advantages it is obvious that the reusable disposal facility has definite advantages over the conventional land disposal methods used in the past. However, it is not a panacea for land disposal problems. There will be areas where disposal area reuse concepts will not be feasible,

but it appears that there are wide areas of potential application.

7. At this time the reusable disposal area is only a concept. But progress has been made toward development of the concept and results from initial field demonstrations should be forthcoming in the near future.

Functions of Reusable Disposal Facilities

Degrees of area reuse

8. The reusable disposal area is essentially a transfer station where dredged material is collected and possibly dewatered, separated, or treated to control contaminants and either used for productive purposes or disposed of.

9. Figure 2 shows a functional diagram for disposal area reuse. As can be seen from this figure, the major factors of a reusable site are dredged material separation (solids and liquid), treatment to control contaminants, and removal of the solids from the site. Such a

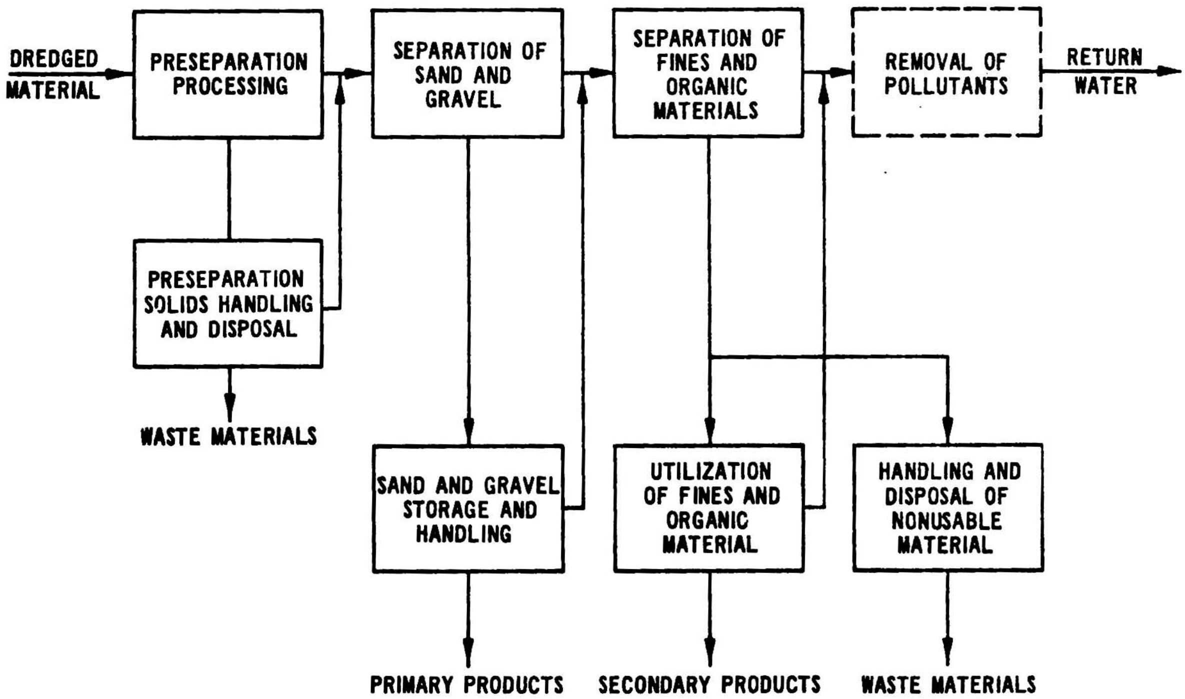


Figure 2. Functional diagram for disposal area

facility requires complete prior planning and design. All possible elements which must be considered are illustrated in Figure 3.

10. Figures 2 and 3 show the processes necessary to provide the ultimate reusable disposal area. However, all of these processes may not be needed in every situation to develop a reusable disposal site. A reusable disposal site is considered to be any site where planning and operations are carried out to extend the life of the site.

11. Conventional disposal practices may be combined with limited processing as shown in Figure 4 to reduce considerably the volume of material requiring disposal.

12. Site reuse in its simplest form involves dewatering dredged material in the containment area through natural processes as shown in Figure 5. Densification of the dredged material and subsequent increased storage volume for future dredged material disposal operations would be provided. This approach may be used in rejuvenating old sites for future use.

13. Regardless of how simple or complex the reusable facility may be, information must be drawn from several research areas of the DMRP to provide the necessary input into the development of the reusable disposal facility.

14. Figure 6 shows the interrelationship among research areas of the DMRP. As shown, the disposal area reuse concept will draw upon the research from four areas and, in turn, provide input into productive uses research.

15. Input from all of the research areas shown in Figure 6 will serve to develop a technically sound and environmentally compatible dredged material disposal area that can be reused for long periods.

Separation and handling

16. If a significant quantity of coarse material is present, it may be advantageous to separate the dredged material into coarse and fine fractions prior to any dewatering effort. Separation can aid in marketing of material for removal off-site, since separated sands and gravels may be utilized with no further processing. Research has been performed to determine the feasibility of separating, drying, and

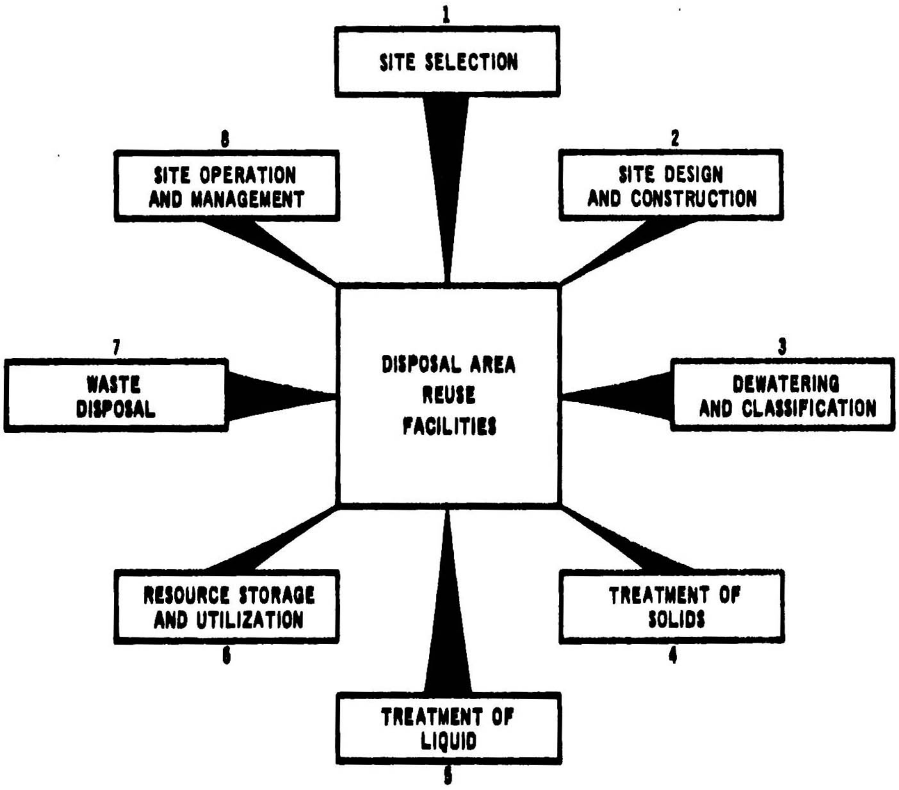


Figure 3. Considerations for area reuse planning and design

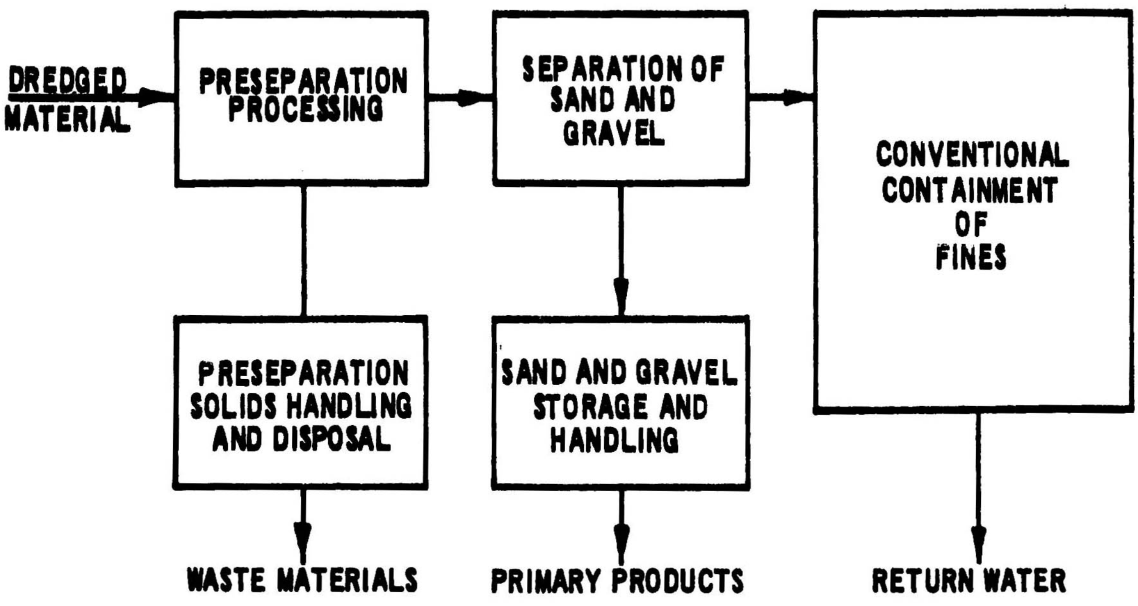


Figure 4. Functional diagram for site reuse through limited handling and processing

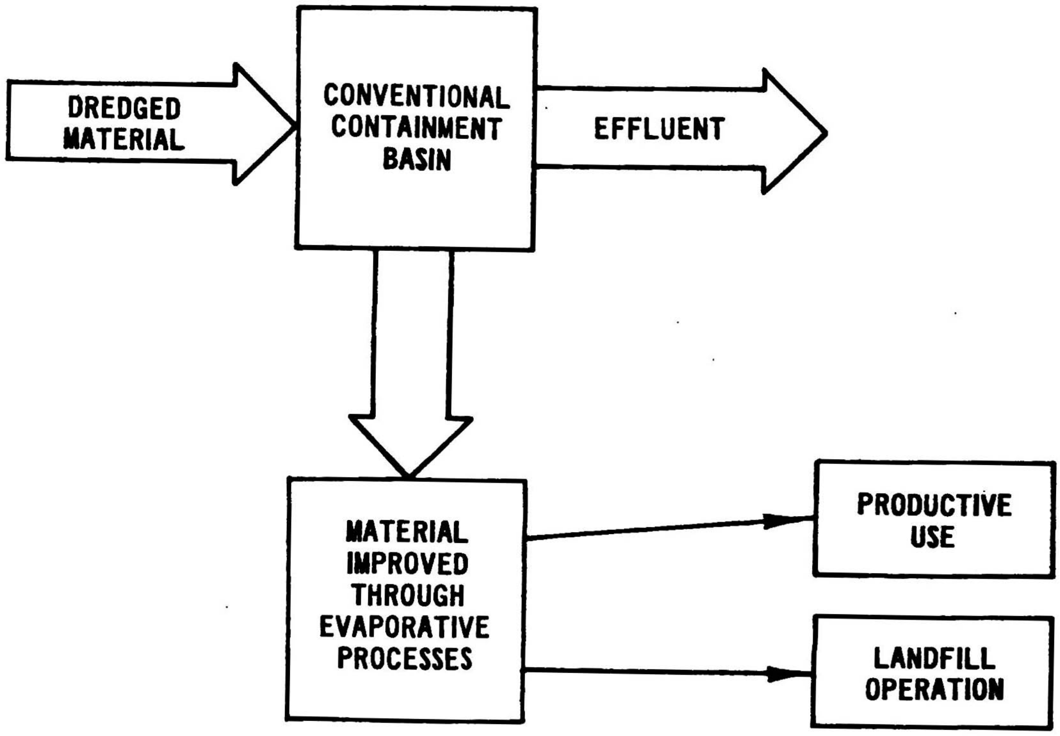


Figure 5. Rejuvenation of conventional disposal sites for reuse

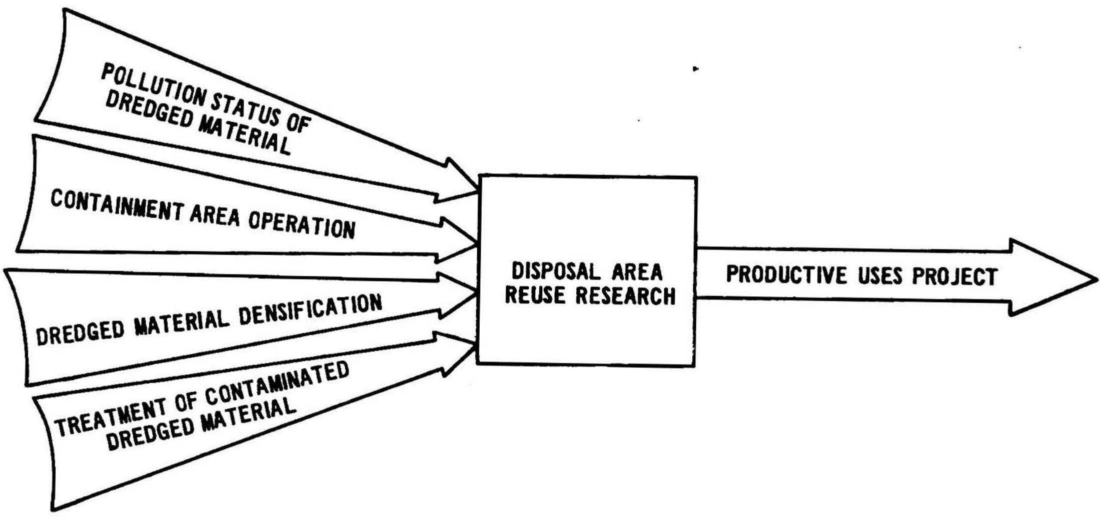


Figure 6. Research relationships for area reuse

rehandling dredged material to improve its potential as a resource.[3] The use of naturally occurring sedimentation and mechanical and chemical separation were evaluated. Results of the research indicated that separation of the sand and silt fractions is feasible using commercial equipment and separation basins. It was also found that chemical coagulation can improve clay separation. Other research is being initiated for mechanical separation of fine-grained material using a vacuum filtration system.

Dewatering

17. The removal of water probably will be essential in the transformation of a dredged material slurry into a usable resource material and is instrumental in the densification of dredged material and extension of disposal area life. Also, dredged material usually must be in an essentially dewatered condition to exhibit desirable properties for removal off-site for productive use. Dewatering is therefore a most important aspect of any disposal area reuse scheme.

18. The fine-grained dredged material presents the difficult problem in this area. Given a set of specific properties, the fine-grained material will decrease in volume in proportion to the amount of water removed up to a limiting value (the shrinkage limit). This relationship is shown for an idealized fine-grained dredged material in Figure 7. The usual practice followed at most disposal areas allows natural evaporative processes to dry the material between dredging phases.

19. A major problem here is the fact that mother nature tends to stand in the way. When dredged material is placed in a diked area, evaporation begins immediately. Unfortunately, with most dredged material, the evaporation occurring immediately after the free water is decanted results in formation of a dried crust that effectively retards evaporation from underlying layers. The upper few inches may approach the shrinkage limit while material below is still at an extremely high water content. If dredged material is repeatedly deposited, the site is filled by small zones of efficient storage (dried crust) and large zones of inefficient storage (wet material) as illustrated in Figure 8.

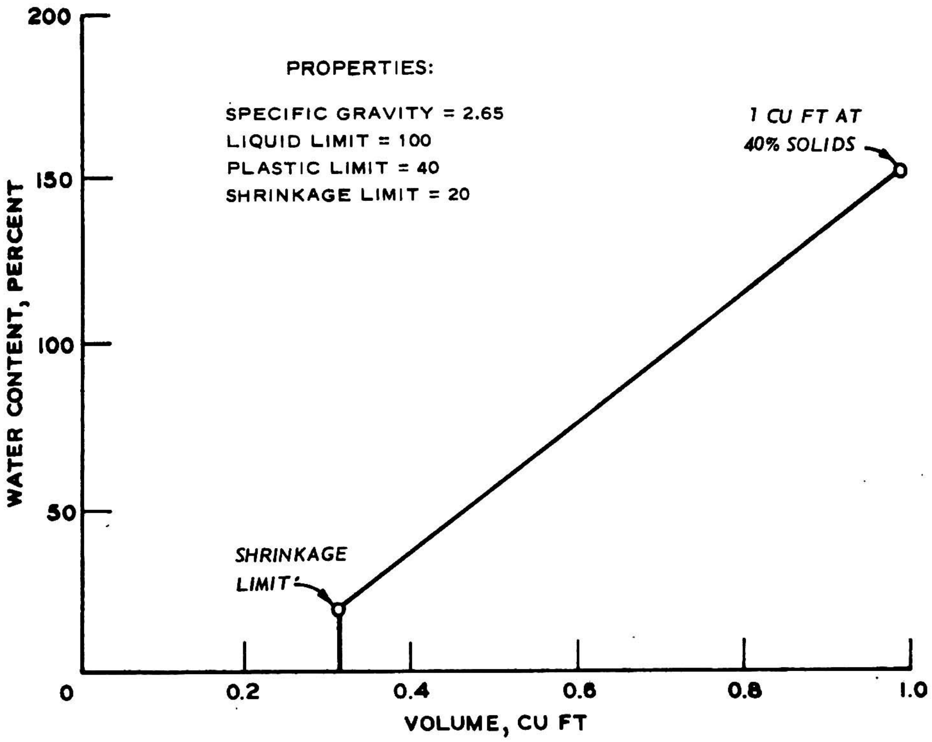


Figure 7. Volume and water content relationship for fine-grained dredged material

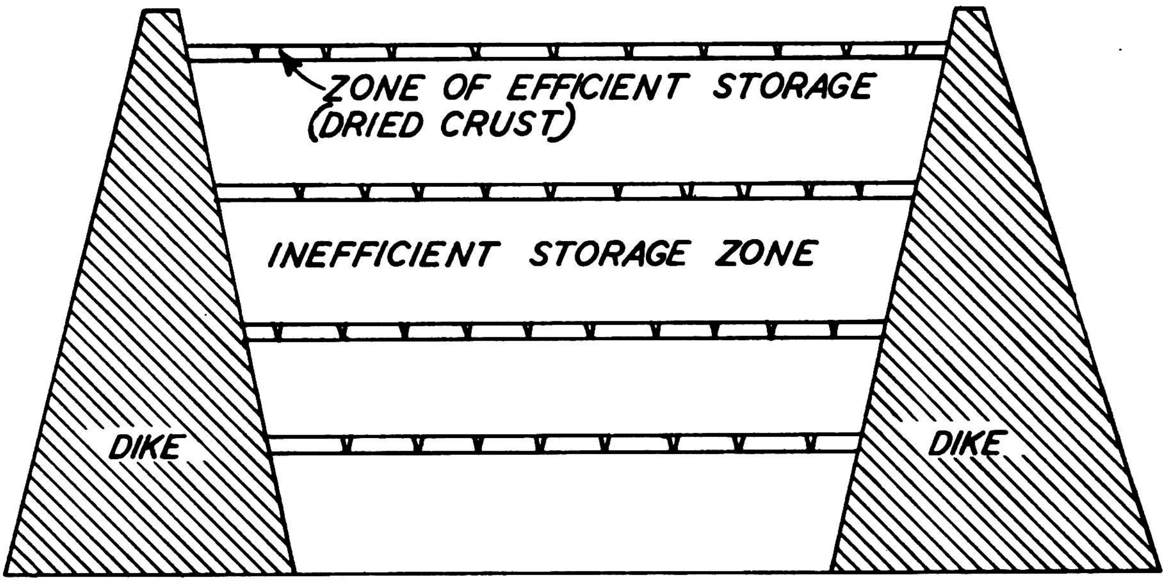


Figure 8. Crust formation in a diked disposal area

The inefficient zones not only waste valuable capacity but limit possible uses of the site after project completion.

20. Dredged material dewatering and densification are being addressed by another research effort under the DMRP. The present state of the art regarding dewatering has been confined to conventional soil mechanics practice for excavations and construction dewatering where rapid dewatering is desired and the areas and volumes involved are usually small. The problem encountered in dealing with dredged material is somewhat different. Here, long periods of time, many months in most cases, can be used for dewatering, and the areas to be dewatered are sometimes hundreds of acres. Cost is the overriding factor. The methods employed can be slow, but they must be inexpensive.

21. One method being evaluated by the DMRP involves a crust management concept and has direct application to area reuse because of the rehandling aspects involved. Figure 9 illustrates how crust management might be used in rejuvenating a filled disposal area. The dry surface crust is removed and stacked to one side within the disposal area, exposing the wet material below to natural drying processes. The

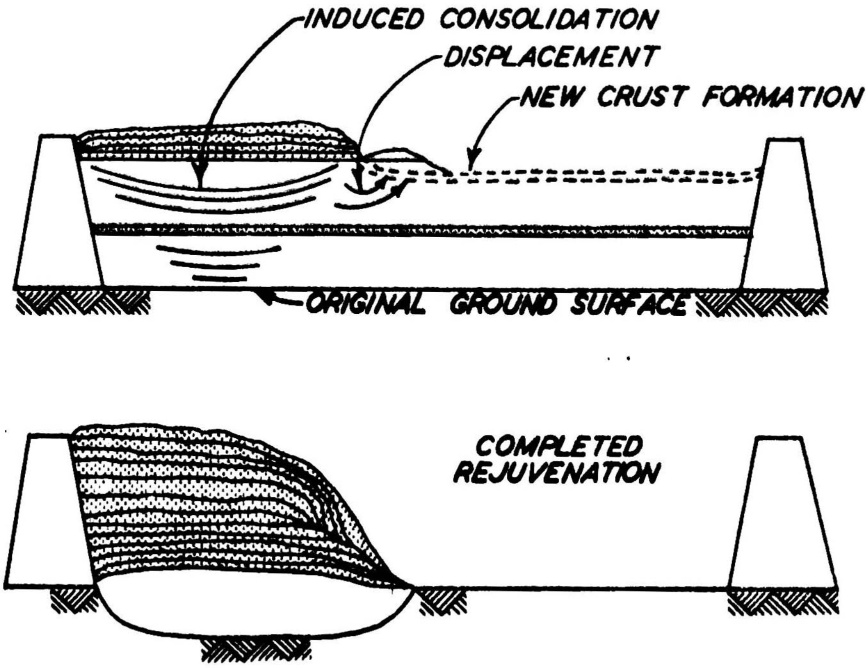


Figure 9. Site rejuvenation through crust management

surcharge effect of the stacked crust material displaces wet material below it and induces consolidation in both dredged material and underlying foundation. Crust again forms on the exposed wet material, which is subsequently removed. After repetitive removals the result is a fill section of stable material and a disposal area that can be reused. The dredged material dewatered by this technique is much more attractive for use off-site as landfill material or for other productive use.

Treatment of contaminated material

22. Many of the uses for dredged material removed from reusable disposal areas require that it be relatively free from contaminants. Therefore, some treatment of the material itself and effluent water may be a required operation at reusable areas.

23. Contaminants found in dredged material are usually identical with those present in domestic and/or industrial wastewaters. However, treatment processes may be substantially different due to the variable nature of dredged material and the unusually high percentage of solids as compared with most wastewaters. The DMRP is investigating the character of contaminants and methods of treatment for dredged material both during and after disposal. The information gained through treatment research will be directly applicable to the dewatered effluent and solids removed from reusable disposal areas.

District input

24. The reusable disposal area concepts are being developed to meet the needs of the Corps Districts. A study team is currently visiting selected Corps Districts to gather information regarding their interest, needs, and comments on this new approach to dredged material disposal and to identify potential field demonstration sites (Figure 10). The Districts will play a significant role in the development of viable concepts for disposal area reuse. For such a concept to be implemented, it is likely that many of the Corps Districts will have to modify their philosophy toward the disposal of dredged material. Considerably more planning, design, and management will be required to implement reusable disposal areas. However, in view of current shortages of suitable acreage for disposal, high construction costs, and

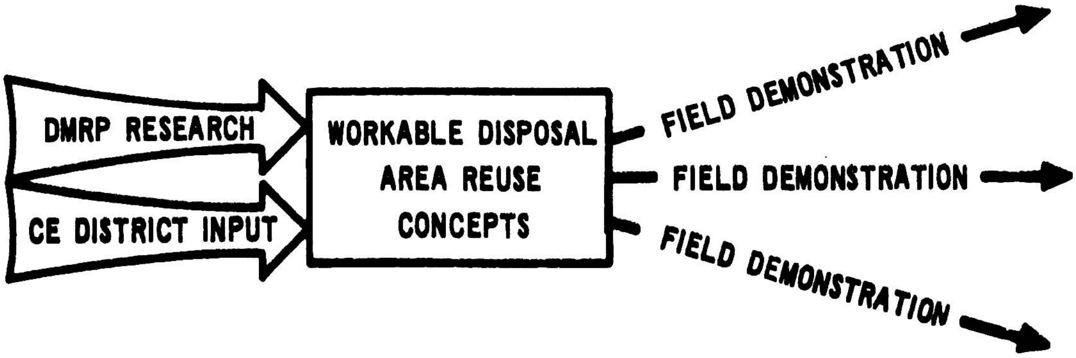


Figure 10. Survey of Districts for needs and areas of potential applications of reusable dredged material disposal sites

public objection to conventional disposal, the reusable area concept appears to be an attractive land disposal alternative. It is time that positive steps be taken to solve land disposal problems rather than rely on past practices that have only postponed the problems for a few years.

Use and Disposal of Processed Dredged Material

25. A major consideration of the area reuse concept is the use or disposal of materials necessary to permit reuse of the facility. The reusable area may be called a reusable dredged material collection and treatment facility as shown in Figure 11. This figure shows four alternatives for disposal of solids from dredged material processed in the facility. These are reasonable alternatives for maintaining the dredged material capacity of the facility for future dredging operations. But use of these alternatives will depend on the characteristics of the solid fraction of the dredged material processed.

Productive uses

26. Landfill and construction material. The most obvious use of the dried material is for landfill and construction purposes. In many urbanized areas there is a severe shortage of suitable landfill and construction material. Completed research has related the regional requirements for landfill to the availability of dredged material.[4]

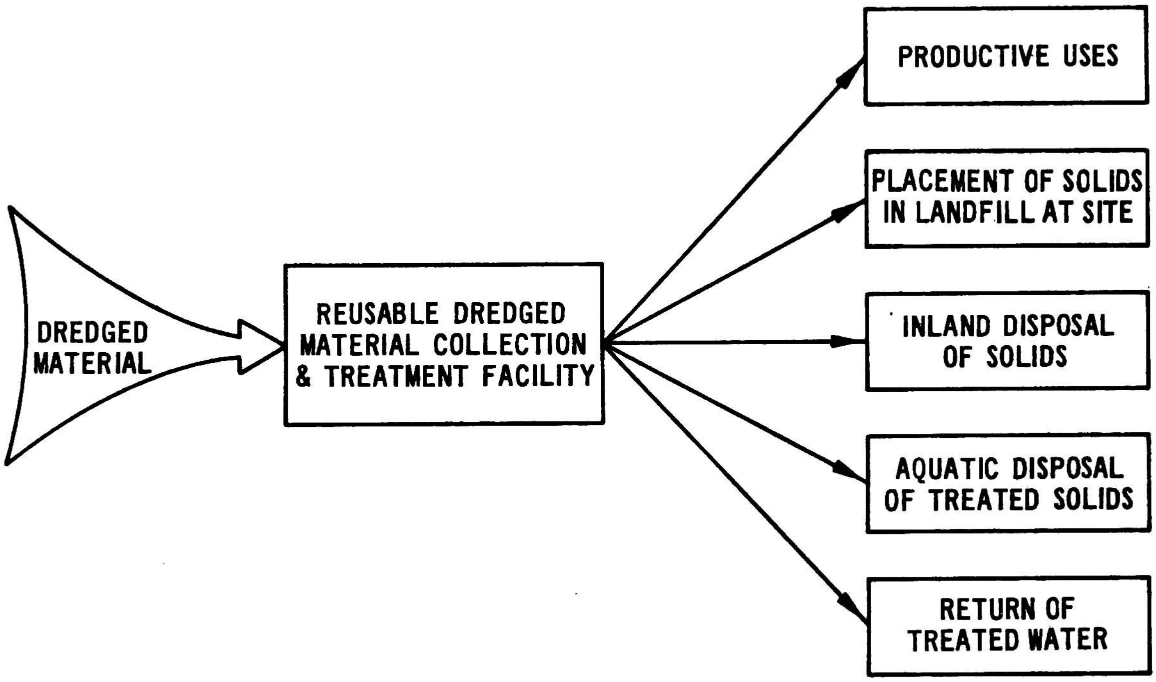


Figure 11. Flow diagram for disposal area reuse

The types of landfill projects evaluated are shown in Table 1 and are divided into the four main categories of resource, environmental, economic, and urban needs. Contacts were made through regional planning groups, chambers of commerce, port authorities, state and local Government agencies, and similar organizations. Evaluations were made on a regional basis, using coastal zone patterns as shown in Figure 12. General trends for all four categories indicated a high demand for landfill requirements in coastal areas and a decreasing demand inland. The total demand for dredged material for landfill use was in excess of available material from dredging activities. However, use of dredged material as landfill will depend upon convincing the state and local agencies involved that the material can be suitable for this purpose. Use of terms such as muck, slurry, mud, or spoil to describe dredged material has resulted in negative opinions regarding its potential value as a resource. With the possible exception of some purely industrial sediments, dredged material can be considered as soil at an abnormally high water content. Once dewatered, dredged material

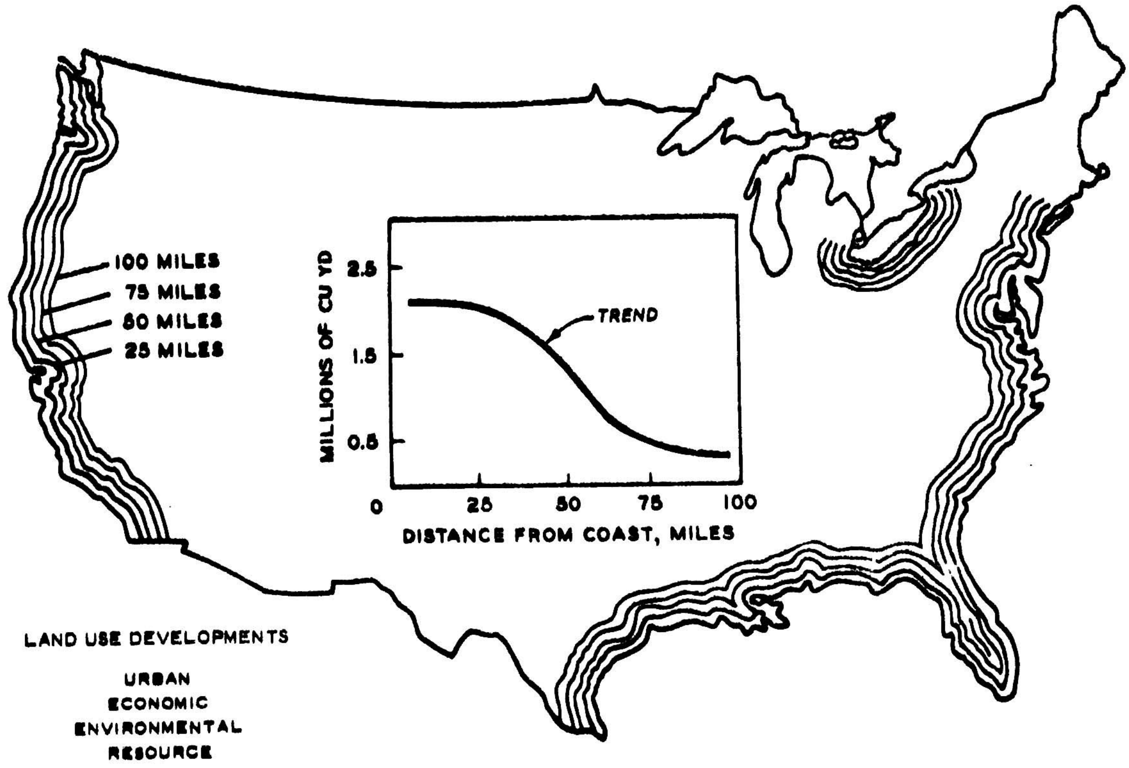


Figure 12. Nationwide landfill and construction material needs

exhibits engineering properties similar to in situ soils. To prove this, an engineering characteristics study was performed by WES to determine such properties of dewatered dredged material as shear strength, density, permeability, and consolidation characteristics.[5] It was concluded that most dredged material when adequately dewatered is acceptable landfill material.

27. <u>Other productive uses off-site.</u> Productive use of dredged material off-site could contribute to the possible removal of material and restoration of capacity in disposal areas. The constituents of many types of dredged material provide most of the needed assets of good topsoil. Therefore, use of the material as an agricultural enhancement is being evaluated as part of the DMRP's Productive Uses Project. Other possibilities, including restoration of strip mined areas and pits, are being considered along with transport considerations.

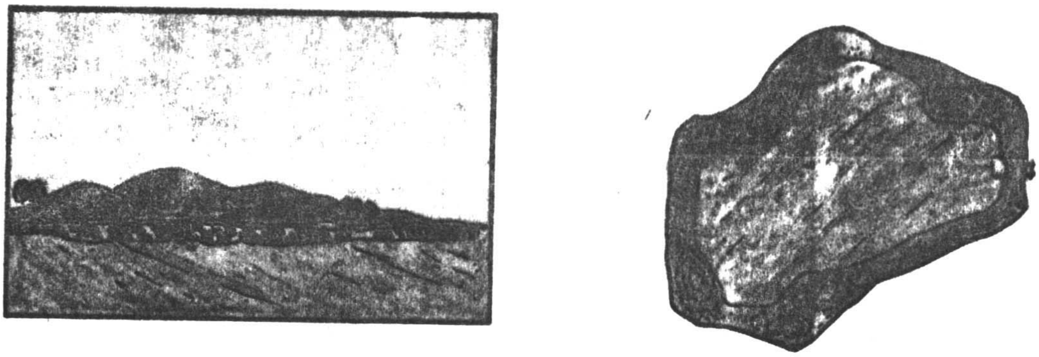
28. <u>Habitat development.</u> The use of dredged material for wildlife habitat development and marsh creation is an environmentally

attractive disposal alternative. However, many technical problems relating to confinement of the dredged material and achieving stable tidal elevations are caused in part by the use of slurry for the substrate or base material (mudflows, resuspension due to tidal action, etc.). A possible method of habitat creation that would bypass this difficulty involves the concept of using dewatered dredged material taken from diked disposal areas for the substrate. The placement of the dewatered material would result in more stable elevations and would require erosion control measures but no confinement structure. Capacity would be restored to existing disposal areas, and encroachment on these valuable lands due to new disposal area requirements would be eliminated.

On-site placement of solids

29. On-site landfill. Although the optimum area reuse schemes involve removal of the material from the site, the useful life of disposal areas can be greatly increased without actual removal of the material. In addition to required dewatering, other actions can be taken to substantially densify the dredged material mass within the disposal area. Through proper crust management (see Figure 9), the material can be densified and can be used to create on-site landfills. Not only is the material densified, but the potential use of the site is greatly enhanced due to increased bearing capacity. Another alternative is the placement of material within the right-of-way or easement but outside of the diked area. In this way the expense of diking at new sites could be limited to smaller areas sized for effluent quality only and not for total storage capacity. This alternative requires proper crust management, i.e. periodic removal of the dried material from the containment area to the adjacent landfill, allowing the containment area to be reused. If right-of-way outside the diked area at older sites is not available, the landfill can be placed within the dikes, as shown in Figure 9.

30. Mounding. An interesting variation of this concept is shown in Figure 13. Completed research on disposal site landscaping includes concepts for landfill moundings created by dredged material taken from the site interior.[6] Not only is the capacity of the site increased by



MOUNDING

GUIDELINES AND SPECIFICATIONS:

1. BREAK UP THE RIGID ELEVATION VIEW OF THE FACILITY.
2. GROUP MOUNDS AND VARY THE HEIGHTS.
3. GROUP NEAR THE INTERSECTIONS OF THE PERIMETER STRUCTURE.

Figure 13. Landscape mounding at dredged material disposal areas (after Roy Mann Associates, Inc.[6])

the mound creation, but the site can be made more aesthetically pleasing and environmentally compatible and therefore more acceptable to adjacent land owners. The use of such mounding tends to blend the site into its surroundings so that it tends to lose its disposal area identity.

Aquatic or upland disposal

31. The disposition of unusable portions of dredged material and effluent water is a significant aspect of site reuse. Contaminated effluent water can be simply returned to the stream following required treatment. However, the unusable solids resulting from any treatment processes must he handled and eventually disposed of. After treatment to control contaminants, this material can possibly be placed in aquatic disposal sites or transported to less expensive inland disposal areas. This same principle can be applied to unusable solids in slurry form not easily suited to dewatering. The material could be treated at the reusable disposal area and then disposed of in aquatic or upland areas. A major consideration with this concept is the feasibility of

transport by pipeline over long distances.

Active Field Study

32. Completed research has shown the disposal area reuse concept to be feasible, and input from the Corps Districts should provide added workability to the concept. But these concepts must be proven in the field before any widespread use and benefits can be achieved. A field demonstration of inexpensive dewatering/densification of dredged material and possible subsequent area reuse is under way in the U. S. Army Engineer District, Mobile.

33. The Mobile District uses two diked disposal areas on Blakeley Island adjacent to the Mobile River. These sites are used for disposal of fine-grained materials that are carried in a colloidal state in the fresh waters of the Mobile River and Chickasaw Creek, but upon reaching the saltwater interface, tend to precipitate into a dark gray to black sediment. After decantation in the diked areas, the dredged material takes on the appearance and consistency of heavy axle grease.

34. One alternative in the Mobile District's long-range plan included a large expansion of diked areas onto adjacent marshland, but this alternative was abandoned due to environmental constraints. The sites have a remaining capacity of only two years dredging, but must be used for all future work in the area. Therefore, a real need for dredged material densification and area reuse principles exists.

35. The field study will involve efforts to drain the upper Blakeley Island site and evaluate field results with prior laboratory predictive work. Consolidation will be induced within the dredged material and plans formulated for later removal of dewatered material and restoration of the site storage.

36. The dewatering scheme will employ open ditches constructed by both conventional equipment and by the use of the Riverine Utility Craft (RUC), a special-purpose vehicle designed for the U. S. Navy. A conceptual view of the field study is shown in Figure 14. The RUC employs twin helical screws as a means of propulsion, and ditches are

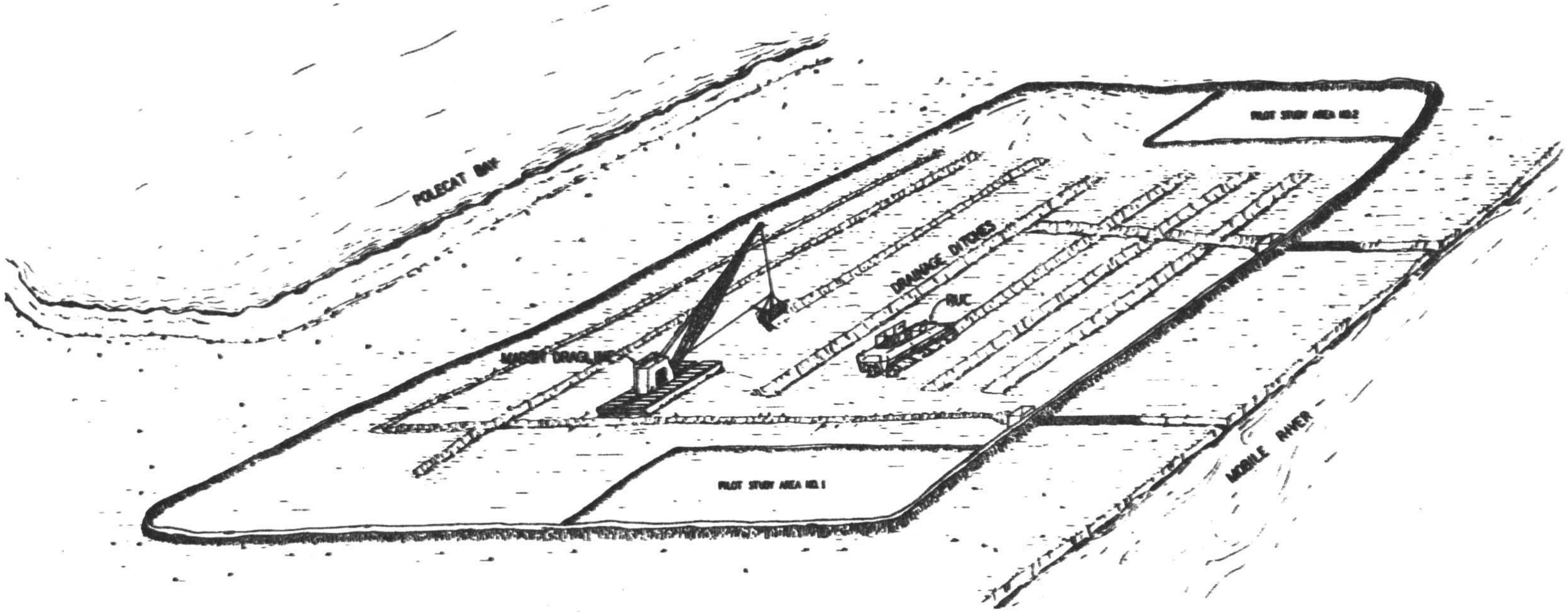


Figure 14. Conceptual view of dewatering operations at the Blakeley Island field study site (Mobile District, CE)

created in soft material after several passes of the vehicle in the same path. The relative ditching performance of the equipment will be evaluated along with comparative benefits gained from the dewatering/densification. Effluent water quality will also be monitored.

37. Sampling was performed at selected locations at the upper disposal area as shown in Figure 15. A comprehensive laboratory testing program will determine soil conditions, volume-density relationships, and consolidation characteristics. Periodic groundwater measurements at observation wells located throughout the site will evaluate efficiency of the ditching scheme for dewatering. Surveys will determine volumetric changes of the material and benefits gained by densification.

Legal and Economic Considerations

Legal aspects

38. The Corps is usually granted use of real estate for disposal through sponsorship by local interests. Actual ownership of the areas can be held by the Corps, local or State governments, or, in some cases, private concerns. Legal questions arise as to the status and ownership of dredged material placed in these areas, and the legality of its removal and use. A comprehensive study was performed to determine any legal, policy, or institutional constraints associated with dredged material marketing and land enhancement.[7] It was found that, provided the material is environmentally safe when it is donated or sold, there are few hard and fast legal prohibitions against the productive use of dredged material. However, there are a number of both Federal and State laws dealing with water quality, land use, and wetland protection that contain expressions of policy that will restrict temporary storage and some beneficial uses of dredged material.

Economic considerations

39. The concept of reusable disposal areas will gain widespread acceptance only after economic feasibility is established. Many factors must be considered in evaluating the economic comparisons between conventional disposal and use of reusable disposal areas. Taken

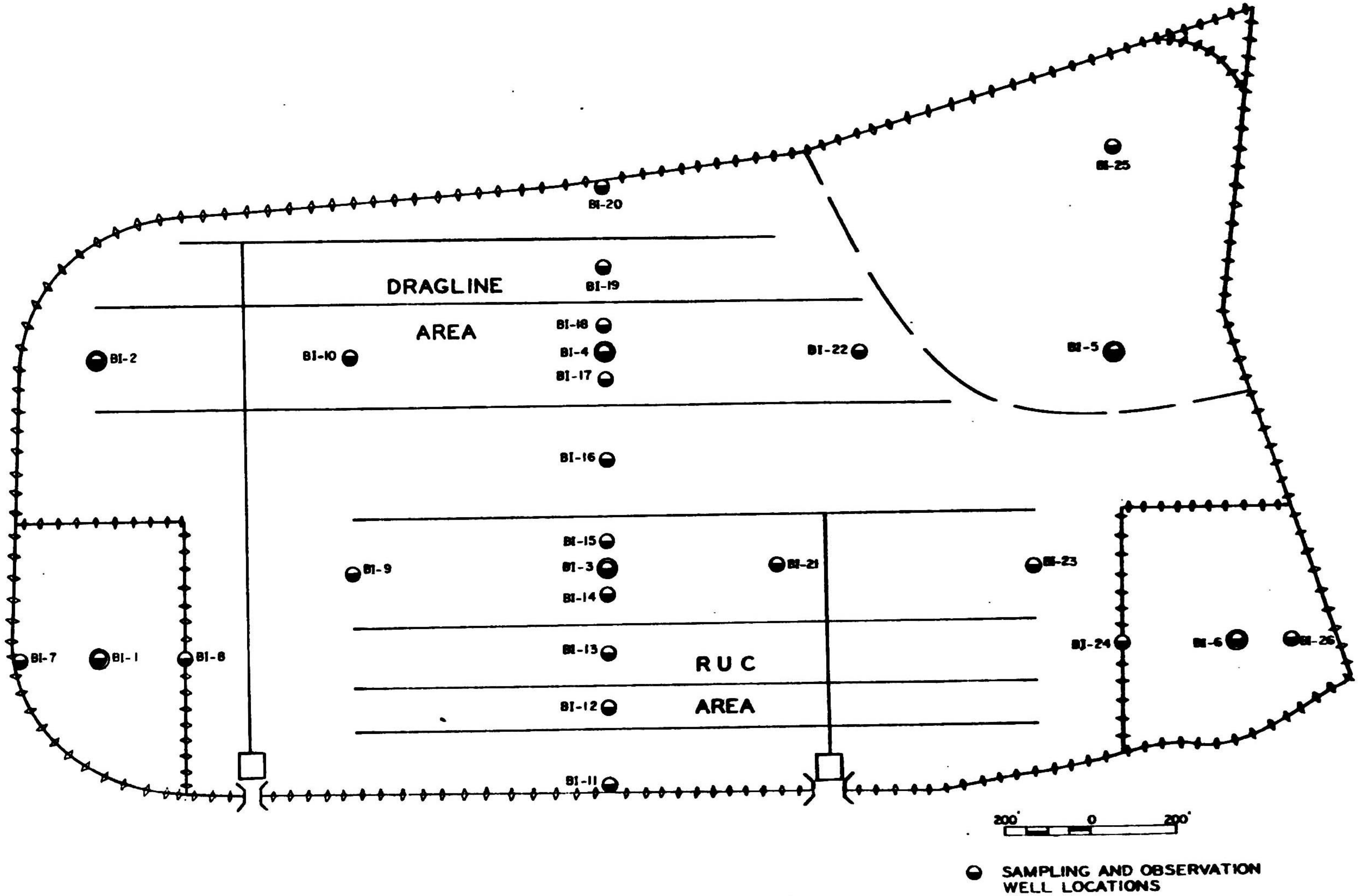


Figure 15. Blakely Island field study site plan

at face value, the costs involved in dewatering, densification, and rehandling material for removal off-site seem much higher than conventional disposal practices. However, many aspects of site reuse tend to defray added expense and may result in area reuse being more economical on a unit basis than continued conventional disposal. Personnel from the U. S. Army Engineer District, Philadelphia, estimated that removal of 1 cu yd* of dredged material from an existing site results in a savings of $0.65, considering costs of land and dike construction.** Increasing scarcity of available land in urban areas and economic trends would cause the potential savings to increase with time. The Philadelphia District has proven that site reuse concepts can be economically feasible through a program of dredged material sales.** Table 2 summarizes the results of the Philadelphia program over a period of two years. Not only did the District realize significant savings through restoration of site capacity, but considerable income was gained through the actual sale of material (up to $0.82 per cubic yard).

40. Other economic benefits derived through area reuse are difficult to estimate in the general case. These include savings in dredging costs by using existing sites convenient to the operation, income derived through sale of resources, economic benefits resulting from productive uses of dredged material, and prevention of environmental degradation through improved design and operation of the disposal areas.

Conclusions

41. Completed research under the DMRP has determined that reusable disposal facilities are feasible. The facts brought to light include the following:

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

** U. S. Army Engineer District, Philadelphia, CE, "Sale of Fill Material - Sand and Gravel from Disposal Areas," personal communication, Dec 1974.

a. A need exists for land disposal areas that are technically sound in design and are environmentally compatible for reuse over long periods of time.

b. Functions of a reusable disposal facility include dewatering and densification of solids, treatment of contaminated liquids and solids, resource storage and use, and disposal of unusable material.

c. Alternatives for maintaining and/or restoring the capacity of a reusable area include removal of material for landfill or other productive use, landfill or moundings on-site, or disposal of treated material in aquatic or inland disposal sites.

d. Information has been gained on the separation of the coarse fraction of dredged material; however, further research is necessary to develop techniques for mechanical dewatering of fine-grained dredged material.

e. There exists adequate authority for sale or donation of dredged material from reusable areas, and there are few legal constraints prohibiting the use of the material provided it is environmentally safe.

f. Benefits gained through reuse of disposal areas include retention of sites convenient to dredging operations, reduction in land-use and diking requirements, reclamation of valuable resources, and prevention of environmental degradation.

The results gained from further research in the areas of dredged material dewatering, treatment of contaminated dredged material, disposal area operations, and productive use will significantly contribute to evaluation of the reusable area concept. Research efforts will be combined with field studies and input from Corps Districts and Divisions in making area reuse a workable disposal alternative.

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Table 1

Land-Use Developments

Urban	Economic
Residential; housing	Industrial
Commercial	Rail; rapid transit
Resorts; commercial camps	Harbor; ports
	Highways
	Utilities

Environmental	Resource
Wildlife refuges	Artificial islands
Marine nurseries	Agricultural/grazing land
Beach nourishment	Forestry
Public parks and recreation	Land reclamation
Marshland management	Sand and gravel
Other landfills	Material stockpiles
Floodplain control/levees	

Table 2

Sale of Fill Material from Disposal Areas

(Philadelphia District)

Disposal Area	Bid/cu yd	Cubic Yards	Date Awarded
Pedricktown	$0.11	300,000	Oct 1972
National Park	0.11	10,000	Jul 1973
National Park	0.12	300,000	Jul 1973
Fort Mifflen	0.25	150,000	Jan 1973
Fort Mifflen	0.82	100,000	Jan 1973
Penns Grove	0.40	30,000	Oct 1973
Penns Grove	0.35	300,000	Aug 1973
National Park	0.12	60,000	Sep 1973
National Park	0.10	17,000	Dec 1973
Penns Neck	0.15	25,000	Jan 1974
Penns Grove	0.08	4,500,000	May 1974
Pedricktown	0.40	5,000	May 1974
National Park	0.10	15,000	Jun 1974

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Palermo, Michael R
A new concept for dredged material disposal, by Michael R. Palermo [and] Raymond L. Montgomery. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1976.
26 p. illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper D-76-15)
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1. Disposal areas. 2. Dredged material. I. Montgomery, Raymond Lawree, joint author. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper D-76-15)
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