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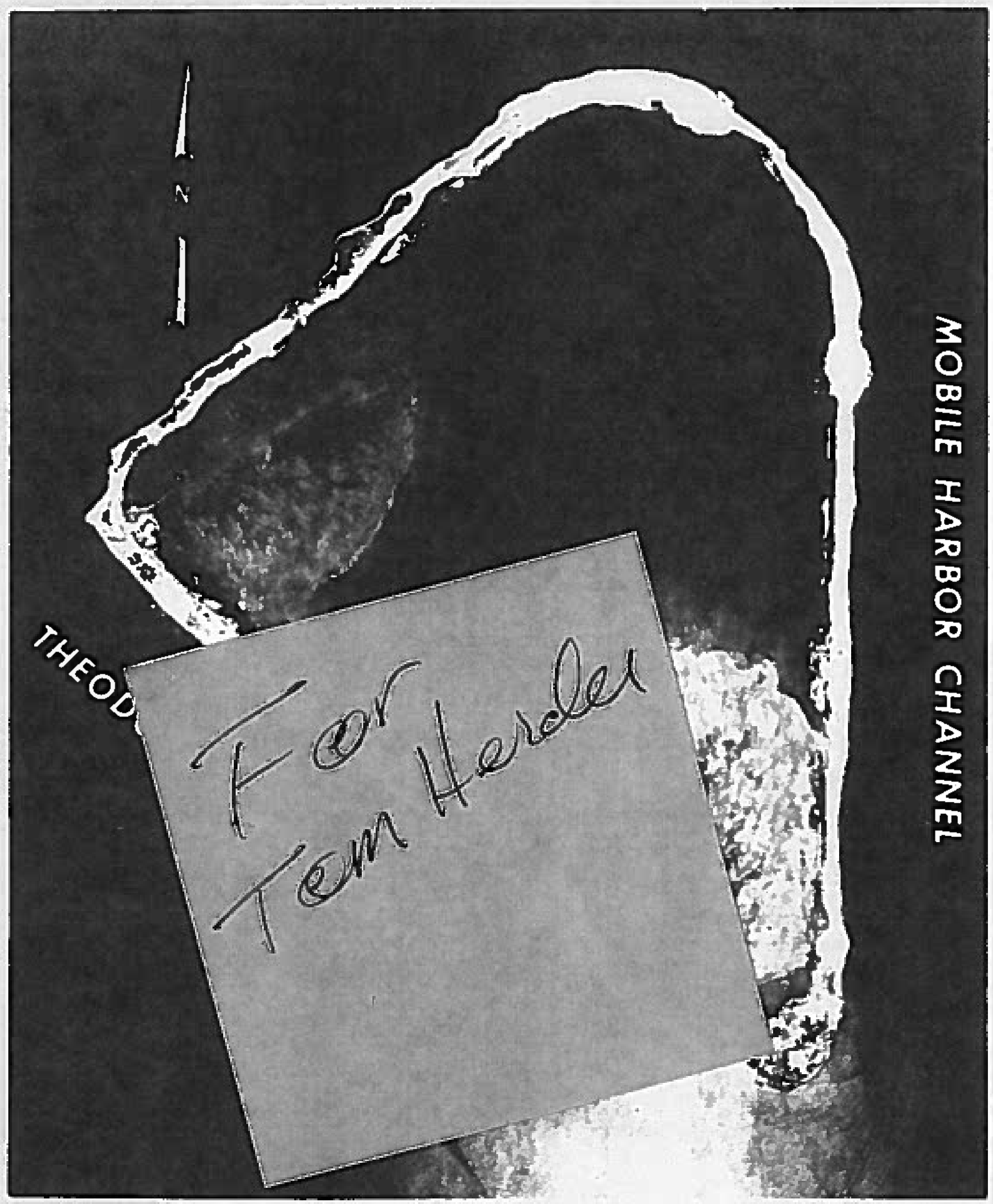
THEODORE SHIP CHANNEL PROJECT

Historical Report



WILSON GAILLARD ISLAND

US Army Corps of Engineers
Mobile District

MARCH 1987

THEODORE SHIP CHANNEL PROJECT

MOBILE, ALABAMA

DESIGN, CONSTRUCTION AND MAINTENANCE

Historical Report

March 1987

US ARMY CORPS OF ENGINEERS
MOBILE DISTRICT
MOBILE, ALABAMA

HISTORICAL REPORT
THEODORE SHIP CHANNEL AND BARGE CANAL EXTENSION
MOBILE, ALABAMA

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PREFACE

The Theodore Project is a unique water resource project, from both an engineering and an environmental perspective. The Mobile District, with the support of the South Atlantic Division, deemed it desirable to document the evolution of the project from its inception through the planning, design, and construction processes with a narrative account of the project to date. Most of the information presented in this report may be found in previously published documents and correspondence; however, the author has supplemented this information with the personal observations of planning, design, construction, operation and maintenance personnel concerned with the project.

This report has been produced in order to contribute to future understanding of projects of this type where sensitivity to public reaction can overshadow a sound engineering and economical approach to the problems. It is anticipated that the information contained herein will alleviate some of the apprehensions, doubts, and legitimate concerns inherent in these projects. The direct application of experience gained on this project must, of course, be tempered by a solid recognition of differing conditions, such as environmental setting, subsurface conditions, physical layout, tides and currents, marine traffic and wave attack. Although it had been hoped to establish more definitive information on the behavior of dredgeu material related to normally established soil parameters such as density, plasticity, grain size and distribution, penetration resistance, and shear strength, it is felt that the approximate parameters established will be very helpful on future projects -- remembering the dearth of definitive data on record at the time this project was planned and executed.

DESIGN, CONSTRUCTION AND MAINTENANCE
THEODORE SHIP CHANNEL PROJECT
MOBILE, ALABAMA

PART I: INTRODUCTION

The Port of Mobile

1. The City of Mobile, located on the west side of Mobile Bay at its landward extremity, is an industrial center with a population in excess of 200,000. The Mobile Standard Metropolitan Statistical Area is comprised of Mobile and Baldwin counties and has a population of over 400,000. Early in the sixteenth century the Spanish explorers recognized the bay area's potential as a valuable seaport. Being 31 miles from the Gulf of Mexico, the mouth of the Mobile River offered a sheltered harbor and access to an extensive river system. Due to its excellent location and temperate climate, the Port of Mobile has evolved into a major shipping center for both deepwater oceangoing vessels and shallow draft inland navigation traffic.

2. The Port of Mobile is served by a deep draft navigation channel which extends from the upper harbor limits to the Gulf of Mexico. The Federally maintained portion of the project includes a 1.5 mile long, 42- by 600-foot channel across Mobile Bar at the mouth of the bay; a 40- by 400-foot channel from the mouth of the bay to the mouth of the Mobile River; a 40-foot channel from the mouth of the river to Cochrane Bridge, extending from Cochrane Bridge to the mouth of Chickasaw Creek, thence 25- by 250-feet up Chickasaw Creek to the mouth of Shell Bayou; a turning basin 40 feet deep by 2,500 feet long by 800 to 1,000 feet wide opposite the Alabama State Docks; a turning basin 40- by 800- by 1,400-feet opposite the mouth of Three Mile Creek; and the currently unmaintained channels and turning basins serving the Brookley Field Ocean Terminal. The Port is also served by the Gulf Intracoastal Waterway, which provides sheltered navigation for barge traffic along the Gulf Coast, and by an extensive inland barge navigation system. This system extends to the Birmingham, Alabama, area via the Black Warrior-Tombigbee system and to Montgomery, Alabama, via the Alabama River. The Tennessee-Tombigbee Waterway, scheduled to open in February 1985, will provide a 9-foot channel and 110- by 600-foot navigation locks from Demopolis, Alabama, to the Tennessee River in northeast Mississippi. The waterway will open the Port of Mobile to the entire central portion of the nation through the upper Mississippi River navigation system. Transshipment of materials at Mobile, particularly bulk commodities such as coal, ore, grain, petroleum products, and chemicals, is expected to expand dramatically with development of traffic on the Tennessee-Tombigbee Waterway.

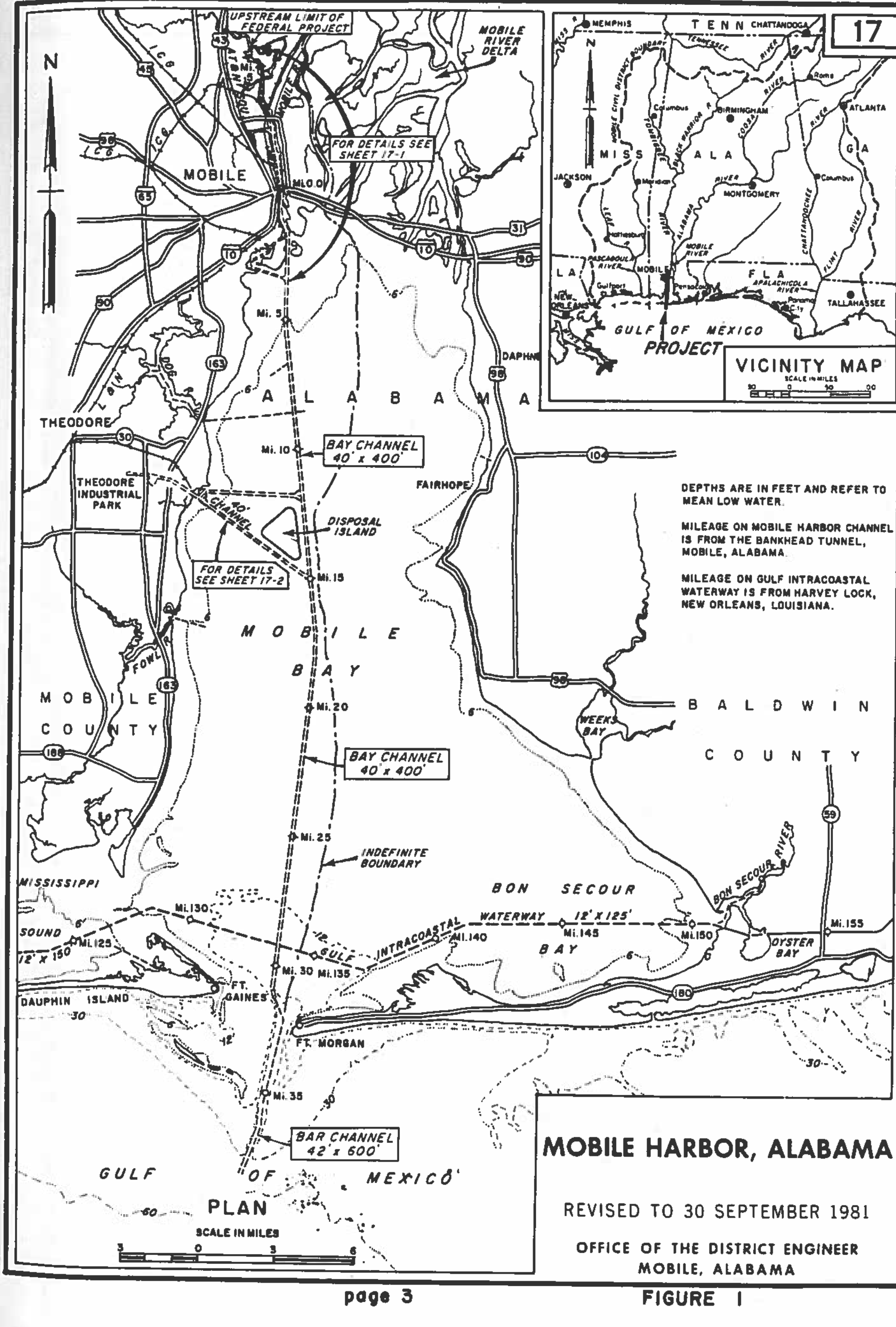
3. Detailed design studies are underway which will lead to the deepening and widening of the Mobile Ship Channel to 55- by 500-feet from the mouth of the bay to a point south of the Interstate Highway 10 crossing of the Mobile River. The grades of both the Bankhead Tunnel and the I-10 Tunnel limit the channel to its present 40 foot depth. This deeper channel will open the port to larger bulk carrier vessels and increase the need for transhipment facilities.

4. The Port of Mobile cannot readily expand upriver primarily because of the lack of suitable land for docks and deep water related industries. The eastern shore of the Mobile River is a deltaic marsh which is extremely important to the ecology of the bay area. It has already been disrupted to some degree by limited industrial development, highway construction, disposal of industrial by-products and material from harbor dredging. Environmental interests strongly oppose any further disruption and even the future maintenance of existing navigation facilities in the upper harbor area is uncertain. Harbor expansion is feasible only on the west bank which is already extremely congested. This, coupled with the draft limitations above the I-10 crossing, caused local interests and the Corps to begin looking at possible locations south of the city to serve the expanding needs of the Port.

Theodore Industrial Park

5. In 1943 the U.S. Army dredged a 32- by 175-foot channel from the Mobile Ship Channel to the western shore of Mobile Bay at the mouth of Deer River. A pier and turning basin were also constructed at the shoreline. Dredged disposal material was placed in open water south of and parallel to the channel forming a peninsula which remained emergent at low tide for a number of years. The facilities were constructed for the loading and unloading of munitions during World War II and were later used during the Korean Conflict. The Government acquired approximately 1,800 acres of land adjacent to the dock area and constructed various buildings, igloos, access roads, utilities and rail facilities. The complex was known as the Theodore Army Ammunition Depot. Following the Korean Conflict the facility was inactivated and placed in caretaker status; the 32-foot channel was abandoned as a Federal project and maintenance ceased.

6. The Theodore Army Ammunition Depot was declared surplus to the needs of the United States Government and in 1965 the land and all improvements were purchased jointly by the Mobile City Industrial Development Board and the Alabama State Docks. The facility was renamed the Theodore Industrial Park and subsequent purchases of privately owned adjacent lands expanded the total property to approximately 4,000 acres. The State of Alabama financed the excavation of a 9- by 150-foot barge canal from the shoreline dock facilities to a point approximately two miles into the Industrial Park. The canal severed Dauphin Island Parkway, a state highway serving the Hollingers Island, Cedar Point, and Dauphin Island areas, and traffic was rerouted west of the canal via Boykin Boulevard and Rangeline Road. Right-of-way was purchased to allow for future construction of a ship



MOBILE HARBOR, ALABAMA

REVISED TO 30 SEPTEMBER 1981

OFFICE OF THE DISTRICT ENGINEER
MOBILE, ALABAMA

FIGURE 1

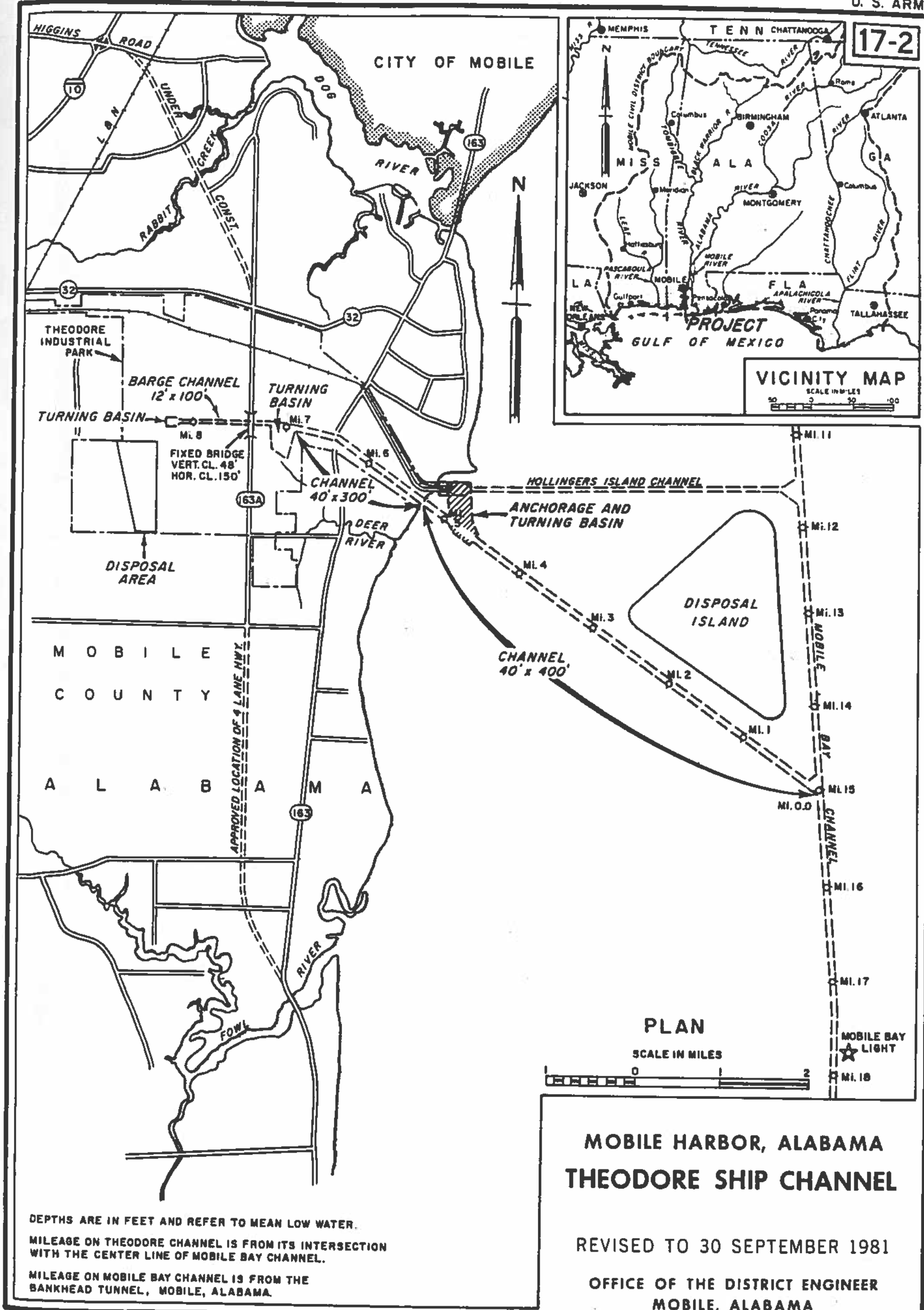

17-2
CITY OF MOBILE
HIGGINS ROAD
DOG RIVER
RABBIT CREEK
L & N
UNDER CONST.
THEODORE INDUSTRIAL PARK
BARGE CHANNEL 12' x 100'
TURNING BASIN
TURNING BASIN
MI. 8
MI. 7
MI. 6
FIXED BRIDGE VERT. CL. 48' HOR. CL. 150'
CHANNEL 40' x 300'
HOLLINGERS ISLAND CHANNEL
ANCHORAGE AND TURNING BASIN
DEER RIVER
DISPOSAL AREA
MI. 4
MI. 3
MI. 2
MI. 1
MI. 0.0
DISPOSAL ISLAND
CHANNEL 40' x 400'
MI. 11
MI. 12
MI. 13
MI. 14
MI. 15
MI. 16
MI. 17
MI. 18
MOBILE BAY CHANNEL
MOBILE BAY LIGHT
MOBILE COUNTY ALABAMA
APPROVED LOCATION OF 4 LANE HWY.
FOWL RIVER
PLAN
SCALE IN MILES
1 0 1 2
VICINITY MAP
GULF OF MEXICO
PROJECT
MEMPHIS
CHATTANOOGA
BIRMINGHAM
ATLANTA
JACKSON
MONTGOMERY
TALLAHASSEE
MOBILE
MISS
ALA
GA
FLA
LA
TENN
DEPTHS ARE IN FEET AND REFER TO MEAN LOW WATER.
MILEAGE ON THEODORE CHANNEL IS FROM ITS INTERSECTION WITH THE CENTER LINE OF MOBILE BAY CHANNEL.
MILEAGE ON MOBILE BAY CHANNEL IS FROM THE BANKHEAD TUNNEL, MOBILE, ALABAMA.
MOBILE HARBOR, ALABAMA
THEODORE SHIP CHANNEL
REVISED TO 30 SEPTEMBER 1981
OFFICE OF THE DISTRICT ENGINEER
MOBILE, ALABAMA

FIGURE 2

canal based on preliminary estimates of the required width. After final design, however, the acquired land proved to be insufficient, requiring the Corps to return to the sponsor to request more.

7. Shortly after establishment of the Industrial Park numerous private and corporate interests purchased adjacent lands and made extensive commitments for industrial development. Among the industries which made immediate use of the barge canal were an oil refinery, an alloy plant and a small shipyard. Two large chemical manufacturing plants were constructed within the park.

PART II: PLANNING

Origin of Theodore Ship Channel Project

8. The Theodore Ship Channel was born of a genuine need to provide the Port of Mobile with suitable lands for development of deep water related industries to meet the expanding needs of the Mobile area and to supplement the existing cargo handling capabilities of the Alabama State Docks. The Theodore Industrial Park was the only logical choice to meet these requirements. Following purchase, expansion and development of the park, local interests requested the Federal Government to provide a deep draft channel from the existing Mobile Ship Channel into the Industrial Park as a modification to the Mobile Harbor project. The Alabama State Docks was designated the local sponsor

9. After preliminary studies the Mobile District prepared a project document which recommended that the Federal project for Mobile Harbor be modified to provide for a channel branching from the main ship channel in Mobile Bay and extending northwesterly to the western shore of Mobile Bay, thence via land cut into a trapezoidal turning basin within the Theodore Industrial Park with an anchorage to be located adjacent to the proposed ship channel near the bay shoreline. The action was authorized in December 1970, under Section 201 of Public Law 89-298, subject to any modifications deemed appropriate by the Chief of Engineers.

Local Cooperation

10. Because the Theodore Ship Channel project was authorized as a modification to the existing Mobile Harbor project, the following conditions of local cooperation were found to be appropriate:

a. Provide without cost to the United States all lands, easements, and rights-of-way required for construction and subsequent maintenance of the project and for aids to navigation upon the request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of dredged material and necessary retaining dikes, bulkheads, and embankments therefor, or the costs of such retaining works;

b. Provide appropriate grassing of disposal areas as required by the Chief of Engineers;

c. Furnish assurances that they will secure or reserve appropriate rights-of-way for channels and turning basins as they may be provided for in the final report, to permit further expansion;

d. Provide and maintain at local expense adequate public terminal and transfer facilities, including a bulk materials handling terminal, open to all on equal terms, and depths in berthing areas and local access channels serving the terminals commensurate with the depth provided in the related project areas;

e. Hold and save the United States free from damages due to construction and maintenance of the project;

f. Accomplish without cost to the United States such utility and other relocations or alterations as necessary for project purposes;

g. Establish regulations prohibiting discharge of pollutants into the waters of the channel and harbor by users thereof, which regulations shall be in accordance with applicable laws or regulations of Federal, State, and local authorities responsible for pollution prevention and control;

h. Contribute in cash 2.0 percent of the construction cost, including engineering and design and supervision and administration thereof, of all work to be provided by the Corps of Engineers, a contribution now estimated at $148,000, to be paid in a lump sum prior to start of construction, or in installments prior to start of pertinent work items in accordance with construction schedules as required by the Chief of Engineers, the final apportionment of cost to be made after the actual costs have been determined;

i. Prohibit erection of any structure within 125 feet of the project channel or turning basin authorized at the time of construction; and

j. Establish a properly constituted public body empowered to regulate and promote the wise use, growth, and development of the area surrounding the channel and turning basin.

The Alabama State Docks provided assurances of local cooperation for the authorized Theodore Ship Channel by letter dated 7 January 1969.

Authorized Plan

11. The authorized plan of improvement for the Theodore Ship Channel

provided for a channel 40 feet deep and 400 feet wide branching from the main ship channel in Mobile Bay at a point 2.8 miles north of Mobile Bay Light and extending northwesterly about 5.3 miles to the western shore of Mobile Bay, thence via land cut 40 feet deep, 300 feet wide, and about 1.9 miles long, generally along the route of the existing barge canal to a trapezoidal turning basin about 42 acres in area within Theodore Industrial Park. The plan included an anchorage area 40 feet deep, 300 feet wide, and 1,200 feet long adjacent to the north side of the channel near the bay shoreline.

12. The channels as described in the authorizing document would have side slopes of 1 vertical on 5 horizontal in Mobile Bay, and 1 vertical on 3 horizontal in the land cut. Excavation would be accomplished by pipeline dredge. The plan provided for an allowance of 2 feet of additional depth for advance maintenance plus 2 feet of allowable overdepth to compensate for inaccuracies in the dredging process. Side slopes would extend from the bottom limits of advance maintenance. Where applicable, the land cut side slopes would be dressed to 1v on 3h and provided with vegetative cover. According to the authorized plan the dredged material from initial construction of the project and future maintenance would be deposited on upland areas and in open water to form five islands adjacent to the channel in Mobile Bay. The bay islands would be constructed to elevations of 10 feet above mean low water and be located a minimum 1,500 feet from the bottom edge of the channel.

State of Alabama Plan

13. Concurrent with their efforts to have the Theodore Ship Channel constructed as a Federal project, local interests applied for a permit to allow the State of Alabama to construct a ship channel to serve the Industrial Park. This illustrates the urgency with which the proposed project was viewed locally. The State plan provided for a 40- by 250-foot channel along the alignment of the existing Hollingers Island Channel with the 11 million cubic yards of material placed in four disposal areas adjacent to the channel. Permit applications were processed for the State plan but were not pursued when the Federal plan was approved.

Phase I Studies

14. Due to the sensitive and controversial nature of this project it was investigated in much greater scope and depth during Phase I studies than normal. An extensive subsurface investigation was performed along both the channel and containment dike alignments. Although most of the data developed was not processed for inclusion in the Phase I GDM (USACEM 1976) it was used in the plan formulation. A physical hydraulic model of Mobile Bay was constructed. Ten island and channel configurations were evaluated in the model to determine their comparative effects upon existing chemical and physical characteristics of the bay. Two experimental test excavations

and fills were performed on bay bottom materials, one using mechanical excavation methods and the other using a hydraulic dredge. Two public meetings were held during Phase I studies to encourage the maximum public involvement. An exhaustive economic, social and environmental assessment was conducted in accordance with Section 122 of Public Law 91-611. These studies addressed the complete spectrum of pre-project conditions and the corresponding impacts of the various alternative plans.

Departures from the Authorized Plan

15. During Phase I studies several aspects of the project, primarily in the realm of economics, came into focus which resulted in significant alterations to the authorized project plan and caused an appreciable increase in the estimated cost. Using updated pricing and interest rates for both the authorized and proposed plans the annual charges increased by a factor of 2.94 while the annual benefits increased by a factor of 6.23 resulting in an increase of the Benefit Cost Ratio from 2.05 to 4.35. Alterations to the authorized plan are as follows:

a. A 9- by 100-foot barge canal extending approximately 6,000 feet beyond the ship turning basin and terminating in a 300- by 300-foot turning basin was added.

b. Disposal of new work dredged material was changed to provide for the use of all material from the deep water facilities to construct one island within the triangle formed by the Mobile, Theodore and Hollingers Island Channels in lieu of the approved plan to place the land cut material on upland areas and the bay cut material in five small islands adjacent to the Theodore Channel. This resulted in increased dredging costs due to the added pumping distances. The option of using material from the barge channel for constructing the island or placing it in an upland area was retained contingent upon scheduling.

c. Anticipated local sponsor costs were substantially increased by the additional requirement to provide erosion protection for the disposal island in the form of revetment and marsh grass establishment.

d. A shoreline turning basin was added to provide deep draft access to additional public and industrial facilities. (This project feature was later deleted because of cancelled public commitments.)

e. The inland turning basin was altered to accommodate plans for development by local interest.

The foregoing changes were deemed of such significance as to require submission to Congress for reauthorization. The Phase I GDM was therefore submitted on 12 March 1976 as a "Special Report" (H. Doc. 95-376). The final authorization was contained in Section 122 of the Water Resources Development Act of 1976 (PL 94-587). Following are significant dates in the history of Theodore Ship Channel:

Authorized in 1970 under Section 201 of the 1965 Flood Control Act and modified in 1976 by Section 112 of the Water Resources Development Act of 1976

Draft Environmental Impact Statement (DEIS) filed with Council on Environmental Quality	October 1975
Revised Environmental Impact Statement (RDEIS) filed with Council on Environmental Quality	July 1976
Final Environmental Impact Statement (FEIS) filed with Council on Environmental Quality	March 1977
Phase II GDM	December 1977
Public Meetings	January 1974 November 1975
Section 221 Contract Executed	August 1977
Barge Canal Contract Awarded Barge Canal Contract Completed	October 1978 January 1980
Ship Channel Contract Awarded Ship Channel Contract Completed	April 1979 August 1981

Environmental Impact Statement

16. The results of environmental assessment studies performed during Phase I were included in the Special Report and provided the basis for the Environmental Impact Statement (EIS). This project was among the first major navigation projects to be subjected to the scrutiny brought about by the National Environmental Policy Act of 1969 (NEPA). The proposed project plan was presented to a gathering of the American Dredging Association and reportedly evoked a great deal of interest. It was viewed by many as a pilot project which would likely set the precedents that would have a significant effect on the future of navigation projects throughout the nation.

17. The first draft of the Environmental Impact Statement was submitted to the President's Council on Environmental Quality in November 1970. On 13 October 1970 copies of the draft were transmitted to the Departments of Interior, Transportation, Health Education and Welfare and to the State of Alabama. The only adverse reaction came from the Department of Interior in the form of a comment recommending that the project be deferred until a physical hydraulic model of the bay could be constructed to determine the effect of the proposed construction on bay currents and water quality. Because of this comment the draft was considered inadequate and it was

withdrawn. Authority to construct the model was requested and granted. The model was built at the Waterways Experiment Station (WES), Vicksburg, Mississippi, and testing began in August 1973. Results of model studies will be discussed later in this report. A new draft EIS (DEIS) was written and filed with the President's Council on Environmental Quality on 3 October 1975. The new draft, increased in depth and scope, included the results of the model studies, archeological investigations, dredging tests and all other investigations conducted to date. It updated the proposed project configuration and presented the current figures on project costs and benefits. The draft was distributed to Federal, State, and local agencies as well as other concerned parties on 18 September 1975. A revised draft EIS (RDEIS) was filled with the Council on Environmental Quality in July 1976. Numerous comments were received from recipients, the preponderance of which were adverse. Some of the most significant comments which influenced to some degree the design of the project or provoked additional studies are addressed below.

Reactions to the Draft EIS and Revised Draft EIS

18. The National Marine Fisheries Service (NMFS) was disparaging of the entire project but specifically attacked the disposal island concept. Their comments were numerous and, at times caustic. They objected to the inconclusive results of the dredge test fill conducted with poor quality material and the Corps' extrapolation of higher retention rates with the use of better nearshore and inshore channel cut materials. They questioned the need for the island based on the model tests, disputed the information given on areas assumed affected by mud flows, and questioned the efficacy of transporting the land cut materials six to eight miles (their figures) to the dike area. They repeatedly suggested further evaluation of upland disposal sites for part, if not all, of the dredged material. The District responded to the NMFS comments in a rational and professional manner, correcting a few errors in the data presented, furnishing some clarifying information, revising language in some judgemental areas but generally reiterating the facts in the EIS which supported the basic design. The response was apparently adequate since there is no record of further comments by the NMFS on the revised EIS (RDEIS).

19. The Department of Interior offered several comments of a critical nature. They pointed out the possibility of a rupture of the aquiclude and consequent lowering of the potentiometric surface in the shallow aquifers underlying the land cut resulting from the removal of cover by the canal and turning basin excavations. This possibility was acknowledged and Section 4 was revised accordingly. They expressed doubt that the establishment of marsh around the island would mitigate the loss of 26 acres of natural marsh at the shoreline. It was explained that the use of the term "mitigate" was not intended to imply an "in kind" replacement but rather would help to diminish the adverse impact of the loss. As further explanation, it was stated that in order to replace the destroyed marsh on an acre-for-acre basis a 190-foot strip of marsh would

be required along the 6,000-foot length of the island shoreline. Interestingly, later correspondence indicated that this was interpreted as a commitment by the Corps to do so. Interior questioned the model study results and its interpretation of salinity effects; they went on to question the need for the island on this basis. The District reiterated its goal of minimum effects on the existing circulation patterns and salinity regimen in the bay and restated the position that the island was required to accomplish this. The District's responses to Interior's comments also appear to have been adequate since the revised EIS (RDEIS) provoked no further comments.

20. The Alabama Water Improvement Commission (AWIC), in a comment on the DEIS, recommended that the water quality studies in the bay be expanded to include the inland channels and Deer River. The District responded with a statement that the treatment of the problem in the EIS was considered to be adequate. It was pointed out that the most significant water quality considerations were the secondary effects of point and non-point sources of pollution resulting from the Industrial Park development, and that adequate legislative controls were available to regulatory agencies to control point sources. It was recommended that control of non-point sources be included in the 208 Program scheduled to be conducted in the area. It was further pointed out, however, that even with a high degree of control, the existing water quality standards could not be met. The question of what effect the disposal island would have on "canal displacement" was posed. The District assumed that this question addressed a possible massive slope failure of the island perimeter of sufficient magnitude to affect the channel sloped. The District responded that the buffer zone between the island and adjacent channels was wide enough to prevent this. AWIC requested clarification of the initial stability of the island, between construction and placement of revetment. The District responded by revising Section 1 to acknowledge that during this period some of the finer material would be washed away but that there would be enough mass in the dike to allow for the loss.

21. In comments on the RDEIS the AWIC again took the position that further studies were essential to the completion of an adequate EIS and that it was incumbent on the Corps to establish and include the cost of all quantifiable environmental impacts including that of establishing necessary controls as well as implementing pollution abatement measures. They further stated that the evaluation of costs should include the potential loss of oyster beds due to altered circulation and increased pollution level in the bay. The District responded that the establishment of a water quality management plan was within the specific jurisdiction of the AWIC and EPA and that no data had been generated to date which would provide a basis for estimating the cost of a plan. Hence, it could not be included in the EIS. In regard to the costs of potential oyster bed losses the District responded that the recommended plan would provide only the slightest deviation from existing conditions and that evaluation of such costs was not considered necessary.

22. The Environmental Protection Agency (EPA) reacted to the DEIS with a number of adverse comments and stated that they had rated the project "ER" (Environmental Reservations) and "2" (Insufficient Information). The questions raised included water quality in the dead-end canal, the rate of shoaling in the bay cut channel, the method of island construction, erosion protection and the anticipated increase in ambient noise levels in the area of the project. In response to the comments on water quality in the canal, the District correctly pointed out that the degree of pollution and the amount of time that poor water quality would exist was dependent upon the degree of control exercised over the point and non-point sources of pollution. Not stated, but properly implied, in the District's response was the premise that EPA would share in such control. On the question of a water quality management plan the EPA took a position similar to that taken by AWIC which appeared to be an effort to shift the responsibility to the Corps, contrary to existing legislation. Again, as was stated in response to AWIC, the District acknowledged the need for a plan and pointed out that legislative controls available to the regulatory agencies along with the Section 201 and 208 plans for the area would provide the basis. A previous meeting called by EPA and attended by the Corps and all planning agencies was referenced in which the Corps had offered the use of the Mobile Bay model, contingent upon the availability of 208 funds, as an aid in developing a pollution control plan. The thrust of the comment on shoaling was their contention that the District may have vastly understated the amount and had thus inflated the Benefit-Cost Ratio. The District responded with a description of the methods and procedures used in estimating the shoaling rate (2,200,000 cubic yards per year) and concluded that this estimate was considered to be conservative since no reduction was made for the shoaling effect of the island nor the disparity of the cross sectional areas of the Theodore and Hollingers Island channels, the actual shoaling rate of the letter being the primary basis for the estimate. Concerning the island construction, the questions raised included the unstable foundation soils, insufficient granular material available to protect all portions exposed to wave action, and the consequent turbidity during a long period of stabilization. The fact that only certain portions of the island were to be protected with revetment was questioned and it was suggested that dead reef shells might be used as erosion protection on the island slopes below the revetment and planted marsh grass as well as on all other unprotected surfaces. In answering these comments the District acknowledged that there would be some problems with stabilizing the island but referred to the tests which showed that an island could be constructed which would effectively contain the dredged disposal material and reasserted that the island could be stabilized. Regarding the island protection, reference was made to a meeting in Montgomery, Alabama, on 14 May 1975 at which the EPA agreed to the protection plan presented in the EIS. Any further protection would be contingent upon need as displayed by the island performance. Regarding noise pollution, the District acknowledged that noise levels would increase with the project construction but reiterated the impossibility of any quantitative projection of magnitude.

23. In responding to the revised draft of the EIS the EPA did not pursue the issues of island construction, rate of shoaling, or increased noise levels but persisted in the issues of canal water quality, prolonged turbidity around the island, and increased slope protection. They also retained the "ER" and "2" ratings mentioned above. The comments were along the same lines as those discussed above and similar responses were made by the District.

24. Several State agencies responded to the DEIS through the Alabama Development Office. Some concurred in the EIS with no comment and most comments which were offered duplicated those which have been previously discussed. Those which raised new issues that are considered significant are discussed below.

25. Several State agencies responded to the DEIS through the Alabama Development Office. Some concurred in the EIS with no comment and most comments which were offered duplicated those which have been previously discussed. Those which raised new issues that are considered significant are discussed below.

25. The Alabama Geological Survey (AGS) requested further consideration of the barge channel cut as a source for salt water intrusion into area aquifers. The District concurred and revised Section 4 accordingly. They requested further modeling of the bay to establish any changes to surface and bottom currents resulting from the channel and island construction and their effects on siltation and erosion. Their attention was invited to the extensive Phase I tests which led to the selection of the final plan and the fact that the tests showed no appreciable velocity changes. They advocated special care during dredging to protect the oyster reef to the north of Hollingers Island channel. The District referred to its response to a similar comment by NMFS in which it was explained that, due to illegal fishing of that reef and the consequent threat to the State's Shellfish Certification, the Conservation Department had moved the oysters and attempted to destroy the reef. The AGS also suggested that further consideration be given to the use of the Hollingers Island channel alignment as a possibly less expensive and environmentally damaging alternative. The District replied that sufficient consideration had already been given this plan.

26. The Alabama Highway Department stated their concern over the transportation problem created by the removal of Dauphin Island Parkway bridge over Deer River for the construction of the existing barge canal. They further stated that they were committed to replacing the bridge but since the ship channel would require a bridge of much greater height and span it was beyond the range of their economic feasibility and should be financed as a part of the ship channel project. There was and still is apparently no satisfactory answer to this problem. The completion of Rangeline Road will alleviate the problem for through traffic but for those residents living east and south of the project, the inconvenience will remain. It appears doubtful that a bridge can be economically justified. The District responded to this comment by simply referring to

the discussion in the Phase I GDM. A similar letter was received from the Highway Department in response to the revised draft EIS with a similar answer by the District.

27. Three individuals responded to the draft EIS, one a homeowner in the Theodore Industrial Park area, one representing the Mobile Bay Audubon Society and the other a member of the Theodore Advisory Committee (TAC). The homeowner listed a series of existing and anticipated conditions in the park area which adversely affected him as a resident and requested that his comments be placed in the record. The TAC member was adamantly opposed to the project and offered a large number of adverse comments, most of which questioned judgmental conclusions stated in the EIS without offering any evidence to the contrary. Some specific comments concerned the possible disparity between the bay model and prototype due to wind effects; the theory that most of the reptiles and small mammals in the land cut area would retreat into burrows and be killed; the uncertainties of marsh development on the island and the characterization of the proposed island construction as an "experiment". In response to the comment on wind effects the District conceded that wind could not be build into the model but stated that the verification between the prototype and model is considered to be good. The District also conceded that most of the small animals in the construction area would be killed, and revised the statement accordingly. Likewise the uncertainty of the marsh establishment was acknowledged and proper revisions made to the EIS. In characterizing the island construction as an experiment the TAC member suggested that the dredged material would be uncontained and would spread over an area in excess of five square miles rather than two square miles as stated in the EIS. In response, the District reiterated that, based on the test dredging, a dike could be constructed which would effectively contain the dredged material. Although it is not considered a valid comment, and had no impact on the project design, it is interesting to note that the TAC member compared the 1.47 to 1 Benefit to Cost (BC) Ratio of the Environmental Quality plan to the 4.31 to 1 ratio of the proposed plan and apparently concluded that the otherwise unquantified environmental and social costs had been used to lower the BC Ratio of the Environmental Quality plan. In response, it was explained that unquantifiable environmental and social costs or benefits were not included in the Benefit-Cost calculations for either plan. The Audubon Society (AS) representative appeared to have accepted the project as inevitable but expressed strong opposition to the island concept and appeared to equate it with open water disposal, being apparently convinced that the island could not be constructed and that both the new work material and future maintenance disposal would be spread over the bay indiscriminately. Again, it was pointed out that the Phase I test studies had proven the viability of the island concept and that the EIS properly addressed the problems expected to be encountered in the island construction and stabilization. Numerous other comments were offered, all of which had been received in one form or another from other agencies or individuals. The AS representative insisted, as did the TAC member, that environmental and social costs and benefits be included in the BC Ratio computations and presented a lengthy list for consideration. The District

responded that it is not possible to consider non-quantifiable entities in the BC calculations. The response, however, was not accepted for the AS member's comments on the revised draft EIS again criticized the system and offer a new list of costs and benefits.

28. The comments of those agencies and individuals who responded to only the draft or the both the draft and the revised draft were discussed above. Following are comments of those who responded only to the revised draft. Health, Education and Welfare (HEW) reacted to the revised draft (RDEIS) with a series of comments relating to the declining bacteriological quality of Mobile Bay waters and the likely acceleration of this decline due to increased pollution from the project; impacts upon disease vectors; the adequacy of health care facilities in the impacted area; the possible effects of traffic congestion upon access to health care facilities; and increased costs to the taxpayers for the additional community services required such as health care, education, law enforcement, sewage and solid waste disposal, water supply and transportation. HEW had previously stated that "the project will have no significant adverse effect on environmental matters of concern to the department" and were so quoted in the EIS. One of their comments rescinded this statement, giving as a reason the results of an FDA report dated May 1976 entitled Alabama Shellfish Sanitation Review. The only new issue raised by HEW concerned the projects's potential impact upon vector-borne diseases and resulted in the inclusion of a discussion of this subject in the final EIS. A later letter from the HEW Center for Disease Control, Fort Collins, Colorado, expressed concern over the possible breeding of Aedes sollicitans (salt marsh mosquitoes), vectors for encephalitis, in the new disposal areas. The District replied that the project would not significantly add to the naturally existing abundant habitat in the bay area. The other comments were answered by clarifying language in the EIS and some additional studies on existing health care facilities and access thereto. In responding to the comment on increased costs to the community due to the projected population increase (150,000 by the year 2020), the District stated that such costs were dependent upon the future efforts of community planners and therefore unquantifiable. A possibly better answer, which probably occurred to the respondent but was ruled out by discretion, would have been that the issue is redundant since the increased tax base due to the project development should certainly be ample to provide the increased community services. A second letter was received from the Fort Collins Center for Disease Control which cited a precedent where the Corps in Charleston, South Carolina, had provided project funds for mosquito control and suggested similar action at Theodore. The District responded with information showing there has been no increase in mosquito population due to dredge disposal areas in the Mobile District and questioned the wisdom of expending public funds for chemical control. The Alabama Department of Public Health responded to the RDEIS with comments similar to those from Fort Collins. The District cited the expanded discussion in Section 4 of the EIS and their response to Fort Collins in answer to these comments.

Public Meetings

29. Two public meetings were held for the purpose of encouraging local input to the planning process for the project. The first was held on 22 January 1974 and was attended by 227 people. The second was held on 12 November 1975 and was attended by 120 people. Both meetings were held at the Mobile Municipal Auditorium and were presided over by the District Engineer, Colonel Drake Wilson. The preponderance of comments in the records of both meetings, including those presented verbally and those furnished in writing, were in favor of the project with some reservations based on environmental factors. Essentially all of the adverse comments, with the exception of those from local residents who feared personal damage from the project, were the same as those previously discussed under the EIS. The issue of the bridge replacement over the canal at Dauphin Island Parkway came up repeatedly at the first meeting and at least once at the second. It was discussed at length, apparently to the satisfaction of no one, and remains a volatile issue to date. Transcripts of both public meetings are contained in the Special Report (Phase I GDM).

Model Studies

30. A physical hydraulic model of the Mobile Bay was constructed to evaluate effects of various channel and disposal islands in the bay on salinities and flow patterns and consequent impact on oyster production at the lower end of the bay. The model was constructed at the Waterways Experiment Station (WES) and tests were conducted by their staff. The studies were thoroughly documented in WES Technical Report H-75-13 (Lawing, Boland and Bobb 1975) and are discussed in detail in Appendix A to the Special Report and will be discussed only briefly herein.

31. After extensive adjustments to the model to obtain optimum correlation with prototype behavior, base tests were conducted to establish basic hydraulic, salinity, and dye dispersion data for later comparison with that developed from tests incorporating the various project plans. Two channel alignments, one perpendicular to the shoreline and one on a NW/SE alignment were tested, both with and without the presence of disposal islands. Nine different disposal island configurations were tested in combination with the channels. It quickly became apparent that the detailed testing of all combinations was not practicable and an abbreviated testing program was used to eliminate the least desirable ones and reduce the number to a workable level.

32. The objective of the testing was to identify the plan which had the least effect upon salinity and circulation patterns at certain oyster reef locations in the bay. These reefs were ranked according to their importance and assigned a number reflecting the relative rankings. A rating system was then devised using these numbers. Three plans were thoroughly tested in the formal testing program, using minimum, maximum and average freshwater inflows. In addition to salinity, data on velocity, dye dispersion and eddies over dredged channels were collected and used to rank the various plans.

33. The selected plan, which included the diagonal channel and a triangular disposal island in the area between the Theodore, Mobile and Hollingers Island channels was second to the plan having an island on the east side of Mobile Ship Channel considering salinity alone. It was, however, superior to all other plans in other respects and the changes in salinity were so slight that it was considered acceptable. The model tests also proved that intolerable changes in salinity would occur in the bay with the Theodore Channel and without the island.

Environmental Monitoring

34. Two separate but interrelated monitoring plans were developed: one to verify the effects of the constructed project on salinity and current circulation patterns as predicted by the hydraulic model; and the other to accurately check and document the actual environmental impacts of the project on the surrounding areas on the bay. The locations of monitoring stations for the two plans are shown on figure 3. Engineering and environmental studies during planning and design showed that the long-term adverse impacts of the project on the bay environment would be minimal and an unusual amount of effort was made to predict and document the short-term effects. The high level of public interest and concern expressed throughout the project planning and design plus the unique and largely unprecedented nature of the project rendered it essential to verify these predictions. In addition, it was considered prudent from a standpoint of early identification of the causes of possible adverse behavior in order to permit timely corrective action, both during construction and during the period of island stabilization. Elements of the environmental monitoring included turbidity, salinity, temperature, dissolved oxygen, sediment size and mud flow sedimentology, sediment quality, submersed grasses, macro-infauna and dimensal fauna. In addition, salinity, current velocity and tide level data were to be collected for model verification. The program provided for collection of data well in advance of the start of construction in order to establish baseline conditions and establish any natural trends in the study parameters or changes resulting from other ongoing activities. The program also provided for continuation of data collection through construction plus a minimum of one full seasonal cycle after construction.

35. The environmental impacts portion of the monitoring program was conducted by the Dauphin Island Sea Laboratory, Dauphin Island, Alabama, under two separate contracts to the Mobile District. The first phase, referred to as the pre-construction or "baseline" study, was performed between November 1977 and October 1978; a final report was submitted separately for this phase (Marine Environmental Sciences Consortium 1978). The construction and post-construction phase studies were conducted continuously between March 1980 and August 1982. The construction phase covered the period of March 1980 and August 1981 (18 months); the remaining twelve months covered the post-construction phase. This corresponded to the timing of actual construction in the bay: the

first dredge was moved in on 29 November 1979, and dredging was completed on 28 August 1981. Briefly stated, the final report concluded that project activities during both the construction and post-construction periods had no significant impact on the study parameters (Dauphin Island Sea Lab 1983). Regarding temperature, salinity, dissolved oxygen, suspended solids, sediment parameters, and benthic organisms the report states that, although there are differences between some of the individual values of the three study periods, none of the periods are significantly different when compared on a mean monthly basis. From the sediment studies it was concluded that, although one sampling station located south of the Theodore Island showed a notable decrease in the percent of sand, the activities of the project did not significantly change the bottom sediments from a standpoint of texture. The chemical analysis showed what was considered to be a significant increase in the level of total reducing substances at the two sampling stations near the mouth of the land cut channel. It was concluded that, since these substances resulted from the presence of oxygen consuming inorganic materials and none were generated by the channel and island construction, the most likely cause of this change is discharges from one or more of the industries in the Theodore Industrial Park.

36. The model confirmation portion of the monitoring program was conducted by the Waterways Experiment Station. Their final report concluded that the prototype reaction to the project features was predicted by the model with sufficient accuracy (Berger and Boland 1979). All of the monitoring program reports discussed above are on file in the Environmental Resources Branch of the Mobile District Planning Division.

Archeological Studies

37. In 1974 the Gulf South Research Institute (GSRI), under contract to the Corps, conducted an archeological survey of the areas affected by the ship channel project. A magnetometer survey was conducted in the bay covering the areas to be disturbed by the channel and island construction. The land area within 250 feet either side of the land cut ship channel and turning basin was covered by the surface survey. Ten magnetic anomolies and one anomoulous area were detected by the survey. Two of the anomolies fell within the proposed disposal island area and none fell within the channel cut. They were point sources, not indicative of a historic site. They may be the remains of explosive ordnance and would have required investigation and possible removal had they been located in an excavated area; however, since only filling was contemplated at the island location they were of no further concern. Three sites yielding evidence of historic Euro-American occupation were detected in the land survey. The evidence was sparse and inconclusive, consisting of glass, ceramic, and tile fragments plus nondescript metal fragments and a fragment of a copper instrument. All three sites fell outside the proposed construction limits and no further investigations were recommended. The limits of the land and water surveys and the locations of the magnetic anomolies and historic sites are shown in figure 4. The archeological survey is discussed in detail in section 2 of the Final EIS.

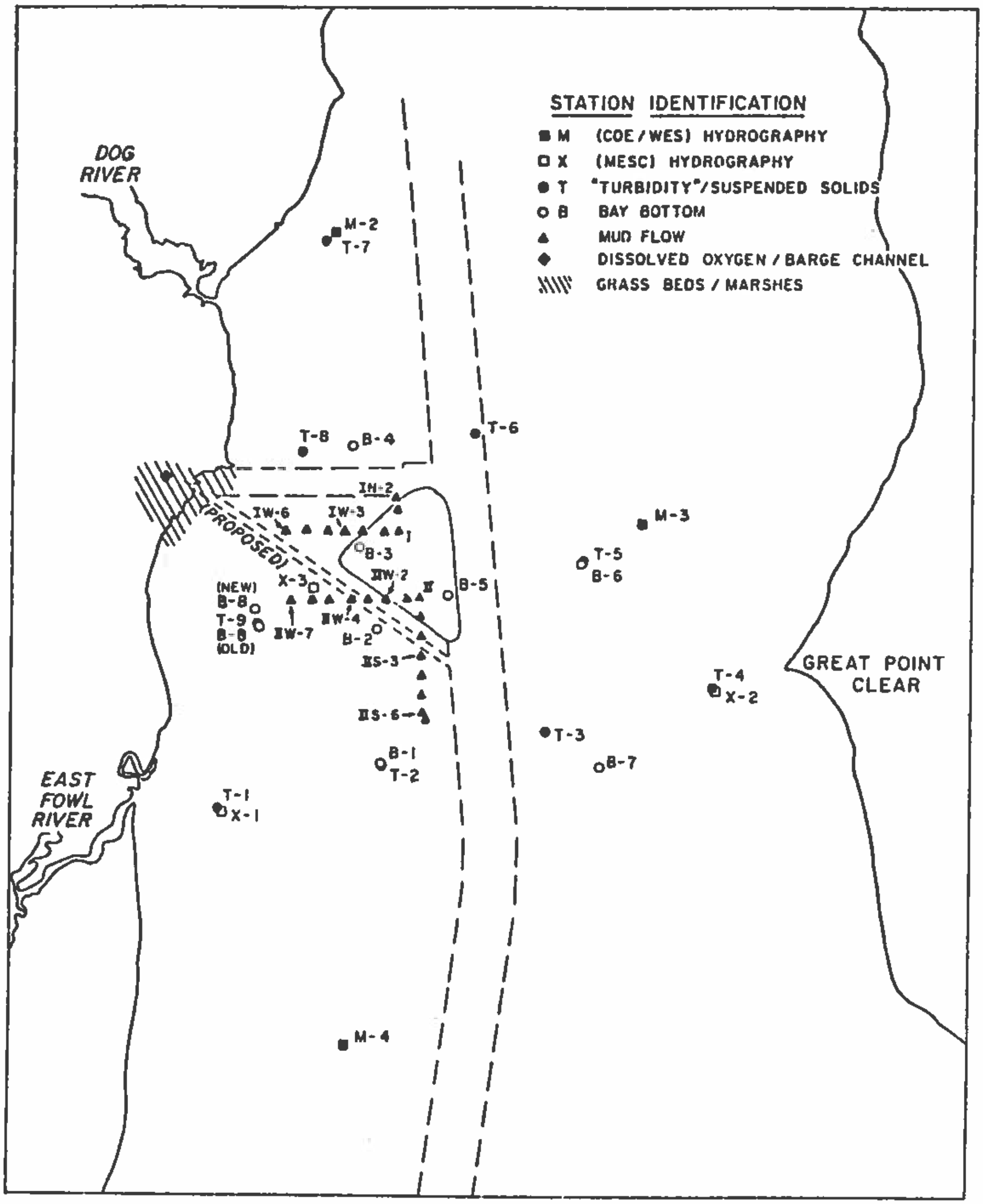


FIGURE 3
THEODORE SHIP CHANNEL
BASELINE ENVIRONMENTAL MONITORING STATIONS

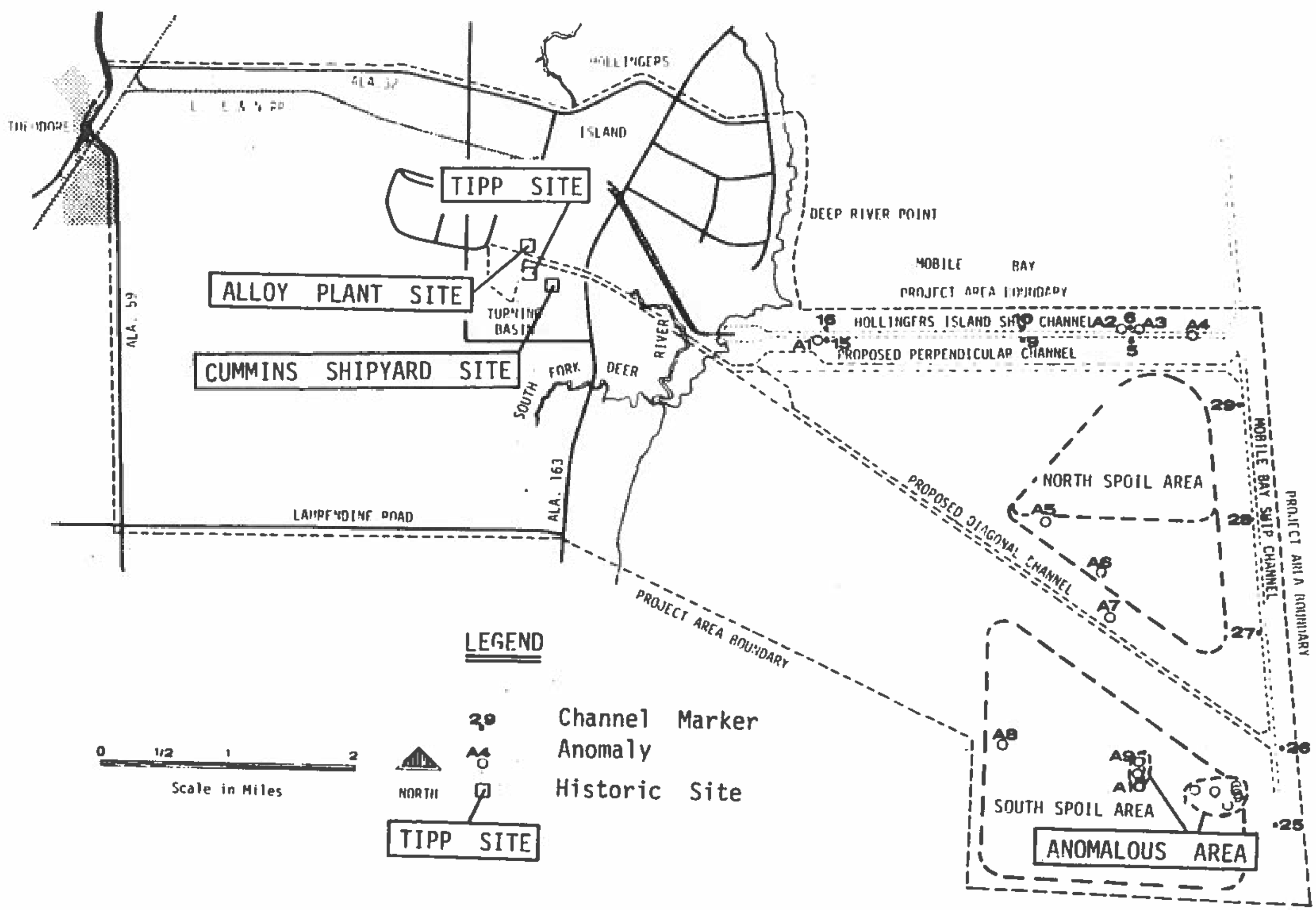


FIGURE 4 ARCHEOLOGICAL SITES AND ANOMALOUS AREAS

38. The barge canal extension was made a part of the Federal project after the surveys were completed by GSRI. Since the areas affected by this part of the project were not covered by their studies they were surveyed by the Mobile District archeologist in April 1977. Three areas of archeological remains were found during the survey, none of which would be disturbed by the project. Two of the areas, each containing aboriginal pottery shards, were located along the slope of the ridge bordering the disposal area on the south. The third area, containing a single-stemmed projectile point, was in the west bank of the Rangeline Road cut south of Deer River. All three sites were outside the construction limits and required no further action.

PART III: ENGINEERING AND DESIGN

Design Problems

39. In 1968, shortly after the planning was initially authorized, a limited series of sample borings were taken along what was to be the final alignment of the ship channel. Although none were taken at the island location or on high ground in the land cut channel and turning basin areas it was possible to extrapolate these boring results to gain a fairly accurate picture of the subsurface condition throughout the project. The design of the channels was envisioned as a fairly straightforward exercise involving the conventional use of soils design methods on the land cuts and relying on the many years of experience with the behavior of the Mobile Ship Channel to design the bay cut. The proposed bay disposal island was an entirely different matter. This feature was viewed with a great deal of concern by practically everyone involved. It would have to be large in order to accommodate 50 years of maintenance dredge disposal material without reaching inordinate elevations. It had to be located in the deepest part of the bay since an onshore or nearshore was not acceptable. It was known that the bay bottom was generally extremely soft with many areas having been worked with a shell dredge. It was possible in many locations to push a pole as deep as 20 feet into the bay bottom with practically no resistance. The island would be subject to wave attack from 360 degrees with wind fetch of up to 20 miles. It would also be subject to tidal currents and ship waves. There was considerable doubt that, with the type of material available and the long pumping distances involved, a dike could even be raised above the water surface. It was hypothesized by some that even if it were possible to raise the dike, the resultant mud wave would close both the Mobile and Theodore channels. With all the uncertainties at that time, the first question was not how to design the island but whether or not the island concept was even feasible. Initially, two islands were contemplated, one at the location as-built and the other, of comparable size, south of the proposed channel. Considering all the foregoing questions, it did not take long to decide that the second island should be eliminated.

40. During consideration of the island concept feasibility, two prior Corps projects involving dredged fill dikes were examined. One was the Craney Island project in Hampton Roads, Virginia, and the other at Charleston Harbor, South Carolina. The Craney Island project involved the construction of a six-mile long dike to enclose a 2,500-acre disposal area for the Norfolk/Portsmouth areas. It was similar to the Theodore project in that the dredge fill dike had to be placed on an extremely soft bottom in some areas, but there the similarity ended. The dike was a horseshoe configuration with each side tied to high ground on the beach as opposed to the Theodore island which was to be three to five miles from shore. Craney Island was in relatively protected waters where Theodore was to be in the open waters of Mobile Bay. The contractor at Craney Island was furnished a borrow area of select sand and required to use it. Theodore would require the use of whatever material came out of the channel cuts, known to be predominantly clay and silt, and with pumping distances up to six miles requiring three or more booster pumps. The Charleston Harbor project required construction of a dredged fill dike using a material known locally as Cooper River Marl which is a stiff, preconsolidated, calcareous silt and clay which was presumed to be much more competent than the soft clay and silts which predominate in the Theodore job. This project, too, was in sheltered waters and required relatively short pumping distances. Both of these projects had been successfully completed only after extreme difficulty and large claims by both contractors. The Government successfully defended against the Craney Island claim but the contractor reportedly went broke during the process. The courts ruled in favor of the contractor on Charleston Harbor. None of the foregoing bolstered the confidence of design personnel on the Theodore Project. However, on the basis of all that could be determined up to that time, no one could, in good conscience, throw out a project that was authorized by Congress, had an exceptional ratio and unlimited local support. Hence, the dilemma continued.

41. Although the draft EIS was not circulated until September 1975, it had become apparent that other Government agencies and environmental groups seriously questioned the island concept and would demand, if possible, an ironclad guarantee that it would be successful. There was general agreement among design personnel that, because of the sheer volume of material available, a containment of some sort could be constructed; however, none were willing to totally guarantee it. In an effort to develop a factual basis upon which a decision could be made, two test fills were proposed. To avoid the high cost of mobilization both were scheduled to coincide with the presence of the required equipment in the bay on other projects. The first test was an attempt to construct a low dike from the adjacent bay bottom material to serve as a toe dike to contain dredged material which would form a larger, permanent dike. Briefly stated, the test was a failure: the reach on the Snagboat ROS, which was used with a 1/2 cubic yard clam bucket, was too short to allow placement of the material to the required elevation on a stable slope without the material sliding back into the excavation. This approach would have very likely been successful with a large machine of sufficient

reach and bucket capacity, say a 200-foot swing diameter and a 6-yard bucket.

42. The second test was predicated on the premise that if an emergent fill could be constructed hydraulically using the worst material placed on the worst foundation in the proposed dike area, then the project could proceed with a reasonable degree of confidence that an effective dike section could be achieved using the better land cut material. This test was performed in June 1975, using a 24-inch pipeline dredge, by change order to the Mobile Ship Channel maintenance dredging contract. A volume of 235,000 cubic yards was pumped over a distance of 2,400 feet and formed a circular fill to elevation +2.5 MLW. The fill was conservatively estimated to contain approximately 90,000 cubic yards above the bay bottom for an apparent retention rate of 38%. Both test fills are discussed in detail in Appendix A of the Final EIS.

43. On the basis of the hydraulic test fill it was concluded by those who carefully analyzed the boring and laboratory test data on the entire project that an overall retention rate of at least 50% could be achieved: the minimum required to construct a satisfactory section. With this assurance in hand a limited consensus was reached within the District, and concurred in by SAD and OCE, that the island concept was feasible; however, support for the position was not totally unanimous and at times, less than enthusiastic. Since the test involved a very short pumping distance, compared to the average prototype distance, a great deal of uncertainty remained as to the behavior of the clays in the land cut. For this reason the "worst case" scenario was presented in the EIS which was based on the assumption that all of the land cut clays would slurry and run off leaving only the sands in the Phase I or outer portion of the dike. This would likely result in a dike that would only attain an elevation of 0 MLW but would still effectively retain the Phase II bay materials. As expected there was much criticism of the island plan because of this, with the critics generally equating the plan to open water disposal. Although it was obvious from continuing comments that some agencies and individuals never accepted the island plan, the District, with support from SAD and OCE, persisted without change; the Final EIS was promulgated and design proceeded on that basis. With the exception of the routine treatment of conventional aspects of the project (such as stability of cut slopes and handling of storm water runoff into the canals) design concerns from that time forward were primarily directed toward developing (1) a plan of work which would result in the most stable and enduring dike structure and (2) an economical and feasible plan of slope protection for the island.

Subsurface Investigation

44. Due to the uncertainties of the project, the amount of subsurface information and testing was more extensive than had been conducted on other dredging projects in the District. Unfortunately, subsurface investigations for dredging projects in the past have been viewed by some

segments of management in the District as not being worth the cost. On some projects, subsurface investigations have been minimal, if performed at all. The reasons for this attitude are probably the high cost and time required to mobilize the necessary floating plant, the usually large amount of lost time due to weather delays, and inherently inefficient operations associated with water work. Historically, however, the costs of change orders and contractor claims generated by insufficient or inadequate subsurface data on dredging jobs have completely overshadowed the costs of adequate investigations. In fact, following the settlement of such a claim a former Chief of Engineering Division issued a standing order that no more new work dredging jobs would go out for bids without adequate subsurface data in the contract. Fortunately, on this project sufficient funds were available on a timely basis and proper priorities were set by management which allowed the execution of an adequate investigation program.

45. During design a total of 107 sample borings were made for both the ship channel and barge canal projects. Their locations are shown on figure 5. The program began in 1968 when a series of 10 split spoon sample borings were taken along the proposed channel alignment. All of these borings were made from a barge which meant that sampling began at approximately elevation -15 in the land cut area and excluded the upper 15 to 30 feet of the material to be excavated. The materials above elevation 0 were visible in the existing slopes of the barge canal, however, which provided adequate information for the preliminary planning studies. The next phase of the program consisted of 29 vibracore borings taken along the Phase I or outer portion of the disposal island containment dike in August of 1974. These borings were located approximately 1,000 feet apart. Although the soil conditions were quite variable as a result of shell dredging activity, it was not deemed necessary to closely define the soil profile but rather to establish the best, worst, and average conditions with regard to very soft material which would likely displace and/or result in excessive settlement. In retrospect this phase of the investigation appears to have been adequate. Vibracore borings are an excellent source of cheap and expedient information of this type; however, the drilling process, which involves advancing a sharpened steel tube with a plastic liner continuously into the soil using a pneumatic vibrator, provides no information on the strength or compressibility of the soil. Another disadvantage is that, although it theoretically recovers a continuous sample, in practice the sample retained is usually less than the penetration, typically 6 to 10 feet, for a 30-foot tube in clayey material. This leads to considerable inaccuracy in logging material changes but with an experienced inspector, the results can be within acceptable limits for this type of work. In the absence of any data on penetration resistance it is essential to provide a good description of the soils with particular emphasis on consistency. With the aid of a Torvane device, the vibracore samples of clays and silts were logged as very soft, soft, firm, and hard. The primary advantages of the vibracore sampler is that it does not require a steady platform for operation and typically requires less time to take a 20- to 30-foot sample than it does to move between hole locations. The borings in the disposal island area

were taken prior to the test fill construction and while feasibility of the island concept was still in doubt. The primary objective was to establish some basis for predicting the depth of penetration into the bottom and the volume of fill that would be used in the process.

46. The bulk of the field exploration on the project was performed July through September 1975. Additional borings were made over the entire length of the ship channel and the land cut turning basin was explored for the first time. Three borings were made specifically for the shoreline turning basin which later fell out of the project. This feature will probable be constructed eventually and this effort will not have been wasted. Sixteen new split spoon borings were made along the ship channel alignment in addition to the 10 made in 1968 for a total of 26. Seven of the new borings fell in the bay or existing barge channel or were close enough to the channel to be reached by a barge mounted crane and were vibracored for the first 30 feet and split spooned for the remaining depth. Five split spoon borings were made in the land cut turning basin. Most of these borings penetrated to elevations of -55 to -60 in anticipation of the possible future deepening of the project It was also necessary to establish that no weak strata existed below the channel bottom that might affect the stability of channel slopes and also to define any shallow aquifers that might be affected by the project. One boring, located near the center of the land cut turning basin, extended to elevation -79.5. During this period an additional 17 vibracore borings were made along the channel alignment. All of these made with the 30-foot vibracore device and penetrated to elevations of -30 to -45 MLW depending on the surface elevation. In one instance refusal was met on a hard clay layer at elevation -30.5. Although a number of these borings did not penetrate to the bottom of allowable cut (-44 MLW) the information gained was relatively inexpensive and quite helpful in filling in the gaps between the deeper split spoon borings. During the 1975 period three undisturbed sample borings were taken, one in the land cut turning basin area and two at the island dike location. Seven 5-inch shelby tube samples were taken at selected depths at the location of boring SS32-75 in the turning basin. Two undisturbed borings were attempted in the disposal area dike foundation on the southwest leg near the southeast corner of the island. One (UND2-75(1)) was attempted in the test fill and the other (UND2-75) was located near, but out of the influence of, the test fill. In UND2-75(1) several attempts were made to push a 5-inch shelby between the bay bottom at elevation -2 and elevation -7.5 with no penetration and no sample recovered. A split spoon sampler was used from elevation -7.5 to elevation -18.0 and the material was found to be a mixture of fat clay and shells. One undisturbed sample was obtained from elevation -20 to -22. With the exception of the top 4 feet, which was too soft to sample, a complete series of 5-inch undisturbed samples were taken from UND2-75 extending to elevation -26.

47. In March 1976 concerns arose concerning the stability of the bulkhead on the property of Airco Alloys adjacent to the existing barge canal and a short distance from the ship channel cut. One boring was made adjacent to the bulkhead to assist in evaluating the possible effect of the channel

cut on its stability. It was concluded that the bulkhead would be safe, given certain restrictions on the excavation slopes.

48. In late 1976 the barge canal extension was authorized by Congress and officially became part of the Federal project. The Corps had not previously explored the 6,000 foot long alignment but the State Docks had engaged a private geotechnical firm to make 13 borings in anticipation of State financed construction of the canal extension. Since these borings were of sufficient depth, properly located and performed, using the same methods as the Corps, they were used in design and included in the contract documents. However, they did not cover the barge canal turning basin nor the channel east of Rangeline Road and since it was considered advisable to confirm the accuracy of these borings they were supplemented with 10 additional ones performed by the Corps in February 1977.

49. The results of the borings made through the test fill in 1975 were less than satisfactory and as the design effort progressed, my unanswered questions remained about the behavior of the soft bay bottom when loaded with the proposed containment dike. In April 1977 a decision was made to again attempt to explore the test fill and underlying undisturbed clay. At the first boring the top of the test fill was at elevation -4.1. Starting at this point five attempts were to push a 5-inch shelby tube with no penetration and no recovery. On the sixth attempt, beginning at elevation -16.6, enough material was obtained to provide a jar sample. From there to elevation -31.6 seven 5-inch shelby tube samples were recovered. In the second boring, located near the first and in the same depth of water continuous split spoon samples were taken from elevation -4.0 to elevation -19.0. Vane shear tests were made at 2.5 feet intervals from elevations -14.5 to -27.0 in this boring. It was determined from these two borings that the test fill had penetrated to elevation -22.8 and was composed of sand to gravel size shell fragments in a matrix of clay. The depth of fill penetration correlated with the depth in nearby boring VC 22-74 where the material upon which the fill had stopped penetrating was in the range of 160 to 180 psf. This provided some basis for estimating the amount of bottom displacement to be expected from the prototype fill.

Laboratory Testing

50. The objectives of the laboratory testing program were: to establish shear strengths of the materials in the land cut slopes for use in slope stability analyses; to establish the strength and compressibility of the bay bottom soils in order to estimate the amount of displacement during dike construction and predict the magnitude and rate of long-term settlement of the island; and to learn as much as possible about the soils to be dredged in order to predict retention rates. Nine unconsolidated undrained (Q) triaxial shear tests, 6 consolidation tests and 24 classification tests were performed on the bay bottom soils from the island area. On the land cut soils, cohesive materials were subjected to Q triaxial and R triaxial tests (CU shear with pore pressure measurements)

as well as classification tests. The cohesionless soils were subjected to direct shear consolidated drained (S) tests and classification tests. Approximately 200 jar samples from the split spoon and vibracore borings in the channels and turning basins were selected and sent to the SAD Laboratory for gradation, Atterburg limits and water content testing.

Subsurface Conditions

51. Land Cut Channel and Turning Basin. The land cut channel was aligned to take advantage of the existing cut for the barge canal; therefore, the northern portion had been excavated to elevation ranging from -14 to -16 MLW while the southern portion remained at original ground which ranged in elevation from 0 at the shoreline to +23 in the turning basin. Typically, at the higher elevations there were 10 to 15 feet of sandy soil at the surface, usually classified as silty or clayey sand underlain by thick deposits of soft to stiff fat clay and clean poorly graded sand. A fairly continuous stratum of fat clay crops out in the channel and turning basin slope between approximate elevations +10 and -20. It has an undrained strength of approximately 600 psf and a drained phi angle of 19.5 degrees. The clay is underlain by a 12- to 20-foot thick sand stratum throughout the turning basin. In the channel area this sand stratum appears in a few borings but is generally absent. Below elevation -40 the clays are stiff in all cases with undrained strengths ranging from 0.5 to 1.5 tsf. The entire land cut ship channel and turning basin contained approximately equal quantities of sandy soils and fine grained soils within the cut.

52. Barge Canal Extension. The reach of the barge canal extension between the land cut ship channel and Rangeline Road was cut through predominantly soft clays with occasional sand lenses. From Rangeline Road to a joint just east of the barge canal turning basin the canal cut was made through a Tye-Tye swamp which was mantled with from one to six feet of humus or peaty soil. Beneath this material were generally clean sands for the remaining depth of cut. The extreme western end of the canal and turning basin were cut through a formerly cultivated upland area with surface elevations ranging up to +28 msl. The soils encountered were predominantly sands with occasional clay strata. Of the 1.6 million cubic yards of material from the barge canal extension it was estimated that well over 1.0 million yards was good clean sand which would have been excellent material for the island construction. Efforts were made to accomplish this but there were too many opposing factors, mainly the added cost of the long pumping distance, scheduling difficulties, and complications involving charges to the local sponsor. The sandy soils in the higher cut slopes have caused severe erosion problems. This will be discussed in more detail later in the report.

53. Bay Cut. The soils in the bay cut were predominantly fat clays with a minor amount of sandy material occurring in the cut within 1.5 miles of the shoreline. A small amount of clean sand was present but most contained a significant quantity of silt and clay fines. The average

percent passing the 200 sieve for these materials was 18. The clay materials ranged in consistency from very soft or soupy to hard, increasing in quality with depth and decreasing with distance from the shoreline. Some amount of sand and shell fragments were present in all of these clays, even those of very soft consistency. From fifteen gradation tests the average percent retained on the 200 sieve was 19.1. In the borings which were sampled by vibracore the clays were assigned a description of consistency based on Torvane tests. The consistencies were very soft, soft, firm and hard. In the split spoon borings no consistency descriptions were logged on the assumption that the blow count would be more reliable. This was a bad assumption, as it developed, because much of the material which showed zero blow count actually produced good clay balls. As a matter of fact, this material which was assigned the classification of soft in the vibracore borings, was largely responsible for the success of the island construction. When freshly pumped, the clay balls, which were obviously chunks of undisturbed clay, could be penetrated with a finger with only slight resistance. The breakdown of material percentage based on the boring logs and laboratory tests was very soft, fat clay 31%; soft, fat clay 21%; firm to hard, fat clay 34%; and sandy materials 14%. The contractor's daily dredging logs show a substantially different breakdown in the soils classifications but little credence can be placed in their figures. Presumably they classify the materials by the dredging action and occasional observation of the discharge which could be roughly equated to the value of a wash boring. Some pockets of almost pure oyster shells were logged in the borings as were a few scattered layers of limonite. Their presence was confirmed in the dredging process with each causing the contractor some problems with plugged pipes and alleged damage to pumps which resulted in claim notice letters.

54. Geology of the Mobile Bay Area. The Mobile Bay is located in the Pine Meadows Subdivision of the East Gulf Coastal Plain Section. This region ranges in elevation from sea level to about 100 feet and is characterized by low, smooth hills developed on Pleistocene and Holocene terrace, alluvial and beach deposits. These deposits overlie older Miocene and Pliocene beds which form the high ground which flanks Mobile Bay to the east and west. Generally the Holocene alluvial deposits are less than 70 feet thick except in the Mobile River basin where they are as much as 150 feet thick. Lithologically, the Pleistocene and Holocene deposits consist of white, gray, orange, and brown, partly carbonaceous, very fine to coarse grained, gravelly sand. Soft to firm clay beds also occur and make up a large portion of the material underlying Mobile Bay. Excavation for the ship channel occurred in these unconsolidated Pleistocene and Holocene deposits.

Stability Analysis of Slopes

55. Barge Canal and Bay Cut Ship Channel. Stability analyses were not conducted for either of these project features. The project depth for the barge canal was only 12 feet and the alignment was through undeveloped

land. Further, at the higher elevations where the cut would exceed 20 feet in height the soils in the cut were competent, sandy materials; therefore, stability studies were not justified. The bay cut portion of the Theodore project was identical to the existing Mobile Ship Channel in design and was to be cut in similar materials. The experience with the Mobile Ship Channel, the fact that the slopes would be constantly submerged and the minor consequences of a slope failure in the bay cut all served to render a formal analysis unnecessary.

56. Land Cut Ship Channel and Turning Basin. It became apparent early in the geotechnical investigation that the slopes, as conceived in the planning documents, were questionable. At the time that the local sponsor acquired the right-of-way for the existing barge canal additional land was also purchased and dedicated to the future widening and deepening of the project for oceangoing vessels. The width of the right-of-way was predicated on a 300-foot wide channel cut to elevation -42 with 1 vertical on 3 horizontal slopes. It developed during the investigation that the 1 on 3 slopes were unstable and had to be flattened. The local sponsor was required to go back to the property owners for additional right-of-way. This will be discussed further under Lessons Learned.

57. The stability analyses were conducted in accordance with Engineer Manual 1110-2-1902 insofar as this manual treats excavation slopes. The two conditions which were considered applicable to this project were the end of construction and partial pool conditions. Three sections were analyzed: one on the north slope of the ship channel where the height of cut was maximum and the soil conditions least favorable; one on the east slope of the turning basin; and a third on the north slope of the turning basin which cut through the existing Airco Alloys bulkhead. All three sections were analyzed for both circular arc and sliding wedge failure using a computer program with manual verification of low points. For the construction condition triaxial undrained (Q) shear strengths were used for cohesive soils and direct shear drained (S) strengths for cohesionless soils. For the partial pool condition a comparison was made between the consolidated drained (S) strengths and the consolidated undrained (R) strengths. If the S strength was the higher, the average was used; if it was less, then the S strength was used. For both conditions the water table was assumed to slope from its normal elevation at a point beneath the top of the slope to the point where the mean low water surface intersects the slope. For the partial pool condition with a uniform 1 on 3 slope the analysis produced a safety factor less than 1.0 for the north slope of the ship channel. A 25-foot berm was added at mean low water and the slope was flattened to 1 on 4 above the berm. This raised the safety factor to 1.33, still below the minimum required by the manual but judged to be adequate since the data used was highly conservative. Further study showed that whenever the natural ground exceeded elevation 7 the berm and 1 on 4 slope were required. A uniform slope of 1 on 3 was used elsewhere. For the section through the Airco retaining wall the indicated factor of safety was 1.17 for partial pool condition. The configuration of the failure arc was such, however that the channel cut had very little influence on the safety factor, indicating that the stability of the wall

was inherently questionable. The dock wall has reportedly failed within the past few months and the Corps has taken the position that the channel cut did not contribute to the failure. In the preparation of this report the stability analysis for this section was modified to eliminate the channel cut and the factor of safety increased by .05 to 1.22 which is insignificant considering the inaccuracies in the system of analyses. All safety factors other than those discussed above were greater than the specified minimums. The stability analyses, with computations are contained in Appendix A of the Phase II GDM on the project (USACEM 1977).

Settlement Analyses

58. An attempt was made to predict the magnitude and rate of settlement under the containment dike for the disposal island. There were many uncertainties inherent in the process as to how much of the bay bottom muck would remain under the dike, the final height, and the characteristics of the fill material. Therefore some reasonable assumptions had to be made. Boring UND2-75 indicated that the test fill had penetrated 7 feet into the bay bottom, displacing that amount of muck. It was reasoned that since the test fill had only been constructed to elevation 2.5 and that it was built with bay cut material the additional height and higher unit weight in the prototype fill would displace an additional 3 feet for a total of 10 feet. Actually, a later boring through the test fill indicated about 12 feet of displacement. The calculated ultimate settlement of the dike at the centerline assuming a fill height of 4.0 feet above MLW and 10 feet of muck displaced, was approximately 4.0 feet. The calculated settlement after 6 months, 1 year, and 2 years were 6, 9, and 12 inches respectively. To assist in predicting the future capacity of the island, settlement was also computed at its center, assuming lightweight maintenance dredging fill. With the fill up to elevation +10, total settlement was calculated to be 5.0 feet. The calculated settlement at the end of 6 months, 1 year, and 2 years were 8, 11, and 17 inches respectively. With the fill at elevation +20, the calculated ultimate settlement was 6.75 feet.

59. Settlement plates were installed at two locations before construction began but they were both destroyed by the contractor's operations before the fill was placed. They were thought to be contractor-proof and would possibly have survived except for the heavy traffic involved in the barge-haul operation. They consisted of heavy drill stems driven into the stiff clay to refusal with a 350-lb. hammer, having a section of larger pipe with a steel plate welded and braced at the bottom which was placed over the drill stem and free to slide up or down. Had they survived, the plates would have measured both initial displacement and settlement during and after construction. Having lost the gauges there was no way to monitor settlement until control points and gauges could be installed on the island.

60. Twelve settlement points were installed and initial readings taken in October 1981. They were surveyed at one month intervals for the first year and at six month intervals thereafter. After two years the measured settlement ranged from 1.7 to 20 inches. Of course, this does not reflect that which occurred during construction and between topping out and installation of the gauges. The wide disparity between gauges is suggestive of error; however, it is not inconceivable that the data could be accurate if one takes into account the variability of the bay bottom subsurface. Where the shell dredge has operated the natural reef structure has been completely destroyed to considerable depths leaving trenches filled with soupy material, whereas in undisturbed areas the natural bottom structure is probable competent to support the relatively light load of the dike with minimal settlement. At any rate if the two extreme readings are ignored, the readings from the remaining gauges range from 3.2 to 16.9 inches with an average of 10.3, which compares favorably with the 12 inches predicted for the first years.

Slope Protection

61. Channel Slopes. It was reasoned during design that the cost of providing riprap protection for the side slopes of the land cut channels was not warranted. In the higher cuts (seven feet and above) of the ship channel the berm at mean low water would serve to dissipate the energy from ship wakes before reaching the exposed toe and the consequences of erosion on the lower slopes would be minor. The use of stone protection adjacent to areas subject to maintenance dredging can cause serious problems and should be avoided wherever possible. It was further reasoned that, by the time traffic becomes heavy enough to cause problems with the slopes, most of the property along the channel will have been protected by bulkheads. In this connection, the local sponsor agreement requires that all bulkheads be a minimum distance of 200 feet from the bottom edge of the ship channel and 75 feet from the bottom edge of the barge channel. Similar reasoning was used in not providing riprap for the barge canal; however, it was recognized that erosion would probably be severe on the higher sandy slopes of the barge canal. The design called for seeding and mulching of all cut slopes and seeding only of other areas cleared for construction.

62. Disposal Island. As discussed in the Planning Section of this report the stability of the disposal island was the center of a great deal of controversy and the method and extent of revetment was of particular concern. The fact that this was to be a local sponsor cost added further complexity to the issue. In the early stages of planning the use of articulated concrete matting similar to that used on the Mississippi River was tentatively proposed. At that time, it was assumed that the entire island perimeter would have to be revetted. The reasoning was that this type revetment would probably be less expensive, would offer less difficulty in placement, and would not require reshaping and dressing of slopes. Slopes as steep as 1v on 8h for the island perimeter were envisioned at that time, possibly entailing the use of pocket pipe and

other discharge techniques to produce them. This was later determined to be infeasible due to the extremely soft bottom and types of material to be dredged. When it became apparent that the slopes would be in the range of 1v on 30 to 50h, this type protection was ruled out because of the excessive quantities required to reach the upper and lower limits of elevation required for protection on such flat slopes. It was also determined that the metal strands used in fabricating the meeting have a short life in a saltwater environment. It was subsequently decided that where revetment was required the only feasible alternative was quarried stone riprap, properly filtered and placed on a prepared surface.

63. It was recognized as practically impossible to place any sort of effective revetment on the island immediately after construction and a minimum one year waiting time for consolidation and strengthening of the dredge materials was adopted. Part of the reasoning behind this was to retain some amount of flexibility in the type and amount of revetment used in order to use the available funds most effectively based on observed behavior. Another significant factor was the expected higher initial rate of subsidence and the need to reduce the amount of future raising of the revetment to compensate for this. The possibly higher levels of turbidity in the bay during this period was accepted as a negative impact in the EIS and was the target of considerable criticism. This plan was adhered to and its validity has been confirmed. Increased turbidity levels over the background levels in the bay since immediately after construction ended have been insignificant and confined to a few areas, notably the two corners adjacent to the Mobile Ship Channel, where clay balls are exposed in the slope. Throughout most of the length of the dike, sufficient sand was present in the zone of wave energy to provide a naturally armoring veneer after a short period of sorting.

64. On 13 May 1975 a meeting was held in Montgomery, Alabama, between the Corps, represented by the Mobile District Engineer and several staff members, and high level officials of the State and other concerned Federal agencies. An agreement was reached at this meeting that the east leg of the island dike, extending around the south and north corners to the PC and PT respectively, would be armored with riprap; the northwest leg from the termination of riprap to the PC of the southwest corner would be planted in marsh grass; and the southwest leg, including the southwest corner, would be left to vegetate naturally. This agreement provided a basis upon which the design proceeded and funds allocation by the local sponsor was set.

65. The slope protection plan presented in the Phase II GDM followed the terms of the agreement as to type and extent. The Design Riprap section of the GDM required a toe trench to be excavated to elevation -3.75 MLW, the slope dressed to 1v on 2.5h to elevation +5 MLW and 3 feet of graded riprap placed on a filter cloth placed on the prepared slope and toe trench. The design of the riprap section as to size and thickness was performed in accordance with the Shore Protection Manual (CERC 1973). The design wave height and period (H = 3.0 feet and T = 4.2 sec.) were determined from the methods given in the manual based on an assumed wind

speed of 50 mph. Design for gale and hurricane force winds was not considered justified since these winds are normally accompanied by abnormal tides which would either elevate the zone of wave energy above the protected zone or lower it to the point that the shallow depth of water would preclude development of damaging waves. The possibility exists that wind velocities in excess of the design value can develop from localized storms which would not produce radical changes in tide levels. In this situation possibly severe damage to the island could occur but the risk is considered warranted. The design riprap gradation is given below.

Cumulative Percent Lighter by Weight	Stone Weight (lbs.)
100	700
80-90	400
50-70	200
20-40	100
5-15	50
0-5	Less than 30

66. During the early stages of planning some consideration was given to the use of steel sheet pile to contain the dredged disposal material and serve as erosion protection for the island perimeter. In fact, the Environmental Quality Plan, which had a very low BC ratio was predicated on the use of steel sheet piles. A significant quantity of Government-owned used piles were left over from navigation projects on the Alabama and Warrior Rivers and it was reasoned, probably incorrectly, that their use could be an economical solution to the environmental problems associated with the island. As it developed there were vehement objections by some environmental interests to the use of sheet pile to form a conventional, emergent bulkhead because of the barrier effect on marine organisms at the waterline. This is perhaps fortunate since it later developed that the Government-owned piles were used to a better advantage on other projects and the cost of new piling plus all the necessary soldier piles, walers and tiebacks to produce a stable structure would have been extremely expensive. Another factor, not given sufficient consideration at the time, is the short life span of emergent steel structures in a saltwater environment. The Phase II GDM still retained the option of limited use of nonemergent steel piling as a toe wall to conserve riprap and preclude undermining of the riprap toe, but this concept is presently considered to have little merit. A pilot contract to allow evaluation of construction feasibility and effectiveness of different revetment sections was attempted subsequent to the stabilization period. This will be discussed in detail in the Operation and Maintenance section of this report.

Groundwater Studies

67. The land cut ship channel excavation penetrated one or more shallow

aquifers and partially removed the impervious cover over others. These aquifers are the source of potable water for a number of residents in the project area as well as irrigation water for local nurseries. Questions arose as to the possible effects of construction on these aquifers from a standpoint of saltwater intrusion and possible rupture of aquicludes and loss of head. The District contracted with the Alabama Geological Survey to perform a study of groundwater conditions existing in the project area and to determine the probable effects of project construction on the groundwater regime. The study consisted of literature research, a survey of existing wells in the area, drilling of several additional exploration borings, the installation of a well and piezometers, a field pumping test and extensive chemical analyses of water samples. It was concluded that the various sand strata encountered by the construction cut were parts of one common shallow aquifer, a major water bearing zone, which appears to be present over most of the area at elevation -30 to -50 feet and ranging in thickness from 10 to 100 feet. It is reported to be 300 to 400 feet to the next deeper aquifer which would seem to rule out the possibility of causing damage to deeper water bearing strata by rupturing of confining beds.

68. The quality of water from the shallow aquifer was determined to be generally good, but containing excessive amounts of iron and having a low pH which caused deterioration of copper pipes and blue staining on porcelain fixtures. Water from aquifers of shallow and moderate depth showed generally low chloride concentrations.

69. The conclusions from the study were that if the number of wells and pumping rates in the Theodore area remained about the same there would be very minor, if any, detrimental effects due to saltwater intrusion. It was pointed out however, that if a number of high capacity wells were added in proximity to the channel the result would probably be localized encroachment of saltwater within the zone of pumping influence and consequent destruction of the aquifer's usefulness as a freshwater source in this vicinity. The District made this information available to the local sponsor with the recommendation that a water management plan be initiated in the area. The local sponsor, after discussing the matter with their legal department and other concerned State and local entities, acknowledged the problem at Theodore and went on to state that it was a statewide problem that should properly be addressed by the Legislature. They further stated that until the Legislature acts on the problem, their policy would be to deal with any problems on an individual basis. The report submitted by the Alabama Geological Survey with supporting data is contained in Appendix C to the Phase II GDM. The piezometers installed in connection with the studies have been monitored on a regular basis and there have been no apparent adverse effects on the aquifer caused by construction of the project.

Instrumentation

70. No instrumentation other than the two settlement plates discussed in

paragraph 59 and shown on Plate 19 in Phase II GDM was installed One of the most troublesome aspects of a dredging job such as the Theodore project, is survey controls. The difficulties involved in keeping dredges and spill barges on the proper alignment in open water up to five miles from shore during a 24-hour per day, year-round operation can well be imagined. This difficulty was anticipated and, considering the necessity of properly locating the disposal island dikes with respect to the channels, it was considered essential to provide permanent reference points for the contractor's use. Prior to the award of the ship channel contract the Corps engaged the Coast Guard to install survey towers at each of the three PI's for the Phase I island dikes and a line of piling along a baseline 500 feet south of the proposed channel. The towers were similar in construction to the tripod structures used for channel beacons consisting of creosoted timber piles driven by a buoy tender, bracing, and a work platform. The tower a the southwest corner was struck by one of the contractor's barges during the barge/haul operation but was strong enough to survive. It was knocked out of plumb by the impact but served its purpose throughout the contract as did the other two. Considering the difficulty that the contractor had in maintaining temporary markers, particularly during the barge/haul traffic, misdirected excavation and misplaced material would probably have been a common occurrence without the permanent markers.

Barge Canal Drainage

71. The barge canal extension was cut through a swamp at the head of the middle fork of Deer River and severed numerous local drainage features, most of which sloped toward the canal. In order to prevent the formation of gullies with consequent heavy silting at these points of concentrated drainage it was necessary to collect the drainage at the tops of the canal slopes and provide drop structures to pass it into the canal. Fortunately the local sponsor had provided sufficient right-of-way to allow this. At the time the land for the right-of-way was dedicated it was assumed that 1v on 3h slopes would be required for the canal. It was later determined that 1v on 2h would be adequate which provided up to 60 feet of additional width for construction of the drainage structures. The drainage system was designed to handle runoff from a storm with a recurrence frequency of 10 years. Collector ditches constructed parallel to the canal and within the right-of-way were provided wherever the natural ground sloped toward the canal. The ditches were set back to allow a minimum of 30 feet between top of canal cut and top of ditch cut. This was considered necessary to prevent instability of the canal slopes due to seepage from the ditches during storms. Natural drainage features leading into the canal were filled and nine drop structures were constructed in the canal banks, four on the north side and five on the south side at points dictated topography. The locations and details of construction are shown on Figure 6.

72. Unfortunately, on 18 May 1980, within six months of construction completion, a storm which exceeded the design storm occurred and all of the structures suffered damage to some degree. The largest structure, located on the south side at Station 38+70, was apparently flanked by the excessive flow and completely washed out. The eroded material formed a bar in the canal which almost closed it. The other structures were undermined to some degree at the lower edge of the sack riprap. The damage can be directly attributed to the greater than design storm but in hindsight, it can probably be stated that the structures would probably have failed eventually anyway, if not from storm runoff then probably from wake and propeller wash as traffic developed on the canal. The extreme erodibility of the sandy soils in the canal cut was underestimated and the sack riprap forming the flumes was terminated at too high above the toe of the slope. This will be treated further under Lessons Learned.

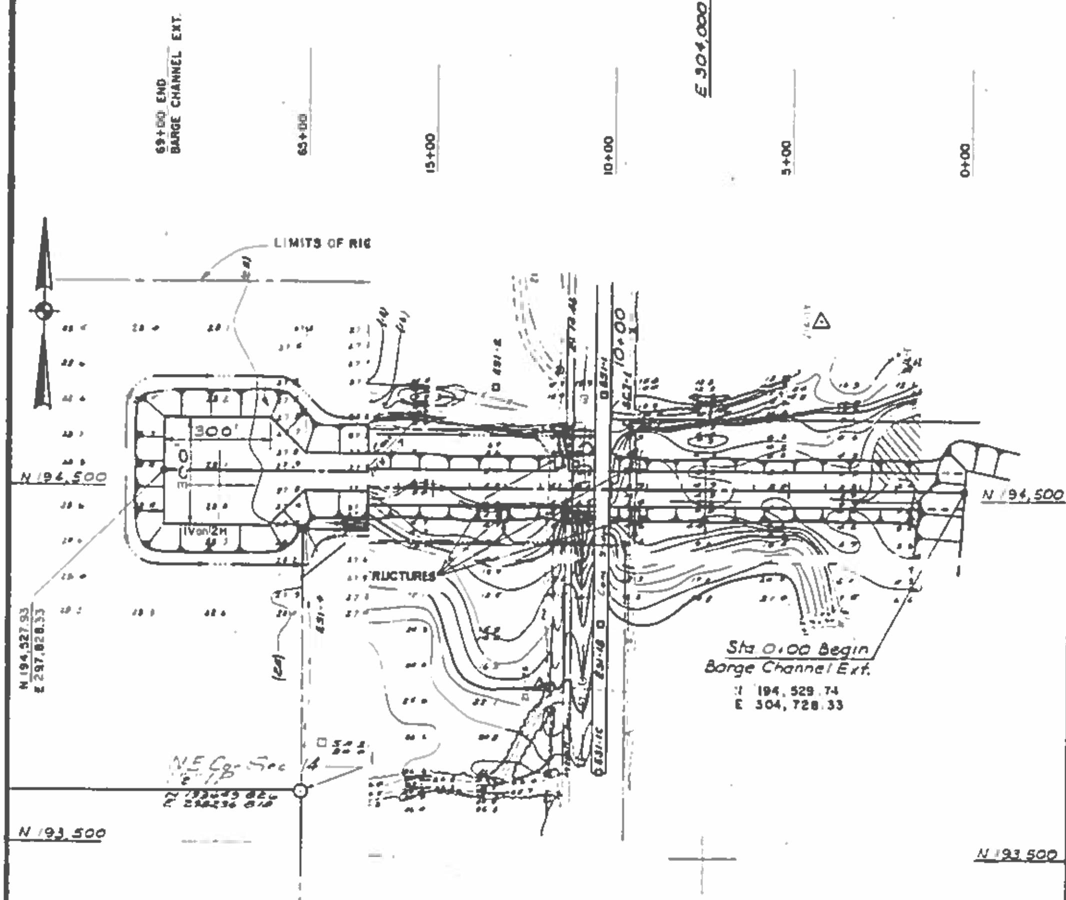
Barge Canal Disposal Area

73. As previously discussed, the sandy material from the barge canal would have been a valuable adjunct to the disposal island construction and would have provided a boost to the sometimes dismal prospects for the success of the island, but in the final analysis, it could not be said that the material was absolutely essential. The barge canal construction was severed from the remaining work and awarded as a separate contract. Under this arrangement the cost of dredging the barge canal would probably have tripled at best. Had it remained in the large contract so that the same pipeline and booster pumps used in the ship channel could have been utilized, the cost would have still been significantly higher. Considering the fact that the island was successful as constructed, the decision to place the sandy material in a nearby upland area was a sound one.

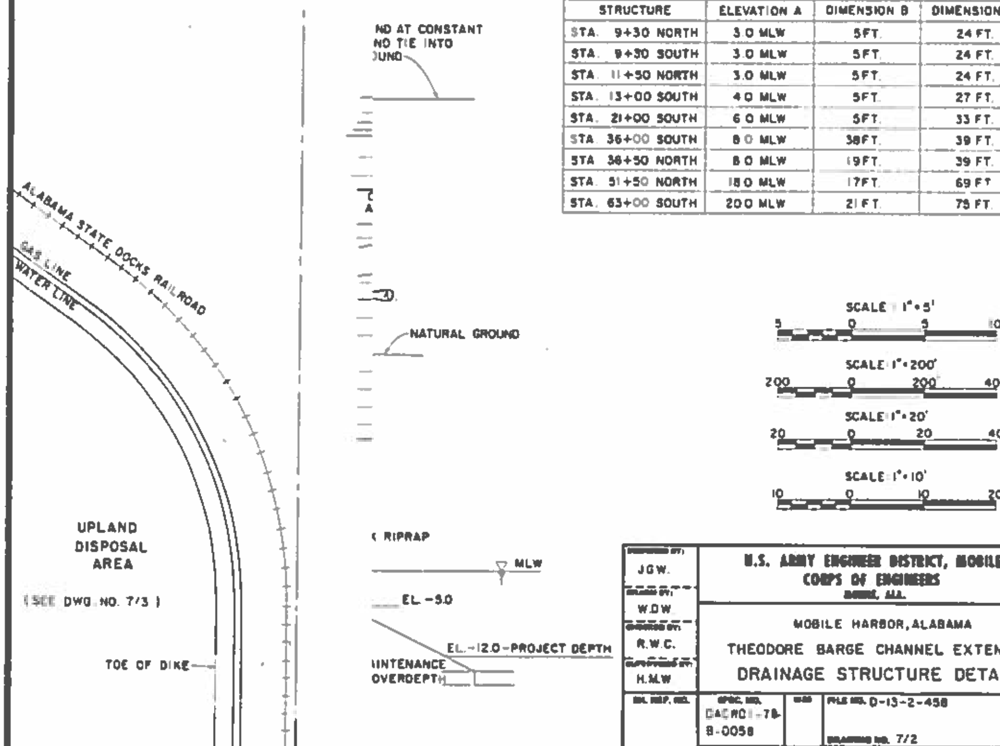
74. A portion of the upland disposal areas is shown on Figure 6. It is located approximately 1/4 mile south of the barge canal turning basin. The topography is such that a horseshoe shaped dike could be tied to high ground to the south. The required height of the dike was approximately 16 feet above natural ground on the low side. It was constructed with materials from a borrow ditch on the inside of and paralleling the dike. A 40-foot wide berm was required to be left between the dike toe and the top of borrow cut. The dike has a 10-foot crest width and 1v on 2h side slopes. The borrow material was very fine silty sand and the water table was very near the surface. In order to insure stability and watertightness, the contractor was required to spread the material in 24-inch lifts and walk it down with the spreading equipment. This caused some problems which will be discussed further under Lessons Learned. The contract required the contractor to install a weir structure of his own design capable of providing the necessary retention time to lower turbidity to acceptable levels. The contractor was also responsible for providing a route for the return water from the disposal area to the canal. The barge channel cut had to be made beneath the newly constructed high level bridge on Rangeline Road.

CORPS OF ENGINEERS 1 U. S. ARMY

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVED
1	B-2	DELETED JUTE MATTING		



DRAINAGE STRUCTURE DATA			
STRUCTURE	ELEVATION A	DIMENSION B	DIMENSION C
STA. 9+30 NORTH	3.0 MLW	5 FT.	24 FT.
STA. 9+30 SOUTH	3.0 MLW	5 FT.	24 FT.
STA. 11+50 NORTH	3.0 MLW	5 FT.	24 FT.
STA. 13+00 SOUTH	4.0 MLW	5 FT.	27 FT.
STA. 21+00 SOUTH	6.0 MLW	5 FT.	33 FT.
STA. 36+00 SOUTH	8.0 MLW	38 FT.	39 FT.
STA. 36+50 NORTH	8.0 MLW	19 FT.	39 FT.
STA. 51+50 NORTH	18.0 MLW	17 FT.	69 FT.
STA. 63+00 SOUTH	20.0 MLW	21 FT.	75 FT.



DESIGNED BY: J.G.W.	U.S. ARMY ENGINEER DISTRICT, MOBILE CORPS OF ENGINEERS MOBILE, ALA.
DRAWN BY: W.D.W.	MOBILE HARBOR, ALABAMA THEODORE BARGE CHANNEL EXTENSION DRAINAGE STRUCTURE DETAILS
CHECKED BY: R.W.C.	
SUPERVISED BY: H.M.W.	
SPEC. NO. DACW01-78-B-0058	FILE NO. D-13-2-458 DRAWING NO. 7/2
SCALE: AS SHOWN	DATE: MARCH 1978

5 1

FIGURE 6

PART IV: CONSTRUCTION

Barge Canal

75. The Invitation for Bids for the barge canal contract went out on 30 June 1978 and bids were opened on 17 August 1978. The low bidder was OKC Dredging Company. The contract was awarded on 23 October 1978 and Notice to Proceed was issued on 16 November 1978. The contractor mobilized for clearing, grubbing, and dike construction in late November 1978.

76. Disposal Area Dike Construction. Construction of the dike actually began around 1 December 1978. As previously described, most of the work area was low, flat and poorly drained. Since the scheduling of construction is almost entirely controlled by the availability of funds -- and funds usually become available on 1 October at the beginning of the Fiscal Year -- the time involved in the contract award and Notice to Proceed procedures almost invariably requires contractors to mobilize and begin work at the worst possible time of year; that is, when winter rains and poor drying conditions greatly impair earthwork construction. Often the result is sloppy construction, added cost to the contractor, and delays which extend the contract completion beyond what would have resulted from delaying Notice to Proceed until the following spring, not to mention the usually resulting contractor claims. The barge canal contract was no exception.

77. The contractor began constructing the east leg of the dike at its southern terminus at high ground. The construction procedure involved use of two draglines with 70 foot booms and 1.5 cubic yard buckets, one walking ahead of the borrow trench and placing the material on the 40-foot berm and the other walking on the berm and taking the material from the berm and placing it in the dike. A small, wide track, low ground pressure dozer attempted to spread the material and walk it down in accordance with the specifications. When the contractor reached a point where the ground elevation was approximately elevation 28, he encountered problems handling the wet material. He then moved to a point approximately 1,000 feet west of the northeast corner and tried again encountering the same problems as before. The Area Office requested assistance from Engineering Division at this point and a field inspection trip was arranged on 28 December 1978. The contractor had excavated a borrow trench approximately 200- by 25-feet in plan and approximately 10 feet deep. The top 2 to 3 feet of material excavated was cohesive clay and/or silt underlain by extremely fine water bearing sand. The static water table was at or above the surface in the area. The contractor had been attempting to dewater the hole but the inflow had exceeded his pump capacity; excavation was shutdown while a larger pump was set. The fine sand was running into the hole and undermining the surface material causing extensive sloughing. The contractor was reportedly having problems with the sloughing material covering up the pump suction and complained of low production due to the wet, runny material. The Government's concern was that the sloughing slopes would encroach into

the berm and endanger the dike stability. A secondary concern was the wet condition of the fill being placed in the dike from a standpoint of strength.

78. It was agreed by Government personnel that the site and subsurface conditions were to be expected from the contract documents and that the problems resulted from the wet season and poor site drainage. The contractor was in the process of cutting a ditch to the northeast for the dredge water return and it was postulated that, this plus the gradual drawdown of the groundwater table ahead of the excavation, would alleviate the instability of the cut. It was concluded that the sloughing was not a danger to the dike but that if it progressed to within 20 feet of the toe, some action would be required. After observing some of the fill which had been in place for a few days it was agreed that, given time, it would drain and stabilize. It was suggested to the contractor that he could, under the terms of the contract, make a wider, shallower cut to ease the groundwater problems. One of the primary reasons for the problems was the fact that the contractor was only operating the pumps during the day, and with the small excavation being fed from a water table which had been pulled down only locally, the hole would be full each morning and the problem would start over again. He should have been pumping around-the-clock but Government personnel are reluctant to direct a change such as this since the contractor can claim extra payment for anything not specifically called for in the contract. For that reason this was not made an issue. The same applied to the excavation of a pilot ditch in advance of the borrow cut which, no doubt would have accelerated the drawdown but, would have required an additional piece of equipment. The problem gradually solved itself as the weather improved and drawdown of the groundwater over the area was attained, but not before the contractor had expended a great deal of unnecessary effort in his "brute force" approach to the work.

79. Another meeting of representatives from Engineering Division, Operations Division, Mobile Area Office, and the contractor was held at the worksite on 5 January 1979 in response to the contractor's complaints about site conditions and the Government concern over lack of progress. No work was in progress during the visit and the excavation had been allowed in the way of drawdown. The contractor had not widened the borrow trench because of the added expense of grubbing the extra width. Heavy rains had occurred over the previous weekend and the picture at that time was altogether dismal. A portion of the dike foundation had not been grubbed due to high groundwater and standing surface water. The prime and clearing subcontractors were in a standoff as to who was to perform the necessary drainage work. The same issues were rehashed with a couple of new ones interjected. The contractor was questioned whether the designated borrow area for the dike contained a sufficient quantity of material. The Government's position was that the dimensions shown on the borrow area were minimums (width shown as "min" and elev "+/-) and that the contractor had the option of expanding the area either laterally away from the dike or downward as required. The contractor requested and was given the option to excavate and haul dry material from high ground

within the borrow area to construct the dike at the northeast corner of the disposal area.

80. On 13 February 1979 another such meeting was held at the construction site to deal with a new but related earthwork problem. The contractor was having difficulty meeting the specification requirement that the material be spread in 24-inch lifts and compacted by the controlled movement of spreading equipment. He claimed that even after being spread, would liquefy after one pass of a wide track dozer. He contended that this portion of the specifications was unreasonable and impracticable and requested relief. Observation of material behavior confirmed the contractor's contentions. The Government's rationale for the spreading and compaction requirements was to insure adequate density to provide the necessary strength and low level of permeability. After observing the material standing in windrows with 1 on 1 slopes and higher than the proposed dikes, the strength without compaction was deemed adequate. The fact that drainage of the material was extremely slow confirmed that it was sufficiently impermeable in a loose state, and the compaction requirement was waived.

81. Progress on the dike construction accelerated with improving weather and groundwater conditions and it, along with the weir installation and inside slope protection was completed on 29 June 1979. The usual problems with erosion prior to establishment of grass cover occurred on the outside slopes but were dealt with properly. The inside slope of the dike was covered with polyethylene weighted with sandbags which effectively controlled erosion.

82. The contract outlined a procedure which involved construction of the disposal area dike in two phases with the Phase I dike constructed to El. 40 with borrow from the natural subgrade within the area. This dike would contain the new work disposal material. After the channel dredging was complete the second, or Phase II portion, of the dike would be completed to El. 44 using dredged material from within to provide capacity for future maintenance disposal. The contractor proposed and was given permission to construct the dike to full height initially to avoid the added cost of remobilization of mechanical excavation and spreading equipment and regrassing operations in the second phase. In retrospect, had the contract allowed this option some savings to the Government may have accrued in the bidding process.

83. <u>Dredging</u>. On 29 June 1979 the contractor mobilized a 24-inch (discharge pipe diameter) cutterhead dredge to the site. The pump and cutterhead were powered by diesel engines with a combined 3,700 hp. Dredging was begun at Station 0+00 on the east end of the project and progressed to the west, using 9,500 feet of shore pipe and 400 feet of pontoon supported floating line. This dredge had severe problems had severe problems with the engines cooling system which were attributed to clogging of the seawater intakes by floating debris. On 4 July 1979 a 20-inch, 2,200 hp dredge replaced the larger one. The dredging progressed satisfactorily to completion on 30 January 1980.

84. Slope Maintenance During Construction. The slopes between the beginning of the project on the east to the point about midway of the channel extension where the natural topography rose above elevation 10 behaved well. The near surface materials were somewhat cohesive and the extensive root mat present in the swamp helped to prevent erosion. The slopes visible above the waterline were near vertical but remained essentially as left by the dredging operation. Farther to the west where clean,fine sands were exposed in the cut severe erosion began immediately. In addition the ditches carrying storm runoff to the drainage structure on the south side of the canal at Station 38+70 immediately began transporting significant quantities of sediment and depositing it in the newly excavated canal. The sediments were for the most part, originating beyond the right-of-way line and were present to some extent prior to the canal construction; however, the lowering of the outfall and improvement of flow characteristics in the vicinity no doubt caused an increase in velocity and consequent increase in erosion and transport of sediments. When the problem was surfaced by the Area Engineer on 22 April 1980, a significant bar had formed in the canal which would have effectively blocked navigation by the design vessel, had traffic been initiated. This problem was under consideration when a storm occurred on 16-17 May 1980, destroying the drainage structure (photos 11 and 12). Corrective action will be discussed in the O&M section of this report. The contract required seeding and mulching of the canal slopes from MLW to the top of cut and collector ditch slopes; seeding only for flat graded areas and sodding of limited areas adjacent to drainage structures. The contractor was no doubt remiss in respect to timeliness of grading and planting as well as watering of planted areas but it was next to impossible to grade and hold the sandy, 1 on 2 slopes until seeding could be effective. Consequently, rivulets and small gullies would form immediately after each grading and planting. A great deal of erosion has occurred, depositing a considerable quantity of sediment in the canal. In a subsequent contract several of the worst areas were graded and solid sodded and are holding well.

85. Drainage Structures. The contract allowed the option of constructing the drainage structures either before or after dredging the canal but did not specifically require construction in the dry. The contractor elected to construct them after dredging without cofferdams and dewatering. Consequently, he was not able to satisfactorily place the filter cloth and sack riprap down to the specified -5 elevation on the canal slope and to prepare a firm base on which to place it.

86. Contract Modifications. Six modifications were made during the contract. The first simply changed the funds appropriation numbers with no change to cost or time. The second waived the requirement for placing dike fill in 24-inch lifts and allowed placement and spreading in up to 8 foot lifts with no change in cost or time. The third extended the contract completion date from 14 August 1979 to 29 September 1979 to account for weather delays. The fourth provided for the removal of an 84-inch diameter CMP culvert from the canal excavation limits (not shown

on plans) at an additional cost of $4,134, with no extension of time. The fifth extended the contract time to 7 November 1979 for weather delays. The sixth deleted two acres of grassing and a drainage ditch and extended the contract time to 24 November 1979. This modification resulted from additional dredging work performed by the contractor and paid for by the Alabama State Docks. As noted above, the dredging was not completed until 30 January 1980, sixty-seven days after the scheduled contract completion date. At that time several items of other work remained unfinished but were minor in nature and did not preclude the beneficial use of the project. The District Engineer, on the recommendation of the Area Engineer, determined that liquidated damages should be limited to the 67 day period and the contractor was charged $57,553.

Ship Channel, General

87. The Theodore Ship Channel contract was advertised on 22 June 1978 and the Invitation for Bids went out on 7 July 1978. Bids were opened on 29 August 1978. The apparent low bidder was Western Construction Company, with a total bid of $29,430,910. C. F. Bean Dredging Company was second low with a total bid of $48,971,921. The highest of the five bidders was $69,921,830 and the Government estimate without profit was $47,257,830. Western Construction alleged an error in their bid but claimed the right to correct it and remain in competition. A dispute ensued which lasted over seven months while the contract award was held in abeyance. During this period the second low bidder was queried as to whether or not he desired to extend his bid. His answers were affirmative and when the dispute was settled with the apparent low bidder, the contract was awarded to C. F. Bean Dredging Company; Western Construction Company having been allowed to withdraw its bid. The contract award date was 9 April 1979 and Notice to Proceed was issued on 2 May 1979.

88. According to information later submitted by the contractor, at the time bids were received on the contract diesel fuel was available in the Mobile area for 37.7 cents per gallon. By March 1979, when the last bid extension was made by Bean, the price had increased to 48 cents per gallon. By July 1979 it had risen to 74 cents and by April 1980 to 84.5 cents -- an increase of 124% from the time of bidding to one year into the 2.5 year contract -- and projected to go considerably higher. Long distance dredging is probably the most fuel intensive means of moving dirt. The contractor had projected a total diesel fuel consumption of 18,023,000 gallons on this project at a cost of $8,515,830. At the then current price of 84.5 cents his fuel costs were up to $15,229,435 -- an increase of almost 7 million dollars. No attempt has been made to verify these figures (and they may be biased) but it is obvious that the contractor was in serious financial trouble; especially considering the excessive inflation at that time due to the oil crisis. This information is included because of its pertinence to the contractor's performance.

Ship Channel, Land Cut

89. From the Notice to Proceed in May 1979 until 23 August 1979 the contractor was engaged primarily in clearing and grubbing for the land cut channel and turning basin, mobilizing equipment, and setting up a pipe handling yard adjacent to the barge canal at the head of the old ammunition pier. According to the schedule he submitted, dredging was to commence in October 1979. On 12 June 1979 the Corps met with the contractor, at the contractor's request, to discuss a change in schedule. At this meeting the contractor surfaced his plan to excavate the top 25 to 30 feet (to El. -10) of materials from the turning basin and transport it by deck barge to the disposal island and place it in the Phase I dike. He stated his intention to begin the work as soon as the necessary equipment could be mobilized, citing rising fuel costs as the reason and stated their intentions to accelerate the work as a means of reducing their exposure to future inflation. The idea was favorably received by Government personnel and the contractor was requested to submit a formal proposal since this would be a change to the methods specified in the contract. The proposal was submitted on 30 July 1979 and accepted on 3 August 1979. It proposed a small scale operation initially using minimum machinery to see if the operation would be practical and, if so, to expand it later. The proposal stated that the contractor would not claim additional cost or time for the operation.

90. Barge/Haul Operation. The barge/haul operation began on 23 August 1979. The agreed upon plan provided for placement of the barged material in a 1,000-foot wide strip along the Phase I dike to elevation -4 beginning at the southwest corner of the dike and proceeding east to the southeast corner and thence up the eastern leg. A large dragline with a 120-foot boom handling a 6 cubic yard bucket was used for loading (photo 1). A similar machine mounted on a spud barge was used for unloading (photo 2). It was equipped with a D-8 dozer blade with a bridle which was used to drag the material off the deck barges and allow it to fall between the two barges. The barges used initially could haul approximately 700 to 800 cubic yards. Each barge was pushed by a small tug which remained attached and held the barge in place for unloading. The initial haul route followed Hollingers Island Channel to deep water and thence diagonally across to the dump site. Later, after the new channel was cut across the bar, the tows could proceed directly to and from the unloading site avoiding this circuitous route. Bamboo stakes were set in lines 500 feet either side of the centerline and the unloading barge was moved back and forth across the dike alignment attempting to spread the material uniformly. Surveys showed that it rather formed a series of peaks and valleys, sometimes above elevation -4 and more often below. Several problems with the operation became evident, the most serious being damage to the haul barge decks from the unloading drag blade. This was alleviated by installing transverse channel beams on the decks. Other problems were the destruction of alignment stakes by the traffic, grounding of the unloading barge, and coordination of the entire operation to reduce waiting time to an

acceptable level. As the operation continued it became smoother with experience and the contractor concluded that it would be profitable to expand and continue it on a 24-hour per day basis. On 12 September 1979 Hurricane Frederic occurred. Several hundred feet of fill had been placed at that time. Surveys taken before and after showed that the hurricane had very little, if any, effect. Apparently the tidal surge produced a sufficient water depth over the submerged fill to place the wave energy zone above it. The limited operation was resumed after the hurricane and gradually increased in magnitude as additional equipment was mobilized. The operation was still categorized as a test voluntarily initiated by the contractor.

91. On 30 October 1979, prior to any hydraulic dredging under their contract, the contractor concluded that the Phase I dike could not be constructed by the hydraulic methods specified and submitted a mass of data to support their conclusion. This included documentation of their experience on a similar project in Bayport, Texas, data from the Theodore test fill, and studies by a dredging expert on their staff. The bottom line, according to the contractor, was that if the material in the bay was to be successfully contained, mechanical placement of a portion of the material was the only alternative. Inherent in the submittal, but not stated at that time, was the premise that additional cost to the Government for the new procedure would be the case. The contractor's conclusion came as no surprise, considering his problems with inflation and the fact that his representative and those of several other dredging companies had, during the bidding stage, stated that success of the island construction was very doubtful. The data submitted by the contractor was carefully analyzed by personnel from Engineering and Operations Divisions and a number of flaws in the data and analyses were detected. Very helpful was the fact that most of the data presented, including the Bayport job, had been thoroughly examined during design. The District concluded that the barge/haul process did in fact offer some advantages, mainly increased retention and reduced turbidity but could not conclude that it was essential to success of the project. An advisory board consisting of Mr. Arthur Crouse, Assistant Chief, Engineering Division, Charleston District, and Mr. Fred Dreves, Chief, Geology Section, Jacksonville District, was convened in order to obtain some independent advice on the question. The panel members, both of whom were recognized experts in dredging, visited the site in late November and examined the contract documents and subsurface data. They rendered a joint opinion similar to that of the District that a retention rate of about 50% for the hydraulic process was reasonably assured and that at least the Phase I dike could be constructed with the available material.

92. On 16 November, while the submittal discussed above was under consideration, the contractor verbally proposed to begin dredging at Station 220+00 and work toward the shoreline cutting a 200-foot wide by 25-foot deep "flotation channel and pipeline trench" and connecting with the existing barge channel. This would allow the contractor to sink his submerged line to elevation -25 and provide a direct route for the barge/haul traffic. It would require a change order since the contract

specified that the land cut had to be finished before the bay cut could begin. On 23 November a formal proposal was submitted and it was accepted on 27 November as being advantageous to the Government; it contained the stipulation that work would be at contract unit prices and the contractor would be responsible for shoaling in the partial channel. In the meantime, it was noted that the contractor was mobilizing additional mechanical excavation and hauling equipment; he was advised in writing that no provision existed in the contract for mechanical excavation. The contractor did not respond immediately and continued to mobilize equipment while continuing the "test" operation on an expanded basis.

93. On 12 February 1980, the contractor dropped the other shoe in the form of a proposal to excavate 3 to 5 million cubic yards mechanically at an additional cost of $2,122,280. The added cost would cover a proposed new payment item for mobilization of the necessary equipment. The proposal reiterated the previous contention that the island construction could not succeed with hydraulic dredging alone. The Area Engineer responded on 10 March 1980 that the proposal was unacceptable and directed the contractor to cease the test barge/haul operation by 15 March 1980. The contractor then requested to be allowed to continue the barge/haul for his own convenience and was allowed to do so. The contract change was included in a change order issued 22 October 1980.

94. The barge/haul operation peaked in June 1980 with daily production reaching approximately 18,000 cubic yards per day. This figure is actually low since it was based on estimated yardage reported daily by the contractor. The estimated yardage came from comparing empty and loaded displacements to obtain the weight of a load and then converting to yardage using an assumed average unit weight. The contractor reported a total excavation of 2.3 million cubic yards using this method while Government surveys showed 3.1 million. This indicates that the estimates were in error by 35% and that daily production probably reached over 24,000 pay yards and the average was around 13,000 yards. The operation was terminated on 7 August 1980 with fill placed from Station 13+00 to 200+00 with a gap between Stations 50+00 and 60+00 to allow access through the dike by haul barges, spill barges and pipeline servicing vessels.

95. Hydraulic Dredging. The contract specified that the turning basin would be dredged completely as the first order of dredging work, followed by the land cut channel to be dredged from west to east in 500 foot segments to complete project depth. All dredging in the land cut was to be complete before starting the bay cut. This was to allow use of the better land cut materials to construct the Phase I, or outer, dike around the disposal island in order to contain the lesser quality bay cut materials. As discussed above, the contractor initiated the barge/haul operation prior to commencing dredging and the Corps agreed to alter this sequence as a trade-off between the more promising mechanical methods and possible adverse effects of placing bay cut material in the Phase I dike. Therefore, hydraulic dredging did not begin in the land cut until

the Dredge DAVE BLACKBURN crossed the dividing point at Station 274+00 proceeding west on the 25 x 200 foot flotation channel cut on 15 February 1980. As it developed, the nearshore bay cut material behaved better than had been anticipated and the concerns which had dictated the specified order of work were somewhat eased. The BLACKBURN was the second dredge to be mobilized; to avoid congestion and possible interference, the JIM BEAN, which had been mobilized in November 1979, was allowed to continue in the bay cut until she departed to resume work on another project on 17 April 1980. The BLACKBURN worked continuously in the land cut from February 1980 until 15 December 1980, pumping material some 30,000 feet to the disposal island, through 30-inch diameter discharge pipe, using two booster pumps (photo 3). When the JIM BEAN returned to the job on 3 January 1980 she was to complete the turning basin excavation, finishing on 10 February 1981. The total yardage measured in the land cut, and paid for at the Contract Unit Price of $2.216 per cubic yard, was 11,456,738 cubic yards; 3,129,379 cubic yards of which was excavated mechanically and 8,327,739 cubic yards hydraulically. The estimated quantity in the contract for the land cut was 11,532,000 cubic yards.

Ship Channel, Bay Cut

96. Dredging began in the bay cut on 23 November 1979 when the Dredge JIM BEAN initiated the flotation channel at Station 220+00. She completed the 200- by 25-foot cut to Station 263+30 where the BLACKBURN took over and continued on into the land cut. The BEAN worked for the next three months in the channel reach between Stations 208+00, excavating down to project dimensions. After her departure there was no further dredging in the bay until the BLACKBURN finished her portion of the land cut and moved back into the bay on 15 December 1980 where she remained until 28 July 1981. The JIM BEAN returned to the bay after completing the turning basin 10 February 1981 and, except for four days of sweeping the turning basin in May 1981, she remained until 29 August 1981.

97. Dust Pan Dredge. On 6 November 1980 the contractor submitted a multi-faceted proposal to provide a 200- by 25-foot channel from the Mobile Bay Channel to the Ideal Basic Industries and Autland Manganese Plants by 15 May 1981. It was also proposed that the bay cut work commence prior to completion of the land cut and that the material form Stations 150+00 to 207+00 be placed in the Phase I dike with the remainder to be placed inside the Phase I dike, primarily along the southwest leg. The contractor proposed to mobilize the required equipment for the sum of $667,000. Inherent in the proposal, but not stated, was the fact that the third dredge was to be a dust pan dredge capable of moving large volumes of soft material under low pump pressure with pumping distance limited to approximately 3,000 feet.

98. The proposal was evaluated for economic benefit to the Government and no basis was found for the additional payment. The remainder of the

proposal seemed to have some merit and would possibly serve to ease the inflationary burdens of the contractor with no adverse effect on the Government. A change order was initiated to allow the dust pan dredge to cut full width to elevation -25 between Stations 0+00 and 150+00, to reserve the material below elevation -25 between Station 113+00 and Station 150+00, to close weir gap in the west leg, and to permit the complete excavation of the channel east of Station 113+00 prior to completion of the land cut, all at no increase in cost or time.

99. The dust pan dredge LENEL BEAN was mobilized and began work on 22 December 1980 (photos 4 & 5). Dust pan dredges were developed for use in removing new and unconsolidated bars, usually granular material, from inland rivers and pumping the material a short distance to the bank. They utilize a bank of high pressure water jets to loosen and place the material in suspension so that it can be picked up by a large fan-shaped suction device and pumped through the discharge pipe. The LENEL BEAN made a 30-foot cut on each pass. The operation was highly successful from a production standpoint, but caused some serious concerns over increased turbidity levels; so much so that a special study was made to compare it with a normal cutterhead dredging operation (Crozier 1981). The study showed that while a normal cutterhead dredging operation did not produce turbidity above the normal background levels outside a 30-yard radius, the dust pan dredge produced a bottom plume which extended as much as 1/2 mile depending on tide and wind conditions and turbidity levels which may reach as high as 200 Nephelometric turbidity units (NTU). Surface plumes were observed extending to 500 yards with levels of 100+NTU. The heaviest contributor to the increased turbidity was the dust pan cleaning operation, which involved removing the accumulated mud from the suction device with fire hoses while the dredge backed down to start another cut. Use of the dust pan dredge was allowed to continue since the higher turbidity levels were intermittent and of short duration.

100. The LENEL BEAN removed a total 6,277,463 cubic yards from the channel between Stations 0+00 and 152+00,cutting as deep as elevation -28 in places. According to the daily dredging reports her top production was 85,556 cubic yards in one day. She was on the job for 136 days and her average daily production was 45,790 cubic yards. She typically operated with approximately 2,000 feet of floating pipe and 1,200 feet of shore pipe. She was demobilized on 7 May 1981.

101. Bay Cut Quantities. The quantity of dredging measured for payment at the Contract Unit Price of $0.88 per cubic yard for bay cut material was 19,837,047 cubic yards, compared to the contract estimated quantity of 19,573,000 cubic yards.

Disposal Island

102. General. The disposal island dike was to be constructed in two phases (figure 7). The first, or Phase I, portion was to be up to

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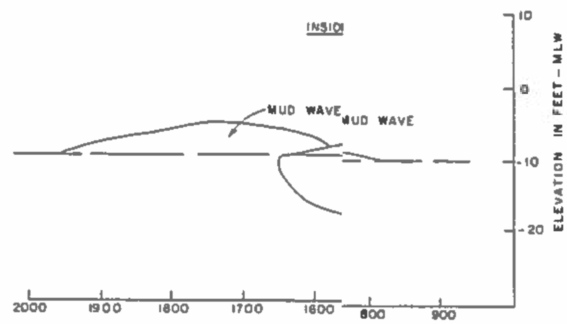
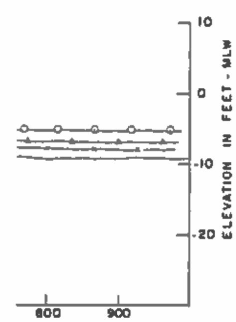
SYM	ZONE	DESCRIPTION	DATE	APPROVED





LEGEND

- o SOUTHWEST LEG
- Δ NORTHWEST LEG
- x EAST LEG

U.S. ARMY ENGINEER DISTRICT, MOBILE
CORPS OF ENGINEERS
MOBILE, ALA.

THEODORE DISPOSAL ISLAND
DESIGN AND AS-BUILT
CROSS SECTIONS

FIGURE 7

elevation +4, have a 100-foot crest width and slopes at the angle of repose. Dredging was to commence in the turning basin and proceed to the shoreline, cutting to full project dimensions. Placement of material was to commence at dike Station 0+00 near the southwest corner and proceed counterclockwise in two passes. The first pass was to be up to elevation -3, and the second to +4. The rationale for this was to insure that, in the event retention was grossly less than anticipated, what material that was retained would be equitably distributed around the perimeter. It was assumed that most, if not all, of the land cut material would be used in the Phase I dike. The second or Phase II portion of the dike was to be similar to the Phase I except that it was to be constructed to approximately elevation +10 on the inside slope of the Phase I. The contractor was to compare the material available with construction progress and adjust the final elevation to provide equitable distribution and a uniform height.

103. As discussed in previous paragraphs this specified construction procedure was radically altered very early in the contract. The contractor's placement of barge/haul material in the southwest leg precluded placement of the dredged material in the specified counterclockwise direction. Approval of the contractor's proposal to construct the flotation/pipeline trench mandated that dredging begin in the bay rather than the land cut turning basin. From that point forward the actual construction procedure bore little resemblance to that envisioned by the contract. It became a matter of trying to influence the various events and processes toward an acceptable finished product rather than trying to blindly enforce the contract. The contract documents relating to the island construction had provided a proper basis for the bidding process and as such, had served their purpose.

104. Material Placement. The placement procedure for the barge/haul material was covered in preceding paragraphs. The JIM BEAN began dredging at channel Station 220+00, pumping through 9,000 feet of discharge with no booster to dike Station 268+00. With 24 hours an emergent fill had appeared. It built up to approximate elevation +2.5 and the spill barge was moved 100 feet to the north (photo 9). The contractor was requested to raise the discharge pipe and the fill built up above elevation +4. After three days there was sufficient emergent fill to permit walking on it. This was especially encouraging since the cut encompassed only the top 15 feet of material, normally the worst at any location in the bay. This particular material was classified as soft clay and was being pumped througn almost two miles of pipe. No booster pump was in use but the JIM BEAN had a submerged pump on the cutterhead dredge plus one booster. As the dredge moved to the west and the spill barge moved to the north the length of discharge pipe gradually increased to approximately 20,000 feet and the clay ball buildup continued. For the first time since the inception of the project the success of the island was assured.

105. The emergent fill was composed almost entirely of clay balls or chunks from golf ball to grapefruit size with occasional basketball sized ones. They were well rounded in shape, indicating some amount of abrading in transportation. Most could readily be penetrated with a finger which obviously meant that they were cut from material with very low shear strength.

106. The spill barge in use initially had a reach of less than 100 feet. Consequently, it stayed aground on the fill a great deal of the time. The procedure for moving the spill barge was not well coordinated and the fill was generally a series of humps and valleys. As the fill built up, particularly when composed of clay balls which sometimes stacked up temporarily on slopes as steep as 1v on 5h, mud waves could be seen around the perimeter (photo 6). In many cases they would break the water surface but shortly disappear.

107. An effort has been made to reconstruct the fill placement sequence from the contractor's daily reports but apparently correctly reporting the location of spill barges was not given high priority. There are many obvious errors which make most of the data questionable. It appears that the entire dike, with the exception of the openings left in the west and south legs, received at least two passes during the Phase I stage.

108. <u>Phase II</u>. By the time the Phase I dike was completed to elevation +4 it was apparent that the remaining material was not sufficient to construct Phase II in the configuration shown on plans to the full height. The contractor proposed on 6 November 1980 that the remaining good material be placed in the Phase I dike and the soft material which could be dredged with a dust pan dredge be placed inside the Phase I dike along the southwest leg similar to the Phase II configuration. This was judged to be the best approach since it would provide more freeboard on the Phase I and improve its integrity while providing more storage for future dredged material disposal. Construction proceeded on this basis and the final configuration of the dike was very irregular in plan with an even surface. The dust pan material had to be pumped over the Phase I dike, requiring up to 1,500 feet of shore pipe. Floating pontoon pipe was used between the dredge and a barge kept beached at intervals along the southwest dike. From the barge to the spill point a conventional shore pipe arrangement was used with a wye valve to allow spilling through one pipe while the other was extended or moved (photo 7). There was a considerable amount of shells in the soft clay and a small amount of sand. The dominant portion of the clay came out as a thin slurry which behaved as a fluid. A few soft clay balls formed however, and they, along with the sand and shells, often build up bars ahead of the discharge and caused the slurry to flow back toward the bay. The contractor kept a dike building crew on the job continuously using a marsh dragline to maintain a small dike behind the discharge point to contain backflow. The entire southeast corner of the containment was filled to approximate elevation +8 with the material (photos 8 and 9). The top of the material was relatively flat at this elevation for a distance of approximately 1,500 feet from the corner and then sloped down

to the inside pool at about 1v to 500h. Along the southwest leg a series of overlapping deltas were formed. The surface was too soft to allow land surveys and no accurate topographic information on the material was obtained. Consolidation of the material has reduced the visible area of fill considerably in the three years since construction.

109. Spill Barges. Construction of the Phase II dike as detailed in the contract would have required the use of shore pipe on the fill if it had even approached the +10 elevation shown. The shortest distance from where a spill barge could float to the Phase I centerline would have been at least 500 feet. A shore pipe operation on the newly placed clay fill would have been a slow and laborious process if it was possible at all. The contractor, based on opinions stated during the bidding period, was convinced that no dike of any consequence could be built and very likely gave little thought to the placement process. He had to face the problem when it became apparent that a sizeable dike would indeed be built. This was no doubt a factor in his 6 November 1980 proposal to raise the Phase I dike rather than place the Phase II. The Corps' acceptance of the proposal made placement possible with a spill barge that the contractor had already mobilized (photo 10). This barge, which was designed and fabricated by the contractor's forces, had a reach of 285-feet. The spill pipe was cantilevered from a 40- by 200-foot flat deck barge using a 10-foot cable-stayed crane boom and six point cable support for the 285-foot pipe. The pipe could be raised and lowered by an onboard winch. The discharge end of the barge normally grounded at each spill location. The tremendous torque caused by the weight of the dredge effluent in the pipe on such a long lever arm was sufficient to rotate the barge longitudinally and increase the draft significantly. When the flow was stopped, however, the pipe drained back and the rotation reversed, helping to free the barge from the bottom. This spill barge was a very significant factor in the successful construction of the dikes and just one of the contractor's innovations which made the difference between success and financial disaster.

110. Final Dike Configuration. The dike as finally constructed did not resemble the neat lines and grades shown on the drawings and described in the specifications. It generally followed the specified alignment but was knobby on the surface, widened at some locations and necked down at others. It was generally short on aesthetics; but to those who withstood the doubters and prophets of doom for so many years - and at times even shared those doubts -- it was a beautiful structure.

111. Based on cross sections taken on 500-foot centers shortly after completion, the average crest elevation was +8.3, the average width at MLW was 592 feet, the average side slope was 1v on 40h, and the average width at the base was 1,264 feet. The averages for each leg are tabulated below.

Leg	Elevation of Crest above MLW - Ft.	Width at MLW - Ft.	Width at Base - Ft.	Average Slope Crest to Toe
Southwest	8.6	695	1429	1v on 48h
Northwest	9.0	601	1094	1v on 34h
East	6.2	494	1261	1v on 42h

112. The cross sections were not extended beyond the waterline on the inside. The base width shown is on the assumption that the inside slope below the waterline is similar to the outside. Also the toe of the dike was taken at the point where the slope flattened to near horizontal which, in most cases, was several feet above the original bottom. The average elevations of this point for the three dike legs are -5.1 for the southwest, -5.6 for the northwest, and 7.5 for the east. The average for the entire dike is -6.2 feet MLW. This compares with an average bottom elevation of -10 MLW existing before construction. It is surmised that this apparent shallowing of the bay around the dike toe is a buildup of extremely soft clay which accumulated during the dredging and probably slopes away from the dike at about 1v to 500h.

113. Retention Rate. Throughout design the most difficult question to be considered in the island construction was how much of the dredged material would remain in the dike template. The term "retention rate" was used throughout the design process to define this parameter. It is simply the ratio of the volume of material finally remaining within the confines of the dike template and the original bay bottom profile to the bank volume dredged, with no consideration given to bulking, shrinkage or bay bottom displacement. This approach is possibly an oversimplification of a very complex matter but it seems to provide the most practical basis for extrapolating empirical data. The magnitude of bulking and/or shrinkage of fine grain soils is practically indeterminate. For clean sands the volume change during dredging is probably insignificant. For silty or clayey sands the fines are generally washed out and go off in suspension but the volume of soil is not necessarily reduced by the percentage of fines by weight. When clays are dredged the portion that is retained is in the form of balls or chunks which are undisturbed and retain their in situ properties. Some of the mass is lost at the cutterhead but more is probably lost by abrasion in the pumps and tumbling through the discharge pipe. There is some evidence to indicate that soft sticky clays might be better for building a hydraulic fill than stiff and hard clays where long pumping distances are involved. The basis for this is that the denser clays tend to be more friable and more susceptible to abrasion. They are also more likely to be chopped up into smaller particles by the cutterhead. The foregoing is offered simply to illustrate the many variables and uncertainties inherent in the process of hydraulic dredging which makes any theoretical approach to predicting the results risky and leads to the conclusion that a simple, practical approach is best. Furthermore, there is an air of mystery surrounding the process of hydraulic dredging somewhat similar to that which permeates water well drilling and pile driving, probably due to the fact

that the action occurs below the surface and is not visible. The apparent lack of understanding of the natural laws and phenomena involved leads to a wide variation of opinions on any question concerning dredging. The only issue on which almost total unanimity was reached, was that the proposed Theodore Island could not be built. That type reaction from the dredging company representatives was probably influenced by the possibility that they might later be in contention with the Government over questions of time, effort, and expense required by the contract, and would be in a better position to prove impracticability if the island was not successful. What was surprising was the number of other experienced dredging people who agreed with them.

114. Based on the surveys made at the end of construction the total quantity retained within the template was approximately 17.6 million cubic yards. The total quantity dredged was 31.3 million cubic yards. The material moved by the dust pan dredge, which was placed outside the Phase I template, amounted to 6.2 million cubic yards. Removing this amount from the total quantity dredged reduced it to 25.1 million cubic yards. This figure was divided into the 17.6 million cubic yards measured within the dike template to obtain an overall retention rate of 70%; considerably more than the 50% minimum assumed for the design of the island. As defined above, this retention rate does not consider any penetration into nor displacement of bay bottom materials. It is known, based on borings taken through the completed embankment, that the fill in places penetrated as much as 12 feet below the pre-project bay bottom. Also, mud waves of displaced bottom material were observed above the water surface on occasions. The borings taken through the completed fill also showed that in a number of locations the bay bottom was as much as 5 feet higher than before construction. There is good reason to believe that the soft bottom materials were moved about during fill placement but for the most part remained within the template and neither added to nor detracted from the quantity of fill that remained. This probably helps to explain the erratic pattern of settlement on the island. There is good reason to believe that most of the bottom displacement occurred during the initial fill placement under the 100-foot wide crest and the resulting mud waves traveled only a short distance before being overridden and encapsulated by the fill running out to form the very flat side slopes. As the dike was raised the overlying newly placed material also ran out on very flat slopes and no further shearing occurred. This phenomenon occurred often in the early stages of the Craney Island project and when the soft bottom clays were found in the dike template, the contractor was required to remove the clays by dragline and replace them with sand. This is not considered to be a serious problem at Theodore due to the random mixture of materials in the dike and the extremely flat side slopes.

PART V: OPERATION AND MAINTENANCE

Barge Canal

115. Due to a lack of commercial traffic on the barge canal it has not been necessary to maintain the project depth and no dredging has been performed as of October 1984. Extensive silting has occurred, primarily in the western half of the channel and in the turning basin. The sandy slopes have eroded badly with the eroded material going directly into the channel and, as discussed before, the ditches leading into the canal have transported and deposited significant amounts of sediment. At Station 38+70 the washout of the drainage structure has practically closed off the canal. When it becomes necessary to provide full project depth a major dredging effort will be required. The upland disposal area dikes are in good condition and will require only minor work when maintenance dredging becomes necessary. There appears to be adequate storage in the disposal area for the life of the project.

116. A contract was awarded in January 1983 to repair the damage caused by the May 1980 storm. The contract amount was $375,851 and covered the replacement of the washed-out drainage structure at Station 38+70 (photo 13), upgrading of four others, restoration and lining of collector ditches, grading and sodding of five badly eroded areas in the canal slopes and seeding and mulching other disturbed areas. The washed-out structure was replaced with one of a different design which should be much more durable. It was continuous steel sheet pile wall driven at the waters edge with a grouted riprap flume sloping up from the sheet pile to a 10 foot wide crest at elevation 10. It also has a grouted riprap back slope which extends down to the ditch bottom at elevation 0, forming a dam. Ten feet of water is impounded behind the dam which serves as a settling basin for sediments carried by the ditch which can be cleaned out with a dragline. A considerable quantity of seepage is passing through and under the dam and is exiting at concentrated points behind the sheet pile wall. It was running clear when observed and is probably concentrated because of the limited openings through the grouted riprap rather than because of piping through the sand fill. All of the structures should be closely observed, however, and if piping is detected drains should be drilled through the grouted riprap and filtered well screens installed. At the other four drainage structures a sheet pile wall was added at the waterline and the remaining sack riprap was grouted. Collector ditches which were eroded by the storm were restored to lines and grades and paved with grouted riprap and/or sod. The five gullied areas in the canal slopes were restored to grade with compacted backfill, topsoiled, and solid sodded.

Ship Channel

117. No maintenance dredging of the Theodore Ship Channel was performed from the project completion in August 1981 until November 1983. During

that time the only traffic into the industrial Area was shallow draft barges and the oceangoing barges serving Ideal Cement and Autland Manganese which require only a 25-foot channel. In the fall of 1983, the local sponsor announced plans to begin a bulk cargo transfer operation in the turning basin and requested restoration of the channel and turning basin to project depth. A contract was awarded and work was initiated in November 1983. A total of 921,615 cubic yards was dredged and placed inside the disposal island. The work was completed in December 1983. Approximately 2/3 of the material was removed from the east end of the channel, near the intersection with the Mobile Ship Channel. No dredging was required over most of the channel length. This is very encouraging from a standpoint of the future magnitude of required maintenance dredging. The estimate used in the project formulation was 2,220,000 cubic yards per year. The actual annual rate for the first 28 months is 395,000 and since this included the period of post-construction stabilization of slopes this figure could logically be expected to go down. It is interesting to note that the District was accused by one of our sister Federal agencies of inflating the BC Ratio by underestimating the shoaling rate.

118. Since closure of the disposal island dike at the end of construction, the pool inside the enclosure had remained somewhat higher than the mean tide level outside. There were no tide gauges set on the inside so no figures are available but it was noted that under the influence of a strong wind the waters would pile up at the downwind leg of the dike and come dangerously close to overtopping. As a part of the maintenance dredging contract a series of pipes was installed through the east leg of the dike to help keep the water levels equalized. On 15 November 1983, three 16-inch plastic pipes were installed. Timber piles were jetted down at the outside ends and pipes were anchored in place with steel straps. Each pipe was fitted with a swing check valve on the outside end to prevent back flow at high tide. Within a matter of days debris apparently accumulated at the pipes, and the combined action of ship wakes and wave wash uprooted the anchor piles, broke off the check valves, and folded the pies back, effectively closing them. On 4 December 1983, the remains of the plastic pipes were removed and replaced with five 24-inch steel pipes (photo 14). These pipes are installed slightly above mean low water at approximate Station 224+00 and are not equipped with check valves. The capacity of these pipes appears to be adequate to keep the inside pool down to a safe level, but during periods of high rainfall the pool remains high enough to maintain flow to the outside at all times except during extremely high tides. They are certainly sufficient to pass the effluent from one large dredge. The timber piles which were installed along the baseline for the channel dredging as well as the survey towers marking the north and south PI's for the Phase I island dike have been removed as hazards to navigation. The tower at the southwest corner PI, which is located in shallow water near the island and has a tide gauge installed on it, remains in place.

Disposal Island

119. Dike Raising. From the comparison of as-built dike dimensions given in paragraph 109, it is evident that the east leg received the least amount of material. A number of cross sections showed the crest elevation to be only slightly above +4 and the entire leg only averaged 6.2. The high rate of settlement plus rapid erosion of the sandy crest, both from water and wind, caused it to recede rapidly. On the south leg, between Stations 50+00 and 60+00 where the gap was left in the dike to permit barge/haul traffic, the contractor encountered difficulty in getting the dike up to grade. There had been recent and extensive shell dredging in the dike foundation, leaving deep depressions. The gap was closed late in the contract with the lesser quality bay cut material and the result was a narrow dike section with a lower than average crest and steep slopes down to berms on either side not much above tide level In February 1982 the dike was breached in this area. The mechanics of failure could not be reconstructed and it is not known for certain whether it overtopped from inside or out; but, considering the fact that it occurred in February when strong north winds prevail, it is likely that it occurred from the inside. With an extreme low tide level in the bay the head differential was likely in the range of 3 to 4 feet. This was sufficient to cause highly erosive velocities through the breach and it was washed out to -2to -3 MLW and up to 25 feet wide. One of the earlier concerns was that if the dike breached, the soft material confined inside would run out. It was apparent after the break that the only material lost was that which had been eroded by the escaping water. The dust pan material adjacent to the break appeared quite stable.

120. A short time after the first break occurred another was discovered in the vicinity of Station 182+00 near the north end of the east leg. (photo 15). Again it was not possible to determine exactly how the break developed but considering the small amount of freeboard it could easily have overtopped from the outside by wave action on a high tide.

121. After the first break occurred some local fishermen discovered that they could navigate the breach with the outboard powered skiffs used for mullet fishing and they began setting their nets in the lagoon. Some phenomenal catches were reported and one of the fishermen contacted the District Office to request that access to the inside be maintained. The request had to be refused because of concern that continued tidal flow through the openings would result in additional enlargement and unnecessary loss of material from the dike section.

122. During the period 2 April to 14 July 1982, the low areas of the dikes were raised to elevation +8 MLW using rental equipment and Government inspection. Included were the two areas which were breached. At these locations it was necessary to rebuild the dike from waterline to waterline in addition to raising the center portion to +8. By the time work began approximately 90% of the east leg, 70% of the south and 40% of the west required some amount of fill. Sufficient borrow was available on

the inside slope within dragline reach throughout most of the work except at the breaches and at a few locations on the east leg where the original dike was especially deficient. At these locations material was double and triple cast with the dragline and pushed with a small dozer. It was dry and hot for several months following this work and grassing was not immediately effective, especially in the sandier areas on the east leg. Erosion took its toll and settlement continued, probably accelerated under the areas which were raised above the initial height and the result is that some areas are again below +4 and in danger of overtopping. In fact, at one location on the east leg overtopping has occurred, as evidenced by the pattern of driftwood and other debris on the debris, but has not breached the dike. The lowered water level on the inside can probably be credited with preventing a breach and washout similar to the previous one on this leg.

123. A contract is underway at this writing (October 1984) to raise the entire dike to +12. Most of the west leg, except for a few short reaches where insufficient material is available within reach of the dragline, is up to grade and work is proceeding down the south leg from west to east. The present plan is to place a small, portable dredge on the inside and move material to where it is needed. The +12 dike should provide sufficient height for several years; assuming good grass cover can be established immediately behind the work. Settlement can be expected to continue at a rate similar that of the past few months and possibly even accelerate in some areas but the potential for loss of height due to settlement is believed to be minor compared to that caused by erosion.

[Added Note, May 1985. The above dike raising contract was not completed due to endangering protected bird nests. Also, suitable material was not available at all locations along the dike. Present plans are to raise the dike to a minimum of El. +8.]

124. Revetment. The island protection plan agreed upon by the State and interested Federal agencies was to provide hard surfacing (riprap) from the PC at the southeast corner continuously to the PT at the northeast corner. This was to be done after a period of observation and stabilization, estimated to be at least a year. Treatment of the remainder will be discussed later in this report.

125. One of the first areas of dike construction was a portion of the west leg extending part way around the long sweeping curve at the northeast corner. The source of material was the top 15 feet of the bay cut from channel Stations 220+00 to 263+30 which was predominantly soft clay with very little sand. The resulting fill was composed entirely of clay balls with only a trace of sand. Erosion began immediately near the center of the curve and extended gradually to the tangents on either side. A low scarp formed at the waterline and became higher as the erosion encroached inland. Within the first year after placement it had advanced up to 60 feet into the fill leaving a flat berm just below MLW.

126. The clay balls are composed of fat clay (CH), from soft to moderately firm in consistency, which are composed of up to 90% montmorillonite. In its natural state this clay, though weak in shear, is very sticky, tough, and resistant to erosion. When it is allowed to dry, however, and again comes in contact with water it practically dissolves. Wetting and drying, to some degree, takes place in the splash zone and this is the cause for deterioration of the clay rather than erosion in the usual sense. In one cycle -- consisting of a period of calm seas, low tides and good drying conditions, followed by high tides and wave action -- the loss of several inches can occur. The deterioration stops whenever there is sufficient sand mixed with the clay balls to form a protective veneer over the clay and maintain a constant water content. In fact, the area described above later received another layer of fill containing some sand and is now characterized by either a sand beach with no scarp or a beach up to elevation +2 to +3 in front of a clay ball scarp from 1 to 4 feet high (photo 16). The deterioration described above is continuing near the base of the scarp due to wave runup It undermines the face and causes cracking and sloughing from above. The encroachment has slowed dramatically but continues at a rate which could probably not be tolerated over the long haul.

127. At the southeast corner the same deteriorating process began as soon as the fill was completed in May 1981. This corner is subject to a longer fetch and more severe wave action. The curve is very short and sharp which makes it more vulnerable to wave attack. Consequently, the encroachment took place at a faster rate and within a year the crest of the dike was threatened. Fortunately, this corner was completely filled by the dust pan operation and loss of the dike would not have been as serious as in other locations. Because of the need to arrest the slope deterioration here and the fact that it would provide the most severe test environment, the southeast corner was selected as the site for a test revetment contract.

128. Eight different types and configurations of revetment were included covering the reach from Station 105+00, 160 feet behind the PC to Station 121+00, 369 feet beyond the PT. Within the eight combinations there were four basic types of revetment, plain oyster shells on the existing beach slope, light riprap on oyster shell bedding on filter cloth on the natural beach slope, a heavy riprap section on an oyster shell core, and a heavy riprap section on a prepared earth slope. The various types of revetment are described below:

Type I - A trench was to be excavated to elevation -3.75 and the slope above dressed to 1v on 2.5h to elevation +6. Filter fabric was to be placed on the trench bottom and slope followed by a 9-inch thick layer of reef shells, overlain with a 3-foot thick layer of graded riprap with 700 lb. maximum size. At the toe the filter fabric was to be folded back to enclose 2 feet of riprap and anchored under the riprap section. Earth fill was to be placed behind the section.

Type IA - Same as Type I except the trench bottom was to be at elevation -2.0

Type II - Same as Type I except that shell was to be used above natural ground to form the 1v on 2.5h slope. It was to be placed in a trapezoidal section with a 5-foot width at elevation +5.0 and 1v on 2h backslope.

Type III - Filter fabric and 6 inches of reef shell were to be placed on the existing slope from elevation +3.5 to elevation -1.5 on one end of the section and -2.0 on the other.

Type IV - 12 inches of 10 to 100 lb. riprap, 6 inches of reef shell and filter fabric were to be placed on the existing slope from elevation +4.5 to elevation -1.5 on one end and -2.0 on the other.

Type V - 6 inches of reef shells were to be placed on the natural beach slope from elevation +4.5 to elevation -0.5 without filter cloth.

Type VI - Same as Type IV except without filter fabric and with bottom elevation of -0.5.

Type VII - A windrow of reef shells was to be placed on filter cloth on the natural slope at elevation 0 and mounded to elevation +2.5.

129. The contract was advertised on 30 July 1982 and bids were opened on 31 August 1982. The low bid was $275,661, compared to the Government estimate of $322,906 without profit. The contract was awarded and work began in September 1982. For various reasons the contractor made very little progress and the work was only 19% complete by the end of January 1983. The lack of progress was attributed primarily to the absence of on-site management, improper equipment and adverse weather and sea conditions. There had been considerably more erosion and encroachment into the dike in the interim, which the contractor claimed as the reason for his lack of progress.

130. On 1 February 1983 the contract was terminated at the convenience of the Government to allow reformulation of the work. The Government bought the construction materials stockpiled on the job and later awarded a rental contract and completed the job with Government supervision. Revetment Types VI and VII were not placed because it became obvious very early in the work that shells alone simply would not remain in the energy zone. Only a portion of the Type II section was placed for two reasons: the first was a shortage of shells on-site and the other was the difficulty of holding the trapezoidal shell core in place until the riprap could be placed. Considering this difficulty it was decided not to reorder shells and to substitute the Type I section for the remainder of the Type II work. Considerable difficulty was also encountered in keeping the shell bedding intact until the light stone blanket could be placed over it on the Type IV and VI sections.

131. The contractor had attempted to move stone from the unloading point to the placement point using a sled towed by a dozer. This was a large part of his problem. The Corps used an endloader and encountered serious problems with trafficability, especially where material had to be spread in a blanket on the natural slope. Later runway mats were used with some degree of success. Most of the mats were lost in the process and could not be recovered, which added to the cost. The contractor attempted to use a crane with a clam bucket to excavate the toe trenches with little success. The Corps used a backhoe which was generally successful.

132. The work was completed in May 1987 at a cost of rental contract approximately equal to 2/3 of the remaining money from the first contract. The rental contractor has filed a claim against the Government for excessive nonwork/nonpay time because of weather and sea conditions. Should the claim be settled in his favor the final cost will approximate the original lump-sum contract amount.

133. The revetment test section was inspected on 29 August 1984, and the Types I, IA, II, IV and VI sections look good (photo 17). There remains a band of turbidity 50- to 75-feet wide beyond the riprap indication that some erosion is still occurring. This is probably a result of slope disturbance down slope from the riprap which hopefully will clear up when sorting is complete and a veneer of sand is reestablished. If it continues beyond a year or so it can possibly be taken as indicative of undermining of the riprap and would ultimately lead to failure.

134. Based on cost, performance to date, and constructability, it appears that Type I, or possibly Type IA, is probably the best of the sections installed. It is too early to compare the two but so far there is no apparent difference in performance. If the Type IA does not fail by undermining in the first two to three years it will be clearly advantageous over the others. By the end of that time it will be approaching the Type I in toe elevation due to settlement, and the riprap stone saved initially by the higher toe can be used to restore the top to grade. It appears that the governing principal here should be placement at the highest elevation that will withstand initial undermining since settlement is inevitable and the top elevation will have to be restored periodically.

135. A light stone filter cloth placed on the natural beach slope appears, at this stage, to have considerable merit also. Of course it has not been tested in a design storm but indications are that it will survive. The main drawback appears to be that the placement is labor and equipment intensive and it requires more material. This would be balanced somewhat by the fact that no earthwork is required. One big advantage is that it places very little surcharge on the subgrade and since settlement will not be accelerated, the cost of maintaining the top at grade should be considerably less.

136. A small stone jetty was placed at each end of the test section. Both are accumulating some sand on one side. The beach to the east of the one at Station 105+00 has filled in almost to the top of the stone and almost the entire length. Erosion continues on the west side, however, and has encroached approximately 6 feet since the jetty was installed and has provide a 4-foot high scarp back to approximate Station 103+00. This scarp becomes gradually lower from the point to the west and plays out at approximate Station 878+50. It appears that some type of revetment will be required over this 1,750 foot reach.

137. The jetty at approximate Station 117+50 has accumulated some sand on both sides. From just north of this jetty to Station 129+50 there is a 2- to 4-foot high scarp that is progressing inland at what appears to be a fairly high rate. For the first 200 feet or so there is very little sand present and clay balls are exposed in both the scarp and the beach slope. This 1,200 foot reach needs protecting in the near future. From Station 129+50 to approximate Station 224+00 there is a good sand beach with the exception of approximately 200 feet near the middle of the east leg where there is a 3- to 4-foot high clay ball scarp. From approximate Station 224+00 to the beginning of the marsh grass planting there are alternating reaches of eroding clay balls and well established sand beaches. This entire section should probably be revetted in the near future.

Marsh Grass Planting

138. Under the agreement reached at the 13 May 1977 meeting in Montgomery, Alabama, between the District, the State, and other Federal agencies, the west leg of the island was to be protected by planted marsh grass. Not everyone agreed that this was practical or even possible. Therefore, like most other facets of this project, it had to be approached on an experimental basis. It has been a joint effort of the Mobile District and Waterways Experiment Station with shared funding.

139. The first experimental plantings were made in May 1981, approximately three months before the project was completed. The site for this work was at the south end of the west leg from Station 294+59 to Station 311+50 and covered about four acres. This planting was made using primarily three species of marsh plants (_Spartina alternaflora_, _Spartina patens_ and _Juncas roemerianus_) with two different spacings and two fertilization rates. The plants initially placed in open water with no wave protection. The survival rate was very low for individual sprigs, ranging from 4% in the deeper water (below 1.7 MLW) to as high as 45.5% at the higher elevations. The low survival rate was attributed to disruption by wave action since the plants fared much better in protected coves. A fixed breakwater constructed of steel runway mats fastened to posts was installed in front of a 1/2-acre plot. The breakwater did not survive for very long but it helped to prove that if the plants were protected long enough to get their roots established, a respectable survival rate could be expected and that once established, the plants would propagate themselves without benefit of a breakwater. WES experimented with several

types of breakwaters, both fixed and floating. The most effective design was one utilizing floating banks of old tires anchored offshore from the planted area. The tires were perforated to permit drainage, partially filled with a chemical foaming agent which set up to resemble Styrofoam, and strapped together using nylon reinforced rubber belting material fastened with nylon bolts. These rafts could be moved from one location to another as needed. Spartina alterniflora was selected as being the most effective plant species. It was found that the degree of success was highly dependent upon the amount and depth of clay soils present. Where clean sands extended to over 10 inches deep the results were almost totally negative.

140. Following the initial test planting, the shoreline along the entire west leg from the PT of the northeast corner to the PC of the southeast corner was planted by mechanical planter in August 1982. Additional hand planting was conducted during the summers of 1983 and 1984 to fill in wash-out areas. At this writing (October 1984), there is a lush growth of marsh vegetation from the north end of the planted area at Station 257+75 to Station 295+00 (photos 18 and 19). It extends as much as 200 feet landward of the water's edge in swales. From that point, about 400 feet south is a sandy area which is somewhat sparse both in marsh and terrestrial plant growth. From there to the southwest corner the marsh plant growth is fairly continuous but not as vigorous and extensive as at the north end. It probably averages 30 feet in width. Some additional plantings have very recently been made in this area. There appears little doubt that the marsh vegetation along the entire west side is sufficiently established and will eventually cover all areas that will support growth.

141. Southwest Leg. The southwest corner is accreting instead of eroding, probably at the expense of the adjacent tangents. About one-half of the curve is clean sand beach and the other half is well covered with marsh and torpedo grass. The beach is very similar to those on the eastern shore of the bay. It slopes down on about 1v on 8 to 10h slope from elevation +2 to -2 and flattens at that point to something flatter than 1v on 50h. The western half of the southwest leg is typified by alternating sand beaches and low, scarped promontories which are well covered with Bermuda and torpedo grass. In some cases a small dune has formed across the coves between promontories creating a lagoon effect which is promoting the growth of marsh type grasses. The eastern half of this leg is typified by almost continuous scarps getting gradually higher and farther into the dike toward the southeast corner. Most of this reach has a sand beach below the scarp but some scattered areas are devoid of sand and show pure clay balls exposed in the energy zone. It appears that this approximate 3,500 foot reach will need some type of protection. Stone or timber jetties at selected locations might most economically provide sufficient shelter to allow marsh vegetation to naturally develop; however, the wave and ship wake energy is so intense over the first 1,500 to 2,000 feet west of the corner that continuous armoring may be ultimately required.

Terrestrial Vegetation

142. As soon as a substantial dike section was produced in the spring of 1980 test plantings of terrestrial type grasses and trees were initiated (photo 20). The first test plots were located in the curve of the northeast corner and included common Bermuda, weeping love, and Bahia grasses. All three types showed satisfactory performance but the Bermuda grass performed best. This area remained undisturbed for almost a year before additional fill was placed over it. By that time it was well covered and the Bermuda grass had spread to surrounding areas. Natural vegetation also began immediately behind fill placement, originating probably from seeds, rhizomes, etc., in the dredged fill as well as from bird droppings. As would be expected the natural plant development was widely scattered and slow to develop. The trees planted initially were Tupelo and black gum. which survived for the most part, but did not flourish.

143. In the spring of 1981 a series of test plantings of trees and shrubs were made in a plot near the west end of the southwest leg. This was done with stock obtained by purchase order using Government labor. The planting included red maple, sweet gum, tallow and loblolly pine. During the winter and spring of 1981-82, a large tree planting and grassing contract was awarded covering the entire island. A wide variety of trees and shrubs were planted and the island was seeded aerially with common Bermuda grass. Later construction activities, primarily the dike raising and test revetment contracts, have taken their toll and some plantings were subsequently uprooted by erosion. Others died during prolonged dry spells, particularly in areas of clean sand subgrade. The results, however, are generally satisfactory and it appears that a sufficient number of the different varieties which are adaptable to the island environment are well enough estublished at this time to assure their continued growth and future propagation. According to the District's agronomist, the most promising species growing on the east leg, which is considered the critical one for island stability, are chase, oleander, autumn olive, loblolly pine and wax myrtle. The most promising, considering the entire island, are loblolly pine, live oak, mimosa, sycamore, cedar, tallow wax myrtle, nuttall oak, river birch, pittosporum and cabbage palm. The least promising are red maple and sweet gum.

144. The Bermuda grass seeding was spectacularly successful. Except in some small areas of totally sterile sand which are high enough in elevation to dry out completely during dry periods, the Bermuda grass completely covered the terrestrial portion of the island by mid-summer. In about this time frame torpedo grass was sprigged at scattered locations on the island and it has spread at an amazingly fast rate. It is competing with the Bermuda grass and has taken over in many locations just above the tide level. In the spring of 1983, some bitter panicum, a type of beach grass, was introduced and is reported to be doing well. Among the volunteer terrestrial plants on the island the most eye catching are large clumps of vines identified as beach bean (Canavalia rosea) which produces large seed pods and spreads like wildfire. Also noteworthy are

occasional colonies of Sesbania punicea, a large woody weed which grows in clumps up to 8 feet tall. In addition to the trees which have been planted on the island it is reported that some volunteer seeding is beginning, most notably waterborne cyprus seeds.

145. The Island as a Bird Sanctuary. The disposal island -- officially named "Gaillard Island" for Dr. Wilson Gaillard, Sr., who is reported to have conceived and promoted the disposal island concept for Theodore -- has become an important resting and nesting area for a wide variety of sea birds. During the spring and early summer of 1984 an estimated 16,000 birds inhabited the island. About 12,000 were estimated to be laughing gulls and the reminder were brown pelicans, black skimmers, royal terns, white pelicans, gulled bill terns, least terns, blue herons, snowy egrets and several other unidentified species. Most were using the island for a nesting ground.

146. Of particular significance is the nesting of brown pelicans on the island: the first documented occurrence of nesting in Alabama (photos 21, 22 and 23). This bird used to be abundant along the entire Gulf Coast and is thought to have nested on the offshore islands of Alabama in the nineteenth century. Between 1957 and 1959 the brown pelican population in the upper gulf area almost totally disappeared. The decline has been blamed on DDT and other pesticides. The species began a slow recovery in 1963 following legislation to control pesticides and by 1973 numbers as high as 100 were counted in Alabama. In the meantime they were placed on the Endangered Species list.

147. Brown pelicans feed on fish, mostly menhaden in this area, and prefer a secluded saltwater environment. They normally nest on offshore islands where human interference is at a minimum, and nests, constructed of twigs, reeds, and leaves, may be on the ground or in trees. Apparently the completion of the island coincided with the resurgence of the brown pelican population in the area and provided an attractive habitat. In June of 1983 two nests were discovered on the east leg of the island. By July the colony had expanded to four nests and the area was marked and posted to discourage human interference. Two of the nests were later abandoned and one was apparently destroyed. From the fourth, two chicks hatched and grew to maturity. In July of 1984 nine nests were counted which produced twelve chicks. As of 29 August 1984, only one chick, which was almost ready to fly, remained; the others having apparently matured and joined the flock or left. It has been estimated that within five years there could be as many as 200 brown pelican nests on the island. There is also good reason to believe that as the island continues to vegetate and food sources increase that it will attract many birds other than marine types.

PART VI: LESSONS LEARNED

Order of Work

148. A detailed and exacting description of the manner in which the ship channel dredging and island dike construction work was to be performed was included in the specifications. Before any dredging was performed, the contractor submitted a series of proposals involving mechanical excavation and placement of a portion of the material, and the early excavation of a partial channel to support this work. The proposals were evaluated and found to be in the best interest of the Government. Acceptance of these and subsequent proposals resulted in an order of work which was totally different from that specified. It might appear at first glance that the specified construction procedure was excessive in detail and perhaps unnecessary since it was almost totally changed in the actual construction work. This is definitely not the case, however, viewing the entire project after the fact it is clear that, with a less conscientious contractor or one more inclined toward claims, the tight specification could easily have been necessary and possibly the difference between success and disaster. At the least, it provided a common basis upon which the prospective bidders could estimate costs and served to elicit bids that were realistic. As it developed, the successful bidder was a conscientious contractor and made a good faith effort throughout the job to provide a satisfactory finished product in spite of extraordinary financial problem. The specifications as written did not preclude the innovative changes to the methods of work employed by the contractor which alleviated his costs problems and possibly resulted in a better product. It is also apparent in retrospect that if it had been necessary to strictly enforce the specifications upon a contractor less inclined to perform, the order of work as specified would have had the best chance of success. Experience on this project indicates that the best approach on similar ones is to clearly define the desired and expected finished product and specify in detail the procedure which has the best chance of success, keeping in mind that in so doing the Government assumes responsibility for success or failure. This approach does not preclude initiative on the contractor's part since contract modifications can be made. Such modifications should be carefully negotiated, however, to insure that the responsibility is shifted to the contractor for alternative procedures initiated by him.

Earthwork Scheduling

149. This item was discussed in paragraph 75 in connection with the earthwork problems which developed on the disposal area dike construction in the barge canal contract but bears further scrutiny here. The barge canal contractor was given Notice to Proceed on 16 November 1978. As is usually the case, the bulk of the work could not begin until after the clearing and grubbing for the canal and construction of the disposal area dike was complete. The contractor mobilized immediately after Notice to

Proceed and made a valiant effort to accomplish this work during the very worst time of year. The water table was high, rain was frequent and drying conditions were bad. The contractor struggled for seven months and finally completed the dike construction on 29 June 1979 and dredging began. The original contract completion date was 14 August 1979. The dredging work was finished on 30 January 1980, some 5-1/2 months behind schedule. The point is that Notice to Proceed could have been delayed until the following April and, with the same construction time the scheduled completion date would have been the same as the actual date. Still better would have been a start date around 1 August which would have allowed completion of the earthwork before the wet season.

150. The above scenario has been repeated many times over the years, more often than not with the Government paying for lost time, additional effort, etc. This project did not require moisture control on the fill but the materials were simply too wet to be handled economically. Commonly, on jobs which do require moisture control, the borrow soils are obviously too wet to compact and the schedule requires placement and compaction at times when drying is impossible. This is not reasonable and places an untenable burden on the contractor. It is not surprising that the courts usually favor the contractor in such situations.

151. That scheduling is controlled by availability of funds is a fact of life and so long as funds continue to become available in the fall, construction starts will probably continue to be in the winter. If all the added costs associated with this could be quantified it would be startling. This system needs to be changed. In the meantime, the best approach is to try to avoid mobilization for earthwork between November and April. If this is not possible, then shoulder the extra cost and provide for the replacement of wet soils with dry borrow, if available, or, where permeability is not a factor, provide for the use of non-moisture sensitive materials such as clean sand and gravel or crushed stone.

Definition of Materials to be Dredged

152. During the ship channel contract the contractor, on two different occasions, encountered materials which he considered to be different than shown in the contract and notified the Government of his intent to file a claim. In the first instance he allegedly encountered rock in the bay cut channel. Investigations revealed that the material referred to as rock was limonite concretions in the sand strata, and they had, in fact, been correctly logged in the borings. It developed that the limonite encountered in the cut was no more extensive than was indicated in the borings and did not cause the contractor any more problems, so the claim was dropped. The second instance involved oyster shells, allegedly more prevalent in the bay cut than shown in the contract, and this also provoked a claim letter. The boring logs showed shells and shell fragments throughout but the contractor claimed that he was encountering heavy concentrations or pockets of shells sufficient to plug the dredge

discharge pipe. The dredge moved temporarily and the Corps mobilized a drill rig and drilled several holes in the problem area. The shells encountered in these borings were generally as shown in the contract. The contractor was so informed and apparently made the necessary adjustments in his dredging procedures. Nothing more was heard from the claim.

153. There is nothing singular in either of these incidents but they serve to illustrate the absolute necessity of defining well the materials to be dredged. Considering the spacing of the contract borings it was entirely possible that the conditions alleged by the contractor could have existed and been missed by the borings. Had this been the case the Government would have been held liable for the additional costs since the principal is well established by law that a contractor has the right to project the information shown on the borings to the whole site. Disclaimer clauses which try to limit the information only to the location of the boring will not stand up. It is also a well established fact that the costs for added work paid for under the differing site conditions clause are almost always many times what they would be if the work was properly identified and paid for under the differing site conditions clause are almost always many times what they would be if the work was properly identified and paid for under the competitive bid process.

154. It is never possible to put down enough borings to totally eliminate the possibility of missing a significant subsurface entity and certainly the point is reached where added borings are not economically justified. However, a sufficient number of borings to well define the subsurface profile is certainly warranted and the importance of detailed, descriptive and accurate logging cannot be overemphasized.

Method of Measurement for Payments

155. Paragraph 9 of Section 2A of the specifications required that soundings for pay purpose be made with an electronic sounding device. During the ship channel dredging it was found that the specified device could not discriminate between the channel cut and light "fluff" present in the channel at certain locations. A change was issued to provide for payment based on leadline surveys in lieu of sonar in these locations. Apparently the sonar device worked satisfactorily in most locations and, since leadline survey are much more costly, it would not seem prudent to discontinue the sonar survey; however, contract disputes could possibly be avoided in the future if the foregoing is recognized and the proper provisions included in the specifications.

Drainage Structures

156. Damage to the drainage structures is discussed in paragraph 72 and repairs are discussed in paragraph 116. The large structure at Station 38+70 failed completely with not enough remaining to allow speculation on

the mode of failure. The ones which were damaged but remained, probably provided the best evidence. In all cases the sack riprap apron was undermined indication a progressive failure by undermining and sloughing. In any case the structures were apparently too fragile to withstand the flow which occurred.

157. More substantial drainage structures reportedly were initially designed for the canal, somewhat similar to the replacement structure, but their cost was considered prohibitive. The decision to go with the cheaper ones was probably influenced by the fact that they were in a sense temporary, and would one day be supplanted by a bulkhead system when the property on either side was developed. In retrospect, however, it would have been cheaper in the long run to have incorporated the sheet pile toe walls in the beginning. There are two things to be learned from this experience: one that the cheapest way was not the best, and two, if revetment of any sort is to be placed on a sandy slope it should extend all the way to the toe. If rock or an erosion resistant clay stratum is present in the slope the revetment should be keyed into a berm at its surface. Further, revetment should always be placed in the dry where feasible.

Earthwork for Disposal Dikes

158. As discussed in paragraph 80, the specifications for the barge canal contract required that the fill in the disposal area dike be spread in 24-inch layers and compacted by the controlled movement of the spreading equipment. The soil would not drain in a reasonable time and would not support the spreading equipment. Considerable controversy, as well as lost time and effort, resulted from this requirement. No compaction requirements should be placed on disposal dikes which are less than 20 feet high with slopes of 1v on 2h or flatter.

Excessive Survey Requirements

159. Paragraph 7.4 of Section 2A of the specifications for the ship channel contract required that the contractor make a centerline profile and take cross sections on 500 foot centers of the Phase I dike within two weeks after fill placement was begun and at two week intervals thereafter until the dike was completed. This requirement was completely unrealistic. Intervals of two months would have been more sensible.

Insufficient Right-of Way

160. When the local sponsor acquired the right-of-way for the initial barge canal construction into the Theodore Industrial Complex, they ostensibly expanded the limits sufficiently to allow for the later construction of the ship channel. The records are not clear as to whether the Corps furnished the requirements or the sponsor made its own

determinations, but the right-of-way limits were set based on a 300-foot bottom width at elevation -42, 1v on 3h side slopes and a buffer strip at the edges for construction access, maintenance, and sloughing. Slope stability analyses showed that the 1v on 3h slopes were not stable and a 25-foot berm had to be added at MLW and the slope above flattened to 1v on 4h where the ground level was above elevation +7. In those areas an additional 50 feet of land was required. The sponsor had to go back to the land owners a second time which was not an easy matter. A considerable amount of hostility toward the project developed. The process of condemnation had to be invoked in most cases. Some went to court while most were settled by negotiation but at a cost far in excess of that which prevailed in the first acquisition.

161. Recognizing that, in a situation such as this, it is not an easy matter to anticipate real estate requirements precisely before final design is complete; this was still a serious blunder. Not only was it an unnecessary expense to the taxpayers, but the local images of both the Corps and the State Docks suffered in the process. A better procedure in this type of situation would be to assume the worst and if error is to be made let it be on the side of conservatism. It is always advantageous to have extra room for construction and with added distance, the chances for encroachment on private land and resulting costly claims and lawsuits are reduced.

PART VII: CONCLUSIONS

162. The Theodore Ship Channel and barge canal extension project has been completed and in an operational status for over 3-1/2 years at this writing. Industry utilization of the project to date has been disappointing but there is no doubt as to the potential. The worldwide economic situation has no doubt been the prime cause. This is confirmed by the dramatically reduced activity at the other shipping facilities in the harbor. The imminent opening of the Tennessee-Tombigbee Waterway is expected to trigger increased shipping activity in the Mobile area and will hopefully include this project.

163. All features of the project are performing better than expected from an engineering standpoint. The initial problems with the barge canal drainage system have been stabilized. Some problems remain with the high sand slopes in the western end but the worst is aesthetics. The shoaling rate in the ship channel to date has been especially encouraging, being only a small fraction of the anticipated rate. The overall performance of the project from an environmental standpoint is far better than expected. Some amount of turbidity persists at some points on the island perimeter but appears very minor compared to that which is naturally generated in the bay. The results of the environmental monitoring program show no adverse effects on water quality. The use of the island as a nesting ground for birds is very positive environmentally and has received a great

deal of local publicity. An article is being written for an environmental magazine with nationwide circulation which is expected to be very favorable to the project and the Corps. The marsh grass planting has been a singular success. In fact, vegetation of the entire island is proceeding at a rate which is most gratifying. The test revetment work showed that, although difficult, protection can be provided where required on the island perimeter at a reasonable cost. The island construction has to be viewed as total success. Most of the credit belongs to the contractor and those who administered the contract. Problems which would have broken most contractors were overcome with ingenuity, innovation and hard work.

164. Settlement of the island will continue which means that the dike crest as well as slope protection will have to be incrementally raised over the years. Selective placement of riprap in the near future is a must. Eventually hurricanes are certain to occur in the area and damage to the island can be expected. The longer vegetation is allowed to develop before one comes, the lesser will be the damage to the island embankment. Since the shoaling rate for the Theodore Channel is much less than expected, consideration should be given to placing dredged disposal material from a six-mile reach of the Mobile Ship Channel in the island to hasten filling the lagoon and lessen the danger of hurricane damage.

165. All things considered, the Theodore project is an excellent example of properly balancing environmental and economic factors.

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APPENDIX A

Photo 1: Large dragline with six cubic yard bucket working in Ship Channel land cut; used for loading barges to transport material to the disposal island (Phase I dike).

Photo 2: Large dragline mounted on spud barge and equipped with a dozer blade unloading barge for construction of Phase I dike.

Photo 3: Cutterhead Dredge DAVE BLACKBURN operating in land cut channel near Ideal Cement dock.

Photo 4: Dustpan Dredge LENEL BEAN operating in bay cut channel depositing material in southwest corner of island.

Photo 5: Close up of dustpan dredge cutterhead.

Photo 6: Mud waves around perimeter of emergent disposal island; produced by displacement of soft bottom materials.

Photo 7: Discharge pipe arrangement of dustpan Dredge LENEL BEAN.

Photo 8: Dustpan material in southeast corner of island shortly after placement.

Photo 9: Dustpan material in southeast corner of island after decanting and drying.

Photo 10: Spill barge with 295 foot reach especially fabricated by contractor for island construction.

Photo 11: Aerial view of barge canal showing washed out drainage structure at Station 38+70, south side.

Photo 12: Close up view of washed out drainage structure at Station 38+70.

Photo 13: Restoration and replacement of drainage structure at Station 38+70.

Photo 14: Steel discharge pipes installed through island dike in December 1983.

Photo 15: East leg of island dike showing breach which occurred in spring 1982.

Photo 16: Island shoreline at northeast corner showing characteristic beach slope beneath a clay ball escarpment.

Photo 17: Completed revetment test section at southeast corner of island.

Photo 18: Results of marsh grass planting on west leg of island dike at Station 295+00.

Photo 19: Close up view of planted marsh grass on west leg of island dike.

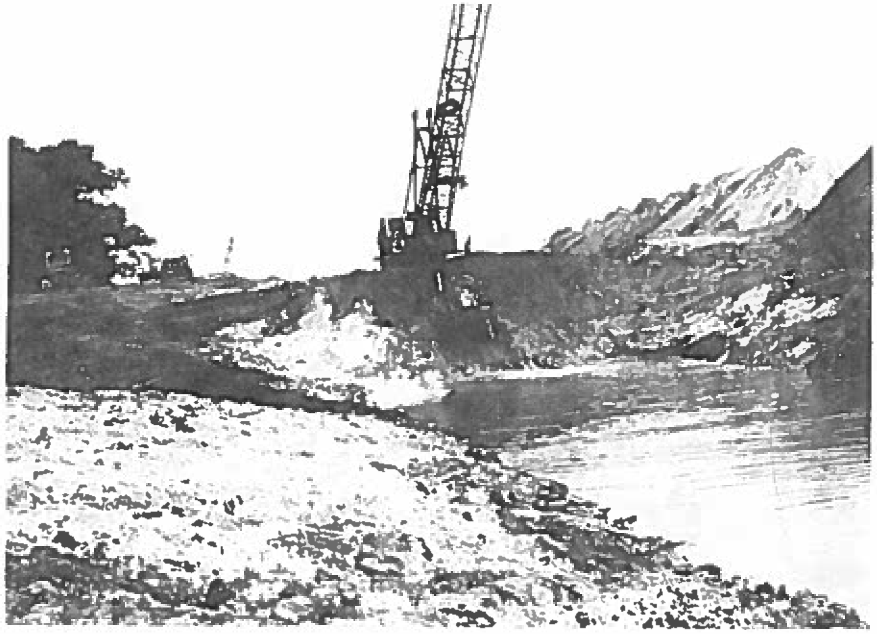
Photo 20: Test plantings of terrestrial type grasses and trees made after initial placement of dike material near northeast corner.

Photo 20: Family of four half-grown brown pelican chicks.

Photo 21: Close up of half grown brown pelican chicks.

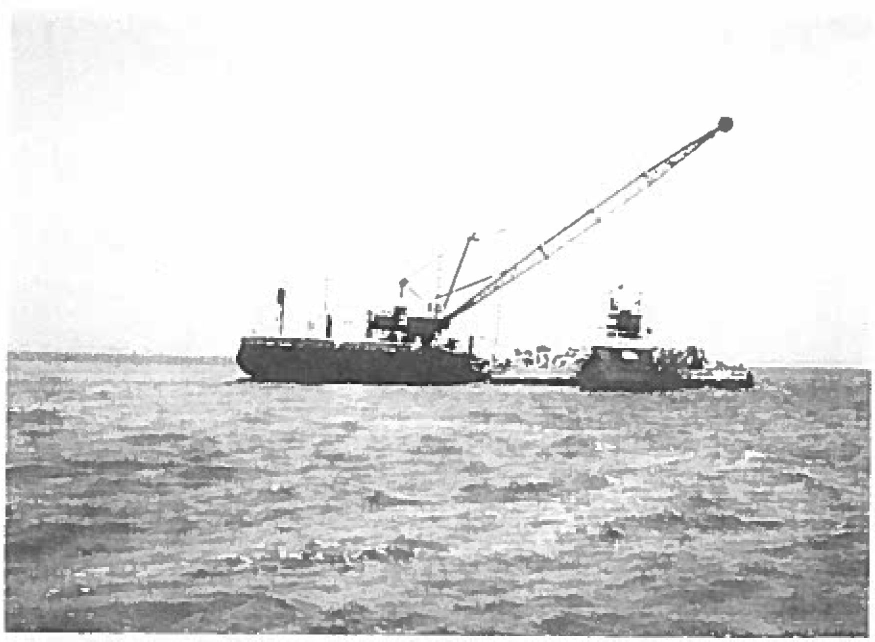
Photo 22: Brown pelican nest on east leg of island dike.

Photo - 1



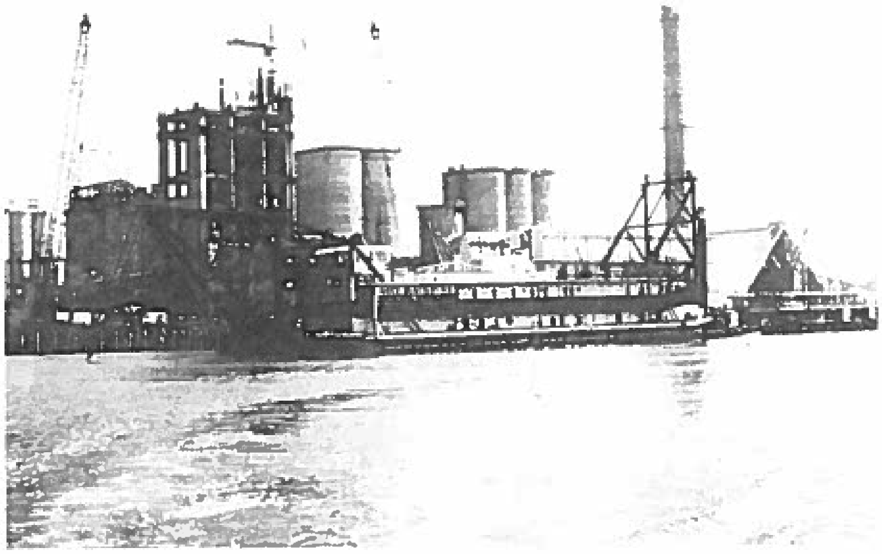
Large dragline with six cubic yard bucket working in Ship Channel land cut; used for loading barges to transport material to the disposal island (Phase I dike).

Photo - 2



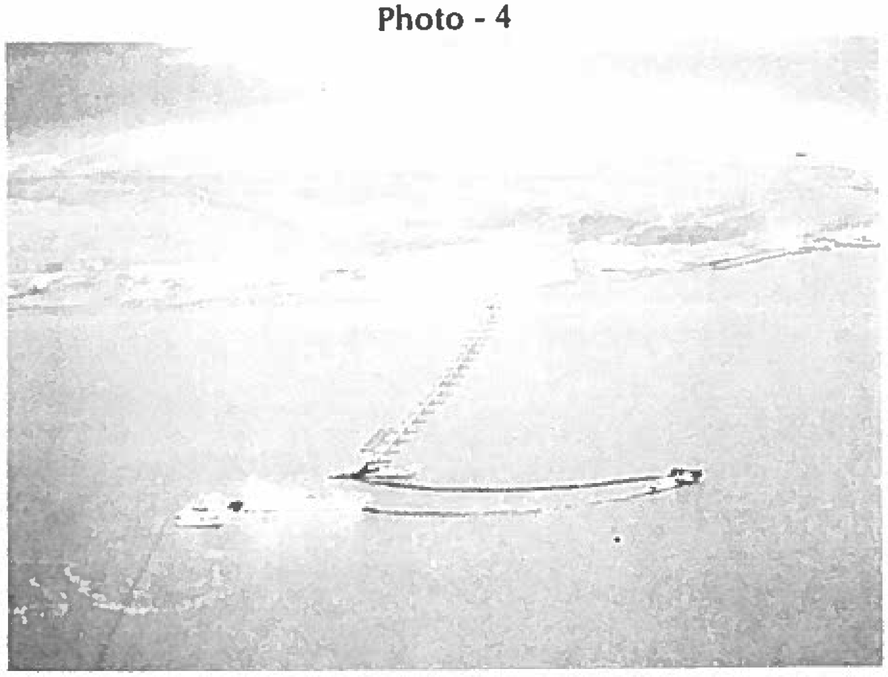
Large dragline mounted on spud barge and equipped with a dozer blade unloading barge for construction of Phase I dike.

Photo - 3



Cutterhead Dredge DAVE BLACKBURN operating in land cut channel near Ideal Cement dock.

Photo - 4



Dustpan Dredge LENEL BEAN operating in bay cut channel depositing material in southwest corner of island.

Photo - 5

Close up of dustpan dredge cutterhead.

Photo - 6

Mud waves around perimeter of emergent disposal island; produced by displacement of soft bottom materials.

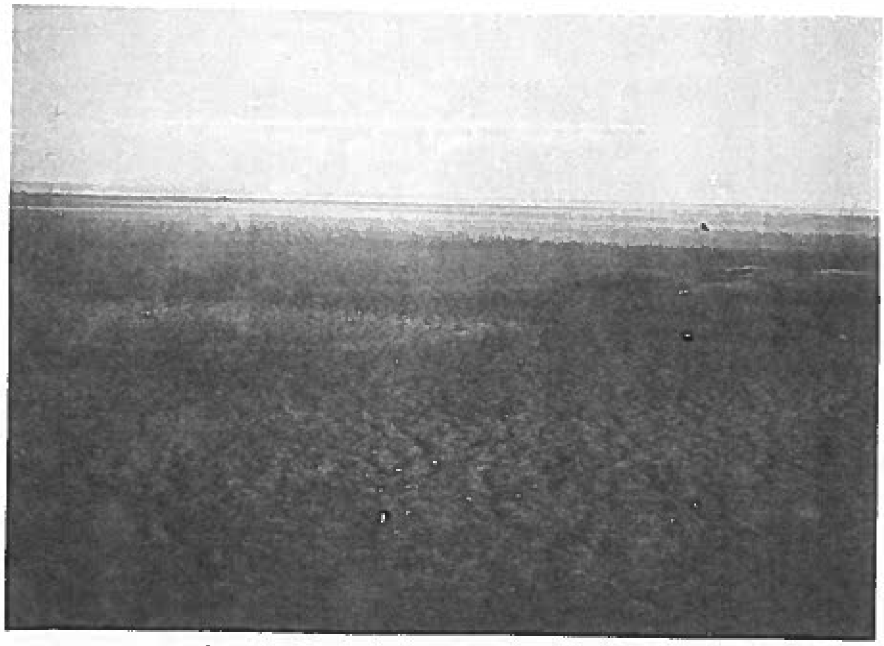
Photo - 7

Discharge pipe arrangement of dustpan Dredge LENEL BEAN.

Photo - 8

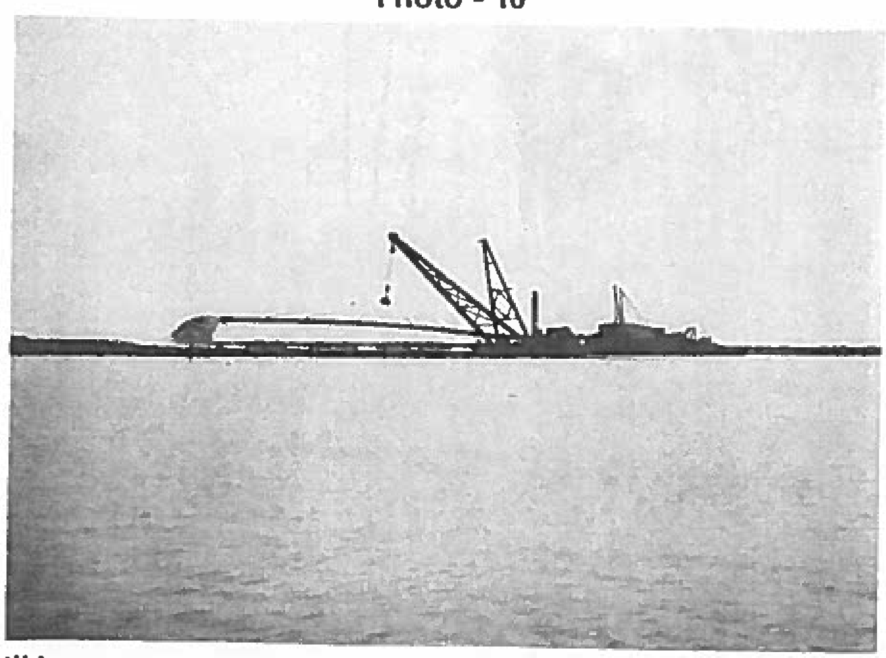
Dustpan material in southeast corner of island shortly after placement.

Photo - 9



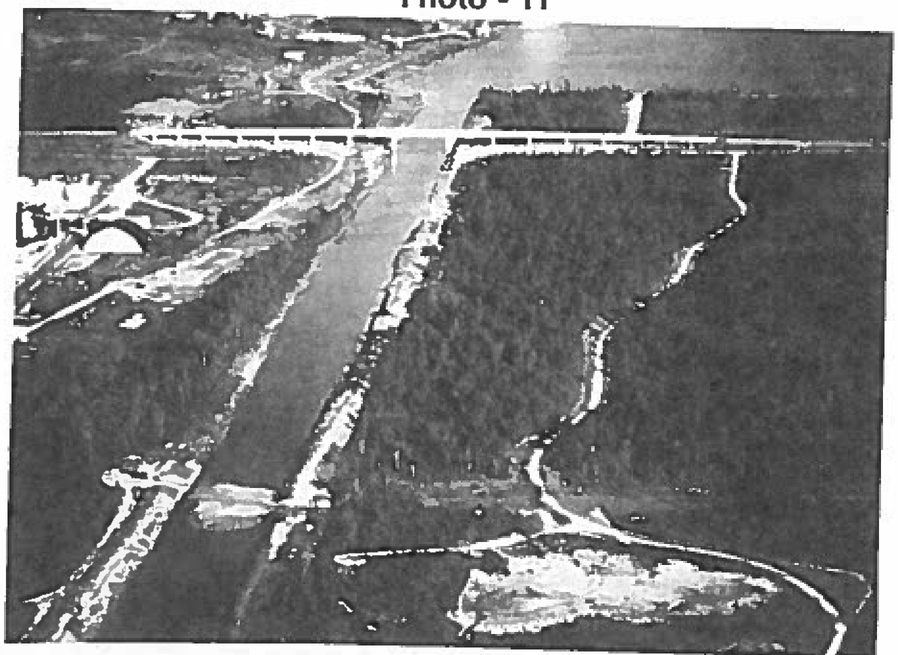
Dustpan material in southeast corner of island after decanting and drying.

Photo - 10



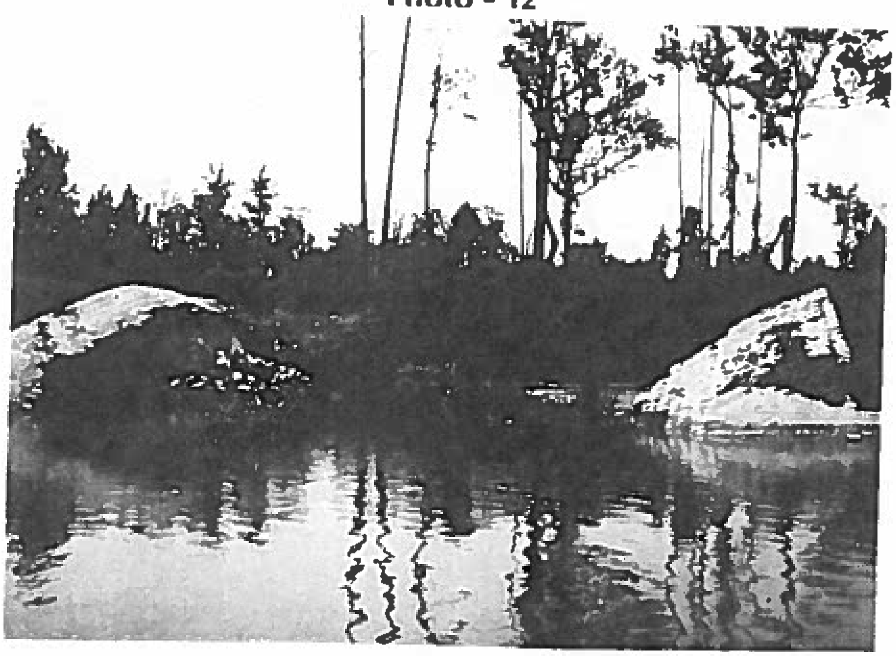
Spill barge with 295 foot reach especially fabricated by contractor for island construction.

Photo - 11



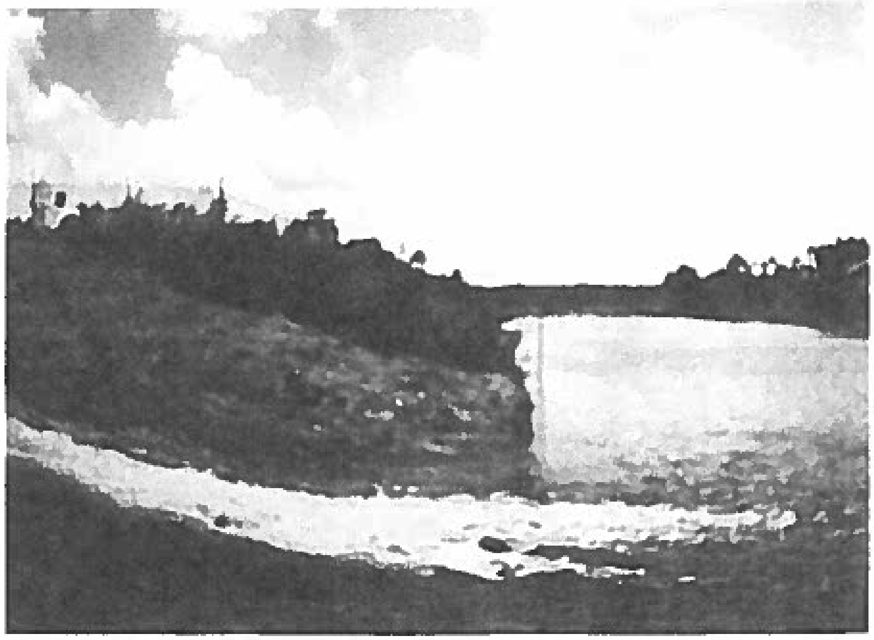
Aerial view of barge canal showing washed out drainage structure at Station 38+70, south side.

Photo - 12



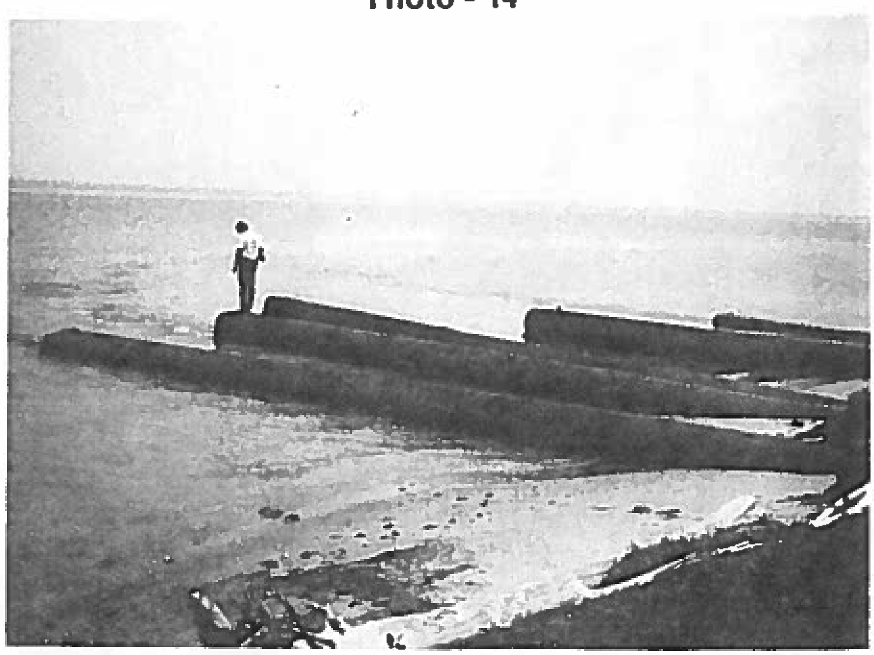
Close up view of washed out drainage structure at Station 38+70.

Photo - 13



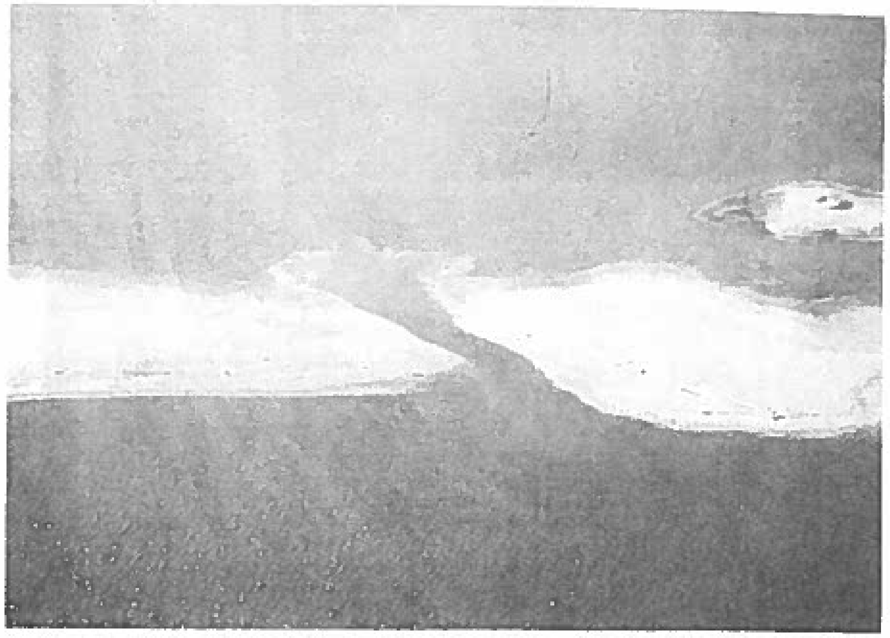
Restoraton and replacement of drainage structure at Station 38+70.

Photo - 14



Steel discharge pipes installed through island dike in December 1983.

Photo - 15

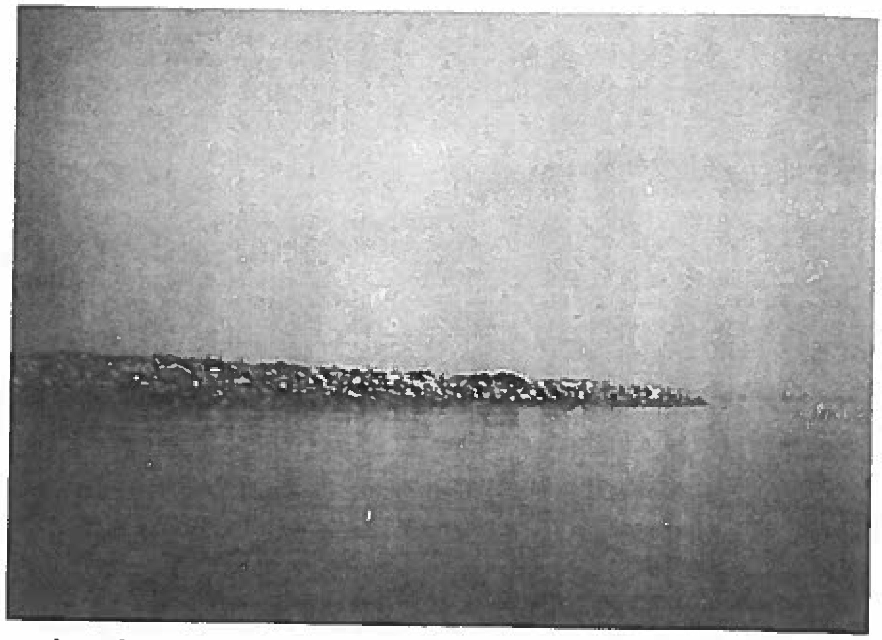


East leg of island dike showing breach which occurred in spring 1982.

Photo - 16

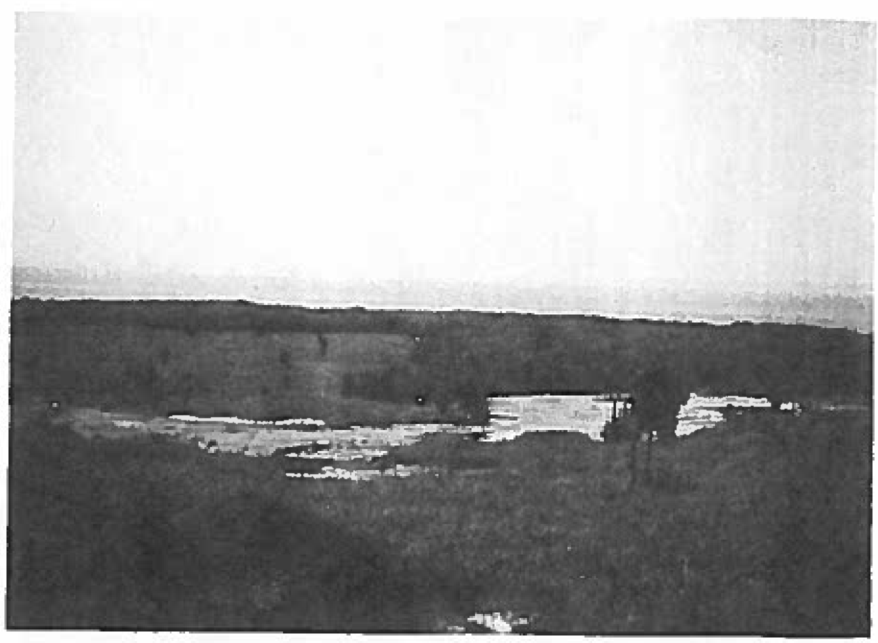
Island shoreline at northeast corner showing characteristic beach slope beneath a clay ball escarpment.

Photo - 17



Completed revetment test section at southeast corner of island.

Photo - 18

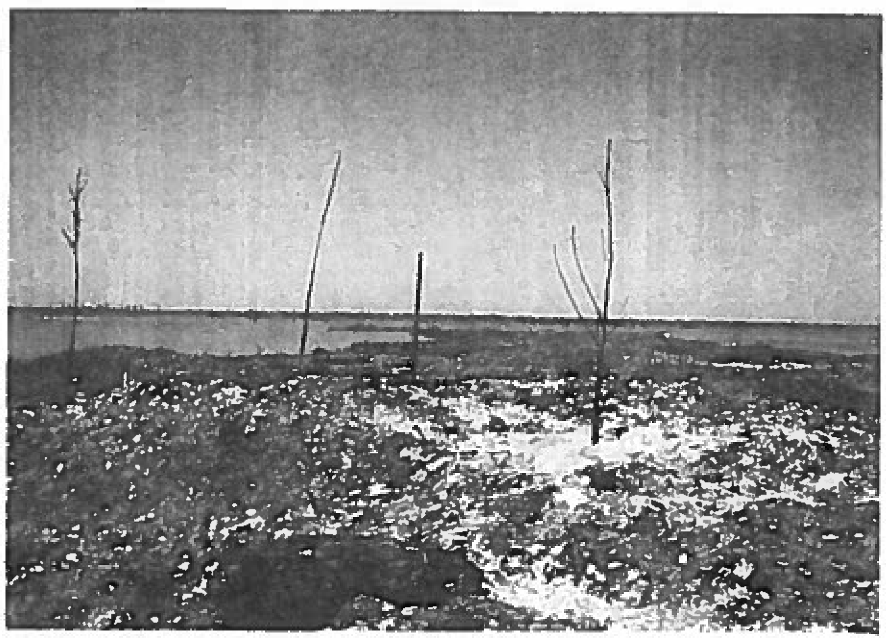


Results of marsh grass planting on west leg of island dike at Station 295+00.

Photo - 19

Close up view of planted marsh grass on west leg island dike.

Photo - 20

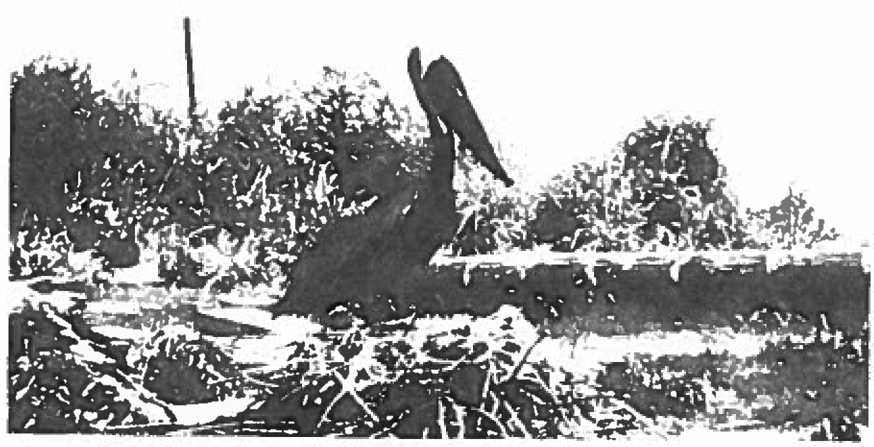


Test plantings of terrestrial type grasses and trees made after initial placement of dike material near northeast corner.

Photo - 21

Family of four half-grown brown pelican chicks.

Photo - 22



Close up of half-grown brown pelican chicks.

Photo - 23

Brown pelican nest on east leg of island dike.

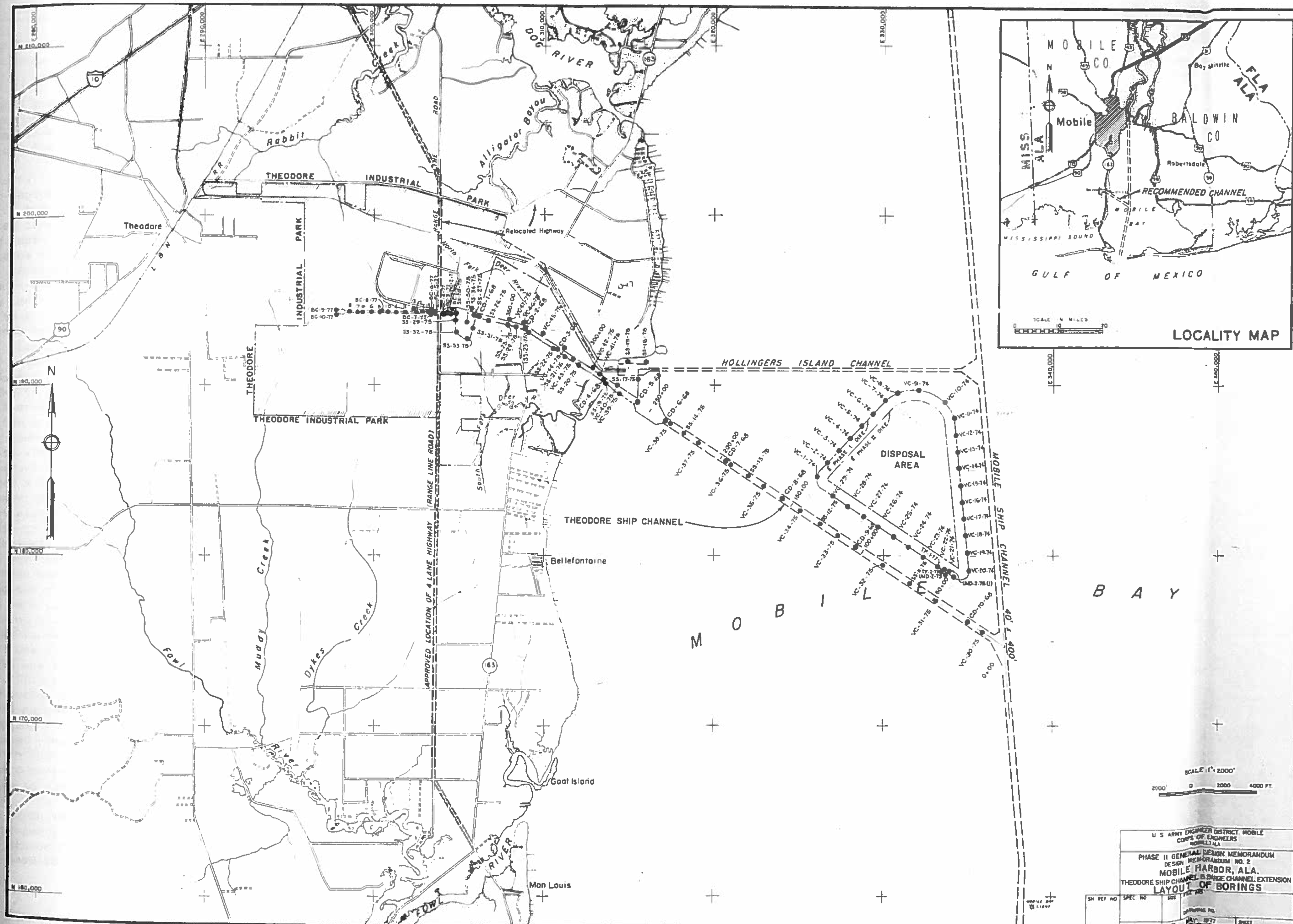
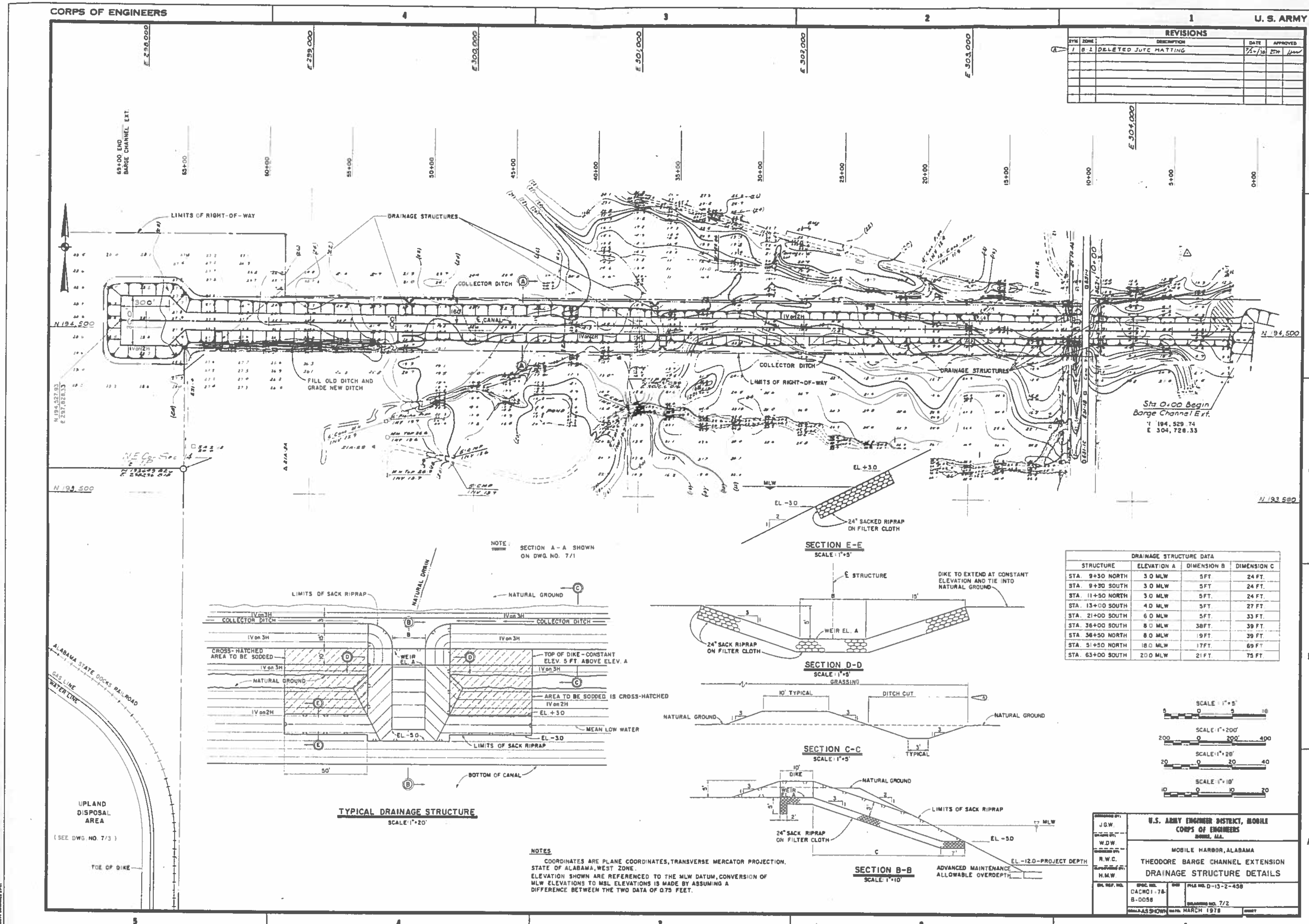

LOCALITY MAP
MOBILE CO
BALDWIN CO
MISS
ALA
FLA
Mobile
Robertsdale
Bay Minette
RECOMMENDED CHANNEL
MOBILE BAY
MISSISSIPPI SOUND
GULF OF MEXICO
THEODORE INDUSTRIAL PARK
Theodore
Relocated Highway
HOLLINGERS ISLAND CHANNEL
DISPOSAL AREA
THEODORE SHIP CHANNEL
MOBILE SHIP CHANNEL 40' x 400'
APPROVED LOCATION OF 4 LANE HIGHWAY (RANGE LINE ROAD)
DOG RIVER
Alligator Bayou
Rabbit Creek
Fowl River
Muddy Creek
Dykes Creek
Bellefontaine
Goat Island
Mon Louis
MOBILE BAY
SCALE 1" = 2000'
U S ARMY ENGINEER DISTRICT, MOBILE
CORPS OF ENGINEERS
MOBILE, ALA.
PHASE II GENERAL DESIGN MEMORANDUM
DESIGN MEMORANDUM NO. 2
MOBILE HARBOR, ALA.
THEODORE SHIP CHANNEL & BARGE CHANNEL EXTENSION
LAYOUT OF BORINGS
MAY 1977

FIGURE 5



DRAINAGE STRUCTURE DATA			
STRUCTURE	ELEVATION A	DIMENSION B	DIMENSION C
STA. 9+30 NORTH	3.0 MLW	5 FT	24 FT.
STA. 9+30 SOUTH	3.0 MLW	5 FT	24 FT.
STA. 11+50 NORTH	3.0 MLW	5 FT.	24 FT.
STA. 13+00 SOUTH	4.0 MLW	5 FT	27 FT
STA. 21+00 SOUTH	6.0 MLW	5 FT.	33 FT.
STA. 36+00 SOUTH	8.0 MLW	38 FT.	39 FT
STA. 36+50 NORTH	8.0 MLW	19 FT	39 FT
STA. 51+50 NORTH	18.0 MLW	17 FT.	69 FT
STA. 63+00 SOUTH	20.0 MLW	21 FT.	75 FT.

NOTES

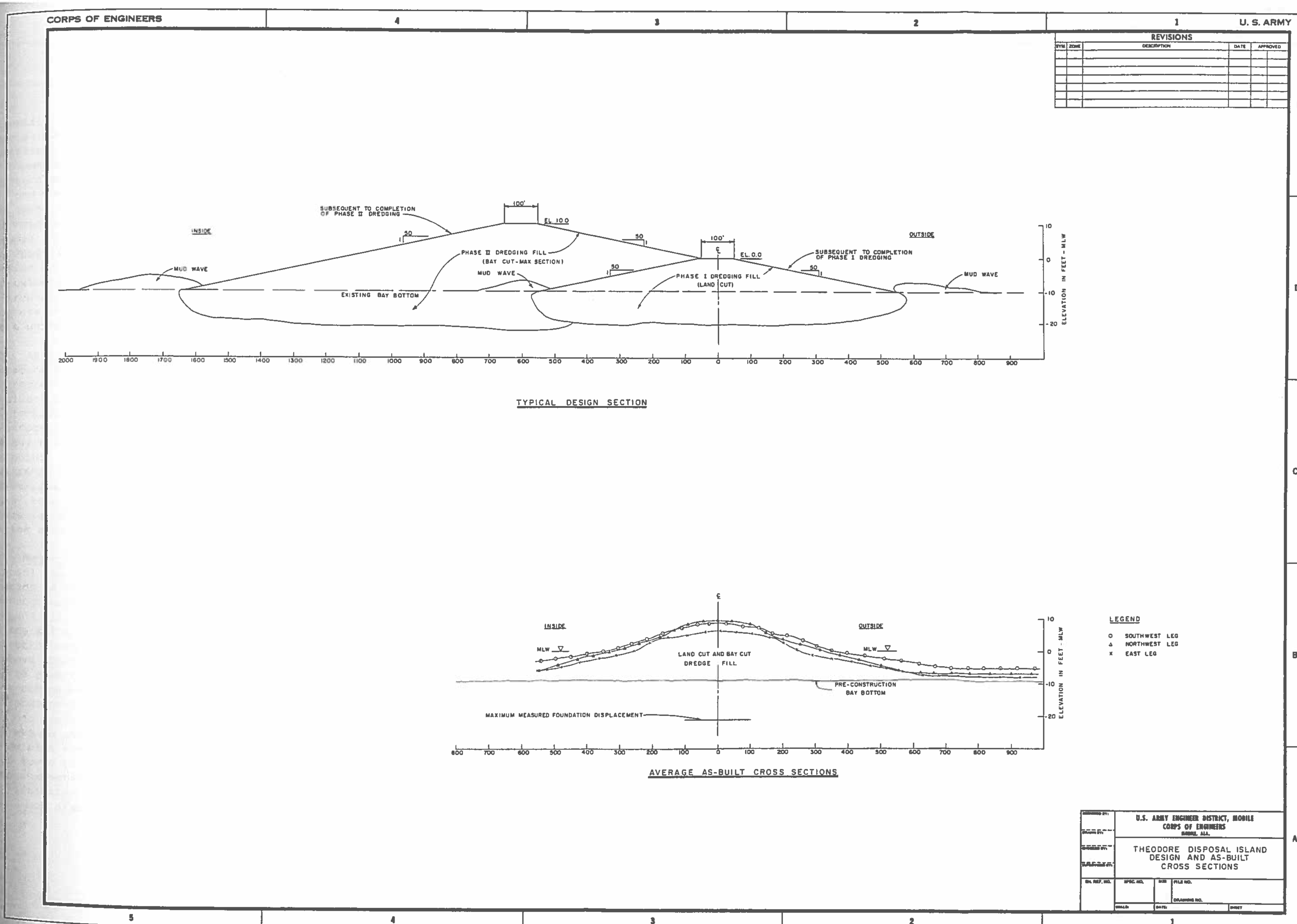
COORDINATES ARE PLANE COORDINATES, TRANSVERSE MERCATOR PROJECTION, STATE OF ALABAMA, WEST ZONE.
ELEVATION SHOWN ARE REFERENCED TO THE MLW DATUM, CONVERSION OF MLW ELEVATIONS TO MSL ELEVATIONS IS MADE BY ASSUMING A DIFFERENCE BETWEEN THE TWO DATA OF 0.75 FEET.

U.S. ARMY ENGINEER DISTRICT, MOBILE
CORPS OF ENGINEERS
MOBILE, ALA.

MOBILE HARBOR, ALABAMA
THEODORE BARGE CHANNEL EXTENSION
DRAINAGE STRUCTURE DETAILS

J.G.W. — W.D.W. — R.W.C. — H.M.W.
SPEC. NO. DACW01-78-B-0058
FILE NO. D-13-2-458
DRAWING NO. 7/2
SCALE: AS SHOWN DATE: MARCH 1978

FIGURE 6



CORPS OF ENGINEERS
U. S. ARMY
REVISIONS
SYM | ZONE | DESCRIPTION | DATE | APPROVED
INSIDE
OUTSIDE
SUBSEQUENT TO COMPLETION OF PHASE II DREDGING
SUBSEQUENT TO COMPLETION OF PHASE I DREDGING
100'
EL. 10.0
EL. 0.0
50
1
MUD WAVE
PHASE II DREDGING FILL (BAY CUT-MAX SECTION)
PHASE I DREDGING FILL (LAND CUT)
EXISTING BAY BOTTOM
ELEVATION IN FEET - MLW
TYPICAL DESIGN SECTION
MLW
LAND CUT AND BAY CUT DREDGE FILL
PRE-CONSTRUCTION BAY BOTTOM
MAXIMUM MEASURED FOUNDATION DISPLACEMENT
AVERAGE AS-BUILT CROSS SECTIONS
LEGEND
o SOUTHWEST LEG
Δ NORTHWEST LEG
x EAST LEG
U.S. ARMY ENGINEER DISTRICT, MOBILE
CORPS OF ENGINEERS
MOBILE, ALA.
THEODORE DISPOSAL ISLAND
DESIGN AND AS-BUILT
CROSS SECTIONS

FIGURE 7