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AUG 78 T A HALIBURTON, J FOWLER, J P LANGAN

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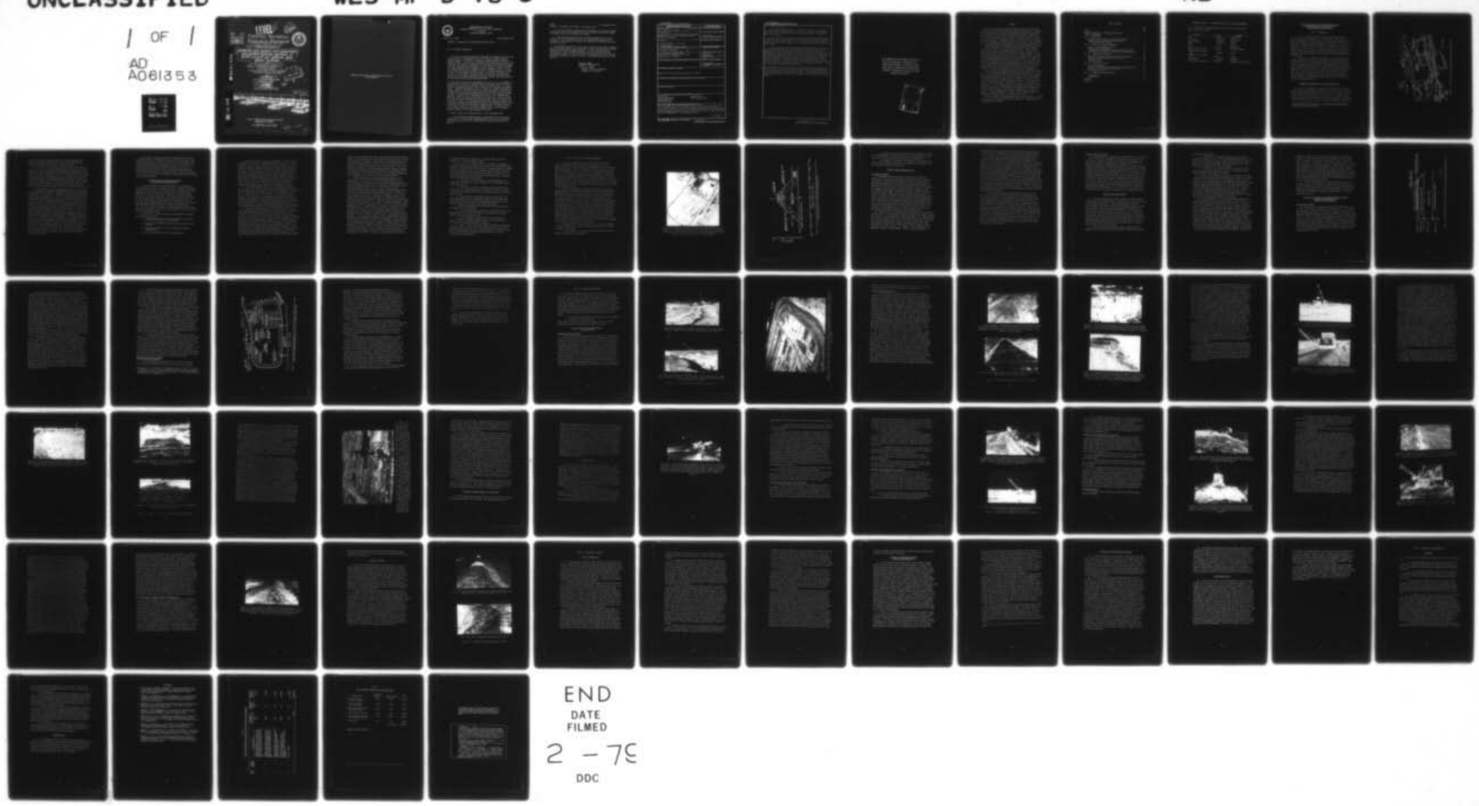

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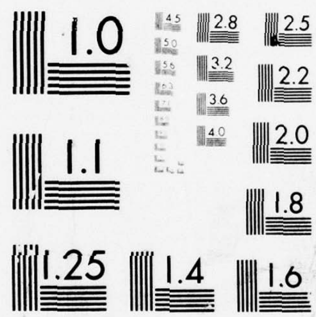

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DREDGED MATERIAL RESEARCH PROGRAM

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MISCELLANEOUS PAPER D-78-3

PERIMETER DIKE RAISING WITH DEWATERED FINE-GRAINED DREDGED MATERIAL AT UPPER POLECAT BAY DISPOSAL AREA MOBILE, ALABAMA

by

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Final Report

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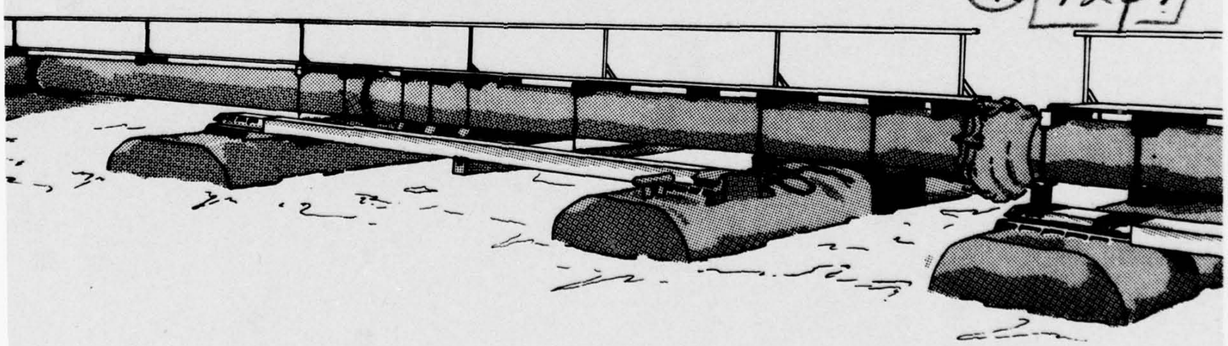

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 5A20

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30 September 1978

SUBJECT: Transmittal of Miscellaneous Paper D-78-3

TO: All Report Recipients

1. The report transmitted herewith represents the results of one of the research efforts accomplished as part of Task 5A (Dredged Material Densification) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 5A, part of the Disposal Operations Project of the DMRP, was concerned with developing and/or testing promising techniques for dewatering and/or densifying (i.e., reducing the volume of) dredged material using physical, biological, and/or chemical techniques prior to, during, and/or after placement in the containment areas. Although the study was conducted as part of Task 5A, concepts developed as part of Task 2C (Containment Area Operations) and Task 5C (Disposal Area Reuse) as well as work conducted as part of the DMRP Productive Uses Project were considered during the planning, design, and construction of the dike-raising activities described herein.

2. The rapidly escalating requirements for land for the confinement of dredged material often in urbanized areas where land values are high dictated that significant priority within the DMRP be given to research aimed at extending the useful life of existing or proposed containment areas. Methods investigated as part of Task 5A included dewatering of dredged material to both increase the volume available in the site and to improve the engineering characteristics of the fine-grained dredged material. Methods were investigated under Task 5C for removing the material either for dike construction or offsite use. Finally, design and construction guidelines were developed under Task 2C to ensure the stability of dikes. The dike-raising activities described herein conducted by the Waterways Experiment Station's Environmental Laboratory in cooperation with the Mobile District combined and successfully applied all of these facets in a full-scale demonstration. In addition, the dike-raising activities provided the Mobile District with disposal capacity required for future dredging activities.

3. Based on this field demonstration, it was determined that:

a. Fine-grained dredged material of high plasticity may be used successfully in large-scale dredged material disposal site perimeter dike-raising activities once the material has been successfully dewatered.

b. The cost of dike raising with the dewatered fine-grained dredged material was less than estimated for use of offsite borrow even though the demonstration site had good haul access.

c. Three different methods for dewatered dredged material borrow removal and three different methods for perimeter dike raising were evaluated. All methods were found to be technically feasible and operationally practical.

4. The procedures outlined in this report should provide general guidance on the planning, design, and construction of dike-raising projects using dewatered fine-grained dredged material. As with any geotechnical construction project, general guidelines are not sufficient and the site-specific aspects of each site must be considered using the detailed guidelines developed in Tasks 2C, 5A, 5C, and within the Productive Uses Project.

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

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

Use of dewatered fine-grained dredged material for large-scale perimeter dike raising was evaluated by a cooperative field demonstration between the U. S. Army Engineer District, Mobile, and the Dredged Material Research Program (DMRP) Disposal Operations Project (DOP) and Productive Uses Project. After conduct of the field demonstration, it was determined that:

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20. ABSTRACT (Continued)

a. Fine-grained dredged material of high plasticity may be used successfully in large-scale dredged material disposal site perimeter dike-raising activities, once the material has been successfully dewatered with DMRP DOP-developed procedures.

b. The cost of dike raising with the dewatered fine-grained dredged material was less than estimated for use of offsite borrow, even though the demonstration site had good haul access. Cost of disposal area storage volume obtained was $0.27/cu yd; 1.2 million cu yd of disposal volume was created by the dike raising.

c. Three different methods for dewatered dredged material borrow removal and three different methods for perimeter dike raising were evaluated. All methods were found to be technically feasible and operationally practical. Tandem dragline relaying was found to be the most cost-effective borrow alternative when sufficient crust volumes and disposal area surface crust support were available. Construction of fabric-reinforced haul roads to obtain interior dredged material borrow may be cost effective if tandem dragline operations cannot be conducted. A two-lift sequential dike-raising technique, whereby a dragline constructed a semicompacted first lift ahead and an uncompacted second lift behind while moving down the perimeter dike alignment, was found to be the most cost-effective dike-raising methodology.

Cont →It is recommended that Corps of Engineers field elements and other interested agencies seriously consider the use of dewatered fine-grained dredged material for large-scale perimeter dike-raising activities, following the construction procedures described and evaluated in the report. Such construction may be extremely cost effective at remote locations where offsite borrow is particularly expensive.

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PREFACE

This report describes a full-scale confined disposal area dike-raising demonstration project using dewatered fine-grained dredged material, conducted as a cooperative effort between the Dredged Material Research Program (DMRP) Disposal Operations Project (DOP) and Productive Uses Project (PUP) and the U. S. Army Engineer District, Mobile (MDO), at the Upper Polecat Bay Disposal Area, Mobile, Alabama. The DMRP was sponsored by the Office, Chief of Engineers, U. S. Army (DAEN-CWO-M), and was managed by the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

Research described in this report essentially completes the DMRP DOP scope of work relative to confined disposal operations. Previous research and synthesis reports have provided guidelines on proper techniques for disposal area design and construction, prediction of volume necessary to contain fine-grained dredged material in slurry form, and methodology for dewatering the fine-grained dredged material back to normal soil form. This report provides data on design and construction methodology for cost-effective removal of the dewatered fine-grained dredged material and its productive use in disposal site perimeter dike raising, thus completing the cycle of operations required for effective confined disposal area operation and management.

Concept formulation and general supervision of the research was conducted by Dr. T. Allan Haliburton, DMRP Geotechnical Engineering Consultant. Onsite research operations were directed by Mr. Jack Fowler, Research Civil Engineer, WES Geotechnical Laboratory (GL), with the assistance of Mr. Robert Gunkel and Mr. William Harper, Engineering Technicians, WES GL. Contractual details, along with general assessment and guidance in conduct of the work, were provided by Mr. J. Patrick Langan, Assistant Chief, MDO Project Operations Branch. The report was written by Dr. Haliburton (with significant contributions by Messrs. Fowler and Langan), under the general supervision of Mr. Charles C. Calhoun, Jr., DMRP DOP Manager; Dr. Roger T. Saucier, Special Assistant for Dredged Material Research; and Dr. John Harrison, Chief, EL.

District Engineer of the MDO during this period was COL Charlie L. Blalock CE, and Director of the WES was COL John L. Cannon, CE. Technical Director of the WES was Mr. F. R. Brown.

TABLE OF 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
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	25.4	millimetres
pounds (force) per inch	175.1268	newtons per metre
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.4535924	kilograms
tons (mass) per square foot	9764.856	kilograms per square metre

PERIMETER DIKE RAISING WITH DEWATERED FINE-GRAINED DREDGED MATERIAL AT UPPER POLECAT BAY DISPOSAL AREA, MOBILE, ALABAMA

PART I: INTRODUCTION

1. Goals of the Dredged Material Research Program (DMRP) Disposal Operations Project (DOP) include, among other activities, organization, conduct, and assessment of research related to confined disposal area operation, maintenance, fine-grained material dewatering, and site reuse. During the conduction of the DMRP, considerable information was developed, assessed, and synthesized in a form for use by operating personnel.[1-4] Use of material contained in these synthesis reports will allow optimized design, operation and management, material dewatering, and site reuse for confined dredged material disposal areas.

2. The majority of information synthesized in the above references was obtained and evaluated by conduct of field demonstrations. Because of DMRP time constraints, the last field demonstration, using dewatered fine-grained material in perimeter dike raising, could not be completed in time for adequate assessment and evaluation prior to publication of previously referenced guidelines. This report presents, in some detail, the rationale, design concepts, and construction concepts necessary to use dewatered fine-grained dredged material in confined disposal area perimeter dike raising, and may thus be considered an addendum to DMRP DOP synthesis data for disposal area operation, management, and reuse.

Background Concerning Upper Polecat Bay Disposal Area

3. As part of a cooperative effort between the DMRP and the U. S. Army Engineer District, Mobile (MDO), the Upper Polecat Bay (UPB) Disposal Area (also called the North Blakeley Island Disposal Area), located as shown in Figure 1, was made available to the DMRP DOP for field evaluation of numerous concepts in disposal area operation and management, material dewatering, and site reuse. Details concerning the 85-acre* site, including general foundation properties,

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 4.

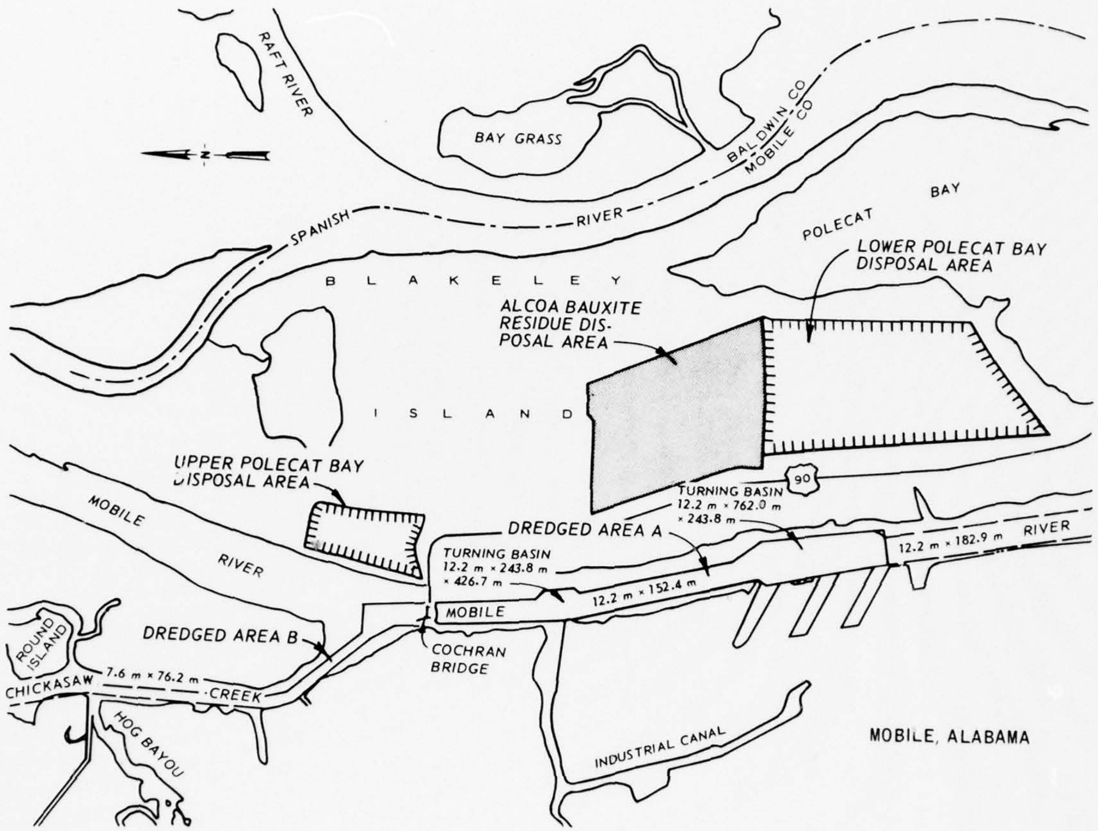

Figure 1. Location of Upper Polecat Bay Disposal Area, Mobile, Alabama

method of original perimeter dike construction, engineering properties of contained fine-grained dredged material, and particular DMRP DOP field evaluations conducted at the site, are available elsewhere.[5]

4. In the fall of 1976, it became obvious that various DOP field demonstrations at the site were successfully dewatering the fine-grained dredged material, such that a considerable volume of dewatered dredged material crust existed over most of the disposal area. At this time, DOP researchers desired to use this material in a productive manner, to establish by field demonstration that the material had considerable potential for reuse in certain activities. This research effort was to be conducted in cooperation with the DMRP Productive Uses Project (PUP), whose research goals were to, among other activities, identify suitable productive uses for fine-grained dredged material.[6]

5. The MDO Operations Division contemplated further use of the UPB site to contain additional fine-grained dredged material from maintenance dredging along reaches of the Mobile River. Estimated disposal capacity required was on the order of 2.4 million cu yd. At the close of DMRP fine-grained dredged material dewatering operations, available site capacity was estimated at 1.2 million cu yd, thus an additional storage capacity of 1.2 million cu yd was needed at the site. The obvious way to obtain desired disposal capacity was to raise the perimeter dike. However, the sand borrow source previously used to construct the UPB perimeter dike was no longer available. Conventional MDO practice when such situations are encountered is to use one or more draglines, operating either from the perimeter dike or immediately outside the dike, to remove undewatered or partially dewatered fine-grained dredged material and cast this material on the existing dike. In such manner, the dike may usually be raised just enough to provide proper freeboard for the next disposal operation. Problems with such a construction procedure include stability of the raised portion and difficulty in obtaining a raise elevation of more than 2 or 3 ft because of the high water content and low strength of the borrowed material. Also, fairly thin raise sections are produced such that, after two or three such raisings, a relatively thin retaining dike of low stability results.

6. As a result of conferences between the MDO Operations Division and the DMRP DOP and PUP, the MDO supported the concept of using dewatered fine-grained dredged material to conduct a single full-scale dike raising at UPB, rather than the three smaller incremental dike raisings they had previously anticipated necessary to obtain the needed capacity of 1.2 million cu yd. This procedure would allow DMRP evaluation of perimeter dike-raising and dredged material productive use concepts and provide the MDO with a perimeter dike of sufficient size and mass to adequately contain material from anticipated future disposal operations.

Conceptual Basis for Perimeter Dike Raising with Fine-Grained Dredged Material

7. Initial construction of confined disposal area retaining dikes is often troublesome and costly, requiring the solution of numerous engineering problems, particularly when a soft foundation exists. Optimized construction guidelines for initial perimeter dike construction were developed by the DMRP[7] and such work may be successfully conducted in almost any situation. However, time and funding constraints, plus foundation problems, often limit the initial height to which perimeter dikes may be constructed. Thus, at some later time in disposal area operating life, dike raising may be necessary. Preliminary DMRP research[8] indicated that perimeter dike raising was one of the most cost-effective methods for obtaining additional confined disposal area storage capacity, with 1975 costs on the order of $0.25 to $0.30 per cu yd of created disposal volume.

8. Four choices are usually available to provide material for disposal site perimeter dike raising:

- a. Purchase suitable offsite borrow for transport to the disposal area and use in perimeter dike construction.
- b. Use onsite coarse-grained material deposited by normal disposal operations.
- c. Use onsite undewatered or partially dewatered fine-grained dredged material.
- d. Use onsite dewatered fine-grained dredged material.

9. Turnkey contracting for purchase and transport of offsite borrow to the disposal area as part of a dike-raising contract is probably the simplest alternative, and the offsite borrow may have optimum engineering properties, allowing a technically superior finished dike. However, this alternative is also likely to be the most expensive, particularly when long haul distances are involved, and is operationally practical only when good haul access is available to the disposal site and along or around the perimeter dike. In many instances, confined disposal areas are located in remote or isolated locations with poor access or, in many instances, offshore, with no access except by barge or boat. Thus, the only practical source of material for perimeter dike raising must come from within the disposal area itself.

10. Coarse-grained dredged material is, in many instances, ideal for use in perimeter dike raising. Normal disposal operations deposit this material in a large mound at the dredge pipe location. Procedures are also available[3] for depositing this material adjacent to existing perimeter dikes to facilitate future raising. The coarse-grained fraction is essentially "washed" by the progressive sedimentation disposal process and is stronger than fine-grained material. Further, construction operations for sand removal are relatively simple. Finally, engineering design of perimeter dikes or raise increments constructed from coarse-grained material is relatively simple.[7]

11. Conversely, sand deposited in confined disposal operations is a rather attractive material for other uses, including construction of disposal site underdrain systems and removal for other offsite productive uses.[6] The material has a higher unit weight than fine-grained dredged material, and its use in dike raising of great vertical extent may precipitate rotational bearing failure of underlying soft foundations. Also, cohesionless material has relatively low erosion resistance, thus causing future dike maintenance problems and necessitating wave protection with sandbags, polyethylene, or other material on the inside dike face during disposal operations. Further, the material has a relatively high seepage permeability. While deposition of fine-grained dredged material slurry inside the disposal area will likely plug a sand dike shortly after disposal is initiated, initial seepage through

the dike or raise increment could lead to piping and resultant dike breaching. Finally, at many disposal area locations where sufficient quantities of coarse-grained material are deposited in single mounds, the existing perimeter dike does not have adequate width or stability for any truck haulage operations necessary to transport the material around the dike perimeter. Also, at many disposal area locations, the confined dredged material is produced primarily from maintenance activities and only small amounts of coarse-grained material may be deposited. Thus, sufficient quantities of coarse-grained material may not be available onsite, even if its use is technically feasible.

12. When, for reasons of either operational practicality or cost effectiveness, offsite borrow or onsite coarse-grained material is not a viable alternative, undewatered and partially dewatered dredged material has been used in perimeter dike raising. As described in previous DMRP research,[3] fine-grained dredged material placed in confined disposal areas at locations where annual precipitation approximates or exceeds annual evaporation tends to remain (beneath a thin desiccation crust) in a semifluid state near the Atterberg liquid limit. Maximum crust thickness (of only several inches) is likely to occur near the disposal area perimeter because of subsurface drainage into and through the perimeter dike and surface drainage toward the center of the disposal area, as a result of foundation settlements. Small draglines may operate on the perimeter dike to remove this partially dewatered dredged material. The material may be cast directly on the dike, a procedure followed by the MDO, or may be cast and spread along the inside face of the perimeter dike for drying, and then subsequently removed and placed on the existing dike crest, a procedure followed by the U. S. Army Engineer District, Charleston. This dike-raising procedure is fairly straightforward and has the advantages of being relatively inexpensive and expedient, in that enough material may usually be obtained to raise the existing perimeter dike just enough for the upcoming disposal operation. However, as a long-term disposal area management practice, the method is essentially self defeating, as enough material is never available to construct a proper base section upon which to stack succeeding raise increments. As a result, the final stable dike elevation obtainable by this procedure is fairly low, and periodic major renovation of

the perimeter dike must be conducted to reestablish proper base section conditions for further incremental raising.

13. If, as part of an overall disposal site operation and management program, dewatering operations had been carried out on the fine-grained dredged material at a disposal site, forming a crust of reasonable thickness, the DMRP DOP and PUP believed that use of this dewatered material in major, large vertical extent perimeter dike-raising activities would, at many locations, be a preferable alternative to the three methods described previously. Advantages of using such dewatered material include:

a. The material is located adjacent to the perimeter dike, is available at no purchase cost, and its removal will create additional storage volume inside the area.

b. The material usually has a lower dry unit weight than either offsite borrow or coarse-grained material available at the site, thus dikes of greater vertical height may be constructed without possibility of foundation bearing failure.

c. The material has considerably better erosion resistance than coarse-grained material, thus reducing future disposal area perimeter dike maintenance, need for wave protection during disposal operations, and possibility of piping behavior during initial disposal operations.

14. Conversely, disadvantages of using dewatered fine-grained material in perimeter dike raising include:

a. The fine-grained material may have a lower strength than coarse-grained material, thus flatter dike slopes and more material are needed to achieve the same vertical height of dike.

b. Size of digging and hauling equipment that may operate on a crust of dewatered fine-grained dredged material is relatively limited,[1] and special excavation techniques may be necessary.

15. In order to evaluate the design concepts and construction procedures necessary to properly conduct large-scale dike-raising activities with fine-grained dewatered dredged material, a field demonstration was conducted at the UPB site using dewatered fine-grained material produced as a result of previous DOP field demonstrations.

PART II: DESIGN OF UPB FIELD DEMONSTRATION

16. The 85-acre UPB disposal area, located as shown previously in Figure 1 and used for conduct of DOP field experiments,[5] is shown in Figure 2 at the close of site dewatering field demonstrations. These dewatering field experiments produced a surface crust thickness ranging from 12 in. to 5 ft in various parts of the disposal area. During discussions with the MDO relative to a perimeter dike-raising field demonstration, it was determined that the perimeter dike needed to be raised from existing El. 14 to 16 Mean Sea Level (MSL) to El. 24 MSL, to provide an additional 1.2 million cu yd o disposal capacity. The area surrounding the UPB site is at El. 1 to 4 MSL and, after dewatering activities were terminated, contained dredged material existed to about average El. 8 MSL.

17. Existing perimeter dikes at UPB had been constructed of coarse-grained material by end-dumping displacement, and the coarse-grained material displaced underlying soft foundation material to a depth of approximately El. -16 MSL. More detail on original perimeter dike design and construction is available elsewhere.[5] The existing dikes had suffered somewhat from erosion and traffic during conduct of DOP field demonstrations, but would provice a stable base section for dike raising. As a result of previously mentioned discussions, it was decided that the perimeter dikes would be raised to El. 24 MSL using dewatered fine-grained material available in the disposal area; the cost of dike raising would be assumed by the MDO; and that the DOP and PUP would be responsible for preparing appropriate dike-raising designs, provide specifications and cost estimates for MDO contract advertisement, provide engineering personnel to direct the dike-raising construction activities, and prepare a written evaluation on the project. Based on this agreement, four subtasks were established by the DOP and PUP:

a. Development of a proper design for the raised dike, including foundation exploration, soil sampling, soil testing, and analyses necessary to produce a proper design.

b. Preparation of cost estimates and specifications necessary for MDO dike-raising contract advertisement.

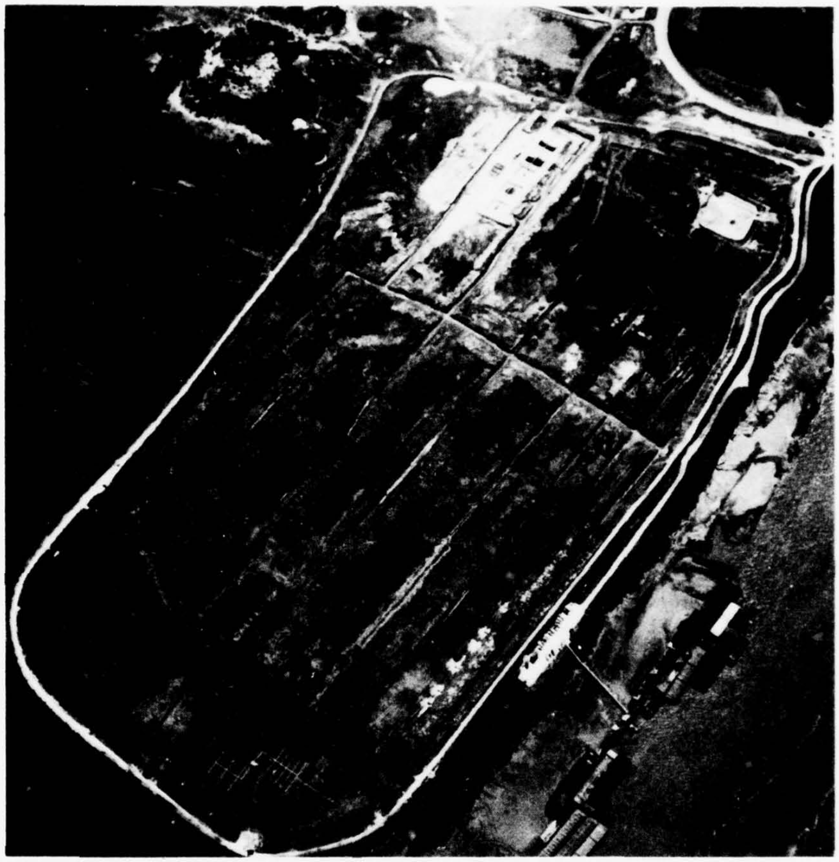

Figure 2. Aerial view of Upper Polecat Bay Disposal Area prior to initiation of dike-raising activities. Note the surface drainage network produced by DMRP DOP dewatering field demonstrations. North toward the lower left corner of the photograph

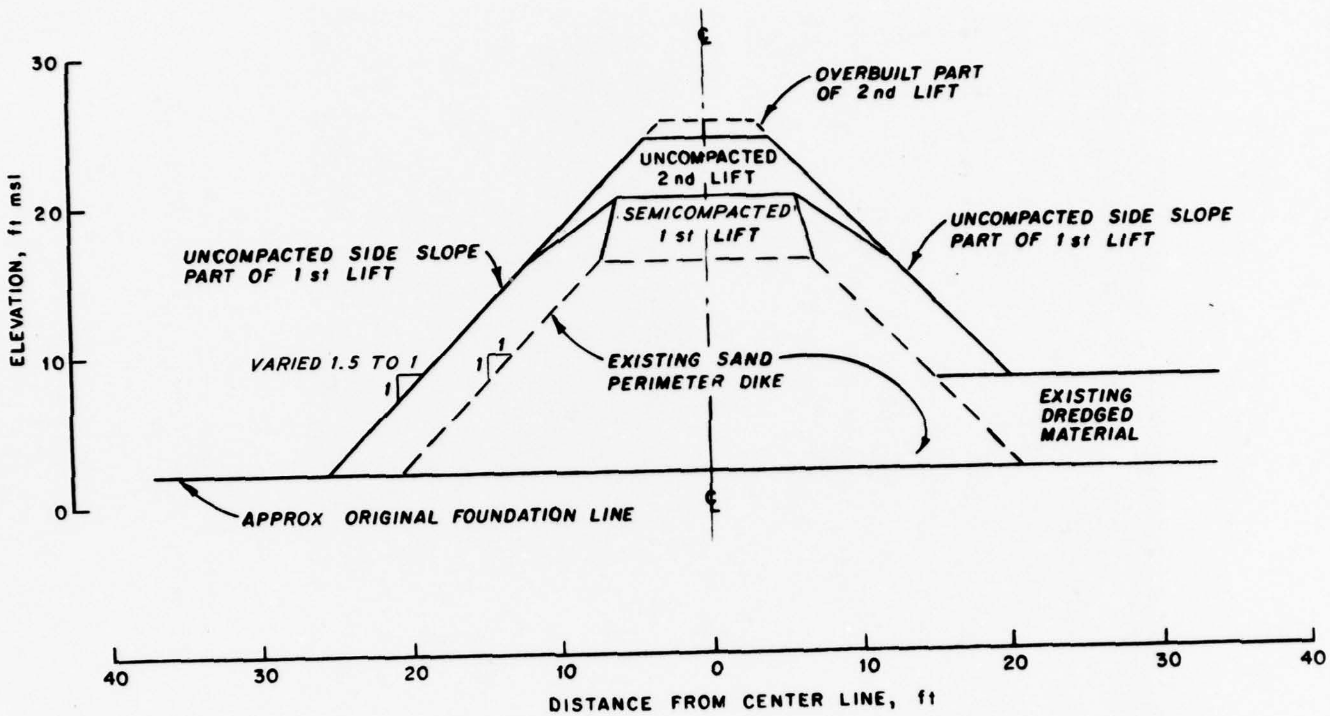

Figure 3. Typical cross section of raised perimeter dike showing semicompacted first lift and uncompacted second lift of fine-grained dredged material

c. Direction of the work, including continual assessment, reevaluation, and modification of construction procedures as necessary, based on the results of day-to-day construction operations and accomplishments.

d. Documentation, evaluation, and assessment of the demonstration. The first three subtasks are described in subsequent sections and parts. The fourth subtask is satisfied by this report.

Design of Raised Embankment Section

Preliminary operations

18. MDO design constraints dictated a raising to El. 24 MSL and construction of a section with finished 8-ft crest width to allow four-wheel-drive vehicular mobility along the perimeter dike for inspection purposes during disposal operations. The existing dike alignment was surveyed by the MDO Mobile Area Office and cross sections, prepared at various locations along the alignment, allowed estimation of material quantities needed to obtain the required raise increment. Borings were carried out through the existing dike into underlying foundation materials by the MDO Core Drill Section, as directed by the DOP. The majority of exploration was conducted along the west disposal area perimeter dike, as this dike had given the most problems during initial construction (from foundation bearing failure) and improvements adjacent to this portion of the disposal area included the Cochran Bridge over the Mobile River on US Highway 90 and a towboat docking facility adjacent to the northwest end of the disposal area. An access road and utility lines were also located parallel with the disposal area west perimeter dike.

19. Various samples of foundation material were tested by the Geotechnical Laboratory (GL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Results of soil testing showed a marked improvement (from predisposal area conditions) in strength of soft cohesive foundation materials under the perimeter dike, reflecting consolidation of these strata under perimeter dike weight. Calculations indicated that the foundation would adequately support a raise increment of El. 24 MSL, except at the southwest corner of the perimeter dike immediately adjacent to Cochran Bridge. In order to obtain satisfactory

foundation stability at this point, the resulting raise design was modified to include a wider and inward-benched section, with the existing dike facing Cochran Bridge to act as a berm and prevent undesired foundation behavior.

20. Detailed engineering property data on the fine-grained dewatered dredged material at UPB are available elsewhere,[5] but, in summary, the material is a CH montmorillitic clay with an Atterberg liquid limit of approximately 100 and less than 5 percent organic material. Dewatering operations conducted by the DOP reduced the average water content of the surface crust to between 30 and 60 percent water content, at or above its Atterberg plastic limit but below its Atterberg sticky limit. Unconfined compression tests on samples of the dredged material crust gave strengths of over 1.0 tsf in the upper few inches of the crust, approximately 0.5 tsf in the portions of the crust where water content was nearer the Atterberg plastic limit, and approximately 0.15 to 0.25 tsf in lower portions of the crust. Below the crust, the material was still in an essentially undewatered state and had semifluid consistency. Vane shear tests conducted on this material indicated a cohesion C of 50 to 150 psf, for testing conducted at various locations and depths between the base of the crust and original foundation line.

21. Field trials with a small wide-tracked dozer indicated that the crust could be successfully bladed and shaped and that semicompaction by dozer track would produce a fairly homogenous and erosion-resistant section. A small ($10,000) rental contract was also let by the MDO to evaluate the technical feasibility and operational practicality of dragline crust removal and placement and to provide data on expected production rates for use in future cost estimate and contract specification preparation. Results of this preliminary study indicated that the relatively small (BuCyrus-Erie 15B) dragline with 5/8-cu yd bucket could operate successfully on the dredged material crust, with an expected minimum production rate of 40 cu yd/hr. Also, it was determined that the fine-grained crust could be successfully stacked to a 4-ft height in an essentially uncompacted manner, and if the side slopes of the material were dressed by the dragline, precipitation quickly ran off without infiltration or erosion damage.

Design of dike cross section

22. Using strength data obtained for the dredged material crust, adjusted to reflect the effects of semicompacted and uncompacted placement after borrow, stability analyses were conducted by the WES GL, using DMRP-developed guidelines for design of dredged material retaining dikes.[7] These analyses determined that, using conservative values for expected fine-grained dredged material strength, a stable section could be constructed on the existing base section using the fine-grained dredged material. The section, shown in Figure 3, would consist of approximately 4 to 6 ft of semicompacted fine-grained dredged material (placed up to El. 20 MSL) covered by a second lift of essentially uncompacted fine-grained dredged material with dressed slopes, placed to El. 24 MSL. Side slopes of 1V on 1.5H were initially used, based on conservative projections of fine-grained dredged material semicompacted and uncompacted strength. Based on better than anticipated field behavior, these side slopes were reduced to 1V on 1.25H and 1V on 1H at some locations during actual construction, without adverse effects on embankment stability.

Design of Interior Haul Roads

23. As part of construction operations necessary to provide adequate borrow (to be described subsequently), it was necessary to operate dump trucks in the disposal site interior. Available DMRP guidelines[1] indicated that the existing crust did not provide sufficient support capacity for dump truck operation. Thus, interior haul roads placed on the existing crust would be needed to obtain required dump truck mobility. Civil engineering fabric (filter cloth) has been used, on numerous occasions, to provide increased support capacity for haul vehicles and other construction equipment across soft ground. However, most such projects have been of a construction-expedient nature and mimimal records could be found by the DOP concerning exact design procedures for given soil types, placement details, required depth of fabric cover, and related items.

24. Design of a proper haul road by currently acceptable Corps of Engineer criteria using the California Bearing Ratio (CBR) method of design

required two determinations:

a. Prediction of the necessary thickness of cover between the applied wheel loads and the base of the existing dredged material crust. The majority of any additional thickness required could be obtained by using a small dozer to shape and semi-compact adjacent existing crust into a low embankment and essentially form a haul road subgrade.

b. Prediction of the required thickness of the material needed between the applied wheel loads and the surface of the dewatered dredged material shaped and semi-compacted as subgrade.

25. The WES GL has extensive data relative to the thickness of cover required for given vehicular loads, load repetitions, and CBR of the subgrade or foundation. For design purposes, it was assumed that 10-cu yd, short wheelbase, tandem-axle dump trucks would be used, with a maximum gross loaded weight of between 50,000 and 60,000 lb, and that between 300 and 600 full truckload repetitions could be expected on a given haul road. The CBR for the subcrust fine-grained dredged material was less than 1.0. However, extrapolation of WES GL design data indicated that approximately 54 in. of cover would be sufficient to dissipate dump truck wheel loadings to the point where they would have negligible effect on the subcrust.

26. In-place CBR values for the fine-grained dredged material crust ranged from between 20 at the dry desiccated surface to 3 at the base of the crust, with values greatly influenced by crust water content. To reduce construction costs, the DOP decided to use a civil engineering fabric available as a waste product from nearby Aluminum Company of America (ALCOA) bauxite residue filtration operations. This fabric, a woven polyester available in 12-ft-square sheets, had an ultimate tensile strength of approximately 400 lb/in.-width. Design criteria available in manufacturer's technical literature for DuPont Typar 3401, a material with approximately 1/5 this ultimate tensile strength, indicated that a CBR of approximately 5 could be gained by its use. The DOP assumed, for experimental design purposes, that a CBR of 10 could be obtained by use of the stronger fabric and that, through careful control of crust stripping and placement operations, an average CBR of 10 could be obtained in the semicompacted crust subgrade. Based on these

assumptions, a fabric cover thickness of between 6 and 12 in. was deemed necessary to provide satisfactory haul road performance, with the thinner cover to be used at locations where a lower number of vehicle load repetitions was expected. The designed cross section is shown in Figure 4. Available high strength cover material (surfacing) included crushed reef shell, locally available at a price of approximately $6/cu yd, and finely powdered Portland cement waste, a waste product with the general appearance of fine sand, produced at nearby Portland cement manufacturing locations and available at no charge. During previous DOP experiments, the cement waste was noted to absorb considerable quantities of water from underlying wetter material and to set into a hard and dense wearing surface.

27. Both types of wearing surface were thus scheduled for use and evaluation in haul road construction. Crushed reef shell is available at almost all dredged material disposal sites located in coastal areas, and data relative to its applicability could be widely generalized. The cement waste was evaluated to determine its applicability with respect to future MDO construction activities.

Development of Construction Procedures, Equipment Required, Preliminary Cost Estimates, and Construction Specifications

Construction procedures

28. Based on the final desired dike cross section and existing cross-sectional data obtained from MDO Mobile Area Office survey, it was estimated that approximately 100,000 cu yd of in-place, semicompacted and uncompacted dewatered fine-grained dredged material would be needed to accomplish the dike raising. To obtain this volume, it was estimated that between 130,000-140,000 loose cu yd (lcy) of fine-grained dredged material would have to be borrowed and placed along the dike alignment. Calculation of crust volumes available within dragline-accessible distance of the perimeter dike and comparison of these data with required construction volumes indicated an excess of dewatered crust in the southern portion of the site and a deficit of material in the northern portion of the site.

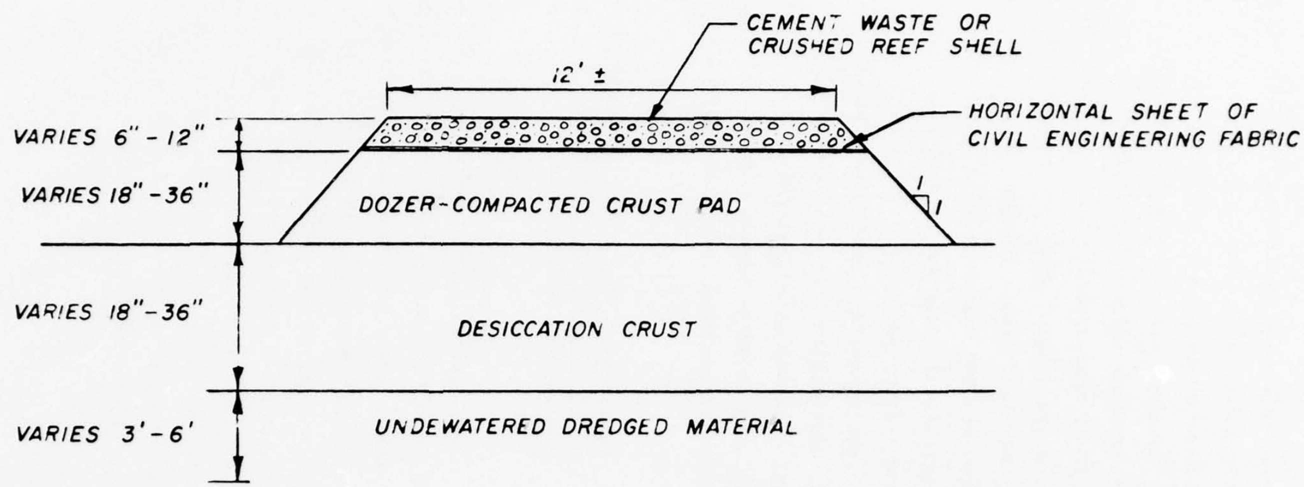

Figure 4. Typical cross section of haul roads constructed on dewatered dredged material crust

29. Two construction alternatives were considered to overcome this problem, which was artificially produced as a by-product of DOP field demonstrations that needed a variable crust thickness to evaluate different vehicle operating capabilities and dewatering methodologies at the same site in a limited time period. The first procedure considered was to double- or triple-handle the material by dragline in the northern portion of the site. Using this procedure, a dragline working on the perimeter dike would remove material adjacent to the dike and also handle material brought to it by a second dragline working in the disposal area interior. The second dragline would remove crust from the disposal site interior and pass it to the first dragline, while also rehandling crust provided by a third dragline, working still further from the perimeter dike. The advantage of this procedure was that essentially all construction activity could be accomplished with dragline equipment. Borrow volume calculations indicated that the three-dragline operation was not needed except in the northern portion of the disposal site where crust thickness was less than approximately 12 to 18 in., and at the corners of the disposal site, where the dike turned an approximate interior right angle and a material deficit thus existed. However, in the northern thinly crusted portion of the site, doubtful crust support capacity existed for the thirdmost dragline.

30. An alternate procedure was then developed for obtaining necessary material, consisting of a tandem dragline operation supplemented by truck-hauled borrow. A large dragline working from the perimeter dike would remove material immediately adjacent to the dike and place it along the alignment. This large dragline would also relay and rehandle material provided by a smaller dragline working inside the site perimeter. At locations where a material deficit existed, additional fine-grained dredged material would be provided by truck haulage from the southern portion of the site. Use of this procedure allowed crust within three dragline boom lengths of the perimeter dike to be used in dike raising. Also, support characteristics of the existing perimeter dike allowed use of a large dragline, with sufficient production capacity to both rehandle all the material provided by a smaller dragline inside the disposal area and remove crust adjacent to the dike, without loss of production efficiency.

31. To provide additional fine-grained dredged material at the northern end of the site and at disposal area inside dike corners, it was proposed to construct interior haul roads out onto the surface crust. Dump trucks could enter the disposal area interior on these haul roads and, after being loaded by dragline, transport the borrow to required locations along the dike alignment. This interior haul road construction scheme was developed after review and evaluation of other methods for expedient and cost-effective interior borrow mining, including use of cable-drawn buckets, scoops, and related items.*

32. Interior haul roads were designed as described previously. As this construction was necessary, it was decided to evaluate the effectiveness of the interior haul road borrow mining concept against that of using a supplemental dragline inside the disposal area perimeter. Accordingly, a portion of the east dike alignment was scheduled for raising with only a single dragline. This dragline would remove whatever crust could be obtained within one boom length of the perimeter dike, and additional material required along the alignment would be provided by truck haulage, allowing comparison between single and double dragline methods of material handling. To properly support the various dragline borrow activities, it was estimated that approximately 40,000 lcy of material was needed from the interior borrow operation.

33. The overall proposed material borrow construction plan is shown in Figure 5. Locations along the dike alignment where various construction schemes were evaluated are noted. Calculations indicated that a main haul road with three spur haul roads was necessary to provide the necessary 40,000 lcy of material, assuming the haul roads themselves would also be removed (as the last operational item) and used as borrow. The perimeter dike in the southeast corner of the disposal area was rebuilt at a new location, as shown in Figure 5, to isolate DOP-dewatering experiments still in progress at the time of dike raising. This portion of the dike, across the sand mound deposited from previous disposal operations, was constructed essentially of coarse-grained material.

Equipment required, cost estimates, and construction specifications

34. Based on estimated production capacities of 40 lcy/hr for small (5/8-cu yd bucket) draglines and 80 lcy/hr for large (1-1/2-cu yd bucket)

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* Haliburton, T. A. and Fowler, J., Memorandum for Record, subject: Evaluations of TerraMarine Scoop as a Trenching and Crust Removal Device in Fine-Grained Dredged Material Disposal Areas, 27 February 1978, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

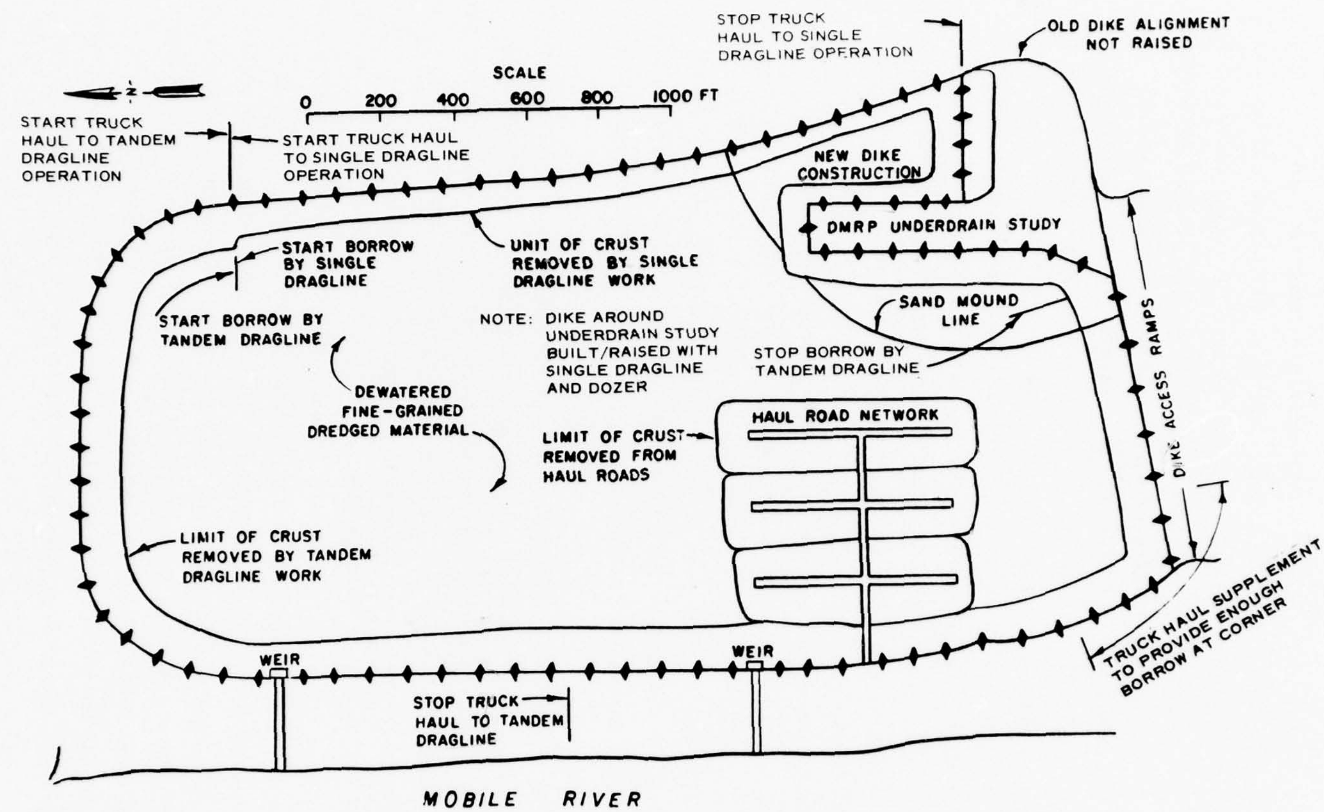


Figure 5. Plan of Upper Polecat Bay Disposal Area showing different procedures used to obtain dewatered fine-grained dredged material for use in perimeter dike raising

draglines, as indicated in previous DMRP-developed studies[1] and confirmed by preliminary UPB field work, construction scheduling was carried out and an overall plan developed for construction. The construction plan would allow evaluation of several different methods for dredged material borrow (Figure 5) and perimeter dike raising while conducting the overall work in an expedient and cost-effective manner. Because of the experimental nature of the project and the need to refine and/or redirect construction activities, based on the progress of work and preliminary findings concerning the experimental operations to be tested, a rental-type equipment contract was believed necessary, i.e., the MDO would contract for the necessary equipment and the DOP would direct the work. The construction contract would be awarded to the low bidder on estimated unit operation quantities for the various construction items.

35. Equipment inventory estimated necessary for conducting the work consisted of one large and two small draglines, one small wide-tracked dozer, and four 10-cu yd, short wheelbase, tandem-axle dump trucks, and hours for common labor work (for use in haul road construction) required. Table 1 shows the information developed by the DOP for MDO rental contract advertisement. In addition, the MDO would provide 200 cu yd crushed shell for contractor haul and placement.

36. The large dragline would work from the perimeter dike, in conjunction with one small dragline, along approximately two-thirds of the dike alignment and would work singly along the remainder of the alignment on the east side of the disposal area. A second small dragline would be used in the proposed interior borrow area to remove fine-grained dredged material crust and load it into the four dump trucks, which would haul material to needed locations around the dike perimeter. These trucks would also be used to haul crushed shell and no-cost cement waste needed for haul road surfacing. The small wide-track dozer was to be used for interior haul road construction, perimeter dike road maintenance, material spreading, and general purpose site work. The laborers were to be used in unrolling and spreading the filter fabric haul road reinforcement, provided at no cost by ALCOA.

37. As may be noted from Table 1, the total of various expected equipment rental costs for the estimated operating hours gave a cost of $3.025 per

in-place cubic yard of fine-grained dredged material, or a total estimated construction cost of $302,500 for the work. Approximately 1.2 million cu yd of disposal volume would be gained by raising the perimeter dike to El. 24 MSL, thus the cost of disposal area storage creation would be on the order of $0.25 per cu yd of volume obtained. This value compares favorably with 1975 cost data for conventional perimeter dike raising by the Corps of Engineers,[8] and the cost of construction was estimated slightly cheaper than the cost of purchasing, transporting, placing, and compacting offsite borrow ($3.50 per in-place cubic yard), despite relatively good haul access to the disposal site.

38. After contract advertisement, low bid on the estimated rental quantities was $317,861 and was accepted by the MDO. The contractor substituted a medium-sized (3/4-cu yd bucket) dragline for one of the small draglines, at small dragline rental cost, which was acceptable to the DOP and MDO. Table 2 shows the items provided and rental rates for the low bid contraction.

PART III: CONSTRUCTION OPERATIONS

39. Initial DOP and MDO planning called for construction activities to be initiated in June, 1977, to take advantage of low precipitation expected during the summer and early fall months in the Mobile area. However, because of delays in the bid advertisement process, actual construction was not initiated until September, 1978. Thus, some construction operations were conducted during less-than-optimum periods of relatively high precipitation. However, this unforeseen construction scheduling allowed evaluation of dike raising with fine-grained material under both optimum and extremely difficult weather conditions. Construction operations were essentially divided into two basic phases:

a. Borrow removal and placement along the perimeter dike alignment.

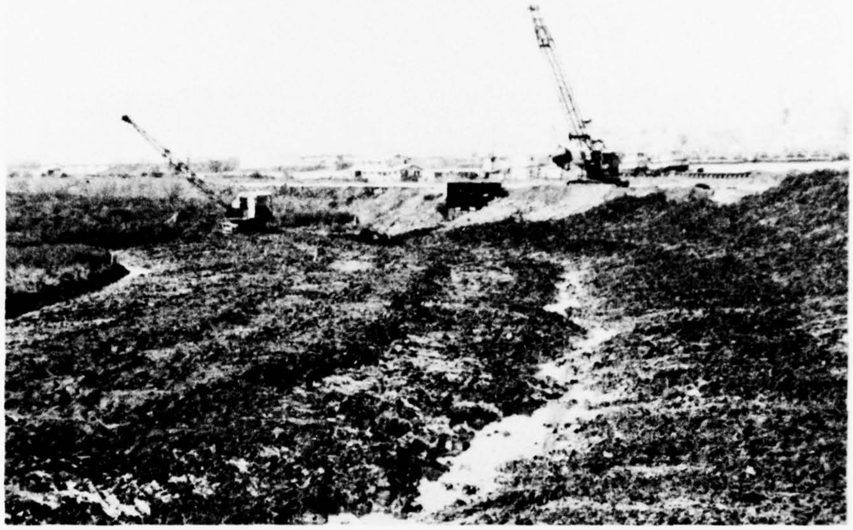
b. Construction of the raised dike.

During conduct of the work, a third phase, remedial repair of some dike sections necessitated by adverse weather conditions, was added.

Dewatered Fine-Grained Dredged Material Borrow Operations

Tandem dragline borrow removal

40. Following the operational scheme shown in Figure 5, tandem dragline borrow removal operations were initiated in the northeast corner of the disposal area, progressing west along the north dike and thence south along the west dike, coincident with the start of site interior haul road construction. Good weather was encountered, and this initial phase of the borrow removal operation proceeded smoothly. Expected production capacity of 40 lcy/hr was obtained and/or exceeded for the small dragline placed inside the disposal area, and the large dragline on the perimeter dike was able to rehandle this material without delay while removing crust from immediately inside the disposal site perimeter. This part of the operation is shown in Figures 6 and 7. As may be seen in the figures, essentially all crust was removed within a swath three dragline boom widths (approximately 150 ft) from the inside toe of the perimeter dike. A drainage ditch was maintained in the remaining dredged



a. Tandem dragline operation removing dewatered fine-grained dredged material. Operation has reached the northmost weir location

b. View of small dragline working on mats inside perimeter dike. Note pile of material placed for large dragline rehandling and drainage ditch maintained after borrow removal

Figure 6. Tandem dragline borrow removal operation

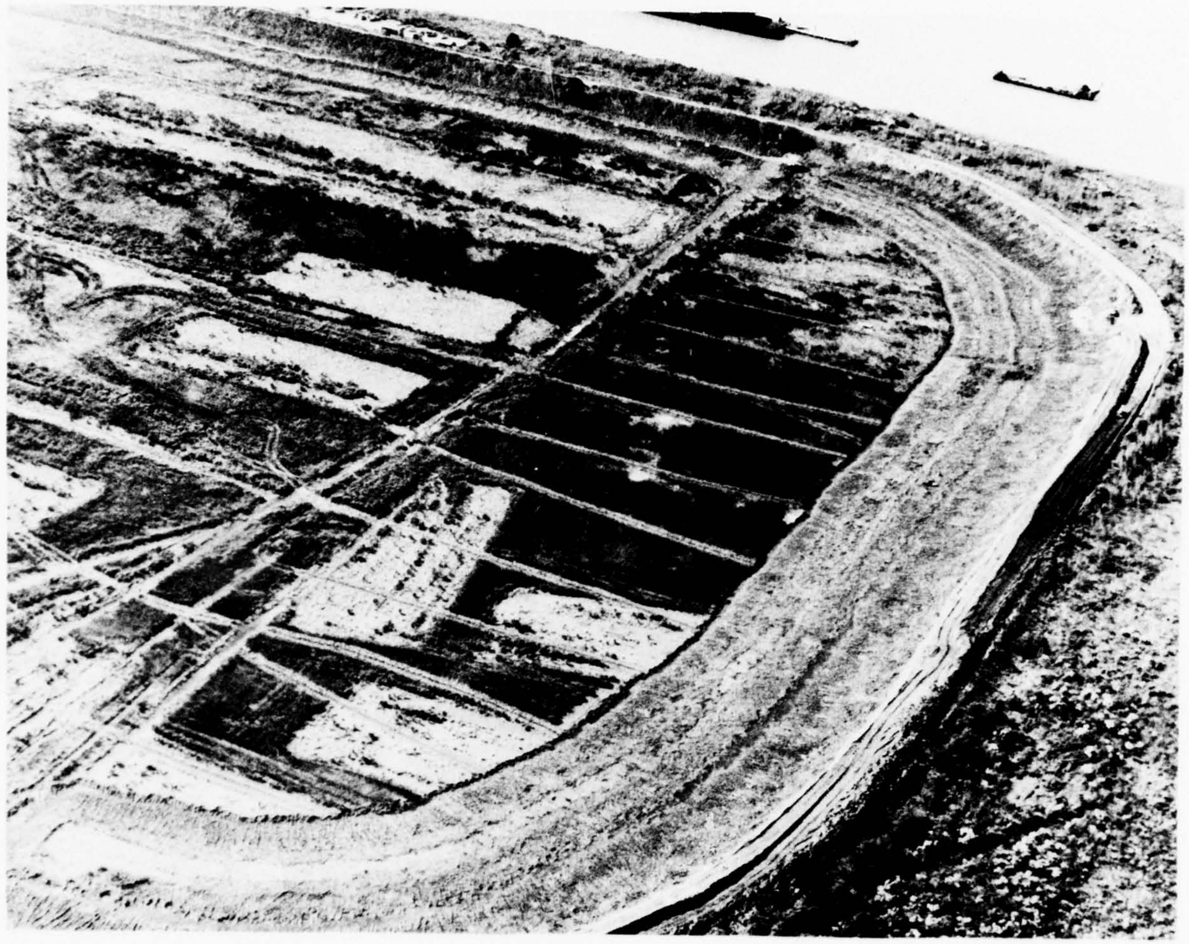


Figure 7. Aerial view of north end of Upper Polecat Bay Disposal Area, looking west southwest from northeast corner. Note strip of dewatered fine-grained dredged material removed around disposal site perimeter

material to facilitate precipitation runoff through a culvert located under the existing perimeter dike in the south part of the west dike.

Interior haul road construction

41. Coincident with the beginning of tandem dragline borrow removal operations in the northeast portion of the site, haul road construction was initiated in the southwest central part of the disposal area (location of maximum crust thickness) as shown in Figure 5. Haul road construction (see Figure 4) was fairly straightforward, aided by good weather conditions, and consisted of initial mounded pad subgrade construction on the dredged material surface as shown in Figure 8a, followed by placement of the filter fabric obtained from ALCOA, as shown in Figure 8b. Filter fabric used in such haul road construction is normally obtained and placed in long strips the width of the roadway and several hundred feet in length. However, the 12-ft-square sheets provided at no cost by ALCOA were found to perform satisfactorily when a 3-ft overlap was maintained between adjacent sheets. Primary difficulties encountered during this stage of operations were those required to educate the contractor's personnel concerning the need for construction of a well-compacted subgrade mound of dewatered crust with a relatively smooth surface and careful placement of the fabric with proper overlap distances.

42. After placement, the fabric was covered by two different procedures. Initially, crushed shell was dumped on a previously covered segment, spread, and track compacted over the newly placed fabric by the small wide-tracked dozer, giving the finished road shown in Figure 9. However, the small wide-track dozer was also used to assist in preliminary shaping of borrowed dredged material and to maintain an acceptable haul road on the crest of the existing perimeter dike. In order to expedite haul road construction when the dozer was occupied with these duties, dump truck placement of the material was attempted. In this procedure, the dump truck backed to the edge of the newly placed fabric, raised its bed slightly, and backed down the haul road alignment. The dump truck tailgate was prevented from opening completely, such that the operation was similar to that possible had the dump truck contained a spreader box. This operation did not provide the uniform crushed shell placement possible from dozer operations, but served to spread the material adequately,

a. Mounded subgrade for interior haul roads was constructed with the small wide-track dozer. Material was bladed from the right of the photograph and semicompacted to form the haul road pad shown in the center of the photograph

b. After the pad was complete, 12-ft-square sheets of filter fabric were laid on the pad and overlapped

Figure 8. Details of interior haul road construction

Figure 9. Photograph of completed haul road section showing dredged material surface, semicompacted subgrade mound, and shell surfacing. The fabric was placed at the interface between surfacing and subgrade

Figure 10. Rutting in the fabric-supported subgrade occurred when trucks backing down the haul road spreading shell continued to back after their load was exhausted. The photograph illustrates the need for fabric cover to obtain desired roadway performance

and only a slight amount of finish work and track compaction by the dozer was required to make the haul road ready for traffic. The main problem encountered in truck spreading was the tendency of the vehicle to back off the fabric-supported roadway or to continue backing when its load of shell had been exhausted. In both instances, rather deep rutting was produced in the uncovered fabric, as shown in Figure 10. This figure graphically shows the increase in support capacity provided by the covered fabric, as compared to fabric support capacity in its unanchored condition. Another problem encountered in this phase of operations was the hesitancy of the contractor's truck drivers to venture out onto the completed haul roads, as their observations of equipment support capacity available from the dredged material crust surface alone and of the physical properties of the undewatered subcrust did not inspire confidence in the ability of a thin sheet of shell-covered fabric to properly support their vehicles. Nevertheless, after each driver had made an initial trip into the disposal area on the haul roads, no further doubts were raised.

43. After constructing the initial haul road segments, the medium (3/4-cu yd bucket) dragline moved into the disposal area interior down the haul roads and began to remove crust. Operations were conducted both with the dragline on the haul roads and with mats on the crust adjacent to the roads. Cone penetration data obtained by the DOP indicated that the dragline could work without difficulty on the existing crust if mats were used to lower its effective ground pressure to approximately 1 psi.[1] These criteria were followed and no mobility problems were encountered by the dragline, even though this piece of equipment was slightly larger than originally specified in contract advertisement.

44. Once a haul road spur had been established, the dragline loaded the short wheelbase, tandem-axle, 10-cu yd dump trucks with fine-grained dredged material available within one boom length of the haul road, as shown in Figure 11. Figure 12 is a closeup view of the haul road surface on a spur haul road after approximately 300 load repetitions. Note the relatively small amount of rutting that has occurred in the dump truck wheel paths. Most deep rutting observed on the haul roads apparently resulted from trucks getting too close to the haul road edge.

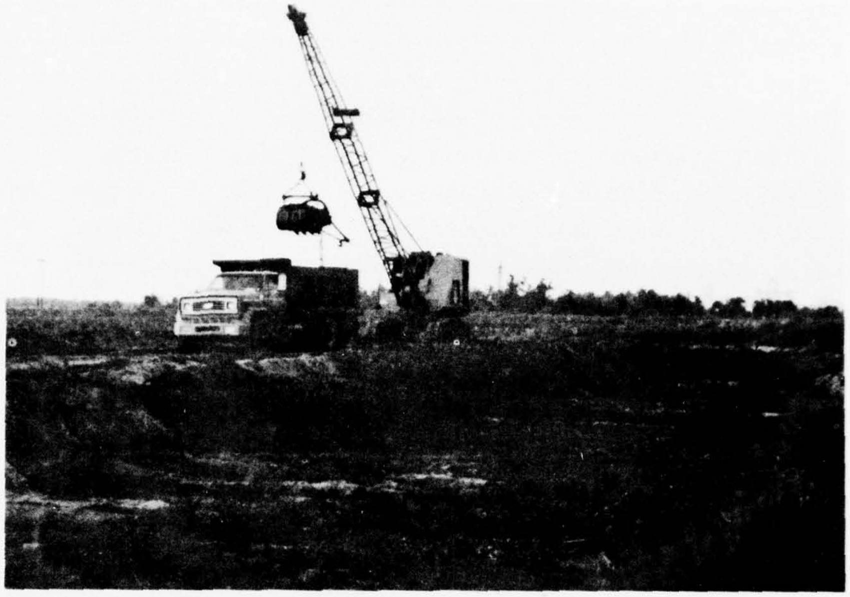


Figure 11. Medium dragline shown loading dump trucks with dewatered fine-grained dredged material in interior borrow area

Figure 12. Photograph of spur haul road surface after approximately 300 load repetitions. Note relatively good condition of surface with minimal rutting in wheel paths

45. After initial dozer spreading and track compaction of the crushed shell, dozer backdragging to relevel the surface was conducted after 1 day of dump truck haulage. It is hypothesized that initial rutting produced by dump truck haulage served to "set" the fabric, removing wrinkles and inducing tensile strains necessary to improve haul road support capacity. After the initial backdragging, further maintenance was required only in localized areas, usually at points where proper fabric overlap had not been obtained. Figure 13 shows a typical spur haul road after dredged material crust has been removed along one side. Borrow removal operations are now being conducted on the other side of the haul road. Despite continued operation of loaded dump trucks, no evidence of lateral bulging, foundation bearing failure, mud waves, or other unsatisfactory behavior was observed in the adjacent subcrust dredged material.

46. Two of the six spur haul roads and approximately one-third of the main haul road were surfaced with finely powdered Portland cement waste. This waste, a by-product of local Portland cement production, had too high a specific surface area for use as Type I Portland cement and was "contaminated" from hydration by exposure to air. It is normally trucked to rural areas for controlled disposal. However, such material had been obtained at no charge and evaluated experimentally in stabilization of the original sand perimeter dike roadway during prior DOP field demonstrations. The material was found to set upon wetting and give a relatively hard, impervious surface, improving vehicle mobility along the disposal area perimeter dike. Because of MDO interest in this no-cost waste material, it was decided to evaluate the cement waste as an alternative to crushed shell surfacing. Appropriate waste disposal permits were obtained from the State of Alabama by the DOP, and one of the four dump trucks rented for borrow haulage was used to transport this material to the site. Material was also provided by dump trucks under contract to the cement plant owner.

47. Figure 14a shows the cement waste being placed on the ALCOA-provided filter fabric. Initial attempts at dozer-track compacting this material in a dry state were essentially unsuccessful. Some attempts were made to haul water to the material in the contractor's dump trucks; these attempts were only partially successful. The most successful construction technique for compaction

Figure 13. View along edge of spur haul road after dredged material crust had been removed. No evidence of subgrade bulging, foundation bearing failure, or mud waves is seen in the photograph

a. Cement waste evaluated as road surfacing is shown being placed on the fabric-covered subgrade. Note the resemblance of the partially hydrated cement waste to sand

b. Condition of cement waste surface on spur haul road after approximately 400 load repetitions

Figure 14. Details of haul road surfacing with cement waste

of this surfacing was to complete the haul road (including cement surface) well ahead of the anticipated time it would be needed and wait for naturally occurring precipitation to wet the cement waste. After wetting, the material could be satisfactorily compacted by dozer track and would set into a hard, durable surface. Figure 14b shows the condition of the cement waste surface after approximately 400 load repetitions. Evaluation indicated that the cement waste was an equally effective alternative to use of crushed shell.

48. Figure 15 is an aerial view of the haul road area. As may be noted from the photograph, material has been removed from the lower left portion of the photograph and the spur haul road that extended into this area has also been removed. Borrow removal has taken place along one haul road, and another haul road is being removed. An already constructed but not yet used haul road may also be seen in the photograph, as well as fabric placed for another spur haul road.

49. After loading, dump trucks proceeded along the perimeter dike to their dump point, where the material was dumped in mounds along the crest of the existing perimeter dike. Care was taken to leave enough width for vehicle access on the outside crest of the dike. The small wide-track dozer was used to shape the dumped material in such a form to ensure rapid precipitation runoff without ponding and infiltration and also to maintain an adequate width roadway around the dike. Initially, material was transported to the northeast corner of the dike and loads dumped progressively west along the north dike and then south along the west dike, paralleling the tandem dragline operation. Based on required material volumes to construct the raised embankment (as determined from cross-sectional surveys of the existing dike prior to starting construction), deposit of hauled material was controlled by DOP onsite personnel. Exact quantities of hauled borrow needed along portions of the dike alignment were recomputed periodically, based on comparison between estimated and actual production volumes the tandem dragline operation could remove from crust adjacent to the perimeter dike. From time to time, one or more of the trucks was diverted to other dump points inside the disposal area, as necessary to maintain optimum routing of the trucks and most efficient production from the borrow area. Other dump points included the southwest corner of the disposal

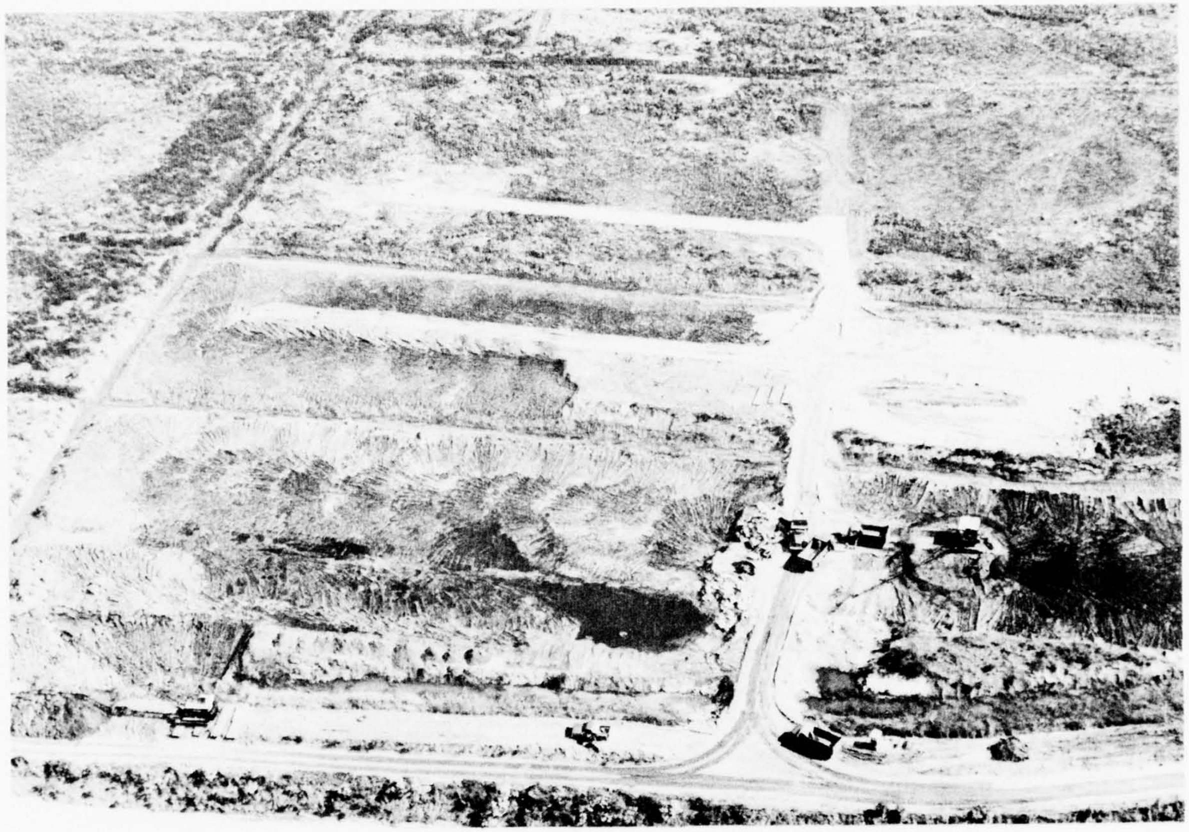


Figure 15. Aerial view of interior borrow area looking east. Note main west-east haul road entering roadway from existing dike crest. The first spur haul road in the left corner of the photograph has already been removed, along with the borrowed crust. Partial borrow operations have been been conducted along the second spur haul road and the dragline is currently removing the other arm of the first spur haul road. Also seen in the photograph are a completed haul road spur, not yet in use, in the right center of the photograph and fabric placed for a third haul road spur in the upper center of the photograph. The subgrade pad established for the main haul road may be seen as an extension of the existing main haul road in the upper part of the photo

area and the east perimeter dike. Some material was also deposited along the south perimeter dike, after onsite evaluation determined that additional fine-grained material was needed on this portion of the alignment to cover coarse-grained material borrowed from inside the dike perimeter and provide proper erosion resistance to the raised section.

50. In general, the technical feasibility of the interior borrow mining operation may be termed successful, as the haul roads were constructed without difficulty, performed adequately with essentially minimal maintenance, and allowed vehicle mobility to be maintained continuously, even during and immediately after periods of high precipitation. From an operational practicality viewpoint, the operation was successful when closely supervised by DOP onsite personnel, and essentially impractical when operation of the system was left to the contractor's personnel. The dragline had an effective minimum production capacity of 40 lcy/hr in relatively soft and thin-crusted areas, and was capable of 70 to 80 lcy/hr maximum production. Average production was about 50 lcy/hr. However, this production capacity could be achieved only by proper routing of the contractor's dump trucks. When DOP onsite personnel optimized the dump truck routing, the usual result was to have each truck waiting between 2 and 5 min for the dragline to complete filling a previous truck. When such routing optimization was not maintained by DOP personnel, the situation quickly deteriorated into one where the dragline sat idle for 4- to 10-min periods, waiting on an empty truck to load. Whether this relative inefficiency resulted from contractor ignorance, incompetence, or desire to maximize the time period his hourly rental equipment was in operation could not be ascertained positively by DOP onsite personnel.

51. From a cost-effectiveness viewpoint, the interior borrow mining operation was not competitive on a loose cubic yard production basis with the tandem dragline borrowing operation. More detail on comparative production rates for the various equipment combinations is given in a subsequent report.

Transition from Borrow Removal to Dike Raising

52. Once the desired material quantities were in place along the alignment, dike-raising operations could be initiated. The tandem dragline operation

completed its movement from the northeast corner of the disposal area down the north dike, west dike, and south dike to the southeast corner of the original alignment before interior borrow mining operations had completed haulage of all necessary material to the east dike. Dike-raising operations were thus commenced in the northern portion of the site with the small dragline, and the large dragline was sent to the east dike to initiate single dragline crust removal activity as described previously. The medium dragline was retained in the borrow area until all required material had been removed; then exited the area, removing the main haul road in the process. After completing this task, it was mobilized to the south dike and begin dike construction. Figure 16 shows the large dragline operating on the inside perimeter of the east dike, removing crust. The bench immediately adjacent to the dike was left in place and borrowed by the dragline during dike construction operations for use in constructing the second dike lift.

Dike Construction

53. The raised dike section was shown previously in Figure 3. As may be seen from the figure, the raised portion is centered along the previous dike rather than benched inward, primarily because of the stable base section available. As mentioned previously, the raised portion was to be constructed in two lifts: an initial lift semicompacted to El. 20 MSL along the crest with uncompacted spillage down the side slopes, plus a final uncompacted lift with finished crest width of 8 ft at El. 24 MSL. As the uncompacted portion of the dike would tend to subside with time and precipitation, it was initially overbuilt to El. 25 MSL (6-ft crest width) and finished to El. 24 MSL by the small wide-track dozer as the last job operation.

54. Three construction schemes were evaluated for dike raising:

a. The dike was constructed by dragline in essentially two separate operations. A long segment of initial semicompacted lift was placed and then the long segment was covered, on a return pass, with a second uncompacted lift.

b. The entire dike was raised in one operation, using the small wide-track dozer to shape and semicompact the first lift while a dragline,

Figure 16. Large dragline shown removing crust from inside perimeter of east dike. Crust bench under dragline mats will be used for construction of second lift. Note mounds of borrow along alignment placed by previous truck haulage from interior borrow area. Small dragline is shown in background placing second lift in long partial segment construction

working immediately behind the dozer, was used to place the uncompacted second lift.

c. A dragline was used to construct both lifts sequentially, building the first lift ahead and the second lift behind, completing the entire raising as it moved forward.

55. In all three dike construction operations, construction sequencing was developed by DOP onsite personnel to minimize excess dragline boom swing, and, for most properly conducted operations, 90 deg or less boom swing was required. Contractor's operating personnel were advised that, when boom swing exceeded 90 deg and approached 105 deg, it was necessary to move dragline mats to a new position to maintain optimum dike construction rates. As a general rule, the required construction procedures were followed when DOP onsite personnel were in the immediate vicinity of the construction operation, or when it was apparent to equipment operators that their work was being observed. However, when not closely supervised by DOP onsite personnel, general efficiency deteriorated. During unsupervised operations, the general tendency of the equipment operators was to keep their machine stationary for too long a period, obtaining borrow by reaching too far ahead of the equipment with their boom and bucket, thus causing boom swings greater than 105 deg. The net effect of this operation was twofold:

a. More time was wasted in excess boom swinging than would have been consumed in moving dragline mats and repositioning the dragline.

b. When the machine finally moved forward to a new position, dredged material crust stacked adjacent to that location had already been removed, and the dragline was forced to again move forward after only a short interval, or repeat the excess boom swinging operation to obtain desired material.

Long segment dragline partial dike construction

56. In the long segment dike-raising scheme, the dragline constructed a long segment of first lift down the alignment. Dewatered dredged material in sufficient volume to construct the second lift was left stacked along the inside toe of the perimeter dike. After completing a long segment of the first lift, the dragline retraced its path, semicompacting the first lift ahead with mats while placing the second (uncompacted) lift behind, using dredged material

stockpiled against the inside perimeter dike. The dragline also dressed the final side slopes and crest. This construction technique is shown in Figure 17. In Figure 17a, the dragline constructs the initial semicompacted lift, while in Figure 17b, the machine is shown building the second lift as it retraces its steps down a segment of previously constructed first lift.

57. Reasons for evaluating this procedure were threefold:

a. To determine if the dragline alone could successfully construct the entire raised section after material had been stockpiled in appropriate locations. In actual construction, the proper way to use this technique would be for the dragline to construct an initial lift completely around the disposal area, and, upon returning to the starting point, begin construction of the second lift.

b. To determine the effects on stability of the finished dike from leaving the first lift and remaining borrow material exposed to dry during the interval between first lift and second lift construction.

c. To compare, on a production basis, with single and dozer-assisted dragline construction of the entire raise section at one time, as described subsequently.

58. In general, the long segment partial construction technique worked satisfactorily from a technical and operational viewpoint. Comparisons among the three dike-raising methods will be discussed subsequently.

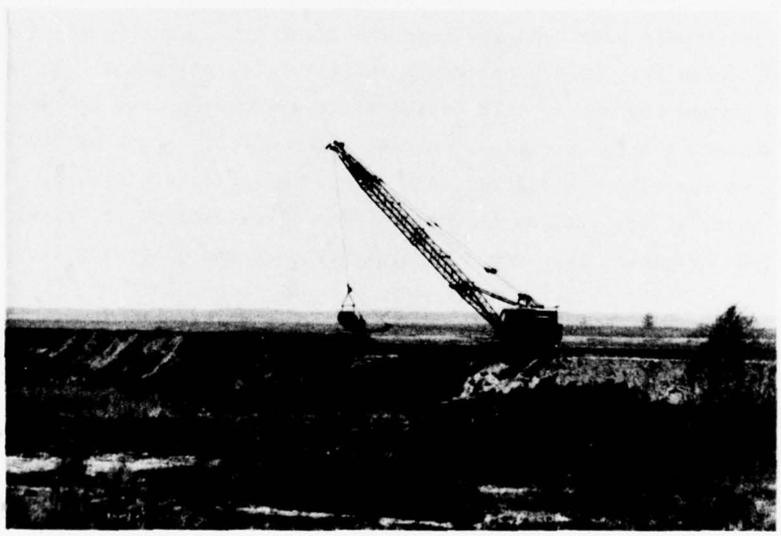
Combination dozer-dragline dike construction

59. In this scheme, the small wide-track dozer was used to shape and semicompact previously placed borrow into the first lift, working ahead of the dragline, which then matted over this initial lift, semicompacting it further, and placed the second lift behind as it progressed down the dike alignment. To facilitate this operation, initial placement of borrow was such that the majority of material was placed along the perimeter dike alignment, and only enough material was left at the base of the dike to place the final lift. As the dragline completed the second lift, it dressed the dike side slopes and crest.

60. Reasons for evaluating this construction procedure were twofold:

a. To compare the relative efficiency of the dozer-assisted dragline operation with the other two dragline alone construction operations.

a. Dragline is shown completing first lift along east dike. Borrow in foreground has been roughly shaped by dozer to facilitate precipitation runoff. Ragging on stake in center of photograph indicates El. 20 MSL, crest elevation for first raise lift



b. After initial construction, the second lift was placed and crest and side slopes dressed by the dragline

Figure 17. Long partial segment dike construction method

b. To evaluate the relative efficiency of the small wide-track dozer in shaping and semicompacting dewatering fine-grained dredged material borrow, as compared with dragline accomplishment of the same work.

61. This operation, shown in Figure 18, was conducted along the center portion of the west dike and the east dike. The operation was technically and operationally successful. Comparison with other dike-building methods is discussed in a subsequent part.

Sequential one-pass dragline dike construction

62. In this construction procedure, the dragline built both lifts sequentially, building the first length ahead for approximately one boom length, then turning and constructing the second (uncompacted) lift behind, while matting forward onto the first lift and semicompacting it. This operation is shown in Figure 19. The dragline completed the entire dike as it moved forward. Crest and side slopes were also dressed. Rationale for this construction method was twofold:

a. For comparison of production efficiency with the single dragline long partial segment and dragline plus dozer dike construction methods described previously.

b. To allow comparison of resulting dike stability with that obtained when a drying and exposure period was allowed for the first lift prior to second lift placement.

63. This dike construction operation was also technically and operationally successful. On a comparative basis, more time was required for the dragline operator to become efficient in operating his machine and optimize the work required for efficient dike construction, compared to the other two construction methods. Difficulties probably ensued from the need for the operator to follow two different construction procedures on a sequential basis and to make continued judgments relative to the optimum time to break off one phase of the operation and initiate the other phase. Cost-effectiveness comparisons among the three dike construction procedures are presented in a subsequent part.

Operational problems

64. Three major types of operational problems were encountered during conduct of the work:

Figure 18. Small wide-track dozer shown constructing first lift while dragline in background of photograph constructs second lift and dresses the crest and side slopes

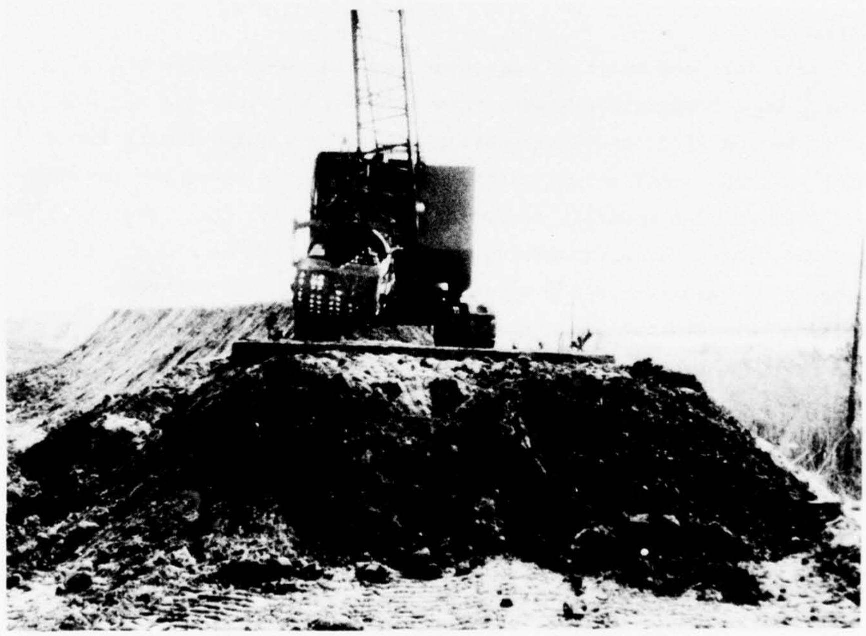


Figure 19. In the sequential dike construction technique, the dragline constructs the first lift ahead for a short distance, then rotates its boom and constructs the second lift behind, while moving down the dike alignment

a. Sloughing and localized sliding by portions of the newly placed second lift, as a result of 10 in. of precipitation received over 2 days.

b. Insufficient strength and stability of fine-grained dredged material borrow and first lift on part of the west dike as a result of precipitation ponding and infiltration.

c. Localized slope erosion from use of coarse-grained material in portions of the second lift.

65. After approximately 4,000 lin ft of finished dike had been constructed, from the northeast corner of the site west along the north dike and south along the west dike, extremely heavy precipitation, amounting to more than 10 in. in 48 hr, fell over the disposal area. This heavy rainfall infiltrated portions of the uncompacted second lift in the vicinity of the northmost weir (Figure 5) and approximately 1,500 lin ft of the second lift suffered side slope erosion damage and generalized slope sloughing and sliding along both interior and exterior side slopes. The underlying semicompacted first lift was unaffected. The rain-induced damage is shown in Figure 20. Evaluation of this failure indicated that, when placing the second lift, the crest had not been crowned sufficiently to allow rapid precipitation runoff. Ponding thus occurred on the dike crest and resulting infiltration both increased the unit weight of the uncompacted second lift material and reduced its effective shear strength. Also, the ponded water velocity at these localized points produced erosion damage. At other locations along the dike where the second lift was in place with proper crown, the heavy precipitation ran off, with essentially minimal damage to the dike.

66. As a result of this unsatisfactory behavior, considerable attention was paid to obtaining proper crest drainage on future portions of the dike second lift, and no further problems were encountered, despite further high precipitation during construction. However, the unsatisfactory dike sections were located in the approximate middle of the completed dike portion, and the produced 6-ft crest width at El. 25 MSL was insufficient to allow dragline traverse to the area. Outside dragline access to the unsatisfactory portion of the dike was not possible and inside access had been eliminated by borrow of dredged material crust within 150 ft of the perimeter dike. As a result,

Figure 20. Rain-induced sloughing and sliding of uncompacted second lift. Note rotational slumping on inside slope with crest subsidence. Underlying semicompacted first lift was not affected

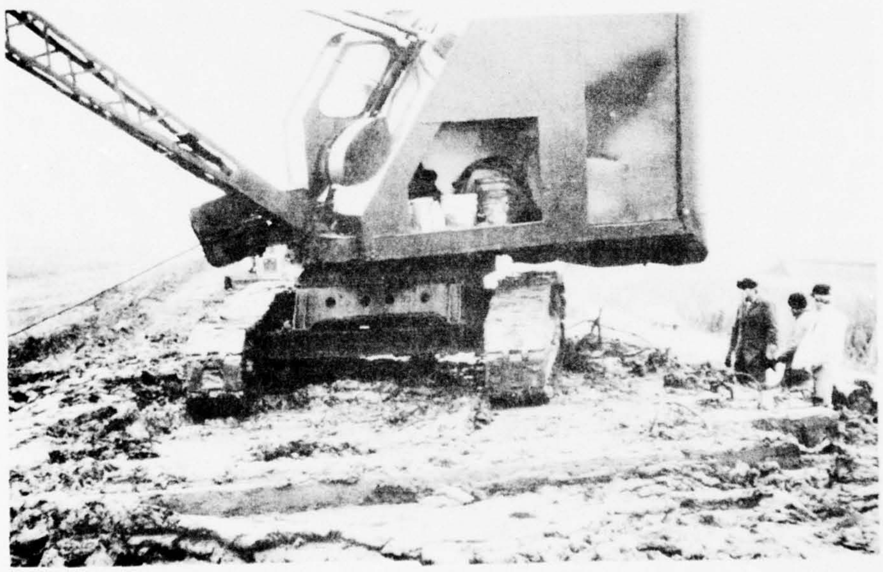


Figure 21. Dragline in mobility trouble on east dike caused from precipitation ponding and infiltration into previously place first lift

it was necessary to remove the finished second lift over almost the entire 4,000 lin ft of completed dike so that matted dragline access could be obtained to repair the unsatisfactory dike section. The small wide-track dozer was used to knock down and flatten the first lift, so a dragline could traverse the dike to effect remedial repairs. Approximately 400 hr of dragline time and 100 hr of small wide-track dozer time were used in this operation, which took essentially 40 working days to level the completed embankment for dragline access and reconstruct both the unsatisfactory portion of the dike and the portions of the dike second lift that had been leveled to allow dragline access.

67. In the process of removing the completed second lift to allow dragling access to the north portion of the perimeter dike, some second lift material, located at approximately the center (north to south) of the west dike, was bladed to the side in such a manner that precipitation ponded on and then infiltrated the semicompacted first lift along approximately 300 ft of the alignment. When the dragline returned south along this dike from completing its repair operations, working on the in-place first lift and constructing the second lift behind, it was unable to maintain mobility on this part of the first lift as infiltration of ponded rainwater had weakened the fine-grained dredged material to the point where the dragline mats sank into the surface and caused lateral bulging of the side slopes, as shown in Figure 21. Dike construction operations were then suspended along this portion of the alignment, and the dragline shifted to dike construction using sand in the southeast portion of the disposal area. The small wide-track dozer had just enough mobility to move the saturated material about and was used to roughly grade and obtain proper drainage for precipitation runoff. Once good drainage was maintained, the material began to dry, despite heavy periodic rainfall. As the surface material desiccated, the wide-track dozer periodically moved the mass of material about, exposing wet underlying material for desiccation. After the material had been dried sufficiently to restore adequate strength, the small dragline returned to the area and continued the dike-raising process.

68. The third operational problem occurred at isolated locations along the perimeter dike where coarse-grained material was placed as part of the second (uncompacted) lift. At one time during previous disposal operations,

the dredge pipe had been placed south of the south weir (Figure 5). Limited disposal operations at that time left a small sand mound in the vicinity, which was subsequently covered with fine-grained material. During interior borrow mining operations, this coarse-grained material was removed along with the fine-grained crust and transported to the dike alignment. The coarse-grained borrow had been identified by onsite DOP personnel and was supposedly placed at locations where it would be incorporated in the semicompacted first lift. However, in several instances, this material was used on the slopes of the uncompacted second lift. As the coarse-grained material had little erosion resistance, the high precipitation levels encountered and dike crest shaping to allow rapid precipitation runoff caused formation of erosion gullies at several locations where sand had been used. When such behavior was observed by onsite DOP personnel, repairs were affected, with either the small dozer or with hand labor, and construction operation scrutiny increased to minimize chances of future occurrence. Also, some fine-grained material was removed from the interior haul road borrow area and transported to the south dike for use in covering second lift side slopes at the southeast corner of the existing alignment where the primary interior borrow product was coarse-grained material.

Dike construction in southeast portion of disposal area

69. As shown in Figures 2 and 5, the southeast portion of the disposal area, where the dredge inlet pipe was normally placed, had been covered with a large sand mound. A DOP underdrainage study described elsewhere[5] was still in progress in this area. Construction of underdrainage test pits had raised elevations in this portion of the site to approximately El. 21 to 23 MSL. The perimeter dike was relocated around this ongoing DOP experiment, the perimeter of the experiment raised to El. 24 MSL, and a short dike segment constructed from the DOP experiment area to the original east dike, located as shown in Figure 5. This dike segment, shown in Figure 22, was constructed up to El. 25 MSL from existing ground elevations in the vicinity of El. 14 to 18 MSL in one lift using essentially uncompacted, coarse-grained material. A small amount of raising around the perimeter of the DOP underdrainage work units was accomplished by the small wide-track dozer. Construction operations in this part of the disposal area proceeded smoothly. As coarse-grained material was

Figure 22. Dike segment of essentially coarse-grained material constructed between east dike and DOP underdrainage experiment location. View looking east from the east dike toward the DOP underdrainage experiment. Note traces of snow on the embankment

used, no problems were expected (nor encountered) with equipment support capacity, and this portion of the work was of a more conventional nature than other parts of the project.

Completion of Work

70. After the entire dike alignment had been raised to El. 25 MSL, the dragline equipment was demobilized and the small wide-track dozer made two passes around the entire perimeter, lowering the final grade to El. 24 MSL while providing some track compaction of the crest. Material bladed from the crest was spilled down the finished embankment side slopes and served to fill in any small erosion gullies. Over most of the alignment, the uncompacted second lift had subsided approximately 6 to 9 in. since construction. Approximately 2 working days were required for the dozer to complete cutting the embankment to El. 24 MSL and shaping the crest to facilitate future precipitation runoff. The dozer operation is shown in Figure 23a and the finished disposal area dike is shown in Figure 23b.

71. Despite extremely heavy precipitation encountered during December, 1977, and January, 1978, operations were completed some 10 working days ahead of the contract time period. Total cost of construction, based on hours actually worked by the various equipment items, was $322,000, representing an approximate $4,000 or 1 percent overrun of the initial estimated construction cost. Considering the fact that this type of project had never previously been accomplished by the Corps of Engineers and that several different experimental construction techniques were evaluated, such close agreement between estimated and actual costs is quite remarkable. Further, it should be noted that production was considerably reduced during many working days because of high precipitation levels, and also that approximately 40 working days of dragline time and 10 working days of dozer time were required to repair conditions caused by the heavy precipitation. Had the contract been let when originally scheduled and the work conducted under more favorable weather conditions, it is likely that a considerable cost underrun would have occurred.

a. As the last construction operation, the small wide-track dozer bladed the dike to 8-ft crest width at El. 24 MSL

b. View of the completed raised perimeter dike

Figure 23. Completion of perimeter dike raising

PART IV: ASSESSMENT OF PROJECT

General Considerations

72. The project may be termed an overall success in that the dikes were raised to required elevation using dewatered fine-grained dredged material borrow taken from inside the disposal area within the allotted construction schedule and with only a 1 percent cost overrun, despite adverse weather conditions. However, more detailed scrutiny indicates that several operational problems were encountered that could have been prevented, and that some construction schemes evaluated were more efficient than others. If the project were to be reconducted in the light of experience gained, it is probable that an approximate one-third cost reduction could be realized.

73. Equipment provided and used during conduct of the study included one large (1-1/2-cu yd bucket), one medium (3/4-cu yd bucket), and one small (5/8-cu yd bucket) dragline, one small wide-track dozer, and four dump trucks. Based on results of the study, it is concluded that the dragline equipment was chosen appropriately. During the latter stages of the project, considerable ingenuity was required by DOP onsite personnel to keep all dragline equipment working efficiently on portions of the perimeter dike where they could be properly demobilized once operations were completed. Had a fourth dragline been included in the contract, it is doubtful that it could have been used successfully during latter stages of the project and probably would not have caused a noticeable reduction in overall project completion time.

74. The small wide-track dozer was easily the most valuable piece of equipment on the job. Its uses were many and varied, including shaping and blading material in various configurations, maintaining the roadway on top of the existing perimeter dike, shaping dredged material crust mounds for haul roads, placing haul road surfacing, raising the dike around the DOP underdrainage research location, pulling out immobilized dump trucks, and conducting final grading and shaping operations along the dike crest. Had a second dozer been included in the rental contract, it could have been utilized continuously during conduct of the work, and the project probably would have been completed

in fewer working days. Future projects of this scope and magnitude should definitely include at least two small wide-track dozers in their equipment inventory.

75. Four dump trucks were used in interior borrow mining and hauling operations. Based on results obtained, a three-dump-truck operation was more efficient for the given haulage routes and essentially one-way traffic allowable on the perimeter dike. With four trucks in operation, considerable attention to proper routing was necessary to keep all vehicles working efficiently. Once this fact was ascertained by onsite DOP personnel, the fourth truck was detached whenever possible for miscellaneous crushed shell, cement waste, and water hauling. Upon completion of these duties, it was deleted from the equipment inventory. In future construction of this scope and magnitude, more attention should be directed, during the planning stage, to potential routing of any anticipated truck haul operations.

76. In general, the borrow mining and dike construction operations proceeded successfully. The dewatered fine-grained dredged material was found to dry even more when borrowed and placed along the dike alignment in a manner that would not pond precipitation. When semicompacted by dozer track or dragline mats at water contents near the plastic limit, the material could be densified into a relatively stable mass. Precipitation on this graded semicompacted surface ran off quickly without infiltration, and unassisted dump truck mobility could be maintained on this surface, even during and immediately after heavy precipitation, much to the surprise of both the contractor and DOP onsite personnel. When the fine-grained dredged material crust was placed uncompacted in the second lift and on the dike side slopes, the side slopes dressed properly, and the crest crowned to facilitate rapid precipitation runoff, no stability problems were encountered and the material had extremely high erosion resistance. In fact, steeper slopes than the originally estimated 1V on 1.5H were constructed without sloughing or sliding. An embankment slope of between 1V on 1H and 1V on 1.25H was used over approximately one-third of the dike alignment.

77. Conversely, when the fine-grained dredged material was placed, either as borrow or as finished dike, in a way that precipitation ponding and infiltration was allowed, considerable strength reduction was noted, resulting in

sloughing and slippage failures in the upper portions of the finished dike and in loss of support capacity in the semicompacted first lift. Future construction operations of this scope and magnitude should expend considerable effort in maintaining adequate drainage conditions, both for stockpiled material and on finished crests and slopes. If care is taken in such detail, the effects of high precipitation will be minimized. This consideration is thought to be extremely important for disposal area dike-raising projects in coastal locations where high rainfall is likely.

78. The only location where foundation problems might occur, based on initial project exploration and testing, was at the southwest corner of the perimeter dike adjacent to Cochran Bridge. A relatively wide base section of approximately 2.5 times normal width was constructed at the corner, and the dike crest benched inward, essentially allowing the existing dike displacement section extending to approximately El. -16 MSL to act as a stabilizing berm and minimizing chances of outward foundation movement toward Cochran Bridge. This portion of the dike was raised successfully, without any noticeable lateral movement of the foundation.

79. Interior haul road construction was carried out successfully, verifying the semiempirical haul road design developed by the DOP. Some 4,000+ loaded dump truck load repetitions down the main haul road produced minimal rutting and no stability problems. Each spur haul road was subjected to approximately 600 load repetitions, again with negligible effect, and the haul roads performed adequately even when crust on both sides of the haul road embankment had been removed. Isolated rutting or loss of surface support capacity at an approximate half-dozen locations during haul road operation could be traced to apparent improper overlap of the ALCOA-provided, 12-ft-square fabric segments. These localized problem areas were repaired by removal of surfacing and placement of another fabric sheet over the failed joint. In future operations of this scope and magnitude where fabric-reinforced haul roads are to be constructed, a more expedient operation will be achieved if fabric is purchased commercially in long rolls and placed continuously down the haul road alignment. Considering the amount of time spent in overlapping and properly placing the individual fabric sheets and the time lost when repairing localized soft spots,

purchase of commercially available fabric in long 12-ft-wide rolls would have been more cost effective for this study.

Evaluation of Fine-Grained Dredged Material Borrow Operations

80. Three different techniques were used to remove dewatered dredged material from the disposal area, as mentioned previously. Location of the various operations was shown relative to the perimeter dike in Figure 5. The tandem dragline operation accomplished by the large dragline on the perimeter dike and the small dragline working in the interior of the disposal area had a maximum measured production rate of approximately 130 lcy/hr, obtained on thicker crust along the south portion of the west dike, and a minimum production rate of approximately 40 lcy/hr, obtained on thinner crust at the northern portion of the site. Thinner crust results in lower production because not only does each bucket bring in a smaller volume of material, but more time is also needed to maintain equipment mobility. Average measured production capacity of the tandem dragline operation was approximately 75 lcy/hr. At a combined dragline rental rate of $84/hr, dredged material borrow was obtained by this operation at an average cost of $1.12/lcy. At the northern portion of the site, where sufficient crust was not available adjacent to the perimeter dike, it is estimated that a triple-tandem dragline operation would have produced approximately 100 lcy/hr at a total equipment rental cost of $122/hr, or an average borrow removal cost of $1.22/lcy. However, this computation is academic for the particular circumstances encountered, as sufficient equipment mobility was not available toward the interior of the thinly crusted portion of the disposal area to support a third dragline.

81. Production from the interior borrow mining operation reached a high of 747 lcy/day and had a minimum measured production of 372 lcy/day. Average production from the interior borrow area was approximately 500 lcy/day or 50 lcy/hr. Total hourly cost for the medium dragline and four dump trucks was $132/operating hr, giving an average unit production cost of $2.64/lcy for borrow removed from the interior of the disposal site. This cost is probably biased slightly on the high side as, during latter phases of the work, only

three of the four dump trucks were actually employed in borrow transport. No comparisons may be made effectively with alternate schemes for removing borrow from the disposal site interior, as the work could not have been efficiently accomplished by multiple dragline relaying and previously evaluated cable-drawn borrow removal equipment was found to be ineffective at this location.*

82. In the northern portion of the disposal area, as indicated on Figure 5, the tandem dragline borrow operation supported by truck haulage provided, on the average, 125 lcy/hr placed along the dike alignment, at a total equipment rental cost of $222/operating hr, giving an average unit production cost of $1.77/lcy for the inplace borrow along the dike alignment.

83. The third borrow operation evaluated consisted of placing the large dragline on the inside toe of the east perimeter dike and supplementing crust this dragline could remove with truck haulage. The large dragline had an average production capacity of approximately 60 lcy/hr while engaged in this operation. This relatively small production for a 1-1/2-cu yd bucket dragline resulted from the necessity for boom swings on the order of 135 deg to efficiently remove in situ crust over the entire boom length and place the material properly along the perimeter dike. Nevertheless, at an hourly operating cost of $46, this crust was obtained at an average unit production cost of $0.75/lcy. An additional 50 lcy/hr was provided from the interior borrow area at the previously computed cost of $2.64/lcy. Thus, for this combined operation, an average of 110 lcy/hr was deposited along the perimeter dike alignment at an average production cost of $1.61/lcy.

84. The cost effectiveness of both the tandem and single dragline-truck haulage-supplemented operations was nearly equal. The single dragline operation placed approximately 15 percent less yardage per hour along the dike alignment at approximately 9 percent less unit production cost. Both operations are considerably more expensive than the hypothesized triple-tandem dragline operation, but in circumstances such as those encountered, the triple dragline operation could not be conducted because of insufficient disposal area mobility.

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* Ibid.

Evaluation of Dike Construction Techniques

85. As mentioned previously, three different construction methods were used to construct the finished dike in two lifts, once dredged material borrow was in place along the alignment. A semicompacted lift to El. 20 MSL and an uncompacted lift to El. 25 MSL were used in both cases, as shown in Figure 3. All three dike construction methods proved technically feasible and operationally practical. After a 1- or 2-day start-up period while dragline and dozer operators became familiar with the required operational sequences, fairly effective production was obtained as long as DOP onsite personnel maintained close supervision of the work.

86. Cost effectiveness of the three construction methods varied considerably. The long sequence construction of the first lift by single dragline, followed by long sequence return placement of the second lift, was the least cost effective of the alternatives. Average effective production rate of the single dragline was approximately 100 lin ft of dike per day, for both the first and second lifts. While considerably more material was required for construction of the first lift, most of the material was already in place along the alignment. During second lift construction, considerable working time was expended in reaching to the base of the inside perimeter dike to obtain needed borrow and in dressing the crest and final side slopes. The effective production rate was thus approximately the same for both halves of the operation. At a rental cost of $38/hr or $380/10-hr working day, average cost of constructing each lift by the long sequence method was $3.80/lin ft. Thus the cost of constructing the finished dike with this technique was $7.60/lin ft.

87. Use of the large dragline assisted by the small wide-track dozer to construct both lifts at essentially the same time was evaluated on both the east and west dikes. This operation averaged approximately 130 lin ft of finished dike per 10-hr working day, at a total equipment cost of $860/day. Average dike construction cost by this procedure was thus $6.61/lin ft of finished dike. Postconstruction assessment by DOP personnel concluded that a smaller dragline could have essentially accomplished the same work in approximately the same time, which would have resulted in a slightly lower unit cost of dike construction.

88. The sequential one-pass dike-building arrangement, whereby a single dragline built the first lift ahead and the second lift behind while proceeding down the alignment, was the most cost-effective construction operation. This operation resulted in average construction of 70 lin ft of dike/10-hr working day at a total equipment cost of $380, giving a unit cost of $5.42/lin ft of finished dike. This operation, while the most cost effective, was also the most difficult technically to carry out, as the equipment operator needed more time (approximately 4 working days vs. 2 for the other operations) before he had mastered the necessary operating sequences for successful production. Further, this operation was the most likely to deteriorate in efficiency if inspection attention of DOP onsite personnel was directed elsewhere.

Miscellaneous Details

89. It should be noted that the cost data presented in the two preceding sections are for only the direct construction operations accomplished. It is probable that the computed cost of borrow production is somewhat low because charges for the small wide-track dozer were not assessed to any of the borrow operations, primarily because the multiplicity of duties conducted by this unit during the course of any working day made relevant breakdown of its cost somewhat impractical. Instead, use of this equipment should perhaps be allocated to general site overhead and its cost of operation reflected in the final cost-effectiveness calculation, that of the unit cost of disposal volume created by dike raising. However, cost-effectiveness comparisons among the three borrow mining techniques and the three dike construction techniques reflect the relative efficiency of the various construction operations, and similar production rates should be expected from such equipment when engaged in similar work. Thus, the data may be used with reasonable expectation of accuracy when predicting construction costs at other locations with different equipment rental rates. Also, no costs per se for design and inspection of the work were included. Assessments, made both during and after construction by DOP personnel, indicate that the various equipment items maintained desired efficiency only when closely supervised by onsite DOP personnel. Whether this condition is a function of

the complexity of operations desired or the fact that an hourly rental contract rather than performance contract was used to conduct the work could not be determined conclusively. Nevertheless, for future operations of this scope and magnitude where rental contract construction is contemplated, it appears imperative that the Government provide a sufficient number of adequately trained onsite personnel to properly direct the work at all times.

90. In summary, despite the use of several previously untried procedures for borrow removal and dike construction, adverse weather conditions, and the general inefficiency at times that resulted from research-oriented work, the dike-raising effort was completed on schedule and at a 1 percent overrun cost of $322,000, providing an additional 1.2 million cu yd of dredged material disposal capacity at the UPB site at an average unit cost of $0.27/cu yd of created storage volume.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

91. Based on the work described and assessed herein, it may be concluded that:

a. Fine-grained dredged material of high plasticity may be used successfully in dredged material disposal site perimeter dike-raising activities, once the material has been successfully dewatered using DOP-published guidelines.[3]

b. At a site with good haul access, the cost of dike raising with the dewatered fine-grained dredged material was less than that estimated for use of offsite borrow. Cost of disposal area storage volume obtained was $0.27/cu yd.

c. When preliminary planning and design are conducted with DOP-developed guidelines[7] and care is taken to place borrow and dress finished dike sections to facilitate rapid precipitation runoff and minimize ponding and infiltration, the fine-grained dredged material was found to have higher than expected semicompacted and uncompacted strength and high erosion resistance.

d. All schemes for borrow removal and dike construction evaluated by the DOP were found to be technically feasible and operationally practical. Choice of the proper borrow removal method to use at other sites will depend on the total volume of material needed and the equipment support capacity and total thickness of the dredged material crust. At locations where enough crust was available adjacent to the perimeter dike, the tandem dragline borrow removal operation was easily the most cost effective. At other sites where more or less uniform crust thickness conditions exist, this procedure should be given initial consideration. If adequate crust is not available or interior disposal area support capacity is not adequate for a multidragline tandem operation, construction of interior haul roads at points of greatest crust thickness may be a cost-effective alternative when overall project costs are computed.

e. DOP-developed empirical criteria for fabric-reinforced haul road construction on surface crust was verified and no major problems were encountered in haul road construction and operation. Locally available Portland cement waste was found to be an acceptable alternative to the use of crushed shell as a haul road surfacing material.

_f_. Once material was in place along the alignment, all three methods used to construct the finished dike were technically feasible and operationally practical. The single dragline sequential dike construction technique whereby a single dragline completed the entire dike section, building the first lift ahead and the second lift behind while moving down the dike alignment, was the most cost effective of the methods evaluated.

_g_. In future operations of similar scope and magnitude, availability of additional small wide-track dozer equipment would probably facilitate project operations. Also, in future operations involving use of several dump trucks along narrow haulage routes with restricted turnarounds and essentially one-way traffic, careful attention should be paid to proper truck routing and scheduling during preconstruction planning in order to obtain more efficient conduct of the actual work.

h. If work of future scope and magnitude is to be conducted by Government equipment rental contract, it appears imperative that adequate numbers of properly trained onsite inspectors be available to ensure that the work will be directed and conducted in an efficient manner.

Recommendations

92. It is recommended that Corps of Engineer field elements and other interested agencies seriously consider the use of dewatered fine-grained dredged material for large-scale perimeter dike-raising activities using the construction procedures described and evaluated in this report. Such construction may be extremely cost effective, especially at remote locations where offsite borrow is particularly expensive or haul access is limited.

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Table 1

Required Equipment Data Developed for MDO Contract Advertisement

Item No.	Number Required	Item Description	Estimated Operating Time hr	Estimated Unit Cost $/hr	Estimated Total Cost $
1	1	Dragline and operator, 1-1/2-cu yd bucket (struck), 70-ft minimum boom length, supplied with mats of size to lower average ground pressure to 2.0 psi.	1,340	40	53,600
2	2	Dragline and operator, 5/8-cu yd bucket (struck), 50-ft minimum boom length, supplied with mats of size to lower average ground pressure to 1.0 psi.	2,080	35	72,800
3	1	Dozer and operator, small, wide-track, IH HD500 or equivalent, maximum ground pressure 2.5 psi.	1,340	35	46,900
4	4	Dump truck and operator, short wheelbase, tandem-axle, 10-cu yd capacity (struck), larger trucks not acceptable.	5,060	25	126,500
5	4	Laborer, Common	270	10	2,700
				Total	$302,500

Table 2

Rental Equipment Supplied by Contract Low Bidder

Rental Item	Rental Rate $/hr	Contract Hours	Cost $
1. Lima 44C Dragline (1-1/2-cu yd bucket)	46.00	1,340	61,640
2. Bay City Dragline (3/4-cu yd bucket)	38.00	1,040	39,520
3. BuCyrus-Erie 15B Dragline (5/8-cu yd bucket)	38.00	1,040	39,520
4. IH HD500 Wide-Track Dozer	40.00	1,340	53,600
5. Short Wheelbase Tandem-Axle 10-cu yd Dump Trucks (4)	23.50	5,060	118,910
6. Common Labor	17.30	270	4,671
		Total Cost	$317,861

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Haliburton, T Allan

Perimeter dike raising with dewaterwd fine-grained dredged material at Upper Polecat Bay disposal area, Mobile, Alabama / by T. Allan Haliburton, Jack Fowler, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, and J. Patrick Langan, U. S. Army Engineer District, Mobile, Mobile, Ala. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

64, [2] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; D-78-3)

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