# APPENDIX B ENGINEERING SAVANNAH HARBOR EXPANSION FEASIBILITY STUDY

Georgia Ports Authority

**July 1998**

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## 3. INTRODUCTION

The existing navigation channel for the Savannah Harbor project was designed for Panamax vessels drafting 38 feet. Presently, vessels drafting in excess of 38 feet are using the harbor and future vessels having design drafts of 46 feet and beams of 140 feet (post-Panamax) are expected to call on the Port of Savannah. A deeper channel is required for safe and efficient operation of vessels this size.

Engineering studies for the Savannah Harbor Expansion project focused on deepening the existing authorized channel by 8 feet and adding bend wideners at selected locations to accommodate the design vessel. Alternatives to deepen the channel 2, 4, and 6 feet have also been included in the engineering studies. However, the detailed designs have been prepared for the deepest, 50-foot, alternative at the request of the study sponsor. The entrance channel will require an extension for any alternative depth selected. Table 2-1 shows the length of the required channel extension for each depth. The entrance channel will be 2 feet deeper than the inner harbor to account for wave and swell conditions which exist in the unprotected offshore area.

**Table 3-1 Entrance Channel Extensions**

| Required Depth FT, MLW | Extension FT |
|---|---|
| 46 | 1,500 |
| | |
| 48 | 15,000 |
| | |
| 49 | 21,000 |
| | |
| 50 | 22,000 |
| | |
| 52 | 25,000 |

The proposed expansion also includes deepening and widening the Kings Island turning basin that is located between Stations 101+500 and 99+000. The total length of harbor improvements will be approximately 35.6 miles.

The conclusions presented in this Engineering and Design Appendix are based on previous studies, studies performed specifically for this project, field investigations, laboratory analyses, available data, and engineering experience in the project area. Additional studies will be conducted during the Continuing Engineering and Design (CED) phase of the expansion project. These studies will develop information for the analysis and resolution of issues which cannot be resolved with the currently available data and information.

The major design elements evaluated in this phase of the study were the existing and proposed channel alignment; characteristics of the design vessel expected to use the project, the geology and character of the soils in the channel and along the riverbanks, impacts to the groundwater aquifer, and the dredged material disposal areas. Extensive detailed numerical modeling has also been performed of the project area to determine the potential impacts the deepest study alternative may have on the adjacent coastline and to the velocity, salinity, and water quality in the estuarine area which surrounds the navigation channel. Results of the modeling are presented in Reference 2.1. This engineering appendix to the Feasibility Report summarizes the results of the engineering studies and presents the basis of the project design.

## 4. REFERENCES

The following manuals, reports, and documents were used in the design and cost estimating for the expansion project:


2.1 Hydrodynamic and Water Quality Modeling of the Lower Savannah River Estuary, February, 1988, Applied Technology and Management, Inc.

2.2 EM 1110-2-1613, "Hydraulic Design Guidance for Deep-Draft Navigation Projects".

2.3 EP 1130-2-520, "Navigation Dredging Operations and Maintenance Guidance and Procedures".

2.4 "Potential Ground-Water Impacts Report", U.S. Army Corps of Engineers, Savannah District, March, 1998.

2.5 ER 1110-2-1461, "Design of Navigation Channels Using Ship Simulator Techniques".

2.6 Technical Report CHL-97-1, "Ship Navigation Simulation and Current Modeling Study, Savannah River, Georgia", January, 1997.

2.7 Preliminary Coastal Erosion Study, Savannah Harbor Deepening, November 4, 1997, Applied Technology and Management, Inc.

2.8 ER 1165-2-131, "Local Cooperative Agreements for New Start Construction Projects".

2.9 Savannah Harbor Long Term Management Strategy, August 1996, U.S. Army Corps of Engineers, Savannah District.

2.10 Alternative Ocean Dredged Material Placement Study – Savannah Harbor Deepening, December 31, 1997, Applied Technology and Management, Inc.

2.11 Volume 2, Results of Prototype Investigations of Savannah Harbor Investigation & Model Study, Corps of Engineers, Savannah, Georgia, July 1961.

2.12 Technical Bulletin No. 8, "Channel Depth as a Factor in Estuarine Sedimentation, March, EM 1965, Committee on Tidal Hydraulics, Corps of Engineers, U.S. Army".

2.13 Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, February, 1998, Applied Technology and Management, Inc.

2.14 "Marine Origin of Savannah River Estuary Sediments: Evidence from Radioactive and Stable Isotope Tracers" by Patrick J. Mulholland and Curtis R. Olsen, Oak Ridge National Laboratory, 10 May 1991. Published in Estuarine, Coastal and Shelf Science Magazine, 1992.

2.15 Instruction Report EL-96-XX, November, 1996, "Program Documentation and User's Guide: PSDDF Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill, U.S. Army Corps of Engineers".

2.16 ER 5-1-11, Project Management.

2.17 ER 1110-2-1150, Engineering and Design for Civil Works Projects.

2.18 ER 1110-2-1302, Civil Works Cost Engineering, dated 13 Mar 94.

2.19 EM 1110-1-1, Engineering and Design, Geotechnical Manual for Surface and Subsurface Investigations.

2.20 EM 1110-2-1802, Geophysical Exploration.

2.21 EM 1110-2-1902, Slope Stability for Earth and Rockfill Dams.

2.22 EM 1110-2-1906, Laboratory Testing.

2.23. Instruction Report K-84-3, User's Guide: Modified Slope Stability Package with Kansas City Analysis (DGSLOPE).

# 5. EXISTING AUTHORIZED PROJECT

## 5.1. Project Dimensions

Savannah Harbor is presently authorized for an inner harbor channel 400 feet wide at elevation -42 feet, mean low water (MLW), between Stations 103+000 and 100+000 and 500 feet wide at elevation -42 feet, MLW, between Stations 100+000 and 0+000; and an entrance channel 500 feet wide at elevation -42 feet, MLW, between Stations 0+000 and -14+000B and 600 feet wide at elevation -44 feet, MLW, between Stations -14+000B and -60+000B. Bend wideners have been constructed at several locations to permit safe navigation of deep-draft ships. The most significant widener is located in the inner harbor between Stations 50+000 and 42+000 in the Bight Channel. This reach of the channel is a tight, U-shaped turn where the tidal flows affect the handling of the vessel because the hull of the vessel is at an angle to the currents.

Advanced maintenance has been authorized in Savannah Harbor. It is the additional depth specified to be dredged beyond the authorized project dimensions for the purpose of reducing overall maintenance costs by decreasing the frequency of dredging. The district's Operations and Maintenance (O&M) appropriations funded the initial and subsequent dredging of advance maintenance. The existing project dimensions and authorized advance maintenance depths are listed in Table 4-1.

**Table 5-1 Existing Project Dimensions**

| Station | Project Depth (-FT, MLW) | Bottom Width (FT) | Advance Maintenance (FT) | Maintenance Dredging Depth (-FT, MLW) |
|---|---|---|---|---|
| 103+000 | | | | |
| | 42 | 400 | 0 | 42 |
| 102+000 | | | | |
| | 42 | 400 | 2 | 44 |
| 100+000 | | | | |
| | 42 | 500 | 2 | 44 |
| 79+000 | | | | |
| | 42 | 500 | 2 | 44 |

| | | | | |
|---|---|---|---|---|
| 70+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 50+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 41+000 | | | | |
| | 42 | 500 | 4 | 46 |
| 24+000 | | | | |
| | 42 | 500 | 2 | 44 |
| 0+000 | | | | |
| | 42 | 500 | 2 | 44 |
| -14+000B | | | | |
| | 44 | 600 | 0 | 44 |
| -60+000B | | | | |

Six feet of additional advance maintenance is presently being dredged in the Kings Island turning basin. It is anticipated that this work will be completed prior to commencement of expansion dredging. Upon completion of this work, the turning basin will have a total of 8 feet of advance maintenance. Two feet of advance maintenance has also been authorized in the entrance channel between Stations 0+000 and –14+000B. This new work advance maintenance has been included in an FY98 maintenance dredging contract and the construction will be completed prior to commencement of expansion dredging.

### 5.2. Operational Procedures

According to the design criteria contained in Reference 2.2, the existing navigation channel is not presently designed to provide two-way traffic for all vessels using the project. However, the harbor pilots indicated that they have instituted their own system of traffic control that allows them to have two-way traffic in certain reaches. The traffic control system generally consists of the pilots onboard any vessel under way being in constant contact with pilots on other moving vessels. This permits the pilots to adjust the speed of the vessel and time meetings when the vessels are in reaches where the currents, channel banks, and/or other moored vessels do not affect the handling of the vessels under way. According to the pilots, deep draft vessels avoid meeting in the City Front Channel (approximately Stations 80+000 to 70+000) and in the Bight Channel (approximately Stations 55+000 to 40+000). These are areas where ships are aligning to transit under the Talmadge Bridge or tidal currents affect ship handling. The harbor pilots also indicated that they require four feet of underkeel clearance to move a vessel. Vessels drafting more than 38 feet will wait for the proper stage of the tide to provide the desired underkeel clearance.

In discussions held with the pilots and the Coast Guard, each indicated a need for a "safe haven" area. Under the without project conditions, once a vessel begins an inbound or outbound transit, it is committed to completing the entire transit. There are no areas along the channel to turn a large vessel except the Kings Island turning basin, which is located at the upper end of the project, or to moor a vessel which becomes disabled during transit so that it will not block the channel, except in a berth which may be vacant. When a vessel in transit is east of Old Fort Jackson, there is no place to moor a disabled vessel without blocking the channel. Suggestions to provide a safe haven area included dredging a widener at a selected location along the channel or increasing the length and depth in one of the existing turning basins. There have been groundings in the harbor in the past. However, most groundings have been the result of loss of power or rudder by the ship. None of the incidents have resulted in the ship completely blocking the channel. Further consideration of a "safe haven" area was determined to be uneconomical and it was dropped from further consideration.

The harbor pilots indicated there are reaches in the channel where they are presently having difficulty maneuvering deep draft vessels. One area is the bend in the vicinity of Station 36+000. They indicated that the currents on the outside of this bend affect vessels on an inbound transit and additional width would help them navigate through this reach. Also the reach between Stations 72+000 and 59+000 is difficult to navigate on the north side during certain stages of the tide. Additional width through this turn would be beneficial.

The docking pilots expressed concern over the size and depths in the existing turning basins. However, the proposed design vessel would not be calling at terminal facilities which use these turning basins, and it was determined that they would not be included in this study. Another concern of the docking pilots was the width of the Kings Island turning basin. They felt that the basin should be wider to accommodate turning the expansion design vessel when vessels are moored across the river from the turning basin in Container Berths (CB) 1 and 2. The docking pilots also expressed concern that turning a vessel moored at the new berth CB-7, presently under construction by the Georgia Ports Authority, would be difficult. CB-7 is located upstream of the Kings Island turning basin and vessels would have to be backed one way between the berth and the turning basin.

### 5.3. Operation and Maintenance Practices

Maintenance dredging in the entrance channel and inner harbor is performed regularly in Savannah Harbor. Dredging is performed in accordance with the practices and procedures outlined in Reference 2.3. Maintenance dredging in the entrance channel is performed by hopper dredges which generally work from December through March of each year. Dredging is restricted to this period to minimize the impact dredging has on endangered sea turtles. Material is placed in the EPA approved offshore disposal site which is shown on Figure 1. Material dredged from the inner harbor is placed in the eight existing upland, confined disposal areas which are also shown on Figure 1. Pipeline dredges perform maintenance dredging in the inner harbor. At the present time, dredging upstream of Mile 12 (approximately Station 63+360) cannot be performed between 15 March and 30 May of each year. This restriction is imposed by the Georgia Department of Natural Resources to protect the spawning of striped bass in the upper estuary of the harbor. Maintenance dredging is generally being performed in the harbor throughout the year except during the restricted times.

Monthly project condition surveys are performed in the channel to assist in planning and directing the operation of maintenance dredges. The results of these surveys are also furnished to the harbor and docking pilots, towing companies, and other navigation and shipping interests. When a shoal 2 feet or more in height above the authorized project depth occurs in any two adjacent quarters of the channel, the contractor is directed to remove the shoal.

Long-term, historical dredging records indicate that the average annual shoaling rate in Savannah Harbor is approximately 7,240,000 cubic yards (CY) per year. This rate has remained more or less constant over the last 45 years. The estuary appears to be in equilibrium, and the inflow from upstream is controlled by a series of major reservoirs. Savannah District constructed and operated a tide gate structure and sediment basin in the Back River between 1975 and 1991. This feature shifted a significant portion of the shoaling from the navigation channel in the Front River to the sediment basin in the Back River. During the period of time the tide gate was functioning, approximately 3.9 million CY, or 54 percent, of the 7.24 million CY of maintenance material dredged from the project was removed from the sediment basin. In 1992, New Cut, which was the connecting channel between Front and Back Rivers, was closed as a separate authorized Section 1135 project. As a result of this closure, the tide gates could not be operated and they were taken out of service. The sediment basin still traps maintenance material and is periodically dredged. However, the basin now only traps approximately 2.4 million CY, or 40 percent, of the total volume of material removed from the inner harbor. The remainder of the material shoals in the navigation channel. Material is easily removed from the sediment basin and is placed in adjacent diked disposal areas at a considerable cost savings compared to the cost of removing the material from the navigation channel.

Advance maintenance dredging has been the procedure used in Savannah Harbor to reduce the frequency and cost of periodic maintenance dredging requirements. The locations and depths of approved advance maintenance are listed in Table 4-1. Without this practice, it would be difficult and more costly to provide a navigable project for vessels drafting 38 feet. The shoaling locations in the navigation channel have changed since New Cut was closed and the need for additional advance maintenance in the harbor has been evaluated. The Kings Island turning basin functions as a sediment trap in the upper reaches of the harbor and 6 feet of additional advance maintenance has been approved. The initial dredging of this advance maintenance will be completed prior to the commencement of expansion dredging. Two feet of additional advance maintenance dredging will be completed in FY98 between Stations 0+000 and -14+000B in the entrance channel.

The confined disposal areas used for dredging the inner harbor are Areas 1N, 2A, 12A, 12B, 13A, 13B, 14B, and Jones/Oysterbed Island. Construction and maintenance of the dikes in these areas is the responsibility of the local assurer for the existing project. Descriptions of each of the areas, its acreage, and a capacity analysis of each area are included in the Dredged Material Management Plan section.

**5.4. Obstructions and Crossings**

Two significant cultural resources exist adjacent to the navigation channel between Stations 59+000 and 58+000. Old Fort Jackson is a masonry civil war structure located on the south bank of the river. The bank on either side of the fort has a history of erosion problems. Since the 1970's, the Corps has pumped dredged material around the fort to raise the ground elevation to reduce flooding, placed riprap on the riverbank adjacent to the fort property, and constructed a steel sheet pile wall at the intake structure which controls the flow of water in the moat. The moat wall of the fort sits on the riverbank and has been hit by a ship on one occasion. The remains of the *CSS Georgia*, a civil war ironclad, are located on the north side slope of the navigation channel across the river from Old Fort Jackson.

Studies were conducted to define the limits of the wreck site, gather information to support the National Register nomination, assess impacts of maintenance dredging operations, and investigate alternatives for avoidance, lessening impacts, or mitigation. Maintenance dredging operations were modified to lessen impacts to the remains of the wreck.

An analysis of the stability of the side slopes at the *CSS Georgia* was performed as part of the engineering studies for the previous deepening project. It was determined that the side slope on the north side of the channel would remain stable if dredging were not performed. Since this reach had 4 feet of advance maintenance, it was determined that no deepening would be required between Stations 59+000 and 58+000. Maintenance dredging has not been performed in this 1,000-foot reach within 100 feet of the north toe since completion of the last deepening.

In addition to the cultural resources adjacent to the channel, there are submerged pipe crossings, one highway bridge, and one overhead electric powerline which cross the navigation channel within the proposed expansion limits. None of these structures presently impact performance of maintenance dredging in the project. Dredges exercise extreme care, however, when dredging in the vicinity of two 30-inch submerged natural gas pipelines located at approximately Station 51+500. These are pressurized pipes and dredges are not allowed to set anchors and/or drop spuds near them when they are performing maintenance dredging. Dredging inspectors and personnel from Southern Natural Gas Company constantly monitor the position of the dredge and the dredge anchors when contractors work in this area.

## 5.5. Site Geology

### 5.5.1. General.

The project area is underlain with unconsolidated and partly consolidated Atlantic Coastal Plain sediments. These sediments generally consist of unconsolidated to semi-consolidated layers of sand and clay; and semi-consolidated to very dense limestone and dolomite and can achieve thicknesses of about 5,500 feet. They range in age from late Cretaceous (approximately 100 million years old) to Recent, or Holocene. The Atlantic Coastal Plain sediments overlie sedimentary strata and volcanics of Triassic age to early Jurassic age (approximately 230 million years old to about 170 million years old, respectively). These rocks overlie crystalline basement rocks of Paleozoic age (from 680 to 230 million years old) consisting of igneous intrusives and low-grade metamorphic rocks. The rock record is not continuous, and time gaps exist where either no sediment deposition occurred or where erosional forces removed the rock record. In the project area, the post-Cretaceous sediments (those deposited within the last 65 million years) are estimated to be about 1,800 to 2,500 feet thick. A discussion of the post-Cretaceous Atlantic Coastal Plain sediments follows, in descending order of occurrence. For the purpose of this discussion, the strata will be referred to based on time-rock units (i.e., rocks deposited during the same geologic time division).

### 5.5.2. Post-Miocene Units

The post-Miocene units consist of sediments deposited during the Pliocene, Pleistocene, and Holocene (Recent) geologic ages (12 million years old and younger). These sediments are comprised of interbedded floodplain deposits of reworked alluvial and beach material and reworked Miocene sediments. Typically, these floodplain sediments are tan, gray, or greenish gray in color.

The post-Miocene unit sediments are found at the surface throughout the area and extend to a depth of approximately 45 feet, though they reach thicknesses of 200 feet in the Brunswick, Georgia area. They consist of phosphatic, micaceous, and clayey sands of Pliocene age; feldspathic sands and gravel with clay beds of Pleistocene age; and varying mixes of clays, silts, sands and gravels of Holocene age. There is very little fossil material in these sediments. In some areas, Pliocene and Pleistocene sediments may be missing from the geologic record. It is uncertain if these sediments exist within the project area.

The Holocene (Recent) sediments generally consist of varying mixtures of clays, silts, sands and, occasionally, gravels. Within the project area, these sediments are represented by low and high liquid-limit clays with varying amounts of sand and organic matter (CL and CH); inorganic, low and high liquid-limit silts (ML and MH); silty sands containing up to 40 percent silts, some clay and mica (SM); and cleaner, poorly graded sands containing less than 12 percent silts (SP-SM and SP). The consistency of the fine-grained soils (silts and clays) can be described as very soft to soft. The coarse-grained soils (sands) can be described as very loose to dense, with the majority being medium. The materials are somewhat cohesive when small amounts of silt or clay are present; however, they tend to slough below the water table when there is little fine material.

The Holocene materials were carried from topographically high areas from the Piedmont and upstream Coastal Plains and deposited during the formation of the floodplain of the Savannah River. The sediments are mixed by hydraulic action of the waters in the river and by erosion and re-deposition of the riverbank and river shoals as the river meanders. There is no active method for sediment accumulation beyond the banks of the river. Consequently, with the exception of accumulations of organic material, there are no materials being deposited there.

#### 5.5.3. Miocene Units

According to Clarke and others (1990), the Miocene units (20 to 12 million years old) can be subdivided into three sub-units (Miocene unit A, B and C), each consisting of three geologically similar beds. The lowest bed of each sub-unit consists of a basal carbonate layer of sandy, phosphatic limestone or dolomite. The basal carbonate layer is overlain by a layer of inter-laminated silty clay and clayey silt. The upper beds consist of sand layers of poorly sorted, very fine to granule sized quartz sand with some phosphatic and dolomitic grains. Each three-bed unit is separated from the beds above and below it by an erosional surface, or unconformity.

The Miocene units at the project extend to a depth of approximately 220 feet in the upper reaches of the project area. They can achieve a thickness of about 470 feet along the coastal area, but range from about 60 to 175 feet thick under the project area. Miocene Unit C, the lowest unit, appears to be missing in the project area.

The beds of the Miocene were deposited during transgressions and regressions (rising and lowering) of the sea. The basal carbonates were deposited in open marine water during full transgressions. During this time, the land surface was at its greatest depth below the water surface. As the sea regressed, the interlayered silts and clays were deposited in a shallower, nearshore environment that allowed for the settling of the fine silts and clays. In this environment, coarser materials were already removed from the sediment and calcareous materials were not a major contributor. The upper sand beds were deposited in a shallow water, nearshore environment. At this time, the water was at its shallowest. Materials deposited during the period the sea transgressed inland were, apparently, removed during some erosional event. As the next sea regression occurred, the next sequence of beds was deposited until the final sequence, Miocene Unit A, was deposited.

### 5.5.4. Oligocene Unit

Sediments of the Oligocene units were deposited between 35 and 20 million years ago. This unit can be as thick as 120 feet, and in some areas it is missing. The unit is estimated at approximately 60 thick under the project area, based on geophysical data.

The Oligocene unit sediments are typically tan colored limestones with varying amounts of micrite (dense, non-porous limestone), fine fossil foraminifera shells, and silt and clay-sized phosphate. The sediments were deposited in an offshore mounded carbonate bank environment, with some sand material being deposited where the bank nears the shore.

### 5.5.5. Eocene Units

The Eocene sediments, deposited between 55 and 35 million years ago, are subdivided into three sub-units: the upper, middle, and lower Eocene units.

#### 5.5.5.1. Upper Eocene Unit

The upper Eocene unit throughout most of the coastal area of Georgia consists of the massive, fossiliferous, Ocala Limestone. There is some glauconite at the base of the unit and an increase in clastic material in the northern coastal areas, including the project area. This unit is more than 200 feet thick throughout the coastal area, and achieves a thickness of 400 feet in some areas. These sediments were deposited in a warm, shallow water, nearshore carbonate bank environment, similar to the other Eocene units.

#### 5.5.5.2. Middle Eocene Unit

The middle Eocene unit is separated from the lower unit by an erosional surface, or unconformity. It is lithologically similar to the lower unit, and can be distinguished based on the abundance of microfossils. The upper beds of this unit are more dolomitic than the upper beds of the lower unit and contrast with the lower limestone beds of the upper Eocene unit. This unit can be up to 1,000 feet thick in some areas. At Hutchinson Island and Fort Pulaski, near Savannah, Georgia, the unit is 700 and 540 feet thick, respectively. This unit is most likely more than 700 feet thick in the study area. These sediments were deposited in an environment similar to that of the lower Eocene unit.

#### 5.5.5.3. Lower Eocene Unit

This unit unconformably overlies the Paleocene unit below it. It consists of carbonate sediments, predominantly glauconitic limestones and dolomites, with sand beds in the upper part. These beds attain a thickness of up to 800 feet in the southern coastal area of Georgia but are only 120 to 180 feet in the project area. This unit was deposited in a nearshore warm, shallow, open marine environment.

### 5.5.6. Paleocene Unit

Sediments of the Paleocene unit were deposited between 65 and 55 million years ago. The Paleocene unit in the northern coastal Georgia area consists of glauconitic sand, argillaceous sand, and medium to dark gray clays. The uppermost beds of the unit consist of a hard, sandy, glauconitic, fossiliferous limestone. The Paleocene unit can be over 425 feet thick, but there is little data in the coastal area to develop accurate estimates in the project area. The Paleocene time marked the beginning of a regional sea transgression that lasted through the Eocene. The sediments represent marine to marginal marine, nearshore depositional environments.

# 6. WITH PROJECT CONDITIONS

## 6.1. Introduction

The purpose of this study was to evaluate problems in Savannah Harbor and to recommend a solution that satisfied the engineering, economic, and environmental criteria to provide a project that will allow the next generation of deep draft vessels to call on the Port of Savannah. The scope of the engineering analyses performed for this project involves analysis of existing conditions and requirements, determining the additional requirements to accommodate the design vessel, and preparing preliminary designs in sufficient detail to develop comparative cost analyses. Dredging quantities were computed for the 44-, 46-, 47-, 48-, and 50-foot projects. Disposal area analyses and designs were also performed for these alternative depths. Information derived from the engineering analyses performed on the channel design and the dike improvements required for the expansion and subsequent maintenance dredging for a fifty year period were used in the preparation of the cost estimates. These cost estimates were used in the determining the selected plan of improvement. The detailed project design for the feasibility study focused on the 50-foot project.

Specific engineering factors which were evaluated include identifying the design vessel and determining its handling characteristics, determining the channel alignment, defining the character of materials to be dredged, computing dredging quantities, evaluating the stability of the channel side slopes and determining the impact of the selected channel on adjacent property, analyzing the required disposal area capacity, analyzing impacts on groundwater, and developing detailed cost estimates for the project alternatives.

The field data collected for the design of this project includes hydrographic and topographic surveys, aerial mapping and photography of the disposal areas, core borings, and standard penetration test (SPT) borings. Hydrographic and topographic surveys obtained for this project were used to compute dredging quantities.

## 6.2. Subsurface Investigations

### 6.2.1. Background

The Geology/Hydrogeology and HTRW Design Section, U.S. Army Corps of Engineers, Savannah District, has performed a number of subsurface investigations within the project over the last 30 years. Several hundred borings have been drilled within and adjacent to the Savannah Harbor. These borings were constructed for the purpose of evaluating the in-situ materials within specific areas of the channel for harbor modification projects. The investigations have used a variety of methods to obtain subsurface data, including Vibracore, splitspooning, and coring. Standard penetration sampling using a split-barrel sampler was the method most often used. Using this method, a 1-3/8 inch I.D. standard split barrel sampler was driven through the material using a 140-pound hammer with a 30-inch fall. The sampler was retrieved and the material was described in accordance with the Unified Soil Classification System. Selected samples were submitted for grain size analysis and specific gravity calculations.

Copies of boring location maps and boring logs completed for this feasibility study and recent dredging projects within the Savannah Harbor are included in the supplemental documentation and are available upon request. These logs contain field descriptions of the materials encountered during drilling and are discussed in the following paragraphs. Copies of laboratory mechanical analysis on a selection of the samples collected during drilling are included in the supplemental documentation and are available upon request.

### 6.2.2. Procedures

The majority of the borings constructed within the channel were drilled from a floating barge using a variety of core drills to recover the samples. The barge was somewhat stabilized using steel spuds or anchors. They raised and lowered with the tide cycle. Drilling was very difficult off these platforms and often had to be terminated due to strong tides that would not allow the drill crew to maneuver the barge to a boring location. Wakes caused by high winds and ship traffic also greatly hampered the ability to drill from such a platform.

This drilling platform was also used to construct the Vibracore borings. This method involved vibrating a plastic tube through the subsurface soils to collect a sample that provided a more representative indication of the in-situ nature of the soils. This method could recover soft muds and loose sands that were often lost using standard penetration methods with a split-barrel sampler. However, this method could not penetrate stiff silts and clays or medium dense sands, or other materials exhibiting some degree of cementation, induration, or other characteristic of lithification. Also, this method did not provide any data that could be related to the relative strengths of the soils penetrated.

During the mid-1980's, drilling was conducted using the U.S. Army Corps of Engineers self-elevating barge *Explorer*. This barge was a powered vessel that could maneuver on its own using twin diesel motors. It also had the ability to elevate itself above the water on three legs to eliminate the actions of the tide cycles and wave action. Drilling from this platform proved to be much more efficient and allowed the employment of more consistent drilling techniques. In addition, the *Explorer* allowed drilling in areas that were inaccessible to the standard barge due to rapid tide currents, deep water, and extreme distances from land.

### 6.2.3. Site Soils

The sediments underlying the project area are largely a result of varying depositional facies. As such, the sediments are discontinuous both vertically and horizontally and numerous variations occur over short distances.

The uppermost sediments are represented by varying mixtures of poorly graded sands (SP), silty sands (SM), poorly graded gravels (GP), organic silts (OH), low liquid-limit and high liquid-limit silts (ML and MH), clayey sands (SC), and low liquid-limit and high liquid-limit clays (CL and CH). Standard penetration tests from borings indicate the consistency of the fine grained soils (silts and clays) range from very soft (0 to 4 blows per foot) to very dense (50 or greater blows per foot), while the coarse grained soils (sands and gravels) range in consistency from dense (30 to 50 blows per foot) to very dense (50 or greater blows per foot). Typically, these soils vary in color from tan, gray, brown, light brown, and greenish to bluish gray. Generally, soils at the river bottom exhibit lower consistency than the deeper soils. These bottom soils are often very loose and semi-liquid and can range from the bottom of the river channel to only a few inches to several feet deep.

The underlying soils consist of silty sands (SM), clayey sands (SC), high liquid-limit silts (MH), and low liquid-limit and high liquid-limit clays (CL and CH). Standard penetration tests indicate the consistencies of the fine grained soils range from stiff (8 to 15 blows per foot) to hard (30 or greater blows per foot), while the coarse grained soils range in density from dense (30 to 50 blows per foot) to very dense (50 or greater blows per foot). In general, these soils are characterized by a significant increase in blow counts. These soils are often grayish green, olive green, and gray.

Lenses of moderately hard to hard limestone have been encountered in borings around the project area. Its occurrence has generally been below the depths of concern for this project. In addition, borings drilled in 1969 identified a compaction shale in the northern end of the channel. This lithology has not been identified in any of the more recent borings and this material may be analogous to the greenish gray to olive green, stiff to hard, fat silts and dense to very dense silty sands.

A high resolution, sub-bottom, acoustic survey was performed in the channel during the early 1990's as part of the investigation program for the recently completed harbor deepening. This survey showed an area of high acoustic impedance within the middle channel (Stations 70+000 to 24+000). Borings drilled in this area and subsequent dredging indicated this material was similar to the greenish gray to olive green, stiff to hard, fat silts and dense to very dense silty sands described above.

### 6.2.4. Possible Effects of the Project on Groundwater

In the past, any proposed deepening of Savannah Harbor has raised questions about the possible effects this action would have on the confining layer of the principal artesian aquifer, known as the Floridan aquifer. Studies conducted for the purpose of the recent deepening project have shown there would be no impact to the Floridan aquifer even if the channel were deepened to -50 feet, MLW. Concerns with the current deepening project have been whether removing additional material below -50 feet, MLW, would have any adverse affects on the Floridan aquifer as well as how the dredging would affect the shallower Upper Brunswick aquifer.

Several studies have been completed concerning the occurrence of ground water in the coastal area. These studies often differ with respect to the occurrence of water-bearing units, or aquifers, within the project area. Though the Upper Brunswick aquifer has been shown to exist in other areas and attempts have been made to identify it as a potential source of ground water in the project area, there is no evidence that it exists within the project area.

Additional information was needed to adequately assess the possible effects of a deepened channel on the Upper Brunswick aquifer (as described by Clarke and others, 1990) and the Upper Floridan (principal artesian) aquifer that underlies the entire project area. It was decided that further studies should be conducted to verify the generalized data available from previous studies (mentioned above) of these aquifers. These studies would look at the potential impacts to the confining layer due to removing some confining and relict stream channel material. The results of these studies are provided in Reference 2.4. The following conclusions were made based on the results of these studies:

The Miocene unit, a confining unit consisting of low-permeability clays, clayey silts, and clayey sands, overlies the upper Floridan aquifer, the most important source of ground water in the study area. Although the proposed project would remove up to 10 feet of the confining unit in selected areas, the minimum remaining thickness of confining unit would be about 40 feet. At no point will the proposed project dredging depths breach the confining unit.

Within the Miocene unit in the project area, no permeable sands occur that could be correlated with what has been referred to by the USGS (Clarke and others, 1990) as the "*upper Brunswick aquifer*". Numerous vertical permeability (K′) values of the Miocene unit indicate low vertical permeabilities, typically in the range from about $4x10^{-2}$ ft/d to $6x10^{-4}$ ft/d.

Leakage rates computed for water moving vertically downward through the Miocene confining unit into the upper Floridan aquifer indicate the increase in quantity of water due to dredging would only be a small fraction of the quantity of water moving laterally through the upper Floridan aquifer. Therefore, the proposed dredging will have no noticeable affect on the quality and quantity of ground water within the upper Floridan aquifer.

### 6.2.5. Potential for Encountering Hazardous, Toxic, or Radioactive Wastes (HTRW)

The Savannah Harbor is home to numerous industries and shipping activities. Each of these presents a potential for contamination to the harbor either due to regular practices or accidents. In addition, there is always the potential for illegal discharges of HTRW, either by an individual or industry. These types of activities are usually reported or discovered and any threats to the environment are minimized. In any instance, discharges of HTRW to the harbor waters usually pose no threat of accumulation in the bottom sediments. This is due to the great amount of dilution and dispersion caused by the regular flow of waters in the harbor.

There is, however, a greater potential for encountering HTRW within the harbor bank sediments that may slough during dredging activities. Since such materials would be concentrated over a period of time due to the lack of dilution and dispersion, concentrated volumes of HTRW could be carried through a hydraulic dredge pipeline and discharged into a disposal area.

A review of real estate along the banks of the harbor where sloughing is anticipated would help locate such areas. Any such search would have to look at not only the current activities at a piece of property but also the historical activities back to a time prior to development of the property.

### 6.3. Design Vessel

The design vessel was determined by examining the size of larger ships that could reasonably be expected to call on the Port of Savannah in the future if a harbor expansion were constructed. Based on the commerce passing through the port, a container ship was selected as the design vessel.

The design vessel used in the engineering and design considerations for this expansion project is the *Regina Maersk*, a new post-Panamax II-class vessel. This vessel was launched in 1996. The ship is 1,044 feet long, has a beam of 140 feet, and a design draft of 46 feet. The *Regina Maersk* was designed to carry approximately 6,000 TEU's.

### 6.4. Channel Design

The design vessel selected for this project represents a significant increase in the size of vessels that are presently calling on the port. Although vessels of similar length have used the port in the past, no vessel with a 140-foot beam or a 46-foot draft has called. This increase in the dimensions of the design vessel required an analysis of the existing channel alignment to determine where additional width would be required for the vessel to safely navigate the entrance and inner harbor channels.

#### 6.4.1. Channel Alignment

The bank-to-bank width of the Savannah River varies between the mouth of the river to the upper end of the project. The reach of the harbor upstream of Old Fort Jackson is generally not as wide as the reach downstream of the fort. The upstream reach of the river has commercial and port development located continuously along the south bank. The north bank has commercially developed areas as well as being the location for a confined disposal area provided by the local assurer which is used to maintain the Federal project and a confined disposal area constructed by a private interest which is used for dredging private berths. There are no commercially developed areas on the north bank in the lower harbor. This area, however, does contain most of the disposal areas which are used to maintain the existing Federal project. The south bank has some commercial development. One of the design objectives for the project was to minimize the amount of real estate which would be required to construct and maintain the improved project. The commercial land values in the harbor are high and in many areas there is insufficient room to relocate existing facilities and still have them remain operational.

There are two constituents that are considered in the channel design. They are the channel alignment and the channel geometry. The alignment is the horizontal position of the centerline of the channel. The geometry is the cross-section of the channel and includes the location of the channel toes with respect to the centerline, the channel width and depth, and the configuration of the side slopes.

At the request of the study sponsor, performance of a ship simulator study as prescribed in Reference 2.5 will be conducted during the CED phase of the project. Therefore the only methods available to evaluate the existing channel alignment are design experience and input from the harbor and docking pilots. Ideally the channel should have as few curves as possible. However in the case of the Savannah River, the navigation channel meanders with the river and the commercial development and confined disposal areas located throughout the harbor makes it uneconomical to make significant modifications to the existing alignment. Several activities were performed to determine the channel alignment for feasibility. Initially the alignment and additional curve wideners were designed in accordance with Reference 2.2. Using the design criteria, a multiplier of 4.0 was used to calculate the required channel bottom width for straight reaches of the channel using one-way traffic for the design vessel. This value was taken from Table 8-2 in Reference 2.2 and is based on a "trench" type channel with a current velocity range of 1.5 to 3.0 knots. Although velocities greater than 3.0 knots have been measured, this was the maximum design criteria available. The engineer manual recommends that the "…design channel width for navigation projects with maximum currents greater than 3.0 knots should be developed with the assistance of a ship simulator study". The product of the multiplier and the design vessel's beam width exceeds the present width of the channel. However, the multiplier may be too conservative for the Savannah Harbor channel since Panamax vessels presently safely transit the harbor in currents which exceed 3 knots. Table 8-3 of Reference 2.2 indicates a multiplier of 6.5 should be used for two-way traffic. This would require a channel width of 689 feet; however, pilots routinely pass Panamax design vessels in the existing

500-foot wide channel. Therefore, certain reaches of the existing channel may accommodate the wider design vessel for the expansion project.

Table 8-4 of Reference 2.2 was used to calculate the necessary width in channel turns for the design vessel. Based on the deflection angle of the channel turn and the ratio of the turning radius to the design ship length, the turn width increase factors were calculated for each turn. Again the factors appeared conservative based on the present channel turn widths. Using the calculated factor, turns were widened where necessary after studying the ship track plots from Reference 2.6 which were determined in the ship simulator study for the last deepening project. In the Bight Channel, only the track plots from the previous deepening ship simulator study were used to determine additional width because no turn width increase factors were available in Reference 2.2 for a channel similar to the Bight Channel. The design manual refers to such turns as special circumstances that "…should be done by using ship simulation testing to develop appropriate channel alignments and dimensions".

After the initial layout was completed, a hydraulic engineer and technical specialist from the WES rode the inbound transit of the *Hanjin Columbia* to determine reaches of the existing project which have problems or where maneuvering is difficult. The *Hanjin Columbia*, which was the design vessel for the last deepening project, has an overall length of 961 feet, a beam of 106 feet, and a draft of 39.3 feet. Using information obtained from the inbound transit, the curve wideners were modified and the centerline alignment was kept the same as the existing project. This revised layout was discussed with the harbor and docking pilots whom recommended a few changes to the curve wideners. The revised channel alignment was reviewed by the Acting Chief, Navigation Branch of the Hyrdaulics Lab at WES who recommended additional minor modifications. The final alignment and channel layout were again reviewed by the harbor and docking pilots and a representative from the Coast Guard. They expressed concern about narrowing the bottom width to accommodate a wider design vessel. However, they concurred with the recommended alignment based on the fact that the ship simulator would be performed in CED.

The Kings Island turning basin was also widened 76 feet. This enlargement was requested by the docking pilots to provide additional width to turn the design vessel when shoals are located in the back of the turning basin. They also requested a longer turning basin which would ease the maneuvering required to turn a vessel moored at the GPA' s new CB-7. A channel widener smaller than the enlargement proposed by the pilots has been included at the upstream end of the Kings Island turning basin which will serve as a transition to assist the docking pilots The desired widener required relocation of an existing dike and loss of a significant portion of disposal area 2A. It was agreed that the docking maneuver at the new CB-7 berth and turning in the turning basin would be included in the ship simulator study to properly size the basin. The smaller widener and the 76-foot enlargement of the basin were included in the project design at this time. The recommended channel alignment for the 50-foot project is shown on Figures 2 through 33.

Preliminary evaluations indicate that the project will have an impact on Old Fort Jackson and the *CSS Georgia*. It has been determined that the design vessel cannot navigate through this reach without deepening the channel. A preliminary evaluation of alternatives to protect Old Fort Jackson and to remove the *CSS Georgia* from the existing channel side slope have been completed and are discussed in paragraphs "Channel Sections 59+000 through 58+000, Old Fort Jackson" and "Channel Stations 59+000 through 58+500, *CSS Georgia* Wreck" in this appendix and in the Environmental Impact Statement (EIS). Based on these plans, the channel will not require realignment through this reach.

### 6.4.2. Channel Width

In discussions with the pilots and the Coast Guard, they each emphasized that the bottom width should be kept as wide as possible. This would allow them the most flexibility in the movement of vessels and would permit them to continue to use the internal traffic control procedures they practice for the existing project. As discussed above, much of the harbor is developed on both sides and there is little room for increasing the width of the navigation channel without having a significant impact on adjacent structures and property. The initial guidance provided by the project's study sponsor was to minimize, where possible, impacts to real estate and structures along the bank. To accomplish this objective, the project was designed to maintain the authorized bottom width at the 42-foot project and to project the side slopes at a 1 vertical (V) on 3 horizontal (H) slope to each alternative depth. If the existing project did not have advance maintenance, the proposed bottom width for the 50-foot expansion project would be 48 feet narrower than the existing project. However, with the advance maintenance that has been previously performed, the bottom width of the channel at each depth will be as shown in Table 5-1. Typical cross-sections for the 50-foot project are shown in Figures 34 through 38.

**Table 6-1 Channel Bottom Width**

| Station | Existing Bottom Width (FT) | -44 Foot Project Depth (FT) | -46 Foot Project Depth (FT) | -48 Foot Project Depth (FT) | -50 Foot Project Depth (FT) |
|---|---|---|---|---|---|
| 103+000 | | | | | |
| | 400 | 388 | 376 | 364 | 352 |

| | | | | | |
|---|---|---|---|---|---|
| 102+000 | | | | | |
| | 400 | 400 | 388 | 376 | 364 |
| 100+000 | | | | | |
| | 500 | 500 | 488 | 476 | 464 |
| 79+000 | | | | | |
| | 500 | 500 | 488 | 476 | 464 |
| 70+000 | | | | | |
| | 500 | 500 | 500 | 488 | 476 |
| 24+000 | | | | | |
| | 500 | 500 | 488 | 476 | 464 |
| 0+000 | | | | | |
| | 500 | 488 | 476 | 464 | 452 |
| -14+000B | | | | | |
| | 600 | 588 | 576 | 564 | 552 |
| -60+000B | | | | | |
| | N/A | 588 | 576 | 564 | 552 |
| Seaward End | -60+000B | -61+500B | -61+500B | -82+000B | -85+000B |

The deepened channel for the expansion project is not designed to allow two-way traffic for the design vessel. Wideners have been included in areas where the pilots indicated they presently have difficulty maneuvering either as a result of tidal currents or bank effects in the channel.

### 6.4.3. Impact on Adjacent Shoreline

An analysis of the potential impacts deepening and extending the entrance channel will have on coastal processes and coastal erosion was performed by Applied Technology and Management (ATM), Inc. The coastal processes of concern are currents and waves. The discussion of the study and the results of the modeling are presented in Reference 2.7. In general, the conclusions are that under average wave conditions, the expansion did produce some discernible change in the wave environment. However, the expansion did not produce any general changes in wave focusing, and the expansion did not induce any changes that appear to be significant along the study area shorelines.

Under storm conditions, the expansion produced some discernible changes in the wave field. The only storm wave that produced noticeable change in wave focusing was the east storm wave condition, which displayed a change in the wave field at the south end of Tybee Island. This should result in decreased potential erosion at the south end of Tybee Island for this storm wave from the east. The east storm wave did not produce discernible changes in the wave focusing along the remainder of the study shoreline. The other storm waves did not produce any general changes in wave focusing along the study shoreline.

The Draft Environmental Impact Statement includes a discussion of the analysis performed to determine impacts the entrance channel extension would have on increasing erosion on downdrift beaches. The analysis concluded that the extension is beyond the zone of active littoral transport and should not impact onshore-offshore sediment transport processes or coastal erosion. Deepening the entrance channel will not result in increasing the volume of maintenance material which presently shoals in the channel reaches which lie within the active littoral transport zone.

### 6.4.4. Sideslopes and Bank Stability

#### 6.4.4.1. General.

The proposed expansion project for the 50-foot depth is approximately 37 miles long (along the centerline of the channel), stretching from the former New Cut Channel to the Atlantic Ocean (Stations 103+000 to –85+000B). There is approximately 20 miles of land on each side of the river (approximately 40 miles of riverbanks) above the low water elevation. The entrance channel is approximately 17 miles long and the channel banks remain under water. Along the 40 miles of riverbanks above the low water elevation there are many properties that could be affected by the project depending, in part, on the proximity of the land to the proposed deepening. With regard to this feasibility study, site inspections were made on all areas that could be affected by the project, by boat and by land. Soil borings were constructed for project real estate acquisition and demolition purposes. Soil testing of specific property is based on analysis of several factors, without regard to ownership of the property. Test results are included in Attachment 1. These factors included:

1) the proximity of the property to the proposed project;

2) the type of material likely to be encountered (as obtained from past soil borings in the vicinity);

3) the slope of the riverbank;

4) the configuration of the existing channel;

5) hydrographic surveys;

6) topographic surveys and aerial photographs;

7) the configuration of the proposed navigation channel;

8) whether the proposed channel intersects with adjacent property;

9) the available budget;

10) the cost of taking and analyzing soil borings (including laboratory testing; and

11) the likelihood that soil sample analysis will yield the necessary information.

In addition, historic information was considered, including:

1) most recent surveys;

2) problems arising out of the most recent projects; and

3) historic land usage, structures and artifacts.

As a result of these studies, several properties were identified for investigation. These properties are identified and discussed within this report.

Computations, sketches and preliminary drawings with regard to channel side slopes for use in project design and preparation of construction plans and specifications have been completed for the expansion project and copies of drilling logs and test results are available upon request. Figures 39 through 48 show plan views for estimated top of slopes and drilling locations. Figures 49 through 53 show design cross-sections for drilling locations. Figures 54 through 61 show the plan and cross-sections for Old Fort Jackson. Figure 62 indicates the main recommendations for protection of Old Fort Jackson due to impacts from the expansion project. Computations are based on drilling data, test results from soil samples taken at drilling locations, the 1996 annual hydrographic survey, the subsequent exam hydrographic survey performed for this project, topographic survey data at specific locations, observations of channel side slopes resulting from the past harbor widening and deepening projects, and other information from previous dredging works regarding channel side slope performance. In general, channel side slopes historically average approximately 1V on 3H for the Savannah River and are expected to remain as such after completion of the dredging project. Areas where possible exceptions might occur have been identified by borings taken during the subsurface investigation program. The soils analysis addresses five known locations or reaches which are possible problem areas regarding channel side slopes, sloughing of materials, and/or real estate acquisition requirements. Additional analysis has been performed separately for the Old Fort Jackson area regarding stability of the structure and adjacent property. Each is discussed separately in the following paragraphs.

#### 6.4.4.2. Channel Stations 103+000 through 101+000, Argyle Island

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 103+000 through 101+000. Analysis further indicates that the proposed acquisition for this area is not expected to impact the existing Disposal Area 2A dike. Specifically, it is recommended that a line between the points identified by GA

NAD 83 coordinates shown in Table 5-2 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-2 Top of Slope Stations 103+000 to 101+000**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 101+408 | 974029.0 | 778792.1 | begin line |
| 101+500 | 974016.8 | 778882.1 | |
| 101+887 | 973897.8 | 779256.6 | |
| 102+000 | 973906.2 | 779371.1 | |
| 102+500 | 973793.6 | 779861.0 | |
| 102+826 | 973738.9 | 780099.2 | end line |

#### 6.4.4.3. Channel Stations 101+000 through 99+000, Argyle Island/KITB

Analysis for this area indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 101+000 through 99+000. Analysis further indicates that the proposed acquisition for this area will require the relocation of approximately 1,100 feet of Disposal Area 2A dike which involves the excavation and replacement of approximately 60,000 cubic yards of soil material. It is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-3 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-3 Top of Slope Stations 105+000 to 99+000**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 98+248 | 975457.4 | 776261.0 | begin line |
| 98+500 | 975789.4 | 777200.8 | |
| 99+000 | 975501.0 | 777619.8 | |
| 99+500 (Omitted) | | | crosses 99+000 |
| 100+000 | 975242.8 | 777958.6 | |
| 100+384 | 975001.3 | 778275.7 | |

| | | | |
|---|---|---|---|
| 100+500 | 974803.4 | 778320.3 | |
| 100+556 | 974706.4 | 778342.1 | end line |

#### 6.4.4.4. Channel Stations 97+500 through 92+286, North Side

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 97+500 through 92+286. Analysis further indicates that the proposed acquisition for this area should also include a sloughing area. The coordinates for the added sloughing area are indicated separately. Specifically, it is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-4 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-4 Top of Slope Stations 97+500 to 92+286**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 92+286 | 978201.3 | 771225.6 | begin line |
| 92+500 | 978062.4 | 771386.5 | |
| 93+000 | 977389.8 | 771770.9 | |
| 93+500 | 977389.8 | 772127.4 | |
| 94+000 | 977100.6 | 772470.9 | |
| 94+500 | 976841.2 | 772898.9 | |
| 95+000 | 976565.2 | 773315.9 | |
| 95+500 | 976341.8 | 773679.3 | |
| 96+000 | 976169.3 | 774149.4 | also begin sloughing |
| 96+500 | 975949.1 | 774598.6 | 1/3 - no sloughing |
| 97+000 | 975723.0 | 775044.3 | also end sloughing |
| 97+500 | 975533.3 | 775507.8 | end line |

Coordinates for the sloughing area only are indicated in Table 5-5.

**Table 6-5 Sloughing Area Stations 97+000 to 96+000**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 96+000 | 976169.3 | 774149.4 | begin sloughing |
| 96+500 | 976015.1 | 774627.4 | Sloughing area |
| 97+000 | 975723.0 | 775044.3 | end sloughing |

**6.4.4.5. Channel Stations 88+500 through 85+000, North Side, Union Camp/SEDA Property**

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 88+500 through 85+000. Specifically, it is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-6 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-6 Top of Slope Stations 88+500 to 85+000**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 85+000 | 982979.6 | 765802.5 | begin line |
| 85+500 | 982623.8 | 766153.1 | |
| 86+000 | 982251.0 | 766486.7 | |
| 86+500 | 981940.2 | 766885.6 | |
| 87+000 | 981574.7 | 767226.9 | |
| 87+500 | 981251.7 | 767613.0 | |
| 88+000 | 981024.8 | 767958.0 | |
| 88+500 | 980689.8 | 768331.9 | end line |

**6.4.4.6. Channel Stations 78+140 through 77+261, Savannah Marine**

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 78+140 through 77+261. The steel sheet pile bulkhead located to the riverside of the estimated top of slope line is anticipated to be undermined as a result of the proposed dredging and this portion of the bulkhead should be removed prior to performing dredging in this area. It is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-7 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-7 Top of Slope Stations 78+140 to 77+261**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 77+261 | 988367.6 | 760428.9 | begin line |
| 77+500 | 988303.8 | 760468.7 | |
| 77+701 | 988126.2 | 760579.4 | |
| 77+945 | 987910.3 | 760714.1 | |
| 78+000 | 987868.3 | 760750.9 | |
| 78+140 | 987774.9 | 760855.2 | end line |

#### 6.4.4.7. Channel Stations 76+170 through 75+500, T.I.C., Inc., North Side

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 76+170 through 75+500. The sheet pile bulkhead and a portion of the existing dock located to the riverside of the estimated top of slope line is anticipated to be undermined as a result of the proposed dredging. Structures located to the riverside of the estimated top of slope line should be removed prior to performing dredging in this area. It is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-8 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-8 Top of Slope Stations 76+170 to 75+500**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 75+500 | 989782.7 | 759622.2 | begin line |
| 76+000 | 989326.5 | 759837.1 | |
| 76+170 | 989175.2 | 759908.4 | end line |

#### 6.4.4.8. Channel Stations 71+680 through 69+665, Fig Island, North Side

Analysis indicates that a normal channel side slope of 1V on 3H should be used for the reach between Stations 71+680 through 69+665. Specifically, it is recommended that a line between the points identified by GA NAD 83 coordinates shown in Table 5-9 should be used as a guide for acquisition prior to an actual taking by the proposed dredging.

**Table 6-9 Top of Slope Stations 71+680 to 69+665**

| Channel Station | X-Coord | Y-Coord | Remarks |
|---|---|---|---|
| 69+665 | 995152.6 | 758439.7 | begin line |
| 70+000 | 994966.3 | 758513.9 | |
| 70+500 | 994466.8 | 758543.6 | |
| 71+000 | 993966.6 | 758552.7 | |
| 71+500 | 993625.0 | 758505.0 | |
| 71+680 | 993429.1 | 758477.6 | end line |

#### 6.4.4.9. Channel Stations 59+000 through 58+000, Old Fort Jackson

Analysis indicates that a normal channel side slope of 1V on 3H is appropriate for the Old Fort Jackson area. Analysis also indicates that the proposed deepening for this area is expected to impact portions of the Old Fort Jackson moat parallel to and nearest to the river channel and the moat tunnel structure.

Impacts to the tunnel and the moat wall consist of loss of an estimated 4 to 10 feet of soil materials existing directly adjacent to the tunnel sheet piling and the existing protective timber wall adjacent to the moat structure. These materials contribute directly to the lateral support for both the piling and the timber wall, which in turn protects the foundations for each structure. Detailed hydrographic surveys of the channel side slope between the toe of the existing channel and the toe of the mean low water line show depressions which indicate loss of material at the toe of the moat wall. Continued erosion of the foundation material will impact the stability of the timber piles supporting the moat. Failure of the timbers would result in a catastrophic failure of the structure. To prevent flanking, it is essential to tie the proposed protection system into the adjacent high ground. Therefore, the entire length of the moat along the river will be protected.

Several options are available to help mitigate impacts to Old Fort Jackson. A few, but not all-inclusive, solutions as proposed in the following discussion were evaluated for implementation.

The first option considered was moving the channel alignment to the north and away from Old Fort Jackson. All indications infer that; if the south toe of the river channel were realigned so it was at least 150 feet from any portion of the fort structure, then the proposed new work dredging would not have a negligible impact. This would place the south toe of the channel approximately 180 feet south of and parallel to the existing channel centerline (Reach 22), rather than the proposed new location 220 feet south of the existing centerline.

A second option considered was the construction of a positive protection system to prevent the loss of riverbank materials supporting the Old Fort Jackson moat foundations.

One protection type considered was steel sheet piling which consists of installing interlocking steel sheet piling along the outside face of the moat. Pile tops should be placed at elevation +0.5 feet, MLW. Pile tips should be driven to a minimum elevation of -44.5 feet, MLW. Minimum pile sections should conform to PZ27 steel sheeting sections or stronger. Each wall end will be anchored to a driven HP12x53 pile, 4 required, to the same top and tip elevations. Whalers are included in the design and, for estimating purposes only, will consist of a minimum of 2 rows of C15x50 channels spaced 4 inches apart. Stiffener plates will be installed at each pile section connection and each through bolted to every sheet pile using four 1-1/8$^{th}$ -inch diameter bolts. A top seal should be included consisting of a 2.5-foot thickness of reinforced concrete. Backfill as necessary between the installed sheet piles and the existing structure should consist of pumped grout and/or concrete. Other aspects and details for steel connections will be formally designed by a structural engineer and basically conform to the 1978 plans for Protection of Existing Tidal Moat Structure.

Another system considered was a flexible mattresses filled with concrete. Flexible grout filled mattresses such as Incomat or equivalent were considered. It is recommended that such mattresses be anchored at the top using HP12x53 piles or stronger, 20 feet on-centers, and connecting whalers at the top, or as recommended by the mattress manufacturer. Piles will be installed to the top and tip elevations as stated for sheet piling above. The bottom of the mattresses will be placed and tied or keyed at elevation –22 feet, MLW. As required, stone fill will be used to bring or adjust the top of slope to elevation +1.0 prior to placing mattresses. An estimated 200 cubic yards of stone will be required. Stone fill will conform to GA DOT Standard Specifications for Construction of Roads and Bridges, Section 805 for Type 1 or Type 3 Rip Rap. Slopes of 1 vertical on 2 horizontal or flatter are acceptable. Steeper slopes are not acceptable. Prior to placing the mattresses, a geotextile drainage fabric will be installed beneath the concrete mattress. Geotextile fabric will be a woven, 25-mil minimum thickness, AOS equivalent corresponding to the U.S. Standard Sieve No. 70, and a minimum grab tensile strength of 600 lb/inch. An estimated 800 SY of fabric is required. Minimum thickness for the mattress should be approximately 20 inches (50 cm). Placement lengths along the moat wall will be the same as for the sheet piling.

Other proprietary solutions considered include the use of articulated blocks or similar, stone filled mattresses, marine cell structures, and/or other interlocking stone or concrete slope protections.

The selected alternative for protecting a portion of the moat wall at Old Fort Jackson is the construction of a steel sheet pile wall. Steel sheet piling has an extensive history of success in Savannah Harbor for providing bank stability and slope protection. A portion of the moat wall around the tunnel structure is presently protected by steel sheet piling. Placement of the sheet piling will result in lower impacts to the fort and adjacent property since excavations are not required to place or anchor the wall. Also the wall will be below the water surface and will not be visible to visitors at the fort. The sheet pile wall has a longer service life than the other alternatives considered and will require minimal maintenance.

#### 6.4.4.10. Channel Stations 59+000 through 58+500, *CSS Georgia* Wreck

Studies indicate that a normal channel side slope of 1V on 3H should be used for the reach between Stations 58+500 and 59+000. Review of the dredging proposed within this reach indicates that dredging will directly impact the *CSS Georgia* and the immediate surrounding area as listed on the Historical Register. In fact, any dredging within this area will have a direct impact on the *CSS Georgia*. However, detailed engineering investigations, analyses and resolution of impacts to the *CSS Georgia* were not performed as part of the Feasibility Study. A more extensive evaluation of the impacts the project will have on the *CSS Georgia* are anticipated to be performed in the next project design phase. The EIS discusses the work which will be accomplished as part of this effort. A detailed analysis regarding the *CSS Georgia* is considered necessary due to the position of the wreck to the existing channel and the apparent differences in elevations. It is anticipated that the *CSS Georgia* will be removed and the channel alignment will not change in this reach. Engineering support for the removal of the *CSS Georgia* is anticipated to include detailed surveys, drilling and testing of soil materials to identify the supporting and surrounding material characteristics, and to provide support for a contract design, plans, details, and specifications for physically moving/removing the wreck from the Savannah River.

#### 6.4.4.11. Channel Stations 52+750 through 50+500, South Side

This area was reviewed closely with regard to the Southern Natural Gas Company submerged pipeline and the realigned channel. The proposed widening does not require the acquisition of real estate. All top of slope elevations occur below the elevation 0 feet, MLW.

### 6.4.5. Underkeel Clearance

Design guidance to calculate the underkeel clearance of a deep draft vessel was obtained from Reference 2.2. The squat, trim, and sinkage resulting from transiting from a salt to brackish water were computed. Calculations were performed for vessels transiting the project at low tide. It was also assumed that the channels were 50 feet deep in the inner harbor and 52 feet deep in the entrance channel.

#### 6.4.5.1. Squat

The entrance channel was evaluated as a "fairway" channel since the overbanks on either side of the channel are relatively deep and the channel cross-section is somewhat symmetrical about its centerline. Also, there are no structures or banks above elevation 0 feet, MLW, which effect the pressure acting against the vessel's hull. The maximum vertical ship motion as a result of squat for a given range of vessel speeds was calculated using formula 6-3 in Reference 2.2. Table 5-10 shows the results of these calculations.

**Table 6-10 Vessel Squat in the Entrance Channel**

| Squat, FT | Vessel Speed, KNOTS |
|---|---|
| 0.3 | 5 |
| 0.4 | 6 |
| 0.5 | 7 |
| 0.7 | 8 |
| 0.9 | 9 |
| 1.2 | 10 |
| 1.4 | 11 |
| 1.8 | 12 |
| 2.1 | 13 |
| 2.5 | 14 |
| 3.0 | 15 |

The inner harbor was evaluated as a "trench" channel because it has overbank depths on each side of the channel. Ship squat in a restricted channel depends especially on ship speed. Therefore the pilots have some control over the amount of squat and the required underkeel clearance necessary to make a safe transit through the harbor. The cross-sectional area of the channel and ship geometry also effect the amount of squat a vessel will experience. Vessel squat was calculated at Stations 93+000, 84+000, 73+000, 57+000, 47+000, and 18+000. These stations were selected to provide varying cross-sectional areas. Table 5-11 provides the results of squat calculations for a range of speeds at two stations in the inner harbor. The squat calculated for varying vessel speeds at Stations 57+000, 47+000, and 18+000 are similar as is the squat calculated for Stations 93+000, 84+000, and 73+000.

**Table 6-11 Vessel Squat VS Speed in the Inner Harbor**

| Squat, FT | Station 47+000 Speed, KNOTS | Station 93+000 Speed KNOTS |
|---|---|---|
| 0.2 | 4.5 | 3.8 |
| 0.4 | 6.2 | 5.3 |
| 0.6 | 7.5 | 6.5 |
| 0.8 | 8.6 | 7.4 |
| 1.0 | 9.5 | 8.2 |
| 1.2 | 10.2 | 8.9 |
| 1.4 | 10.9 | 9.5 |
| 1.6 | 11.5 | 10.0 |
| 1.8 | 12.0 | 10.6 |
| 2.0 | 12.5 | 11.0 |
| 2.2 | 13.0 | 11.5 |
| 2.4 | 13.4 | 11.9 |

It is important to note that the vessel speeds are relative to the speed of the undisturbed water. For example, an outbound vessel traveling at 6 knots against a 2-knot flood tide would experience the same squat as a vessel traveling 8 knots in no current.

**6.4.5.2. Effects of Fresh Water**

The draft of seagoing vessels is usually given in salt water at an ocean salinity of 35 parts per thousand, ppt. Drafts of ships calling at Savannah will increase due to a decrease in density of the water. As stated in Reference 2.2, the vessel's draft will increase 2.619% when transiting from seawater to fresh water. For the design vessel, the draft will increase approximately 1.2 feet when transiting from seawater to fresh water.

#### 6.4.5.3. Safety Clearance

In the interest of safety, a clearance of 2 feet between the bottom of the ship and the design channel bottom was included to avoid damage to the ship's hull, propellers, and rudder from bottom irregularities and debris. An additional 2 feet of underkeel clearance was included in the entrance channel from Stations –14+000B to –85+000B to allow for heave, pitch, and roll of the vessel in wave conditions.

#### 6.4.5.4. Total Clearance

It is anticipated that the present practice by the harbor pilots to provide at least 4 feet of clearance under the keel will continue after completion of expansion dredging. In the event this clearance is not available, pilots will wait to take advantage of the tide. When the project is deepened to 50 feet, vessels can transit the channel and meet the pilot's criteria since the loaded draft of the design vessel is 46 feet. Based on calculations for the expansion project, the design vessel has sufficient underkeel clearance to transit the channel under most tide conditions. Table 5-12 summarizes the underkeel clearances required for the expansion project. To control the vessel squat, vessel speeds in the entrance channel should not exceed approximately 12 knots and in the inner harbor, speeds should not exceed approximately 7.4 knots in the upper harbor and approximately 11.2 knots in the lower harbor. These speeds are relative to the speed of undisturbed water.

**Table 6-12 Underkeel Clearance**

| | Entrance Channel | Station 47+000 | Station 93+000 |
|---|---|---|---|
| Vessel Draft, FT | 46 | 46 | 46 |
| Vessel Speed, knots | 12 | 11.2 | 7.4 |
| Squat, FT | 1.8 | 1.5 | 0.8 |
| Safety Clearance, FT | 4 | 2 | 2 |
| Fresh Water Effects, FT | 0 | 0.5 | 1.2 |
| Required Channel Depth, FT, MLW | -51.8 | -50.0 | -50.0 |

### 6.5. Entrance Channel Extension

The outer end of the entrance channel presently ends at Station -60+000B. This is the location of the -44 foot, MLW, contour. Additional hydrographic surveys were performed to determine the location of the 46-, 48-, 49-, 50-, and 52-foot, MLW, contours and the alignment of any required extension. Table 2-1 provides a summary of the lengths of the extensions required for each alternative depth. Review of NOAA charts also indicated that the shortest distance from the outer end of the existing channel to the -52-foot, MLW, contour was to project the alignment of the existing channel in a straight line.

**6.6. Utility/Bridge Crossings and Obstructions**

Several utilities and one bridge cross the navigation channel and they were evaluated to determine if there is sufficient clearance for the proposed channel. The utilities are four submerged pipelines and an overhead electric transmission line.

One 42" diameter effluent pipe and one 6" diameter electrical conduit are located at approximately Station 89+250. These pipes transfer effluent from Union Camp's mill located on the south side of the channel to the mill's effluent lagoons located on the north side of the river and provide electrical power to the lagoons. Neither pipe will be affected as a result of deepening the river at that location. The elevation of the electrical pipe at the centerline of the channel is approximately –70 feet, MLW. The elevation of the effluent pipe at the centerline of the channel is approximately –94 feet, MLW. There is also an effluent pipe from the lagoon located at approximately Station 91+979. This pipe will not be effected as a result of the dredging.

An abandoned steel hull barge is located on the north bank of the river at approximately Station 82+000. The barge is submerged and a portion is exposed at low tide. It is approximately 130 feet long, 32 feet wide, and 8 feet deep. Since there will be no dredging in the side slopes, it is not anticipated that the expansion dredging will impact the barge or cause it to slide into the channel.

The U.S. Hwy 17, Talmadge Memorial, bridge is located at approximately Station 79+150. The vertical clearance above mean high water is 185.0 feet. The exact air draft dimension for the design vessel has not been made available to date. However, a preliminary range of the air draft dimensions (198.9 feet maximum and 180.4 feet minimum) for the vessels operated Maersk Lines has been obtained. It is not anticipated that this will present a problem for the design vessel since the air draft dimension for most vessels includes masts and antennae which can be temporarily removed. The horizontal clearance between the bridge piers exceeds the bottom width of the channel. The north pier is located above the mean low water line and the south pier is landward of the existing dock located under the bridge.

A steel sheet pile bulkhead is located on the riverfront at Savannah Marine Services, Inc. property between Stations 78+140 and 77+261. A channel widening is planned for this area. Savannah Marine Services has indicated the sheet piles are each 30 feet in length. The proposed channel widening and resulting riverbank side slope for this area are expected to undermine and/or intercept the bulkhead foundation for a distance approximately 350 linear feet. It is anticipated that 350 linear feet of bulkhead will need to be removed prior to dredging for this channel widened area.

Another steel sheet pile dock and timber pile supported dock located on the T.I.C. property between Stations 76+170 and 75+000 are also expected to be impacted by the proposed channel widening. The proposed channel widening is expected to undermine and/or intercept the pile foundations for a distance approximately 300 linear feet. It is anticipated that these piles, bulkhead, and dock will need to be removed prior to dredging for this channel widened area.

Savannah Electric and Power Company has a transmission line which crosses the channel at approximately Station 62+850. The low point of the powerline is 236.0 feet above mean high water. The clearance under the powerline will not have an impact on navigation of the design vessel.

Southern Natural Gas Company has two 30" diameter steel pipelines which cross under the channel at approximately Station 51+500. The lowest elevation of the top of the pipes under the channel is approximately -75 feet, MLW. However, the initial channel alignment for the proposed deepening impacts the pipe at the north toe of the channel. The channel alignment between Stations 52+800 and 49+750 has been shifted to the south approximately 150 feet to avoid relocating the pipeline. Figure 63 shows the location of the pipeline relative to the channel cross-section at Station 51+500. This will provide the same minimum depth of cover over the pipeline which exists for the present channel. This shift results in dredging approximately 94,500 CY of material from the south bank of the channel. It also requires the removal of a section of the South Channel Training Wall remnants. Shifting the channel and removal of this wall will not impact or require acquisition of adjacent property.

### 6.7. Expansion Quantity Calculations

Hydrographic surveys were performed of the inner harbor and entrance channels in March and May 1997. These surveys, shown on Figures 2 through 33, were used to compute the volumes of material to be dredged. Figure 64 shows the typical templates for the 50-foot project and how the volumes were typically allocated to maintenance or new work dredging. Quantity computations for the project alternatives include volumes from the required dredging prism, defined as the project depth plus advance maintenance, and 2 feet of allowable overdepth below the expansion prism. The required dredging prism for the expansion project is defined as the cross-sectional area between the allowable overdepth prism for the existing project and required dredging depth for the selected plan. Table 5-13 provides a summary of the new work quantities to be removed for the 44-, 46-, 47- and 48-foot project alternatives. These volumes were used in preparing the detailed cost estimates for dredging the project alternatives.

Quantities include new work material in the required dredging prism (project depth plus advance maintenance) plus two feet of allowable overdepth.

**Table 6-13 Dredging Quantities for Alternative Project Depths**

| Station | 44-Foot, (CY) | 46-Foot, (CY) | 47-Foot, (CY) | 48-Foot, (CY) |
|---|---|---|---|---|
| 103+000 | | | | |
| | 2,850,600 | 4,359,700 | 5,103,000 | 5,844,600 |
| 70+000 | | | | |
| | 1,435,500 | 2,266,000 | 2,672,000 | 3,078,900 |
| 50+000 | | | | |
| | 1,196,300 | 1,790,400 | 2,086,000 | 2,381,300 |
| 40+000 | | | | |
| | 1,345,900 | 2,185,000 | 2,598,000 | 3,011,600 |
| 24+000 | | | | |
| | 901,500 | 1,778,700 | 2,216,000 | 2,651,200 |
| 0+000 | | | | |
| Subtotal | 7,729,800 | 12,379,800 | 14,675,000 | 16,967,600 |
| 0+000 | | | | |
| | 3,136,800 | 5,923,100 | 7,303,000 | 8,682,200 |
| -60+000B | | | | |
| | 127,700 | 702,600 | 1,162,000 | 1,620,300 |
| -85+000B | | | | |
| Subtotal | 3,264,200 | 6,625,700 | 8,465,000 | 10,302,500 |
| | | | | |
| Total Project | 10,994,000 | 19,005,500 | 23,140,000 | 27,270,100 |

Table 5-14 provides a summary of the new work quantities to be removed for the 50-foot project alternative which was evaluated in detail. Required depth is defined as the project depth plus advance maintenance.

**Table 6-14 Expansion Quantities for the 50-foot Project**

| Station | Required Depth, (FT) | Required Volume (CY) | Allowable Overdepth Qty (CY) | Total Quantity (CY) |
|---|---|---|---|---|
| 103+000 | | | | |
| | 50 | 246,600 | 56,700 | 303,300 |
| 102+000 | | | | |
| | 52 | 1,759,700 | 459,800 | 2,219,500 |
| 97+750 | | | | |
| | 52 | 2,134,700 | 827,700 | 2,962,400 |
| 79+000 | | | | |
| | 52 | 1,381,300 | 435,300 | 1,816,600 |
| 70+000 | | | | |
| | 54 | 2,919,200 | 954,900 | 3,874,100 |
| 50+000 | | | | |
| | 54 | 2,288,000 | 675,300 | 2,963,300 |
| 40+000 | | | | |
| | 54 | 2,908,900 | 915,500 | 3,824,000 |
| 24+000 | | | | |
| | 52 | 2,541,900 | 963,800 | 3,505,700 |
| 0+000 | | | | |
| Subtotal | | 16,179,900 | 5,289,000 | 21,468,900 |
| 0+000 | | | | |
| | 52 | 1,496,900 | 573,700 | 2,070,600 |

| | | | | |
|---|---|---|---|---|
| -14+000B | | | | |
| | 52 | 3,806,100 | 1,349,700 | 5,155,800 |
| -35+000B | | | | |

**Table 6-15 Expansion Quantities (cont'd)**

| Station (cont'd) | Required Depth, (FT) | Required Volume (CY) | Allowable Overdepth Qty (CY) | Total Quantity (CY) |
|---|---|---|---|---|
| -35+000B | | | | |
| | 52 | 3,091,700 | 1,070,700 | 4,162,400 |
| -60+000B | | | | |
| | 52 | 1,586,100 | 1,029,700 | 2,615,800 |
| -85+000B | | | | |
| Subtotal | | 9,980,800 | 4,023,800 | 14,004,600 |
| | | | | |
| Total Project | | 26,160,700 | 9,312,800 | 35,473,500 |

### 6.7.1. Advance Maintenance

The advance maintenance program for Savannah Harbor, which was approved by the South Atlantic Division in their letter dated 9 July 1996, will continue after completion of construction of the expansion project. Existing advance maintenance will be recreated in the expansion project and is reflected as a cost-shared construction cost. Advance maintenance has been justified as the most economical process to maintain the project and meet the demands of the users. It is not anticipated that the expansion will have a significant impact on the location of the shoals. Shoaling locations for the 34-foot project were compared to shoaling which has occurred since the deepening to elevation -42 feet, MLW, in 1994. This represents an 8-foot deepening and, with the exception of the increase in Kings Island turning basin, there has not been a significant change in shoaling patterns. Conditions in the harbor for the 34- and 42-foot projects are similar. The tide gate did not exist when the project depth was 34 feet and New Cut was closed and the tide gate was taken out of operation before the 42-foot project was dredged.

Based on this comparison, there are no plans at this time to change the existing advance maintenance practices.

Sedimentation modeling will be performed in CED to verify that the project will not have significant changes on the shoaling patterns in the channel. If the model indicates that shoaling will change, the advance maintenance program will be re-evaluated.

### 6.7.2. Allowable Overdepth

Reference 2.8 states that allowable overdepth dredging, when practiced in the ongoing maintenance of an existing project, is part of the without project condition. The removal of existing allowable overdepth when dredged as part of a deepening project should be allocated to O&M. The reference further states that the allocation principle applies only to that portion of the channel where allowable overdepth dredging has historically been required to economically maintain the "old" existing project. Shoaling in the existing project typically forms along the channel toes and migrates towards the centerline of the channel. To adhere to the district's internal policy to perform dredging when shoaling occurs two feet above the project depth in any two adjacent quarters, dredging is performed before shoals extend across the full channel width. Dredging only occurs in areas which are shoaled above the required pay prism and the contractor is not directed to remove material in areas which contain material only in the allowable overdepth prism. Shoaling in Savannah Harbor is dynamic and the length, width, depth, and location of shoals are not the same for every contract. In accordance with Reference 2.8, both the without and with project conditions include quantities for dredging two feet of allowable overdepth.

## 6.8. Debris Disposal

Construction of wideners will require the acquisition of real estate on the north bank of the river because the top of slope line is landward of the existing mean low water line. The areas which require acquisition are described in paragraph "Sideslopes and Bank Stability". The riverbanks in these areas contain debris which will require removal prior to commencement of dredging to prevent damage to the dredge. Types of debris include timber and concrete piles, lumber, wooden vessel hulls, riprap, concrete, abandoned pipe, miscellaneous scrap metal, trees, and other vegetation. The contractor will also be required to remove and dispose of 2 steel sheet pile walls and a section of timber pile dock. A 350-foot long section of steel sheet pile wall is located between Stations 78+140 and 77+261. Another steel sheet pile wall and a timber pile dock are located between Stations 76+170 and 75+000. The debris will be removed using land-based and/or marine equipment. Trees, vegetation, and wooden objects may be burned on-site provided the contractor obtains burn permits from appropriate state and local authorities. Two locations will be designated as off-loading points if marine equipment is used to perform debris removal. One location, see Figure 65, is the existing landing site at Screven Ferry Road in the Back River. This area is located near the area where the front dikes for disposal areas 12A and 12B meet. The other area, see Figure 66, is an improved pipe ramp located in disposal area 1N, approximate river Station 111+750. Material is available in disposal area 1N for construction of the improved access ramp. The riprap may either become the property of the contractor, stockpiled at a designated location, or placed in a commercial landfill. The designated stockpile location for riprap is adjacent to the north abutment of the tide gate structure located in Back River. All other debris will be placed in a commercial landfill. The offloading locations provide easy access to highways where commercial landfill sites are located. The contractor will be responsible for improving and maintaining haul roads and access points necessary for the proper disposal of the debris.

It is anticipated that dredges working in the inner harbor will encounter debris in the required dredging prism which is not visible from the existing shoreline. This has been the experience from previous deepening and widening contracts. Types of debris anticipated to be encountered include piling, cable, riprap, miscellaneous steel shapes, timber, submerged trees, concrete, etc. During the last harbor deepening, several training walls and wing dams were removed from areas where wideners were dredged. Material removed from these structures included log and timber cribbing/mattresses and riprap of varying sizes. As a result of the channel realignment between Stations 52+800 and 49+750, the South Channel Training Wall will be removed. This structure is located on the south side of the channel approximately between Stations 51+900 and 49+750. Contractors working near these training wall sites may encounter remnants of these structures. Construction contracts will include bid items for the contractor to provide marine equipment to remove debris encountered by the dredge. This debris will also be disposed of in a commercial landfill.

# 7. DREDGED MATERIAL MANAGEMENT PLAN FOR EXPANSION

This section addresses the disposal of dredged material for the expansion project. The Dredged Material Management Plan is divided into two parts. The first part, Dredged Material Disposal Through Completion of Expansion, addresses disposal of maintenance material and disposal of new work material through completion of the expansion project. The second part, Long Term Dredged Material Management Plan for Expansion, addresses the impact of expansion on maintenance dredging and disposal after the expansion project is completed.

Reference 2.9 provides the base plan for the operation and maintenance of the Savannah Harbor disposal areas. This reference includes details of items such as water management practices within the upland confined disposal areas, mitigation actions for the dike construction of Disposal Area 14A, and a plan for disposal area rotation. Detailed information on the long term operation and maintenance of the disposal areas can be found in Reference 2.9. This plan does not supercede Reference 2.9.

## 7.1. Dredged Material Disposal Through Completion of Expansion

### 7.1.1. Existing Disposal Areas

The upland disposal areas for Savannah Harbor are located on the north bank of the navigation channel as shown on Figure 1. The EPA approved ocean dredged material disposal site is located south of the navigation channel also as shown on Figure 1.

#### 7.1.1.1. Disposal Area 1N

Area 1N is the westernmost disposal area in Savannah Harbor. It is located on Onslow Island which is part of the Savannah National Wildlife Refuge (SNWR). This disposal area has easy access to GA Route 25 by a short dirt haul road. Material from Station 112+500 to 103+000 is routinely placed into Disposal Area 1N. Generally, material is borrowed from the area and reused at about the same rate that dredged material is placed into the site.

#### 7.1.1.2. Disposal Area 1S

Area 1S is also located on Onslow Island on the southeastern tip of the island. This site is not accessible by land. The area is not diked and is heavily vegetated. Area 1S has not been used for maintenance dredging of the Federal navigation channel for several years. The area has not been used because of the costs associated with diking and clearing the area. The area was used for disposal of dredged material recently by the Georgia Ports Authority. A dike was constructed to contain material from the one time dredging event. Sand has been mounded in the area but has not been reused because of the high transportation costs involved with rehandling and removing the material off the island.

#### 7.1.1.3. Disposal Area 2A

Disposal area 2A is located on the west end of Hutchinson Island. A portion of this disposal area is located within the boundary of the Savannah National Wildlife Refuge. The dikes in 2A were last raised in 1997. Area 2A is being used for disposal of maintenance material from Station 103+000 to 79+600 in FY98. However, the area is expected to be filled again by 1999. In addition, powerlines from Savannah Electric and Power Company cross the disposal area. There is not sufficient safety clearance between the top of the dike and the lowpoint of the powerline to allow additional dike raising without raising or relocating the powerlines. Planning is in progress to raise the powerlines again by 12 feet. Currently, it is planned to begin raising the powerlines in August 1998. A concurrent dike raising contract is also planned. The dikes for area 2A can be raised again and the area would again be available for disposal of dredged material. However, this capacity will quickly be filled again by O&M material. Because of the uncertainty of the funding and the unknowns of the dike construction scheduling, for this study area 2A was not considered available for either the disposal of expansion material or maintenance material after completion of expansion.

#### 7.1.1.4. Disposal Areas 12A, 12B, 13A, 13B, 14A, and 14B

Disposal areas 12A, 12B, 13A, 13B are all diked disposal areas located on the South Carolina bank of the Savannah River beginning just downstream of the U.S. Hwy 17 bridge. These areas are continuous from the bridge downstream to Area 13B. Disposal area 14A is downstream of Area 13B but is not diked and cannot be used until the dikes and an interior bird island are constructed in accordance with the requirements in Reference 2.9. Area 14B is downstream of 14A and is diked. Area 12A is the largest disposal area for the harbor. Dredged material from Station 79+600 to 26+400 is normally placed into these areas. Dredged material from the sediment basin is generally placed into 12A, 12B and 13A. Figures 67 through 71 show the aerial photographs taken in 1997 of these disposal areas.

#### 7.1.1.5. Jones/Oysterbed Island Disposal Area

This area is the easternmost upland confined disposal area in the harbor. The area is on a manmade island which was created by deposited material intended to “train” the shipping channel. The island is approximately 5 miles long. A portion of this disposal area is within the limits of the Tybee National Wildlife Refuge. Generally, material from Station 26+400 to 0+000 is placed into this area. Figures 72 through 74 show the aerial photographs taken in 1997 of this area.

#### 7.1.1.6. Ocean Dredged Material Disposal Site

Material from Station 0+000 to the outer end of the entrance channel is removed by hopper dredges and placed into the ocean dredged material disposal site. The site has water depths ranging from elevations –22 feet, MLW, to –47 feet, MLW. To evaluate long term behavior of material in the ocean dredged material disposal site, the elevations were compared between two surveys taken seventeen years apart. The area was surveyed in October, 1980 and in August, 1997. Over the time period between the surveys it appears that the site has been dispersive and no significant accumulation was detected.

#### 7.1.1.7. Existing Capacities

Topographic surveys of disposal areas 12A, 12B, 13A, 13B, 14B, and Jones/Oysterbed (J/O) Island were obtained from aerial mapping which was performed in July, 1997. These surveys were the basis for determining the remaining capacity in each of these disposal areas. The capacities were computed using InXpress® software. The capacities were computed by taking the volumetric difference between the existing surface of the disposal area and a horizontal plane at the lowest elevation of the top of the existing dikes. The lowest dike elevation is the point of maximum ponded water before the disposal area dikes are overtopped. The "Capacity" column of Table 6-1 provides the volume remaining and the estimated surface area in each disposal area. It should be noted that this is the volume between the surface of the dredged material inside the area and the lowest elevation on the top of the surrounding dike. It does not include allowance for freeboard and ponded water which are required during dredging operations. The "Usable Capacity" column has removed an allowance for ponding and freeboard from the total capacity. This more accurately reflects the volume of dredged material that can be placed in the disposal area.

Table 6-1 also lists the surface area for the ocean disposal area which was computed using a hydrographic survey which was performed on August, 1997. Inside the disposal area the elevations vary from about –22 feet, MLW, to –47 feet, MLW. Each one-foot layer of the area provides storage for approximately 5,695,000 CY of dredged material.

**Table 2-1 Estimated Useable Surface Area and Capacity**

| Disposal Area | Surface Area, AC | Min Dike Elev., FT, MLW | Capacity, CY | Usable Capacity, CY |
|---|---|---|---|---|
| 12A | 1087 | 30 | 9,404,850 | 4,143,800 |
| | | | | |
| 12B | 707 | 46 | 9,125,010 | 5,703,130 |
| | | | | |
| 13A | 690 | 27 | 9,752,650 | 6,413,000 |
| | | | | |
| 13B | 620 | 26 | 5,041,945 | 2,041,100 |
| | | | | |
| 14B | 750 | 18 | 4,147,460 | 517,460 |
| | | | | |
| J/O | 754 | 18 | 4,746,780 | 1,097,400 |
| | | | | |
| OCEAN | 3,530 | N.A. | N.A. | N.A. |

### 7.1.2. Disposal of Maintenance Material Prior to Expansion

Since dredging for the expansion project is not expected to commence until July, 1999, it is necessary to evaluate the impact continued maintenance dredging will have on the upland disposal area capacities from present dredging operations to commencement of expansion dredging. There are two maintenance dredging contracts in the inner harbor to dredge the existing navigation channel between Stations 112+500 and 0+000 and to dredge the sediment basin. This work will occur during 1997 and 1998. Two other contracts will be awarded for maintenance dredging between Stations 112+500 and -14+000B and in the sediment basin. Dredging is anticipated to start in June 1998, and will be completed in March 1999. Material dredged as part of these contracts will be placed in the disposal areas that will be used for the expansion dredging. Disposal area management activities such as dewatering and ditching will be performed when dredging is completed and these operations will result in consolidation of the dredged material and short-term gains in disposal area capacity prior to the next scheduled dredging activity. Table 6-2 summarizes the capacity requirements anticipated at the completion of disposal area management activities. These volumes are based on consolidation and shrinking of the fine-grained material which has occurred as a result of ditching and dewatering activities. The average annual volume of maintenance dredging from the existing project is calculated by averaging the dredging volumes from the last three maintenance contracts since deepening in 1994 was completed.

**Table 7-2 Dewatered Maintenance Material Storage Requirements Prior to Expansion**

| Station | DA 12A | DA 13A | DA 13B | DA 14B | DA J/O |
|---|---|---|---|---|---|
| FY97 MAINT | | | | | |
| 0+000 | | | | | |
| | | | | | 350,000 |
| 24+000 | | | | | |
| | | | | 278,500 | |
| 40+000 | | | | | |
| | | | 767,830 | | |
| 60+000 | | | | | |
| | 921,190 | | | | |
| 79+000 | | | | | |
| | | | | | |
| Sed Basin | 1,610,960 | | | | |
| | | | | | |
| FY98 MAINT | | | | | |
| -14+000B | | | | | |
| | | | | | 800,000 |
| 0+000 | | | | | |
| | | | | | |
| 24+000 | | | | | |
| | | | | 278,500 | |
| 40+000 | | | | | |
| | | 383,910 | | | |
| 50+000 | | | | | |
| | 1,402,960 | | | | |
| 79+000 | | | | | |
| | | | | | |
| Sed Basin | | | 1,610,960 | | |
| | | | | | |
| Totals | 3,935,110 | 383,910 | 2,378,790 | 557,000 | 1,150,000 |

### 7.1.3. Disposal Locations for Expansion

#### 7.1.3.1. Ocean Disposal

Four alternative open water disposal sites were considered for material dredged from the entrance channel. These sites are discussed in Reference 2.9. Use of these sites would permit the use of pipeline dredges to deepen the entrance channel since the pumping distances between the dredging and disposal sites would be relatively short. Clamshell or bucket dredges could also be used if these sites were made available due to the relatively short haul distances between the dredge locations and the disposal site.

One area was a nearshore site located seaward of the 6-foot contour off the north end of Tybee Island where material could be placed using a pipeline dredge or shallow draft scows. The dredged material would have the potential to be moved by longshore currents and wave action in the sand sharing system resulting in deposition on Tybee Island or downdrift beaches.

The second alternative was a series of submerged berms which would be located in approximately 15 feet of water on the south side of the entrance channel between approximately Stations –19+000B and –60+000B. The berms would be a minimum of 2,000 feet away from the channel and 2,000 feet apart.

The third alternative was the construction of a nearshore feeder berm. The proposed feeder berm would be constructed parallel to Tybee Beach, 4,000 to 7,000 feet offshore and in water with an average depth of 8 feet. The berm's crest would be approximately 500 feet wide and the top elevation could be no higher than –5 feet, MLW. The berm would be located approximately 5,000 feet away from the channel. The shallow depth of the area in which the berm would be constructed would result in the berm being dispersive, with the deposited dredged material being moved offsite by waves and currents. According to Reference 2.10, the relatively close proximity of the berm to the beach would increase the likelihood that the sediments would migrate to the beach. As waves expend energy moving sediment from the berms, they will have less energy to erode Tybee Island's shoreline.

The forth alternative was to place material in the EPA approved ocean disposal site. This site has an area of 4.26 square miles and is centered at 31°56′54″N and 80°45′34″W. It is approximately 3.7 nautical miles offshore and is in 22 to 47 feet of water. This site is presently used for disposal of material removed during regular maintenance dredging and has also been used for the disposal of new work dredged material. Material generally migrates from the site, as no significant accumulation is evident even though the site has been used for over 30 years.

Based on the data used for the feasibility study, the percent fines was evaluated and determined to be unacceptable for placement in the nearshore zone. The evaluation is discussed in Reference 2.10. As a result, material dredged from the entrance channel will be placed in the EPA offshore disposal site. Additional geotechnical testing as described in paragraph "Continuing Engineering and Design Activities" will be performed during CED. If these analyses indicate an acceptable sediment quality and if feasible excavation and placement designs can be developed, nearshore placement would also be used.

**7.1.3.2. Placement on Tybee Island**

Representatives from Tybee Island have expressed an interest in placing material dredged from the entrance channel directly onto the beach. The reach of the beach in the vicinity of Second Avenue would benefit from the placement of material. This area is exposed to northeast winds and has a rapid erosion rate because of the orientation and alignment of the island. The north end of Tybee was used as a disposal location during the previous deepening project. This material contained fines which washed out and a plume which dispersed, however, there appeared to be no significant adverse impacts from this activity. Based on the data available geotechnical information, it appears that not all of the dredged material is suitable for beach placement. Therefore, this disposal option was eliminated from further study during feasibility. If CED investigations indicate that sufficient suitable material is available, direct placement on Tybee will be reconsidered.

**7.1.3.3. Confined Disposal**

Material dredged from the inner harbor will be placed in upland confined disposal sites. Use of the sites was coordinated with the existing project's local assurer to determine which areas would not be available due to planned maintenance and improvement activities. Disposal area 2A is not anticipated to have any capacity at the time expansion dredging commences. Dike improvements were completed in November, 19987, and when maintenance dredging is completed in 1999, the area will have no capacity. Because of the powerline crossing area 2A, the dikes will not be able to be raised again until the powerlines are relocated or raised. No plans have been executed for these powerline improvements prior to commencement of expansion dredging. Therefore, for this study it was assumed that disposal area 2A will not be used for the Expansion project dredging. Disposal area 13B will also not be available because of a scheduled dike improvement project which cannot be delayed. The confined disposal sites that will be used for the expansion project are disposal areas 12A, 12B, 13A, 14B, and Jones/Oysterbed Island and are shown in Figure 75.

Because disposal area 2A will no longer be available, an analysis was performed to determine if constructing a new upstream disposal area would be more cost effective than pumping material from 103+000 to 79+000 downstream to disposal area 12A. The initial storage capacity requirements for material from 103+000 to 79+000 are approximately 7.9 million CY which includes bulking and maintenance material anticipated to be dredged along with the deepening material. Another criteria was that the site would be located about the same proximity from the navigation channel that the other disposal areas upstream of the bridge are located. The only area that met the requirements was to combine the existing areas 1N and 1S into one large area and to encompass additional marsh. The connecting dike would require filling a small creek that runs between the two areas. The proposed new area was a total of 1,360 acres. This would provide sufficient area to contain the material dredged during expansion. However, this area would require extensive construction before it would be available for dredging. Approximately 11,500 linear feet of dike will require construction. Eight new weirs would be required to maintain effluent water quality. The dike and weir construction costs are estimated to be approximately $3,800,000. In addition to the construction costs the expansion project would be responsible for real estate and acquisition costs. Based on an estimate from the Savannah District Real Estate section, the acquisition mitigation costs for approximately 300 acres of marsh are $8,100,000 using a 5:1 mitigation ratio. Also, approximately 500 upland acres would have to be acquired at an estimated cost of $750,000. The additional cost to dredge the material and place it into 12A instead of 2A is estimated to be approximately $4,030,000. The total costs of $12,650,000 to acquire, mitigate, and construct the disposal area are higher than the incremental dredging cost difference of $4,030,000 to pump the material downstream to disposal area 12A. Therefore, constructing a new upstream area is not an economical alternative.

### 7.1.4. Initial Storage Capacity Requirements for Expansion

Hydrographic surveys of the navigation channel were performed in March and April, 1997. These were used to calculate the volume of new work material which will be placed in each disposal area. The new work volumes provided in Tables 15 and 16 were used for the initial storage capacity requirement computations.

#### 7.1.4.1. Excess Dredging

In all dredging operations, the contractor removes material from outside of the maximum pay prism. This is called excess or non-pay yardage. When dredged materials are placed in a diked disposal area, both pay and non-pay volumes must be included in the capacity analysis. The volume of excess dredging is generally a function of the type of material being dredged, the depth of allowable overdepth, the dredge size and depth of dredging bank, tide range, and, to some extent, the weather. Yardage computation sheets from the deepening project completed in 1994 were used to determine the volume of excess dredging which occurred during that project and to estimate the excess yardage for harbor expansion. Approximately 33% of the total volume dredged was excess yardage for which the contractor was not paid. The contractors dredged approximately 8,975,000 CY of material from between Stations 103+000 and 0+000 in the inner harbor but were only paid for removal of approximately 5,995,000 CY. It should be noted, however, that the contracts for the last deepening did not include allowable overdepth. Therefore, it is reasonable that the excess yardage removed during the 1994 deepening would be higher than another project which included allowable overdepth.

Using the volume of excess yardage, it was calculated that the contractor overdredged the inner harbor by an average depth of 1.5 feet. For the proposed expansion project, it is estimated that the dredge will make at least two passes across the channel width to achieve the required project depth. The second pass will be inefficient for the pumps because of a reduced depth of cut. Therefore, the contractor will overdredge the project as long as the materials are not cemented and can be easily excavated. For this reason, it is estimated that the contractor will remove materials 0.8 feet below the maximum pay prism. Tables 6-3, 6-4, 6-5 and 6-6 are a summary of the volumes of pay and excess yardage used in the disposal area evaluation.

**Table 7-3 Estimated Total Volume of New Work Material to be Dredged for a 46′ Project**

| Station | 46′ Pay Volume CY | Excess Volume CY | Total Dredged CY |
|---|---|---|---|
| 0+000 | | | |
| | 1,778,700 | 341,000 | 2,119,700 |
| 24+000 | | | |
| | 2,185,000 | 330,600 | 2,515,600 |
| 40+000 | | | |
| | 1,790,400 | 236,400 | 2,026,800 |
| 50+000 | | | |
| | 1,699,500 | 243,900 | 1,943,400 |
| 65+000 | | | |
| | 1,695,100 | 220,500 | 1,915,600 |
| 79+000 | | | |
| | 3,231,100 | 454,800 | 3,685,900 |
| 103+000 | | | |
| Totals | 12,379,800 | 1,827,200 | 14,207,000 |

**Table 7-4 Estimated Total Volume of New Work Material to be Dredged for a 47′ Project**

| Station | 47′ Pay Volume CY | Excess Volume CY | Total Dredged CY |
|---|---|---|---|
| 0+000 | | | |
| | 2,216,000 | 349,000 | 2,565,000 |
| 24+000 | | | |
| | 2,598,000 | 325,000 | 2,923,000 |
| 40+000 | | | |
| | 2,086,000 | 318,000 | 2,404,000 |
| 50+000 | | | |
| | 2,004,000 | 233,000 | 2,237,000 |
| 65+000 | | | |
| | 1,971,000 | 216,000 | 2,187,000 |
| 79+000 | | | |
| | 3,800,000 | 447,000 | 4,247,000 |
| 103+000 | | | |
| Totals | 14,675,000 | 1,888,000 | 16,563,000 |

**Table 7-5 Estimated Total Volume of New Work Material to be Dredged for a 48′ Project**

| Station | 48′ Pay Volume CY | Excess Volume CY | Total Dredged CY |
|---|---|---|---|
| 0+000 | | | |
| | 2,631,200 | 349,800 | 2,981,000 |
| 24+000 | | | |
| | 3,011,600 | 325,000 | 3,336,600 |
| 40+000 | | | |
| | 2,381,300 | 232,800 | 2,614,100 |
| 50+000 | | | |
| | 2,309,200 | 238,600 | 2,547,800 |
| 65+000 | | | |
| | 2,246,300 | 215,500 | 2,461,800 |
| 79+000 | | | |
| | 4,368,000 | 446,700 | 4,814,700 |
| 103+000 | | | |
| Totals | 16,947,600 | 1,808,400 | 18,756,000 |

**Table 7-6 Estimated Total Volume of New Work Material to be Dredged for a 50′ Project**

| Station | 50′ Pay Volume CY | Excess Volume CY | Total Dredged CY |
|---|---|---|---|
| 0+000 | | | |
| | 3,505,700 | 385,500 | 3,891,200 |
| 24+000 | | | |
| | 3,824,000 | 366,200 | 4,190,200 |
| 40+000 | | | |
| | 2,963,300 | 270,100 | 3,233,400 |
| 50+000 | | | |
| | 2,905,600 | 286,500 | 3,192,100 |
| 65+000 | | | |
| | 2,785,100 | 269,600 | 3,054,700 |
| 79+000 | | | |
| | 5,485,200 | 537,700 | 6,022,900 |
| 103+000 | | | |
| Totals | 21,468,900 | 2,115,600 | 23,584,500 |

#### 7.1.4.2. Dredged Material Characteristics

A determination of the percentages and types of materials to be dredged is required to determine initial storage requirements for the dredging operations. Fine grained material, primarily silts and clays passing the No. 200 sieve, generally flow through the disposal area and settle across the entire ponded surface of the area. For the purpose of this analysis, it is assumed that the fine-grained material will settle uniformly throughout each disposal area. The coarse grained material can be stockpiled above the ponded elevation and used for future dike projects. Material percentages developed for the last deepening were used to determine the percentages of fine and coarse grained materials. Tables 6-7, 6-8, 6-9 and 6-10 contain a breakdown of the percentages of dredging volumes of fine and coarse-grained materials.

**Table 7-7 Volume of Coarse and Fine Grained Materials in New Work for a 46′ Project**

| Station | Sands % | Volume, CY | Fines % | Volume, CY |
|---|---|---|---|---|
| 0+000 | | | | |
| | 87 | 1,844,100 | 13 | 275,600 |
| 24+000 | | | | |
| | 36 | 905,600 | 64 | 1,610,000 |
| 40+000 | | | | |
| | 68 | 1,378,200 | 32 | 648,600 |
| 50+000 | | | | |
| | 68 | 1,321,500 | 32 | 621,900 |
| 65+000 | | | | |
| | 70 | 1,340,900 | 30 | 574,700 |
| 79+000 | | | | |
| | 54 | 1,990,400 | 46 | 1,695,500 |
| 103+000 | | | | |

**Table 7-8 Volume of Coarse and Fine Grained Materials in New Work for a 47′ Project**

| Station | Sands % | Volume, CY | Fines % | Volume, CY |
|---|---|---|---|---|
| 0+000 | | | | |
| | 87 | 2,231,600 | 13 | 333,400 |
| 24+000 | | | | |
| | 36 | 1,052,300 | 64 | 1,870,700 |
| 40+000 | | | | |
| | 68 | 1,634,700 | 32 | 769,300 |
| 50+000 | | | | |
| | 68 | 1,521,000 | 32 | 715,800 |
| 65+000 | | | | |
| | 70 | 1,530,600 | 30 | 656,000 |
| 79+000 | | | | |
| | 54 | 2,293,300 | 46 | 1,953,600 |
| 103+000 | | | | |

**Table 7-9 Volume of Coarse and Fine Grained Materials in New Work for a 48′ Project**

| Station | Sands % | Volume, CY | Fines % | Volume, CY |
|---|---|---|---|---|
| 0+000 | | | | |
| | 87 | 2,593,500 | 13 | 387,500 |
| 24+000 | | | | |
| | 36 | 1,202,200 | 64 | 2,135,400 |
| 40+000 | | | | |
| | 68 | 1,777,600 | 32 | 836,500 |
| 50+000 | | | | |
| | 68 | 1,732,500 | 32 | 815,300 |
| 65+000 | | | | |
| | 70 | 1,723,300 | 30 | 738,500 |
| 79+000 | | | | |
| | 54 | 2,599,900 | 46 | 2,214,800 |
| 103+000 | | | | |

**Table 7-10 Volume of Coarse and Fine Grained Materials in New Work for a 50' Project**

| Station | Sands % | Volume, CY | Fines % | Volume, CY |
|---|---|---|---|---|
| 0+000 | | | | |
| | 87 | 3,385,300 | 13 | 505,900 |
| 24+000 | | | | |
| | 36 | 1,508,500 | 64 | 2,681,700 |
| 40+000 | | | | |
| | 68 | 2,198,700 | 32 | 1,034,700 |
| 50+000 | | | | |
| | 68 | 2,170,600 | 32 | 1,021,500 |
| 65+000 | | | | |
| | 70 | 2,138,300 | 30 | 916,400 |
| 79+000 | | | | |
| | 54 | 3,252,400 | 46 | 2,770,500 |
| 103+000 | | | | |

### 7.1.4.3. Bulking Characteristics of the Dredged Material

Coarse-grained dredged materials drain quickly and generally occupy the same volume in-situ as they do in the disposal area. However, when fine-grained materials are dredged, they initially occupy a larger volume in the disposal area than when measured in-situ in the navigation channel. This is a result of increasing the void ratio in the sediments during the dredging process and is known as bulking. Laboratory testing was performed in 1981 on maintenance sediments obtained from the navigation channel and sediment basin. These test results were used to calculate the increase in initial storage volume required in the disposal area as a result of bulking the fine-grained material. It is assumed that the physical and chemical characteristics of the fine grained maintenance material have not changed significantly since the last testing and the bulking factors previously calculated can be applied to the material to be dredged for the expansion project. Bulking for initial storage assessment is not required for the coarse grained material. Table 6-11 lists the bulking factors which were applied and the bulked volume of the fine-grained material to be placed in the disposal areas.

**Table 7-11 Fine Grained Material Bulking Factors**

| Station | Bulking Factor % | 46′ Project Volume Fines, CY | 47′ Project Volume Fines, CY | 48′ Project Volume Fines, CY | 50′ Project Volume Fines, CY |
|---|---|---|---|---|---|
| 0+000 | | | | | |
| | 18 | 325,200 | 393,400 | 457,300 | 597,000 |
| 24+000 | | | | | |
| | 18 | 1,899,800 | 2,207,600 | 2,519,800 | 3,164,400 |
| 40+000 | | | | | |
| | 45 | 856,200 | 1,115,500 | 1,212,900 | 1,500,300 |
| 50+000 | | | | | |
| | 45 | 820,900 | 1,037,900 | 1,182,200 | 1,481,200 |
| 65+000 | | | | | |
| | 32 | 758,600 | 865,900 | 974,800 | 1,209,600 |
| 79+000 | | | | | |
| | 32 | 2,238,100 | 2,578,700 | 2,923,500 | 3,657,100 |
| 103+000 | | | | | |

Coarse-grained sands can be stockpiled along the front dike of each disposal area for use in future dike improvements. This material can be mounded above the top elevation of the dike if inflows from the dredge pipe are directed away from the dike. This can be accomplished by placing and moving the inflow end of the dredge pipe during dredging and by shaping the disposal mound and directing flows with earthmoving equipment. The advantage to mounding the sand is that it reduces the disposal capacity required to store the material dredged during expansion. For this project, it was assumed that 50% of the sands could be mounded along the front dike provided a containment berm was constructed inside the disposal area and parallel to the front dike. Tables 6-12, 6-13, 6-14, and 6-15 show the volume of material which could be mounded and the height of the stockpile if the material were contained in the subcompartment.

**Table 7-12 Estimated Height of Stockpiled Sands for 46′ Project**

| Station | Vol. Sand, CY | Disposal Area | Compart, AC | Mound Ht, FT |
|---|---|---|---|---|
| 0+000 | | | | |
| | 1,844,100 | J/O | 221 | 2.6 |
| 24+000 | | | | |
| | 905,600 | 14B | 202 | 1.4 |
| 40+000 | | | | |
| | 1,378,200 | 13A | 209 | 2.0 |
| 50+000 | | | | |
| | 1,321,500 | 12B | 172 | 2.4 |
| 65+000 | | | | |
| | 3,331,300 | 12A | 125 | 8.3 |
| 103+000 | | | | |

**Table 7-13 Estimated Height of Stockpiled Sands for 47′ Project**

| Station | Vol. Sand, CY | Disposal Area | Compart, AC | Mound Ht, FT |
|---|---|---|---|---|
| 0+000 | | | | |
| | 1,115,800 | J/O | 221 | 3.2 |
| 24+000 | | | | |
| | 526,100 | 14B | 202 | 1.7 |
| 40+000 | | | | |
| | 817,400 | 13A | 209 | 2.4 |
| 50+000 | | | | |
| | 760,000 | 12B | 172 | 2.8 |
| 65+000 | | | | |
| | 1,911,900 | 12A | 125 | 9.5 |
| 103+000 | | | | |

**Table 7-14 Estimated Height of Stockpiled Sands for 48' Project**

| Station | Vol. Sand, CY | Disposal Area | Compart, AC | Mound Ht, FT |
|---|---|---|---|---|
| 0+000 | | | | |
| | 2,593,500 | J/O | 221 | 3.6 |
| 24+000 | | | | |
| | 1,201,200 | 14B | 202 | 1.8 |
| 40+000 | | | | |
| | 1,777,600 | 13A | 209 | 2.6 |
| 50+000 | | | | |
| | 1,732,500 | 12B | 172 | 3.1 |
| 65+000 | | | | |
| | 4,323,200 | 12A | 125 | 10.7 |
| 103+000 | | | | |

**Table 7-15 Estimated Height of Stockpiled Sands for 50' Project**

| Station | Vol. Sand, CY | Disposal Area | Compart, AC | Mound Ht, FT |
|---|---|---|---|---|
| 0+000 | | | | |
| | 3,385,300 | J/O | 221 | 4.7 |
| 24+000 | | | | |
| | 1,508,500 | 14B | 202 | 2.3 |
| 40+000 | | | | |
| | 2,198,700 | 13A | 209 | 3.3 |
| 50+000 | | | | |
| | 2,170,600 | 12B | 172 | 3.9 |
| 65+000 | | | | |
| | 5,390,700 | 12A | 125 | 13.4 |
| 103+000 | | | | |

### 7.1.5. Dike Construction Prior to Expansion

#### 7.1.5.1. DOT Dike Construction

The GADOT has plans to raise the dikes in area 12B. They anticipate that the contract will be advertised in April 1998, provided funds are available. The front dike will be raised to elevation 52 feet, MLW and the back dike to 46 feet, MLW. The disposal area evaluation was performed based on the assumption that area 12B would be raised and construction completed by July 1999. Area 13A is currently out for bids to raise the front dike to elevation 42 feet MLW and the back dike to elevation 40 feet, MLW. The GADOT has plans, provided funds are available, to raise area 13B in 1999, and for this reason, it was considered unavailable for the expansion project. Some improvements to the front and west dike in area 14B are planned pending receipt of funds, and are anticipated to be completed prior to expansion. At the present time, there are no plans for improvements to the dikes in disposal areas 12A or Jones/Oysterbed Island by the GADOT.

**7.1.5.2. Estimated Capacities, July 1999**

The existing disposal area capacities will be reduced as a result of two years of maintenance dredging which will be completed before July, 1999. Table 6-16 provides estimates of the capacities which will be available for storage of dredged material from harbor expansion. The maintenance volume of maintenance material to be placed in Jones/Oysterbed Island includes approximately 800,000 CY of new work advance maintenance material which will be dredged between Stations 0+000 and -14+000B in FY98.

**Table 7-16 Estimated Disposal Area Capacities in July, 1999**

| Disposal Area | Usable Capacity, CY | Maintenance Volume, CY | Remain. Capacity, CY |
|---|---|---|---|
| 12A | 4,143,800 | 3,935,110 | 208,700 |
| | | | |
| 12B | 5,703,100 | 0 | 5,703,100 |
| | | | |
| 13A | 6,413,000 | 383,910 | 6,029,090 |
| | | | |
| 14B | 517,500 | 557,000 | Full |
| | | | |
| J/O | 1,097,400 | 1,150,000 | Full |

An analysis was performed to determine if there will be sufficient disposal area capacity available in July, 1999. Tables 6-17 through 6-20 presents a summary of each area based on mounding coarse-grained materials above the top elevation of the front dike. This will require construction of a compartment inside the disposal area to contain the coarse grained material and some of the fine sands. The dredged volume in the table includes the estimated quantity of maintenance material which will be dredged during the expansion project. The negative value in Tables 6-17, through 6-20 means there is insufficient capacity in the disposal area to contain the new work material and the positive value means there is excess capacity.

**Table 7-17 Impact of 46′ Expansion Project**

| Disposal Area | Dredged Volume, NW, CY | Dredged Volume, Maint, CY | Disp. Area Capacity, CY | Difference, CY |
|---|---|---|---|---|
| 12A | 6,328,000 | 2,183,500 | 208,700 | -8,302,800 |
| | | | | |
| 12B | 2,142,400 | 247,300 | 5,703,100 | 3,313,400 |
| | | | | |
| 13A | 2,234,400 | 838,200 | 6,029,090 | 2,956,490 |
| | | | | |
| 14B | 2,805,400 | 485,600 | Full | -3,291,000 |
| | | | | |
| J/O | 2,169,300 | 94,800 | Full | -2,264,100 |

**Table 7-18 Impact of 47′ Expansion Project**

| Disposal Area | Dredged Volume, NW, CY | Dredged Volume, Maint, CY | Disp. Area Capacity, CY | Difference, CY |
|---|---|---|---|---|
| 12A | 7,268,300 | 2,183,500 | 208,700 | -9,243,100 |
| | | | | |
| 12B | 2,558,900 | 247,300 | 5,703,100 | 2,896,900 |
| | | | | |
| 13A | 2,750,200 | 838,200 | 6,029,090 | 2,440,700 |
| | | | | |
| 14B | 3,259,900 | 485,600 | Full | -3,745,500 |
| | | | | |
| J/O | 2,625,000 | 94,800 | Full | -2,719,800 |

**Table 7-19 Impact of 48' Expansion Project**

| Disposal Area | Dredged Volume, NW, CY | Dredged Volume, Maint, CY | Disp. Area Capacity, CY | Difference, CY |
|---|---|---|---|---|
| 12A | 8,221,500 | 2,183,500 | 208,700 | -10,196,300 |
| | | | | |
| 12B | 2,914,700 | 247,300 | 5,703,100 | 2,541,100 |
| | | | | |
| 13A | 2,990,500 | 838,200 | 6,029,090 | 2,200,390 |
| | | | | |
| 14B | 3,721,000 | 485,600 | Full | -4,206,600 |
| | | | | |
| J/O | 3,050,800 | 94,800 | Full | -3,145,600 |

**Table 7-20 Impact of 50' Expansion Project**

| Disposal Area | Dredged Volume, NW, CY | Dredged Volume, Maint, CY | Disp. Area Capacity, CY | Difference, CY |
|---|---|---|---|---|
| 12A | 10,257,400 | 2,183,500 | 208,700 | -12,232,200 |
| | | | | |
| 12B | 3,651,800 | 247,300 | 5,703,100 | 1,804,000 |
| | | | | |
| 13A | 3,699,000 | 838,200 | 6,029,090 | 1,491,890 |
| | | | | |
| 14B | 4,672,900 | 485,600 | Full | -5,158,500 |
| | | | | |
| J/O | 3,982,300 | 94,800 | Full | -4,077,100 |

### 7.1.6. Improvements Required To Contain New Work Material

Based on this analysis, the dikes in disposal areas 12A, 14B, and Jones/Oysterbed Island require raising. The weirs in 12A and 14B will also require extensions to ensure that the weir height is sufficient. No new discharge locations will be needed because the existing outfall pipes will be reused. Existing pipe ramps will be used. The dikes in area 12A require raising because the volume of material being placed into the area exceeds the estimated available capacity. The dikes in areas 14B and Jones/Oysterbed Island require raising to provide sufficient dike height for freeboard and ponded water required for the expansion dredging operations. The additional height the dikes need to be raised is shown in Tables 6-21, 6-22, 6-23, and 6-24. Table 6-25 shows the length of dike which requires raising to provide sufficient storage capacity for each alternative depth. The lengths of dike to be raised can be determined from Table 6-25 by knowing the required additional height shown in Tables 6-21 through 6-24. Because the initial dike raising required for Jones/Oysterbed Island involves only raising a few hundred feet of dike three feet or less is a minor amount a separate dike raising contract is not warranted. The dredging contractor can raise the dike the required amount prior to the dredging and the cost of the dike improvements will be incidental to the cost of dredging. Sufficient sand is available for the Contractor to easily move and place the material in the low areas of the dike.

**Table 7-21 Additional Required Dike Height For 46' Project**

| Disposal Area | Exist. Min. Elev, FT, MLW | Req'd Added Height, FT | Req'd Min. Elev, FT, MLW |
|---|---|---|---|
| 12A | 30 | 4.4 | 34.4 |
| | | | |
| 14B | 18 | 3.4 | 21.4 |
| | | | |
| J/O | 18 | 2.0 | 20.0 |

**Table 7-22 Additional Required Dike Height For 47' Project**

| Disposal Area | Exist. Min. Elev, FT, MLW | Req'd Added Height, FT | Req'd Min. Elev, FT, MLW |
|---|---|---|---|
| 12A | 30 | 5.0 | 35.0 |
| | | | |
| 14B | 18 | 4.0 | 22.0 |
| | | | |
| J/O | 18 | 2.3 | 20.3 |

**Table 7-23 Additional Required Dike Height for 48' Project**

| Disposal Area | Exist. Min. Elev, FT, MLW | Req'd Added Height, FT | Req'd Min. Elev, FT, MLW |
|---|---|---|---|
| 12A | 30 | 5.5 | 35.5 |
| | | | |
| 14B | 18 | 4.1 | 22.1 |
| | | | |
| J/O | 18 | 2.6 | 20.6 |

**Table 7-24 Additional Required Dike Height for 50' Project**

| Disposal Area | Exist. Min. Elev, FT, MLW | Req'd Added Height, FT | Req'd Min. Elev, FT, MLW |
|---|---|---|---|
| 12A | 30 | 7 | 37 |
| | | | |
| 14B | 18 | 5 | 23 |
| | | | |
| J/O | 18 | 3 | 21 |

**Table 7-25 Length of Required Dike Improvements**

| Dike Height, FT | DA 12A | DA 14B | DA J/O |
|---|---|---|---|
| 1 | 18,670 | 1,210 | 50 |
| | | | |
| 2 | 2,970 | 1,500 | 120 |
| | | | |
| 3 | 2,620 | 4,140 | 120 |
| | | | |
| 4 | 3,160 | 4,975 | |
| | | | |
| 5 | 1,320 | 2,200 | |
| | | | |
| 6 | 130 | | |
| | | | |
| 7 | 30 | | |
| | | | |
| TOTAL | **!Syntax Error,** )28,900 | 14,025 | 290 |

The inner harbor dredging can be accomplished using the existing disposal areas. No new disposal areas will be required, however some dike raising will be required to provide storage capacity, ponded water depth, and freeboard. Mounding of coarse-grained material adjacent to the front dike will also be required to minimize the need for dike improvements. This can easily be accomplished with the construction of a compartment inside the existing disposal areas.

### 7.1.7. Dike Construction Required for Expansion

#### 7.1.7.1. Dike Raising - General.

Based on existing disposal area capacities and maintenance dredged material that will be placed in the disposal areas prior to harbor expansion, disposal areas 12A and 14B will need to be raised specifically for the harbor expansion project. The GADOT is currently designing a bird island to be constructed inside disposal area 14B with construction expected to start in 1998. It is anticipated that this island will be constructed by the time disposal area 14B is raised for the expansion project. The bird island would be required to be raised during the dike construction contract to the same elevation as the dike. Paragraph, “Disposal Locations for Expansion”, discusses the choice of disposal areas 12A and 14B. To maximize the benefits of the existing disposal areas, dike raising will be accomplished utilizing available borrow material from within the limits of the disposal areas. Removal of material from within the disposal areas has several advantages. It provides additional area for ponding and storage of dredge materials. It will also minimize the amount of suitable dike construction material that will be covered by fine grained dredge materials. Finally, using on-site material should be more economical than using off-site borrow. It is assumed that the sandier dredged material visually observed along the south edge of the disposal areas will be available in sufficient quantities to complete the required dike raisings. It is also assumed that this material will not be covered by new dredged material prior to construction. Subsurface investigation of proposed borrow sources will be completed during the CED phase of the project.

During harbor expansion, new work dredging will provide a substantial amount of material that is suitable for future disposal area dike raisings. The majority of the material determined to be suitable is sand and silty sand. It is assumed that this sandy material will be stockpiled to the maximum extent practicable to facilitate these future dike raisings. When possible, new work dredged material should be stockpiled along the perimeter of the dike to provide additional surcharge to the foundation and prevent rehandling of material during future dike improvements/raisings.

#### 7.1.7.2. Dike Raising - Required Elevations and Quantities

Based on the project dredging elevation selected, Disposal Areas 12A and 14B will be raised to the minimum elevation shown in Tables 6-26 and 6-27. Approximate maximum dike height and length of levee that will be raised as well as estimated quantities for semi-compacted earthfill, clearing and grubbing, and grass seeding are also shown in Tables 6-26 and 6-27.

**Table 7-26 Required Elevations and Quantities for Disposal Area 12A**

| PROJECT DEPTH (MLW) | -50 | -48 | -47 | -46 |
|---|---|---|---|---|
| Elev. Top of Raised Dike (MLW) | 37.0 | 35.5 | 35.0 | 34.4 |
| Max. Height Levee Raised (FT) | 6.0 | 5.5 | 5.0 | 3.5 |
| Length of Levee Raised (FT) | 11,000 | 8,900 | 8,000 | 6,200 |
| Semi-Compacted Earthfill Required (CY) | 115,600 | 46,800 | 30,000 | 12,500 |
| Clearing and Grubbing Required (AC) | 30 | 23 | 20 | 12 |
| Grass Seeding (AC) | 9 | 7 | 7 | 6 |

**Table 7-27 Required Elevations and Quantities for Disposal Area 14B**

| PROJECT DEPTH (MLW) | -50 | -48 | -47 | -46 |
|---|---|---|---|---|
| Elev. Top of Raised Dike (MLW) | 23.0 | 22.1 | 22.0 | 21.4 |
| Max. Height Levee Raised (FT) | 5.0 | 4.1 | 4.0 | 3.4 |
| Length of Levee Raised (FT) | 16,500 | 15,000 | 13,550 | 13,000 |
| Semi-Compacted Earthfill Required (CY) | 97,200 | 73,600 | 60,500 | 47,250 |
| Clearing and Grubbing Required (AC) | 19 | 19 | 18 | 17 |
| Grass Seeding (AC) | 11 | 10 | 9 | 8 |

The portion of the dikes being raised for the different project depths are shown on Figures 76 and 77. Areas not shown to be raised are already at the minimum elevation required or higher. The new portion of the outer slopes and the crest of the raised disposal area dike will be grass seeded for permanent erosion control. Permanent berms, slope drains, and/or special drainage devices are not anticipated. The dike construction projects will require Sedimentation and Erosion Control Permits from the South Carolina Department of Health and Environmental Control. The Best Management Practices for erosion control will be utilized. The temporary erosion control measure to be used during construction is anticipated to consist of a 2-foot high silt fence placed at the perimeter of all staging and construction areas. As needed, temporary hay or straw bales may be used to control erosion where special attention is required.

#### 7.1.7.3. Dike Raising - Slope Stability

The dikes forming disposal areas 12A and 14B are built over relatively soft salt water marsh soils. Early dike construction generally consisted of a trial and error method; if the dike failed or collapsed, more soil was piled up until the desired height was reached. Later dike stability analysis and dike designs were performed by the US Army Corps of Engineers, Savannah District, and in recent years by the Georgia Department of Transportation. The 2 modes of embankment failure which affect the design most are (1) settlement/displacement - ability of embankment material to remain in place without sinking into the soft soils, and (2) rotational stability - preventing a rotational sliding failure through the embankment and foundation soils. Analysis of the failure modes determines the combination of side slopes, berms, and/or reinforcements possible for a particular site. Although disposal areas 12A and 14B will not be raised over their entire length, a portion of each will be raised approximately six feet above the current elevation; this is comparable in height to a typical O&M dike raising. A subsurface investigation and stability design will be completed for disposal areas 12A and 14B during the CED phase of the harbor expansion project. In addition, a subsurface investigation during the CED phase will better reflect actual site conditions due to on-going maintenance dredging. The side slopes selected for the proposed dike raisings, 1V on 3H, are based on previous experience with disposal area construction and based on a visual inspection of existing dikes.

**7.1.7.4. Dike Raising - Subsurface Investigations**

As mentioned in paragraph "Dike Raising – Slope Stability", subsurface investigations are planned for CED phase of the project. The subsurface investigations will include 3 to 4 borings drilled in a section perpendicular to the dike and in the vicinity of maximum dike raising height. The purpose of the subsurface investigations will be to identify soil properties of the existing dike, foundation soils, and dredged soils. Selected samples will be laboratory tested for engineering design properties. Additionally, hand auger borings will be taken in the existing dredged materials to identify areas and quantities of suitable borrow material for use in dike construction.

**7.1.7.5. Dike Raising - Alignment**

Dike alignments for the proposed dike raisings will be to the inside of the existing disposal area dike crest. This approach reduces the amount of construction material required to achieve a given dike height, eliminates encroachment upon wetlands, and maximizes the possible dike height by performing construction away from the softer foundation conditions known to exist to the outside of the existing dikes. The final dike alignments will be referenced to the existing dike alignment by elevation and offset from the existing dike crest centerline and/or by geographical coordinates (easting and northing coordinates).

**7.1.7.6. Dike Raising - Construction**

Dike raising construction is assumed to be completed using conventional means and equipment. The dike configuration consists of a 12-foot top width and 1V on 3H side slope as shown on Figure 78. The 1V on 3H was selected primarily to keep foundation pressures from the proposed dike construction to a minimum. Steeper slopes would tend to increase foundation pressures and displacements within the soft foundation soils. Such added displacements become difficult to quantify and generally do not result in an overall saving of construction material required. An alternate method that allows steeper side slopes involves using geotextile fabric or other soil reinforcement method(s). These methods usually result in longer construction time and higher material costs. Other considerations included typical construction methods used to place semi-compacted fills, the erosion of semi-compacted fills as observed from previous works, the degree of dike maintenance available for this project, the advantage of providing a suitable foundation for the next planned dike raising, the possible use of structured and compacted fill materials for dike construction, and the experience of lessons learned involving the failures of dikes constructed of semi-compacted soils with steeper side slopes. All of the considered alternate methods were rejected as being more complicated, costly and/or time consuming. The top width of 12 feet was selected to accommodate planned future dike construction, to provide for normal erosion losses between dredging operations, and to maintain a minimum safe top width of 8 to 10 feet over the life of the project.

Grassing of new work on the outer slopes and the outside four feet of the crest will be used for erosion control. Berms, slope drains, and/or drainage devices (other than weirs) are not anticipated. Materials for the majority of dike construction are expected to be obtained from the immediate disposal area and are intended to be placed in layers as a semi-compacted fill. Dike materials placed adjacent to weirs and weir outfall pipes are intended to be layered and compacted to a higher density and the density tested and verified. Semi-compacted fills are generally placed in thin layers and compacted using a few passes of the hauling and spreading equipment only. Compacted fills will require additional equipment capable of producing the specified degree of material compaction. Tolerances for dike height and side slopes will be mandatory and should be limited to +1 foot, minus 0 foot for all proposed earthwork dikes and/or embankments. Materials for construction are anticipated to consist of sand, silty sand, clayey sand and suitable dry silts. Materials not anticipated to be used for construction are the saturated silt and clay soils present within the disposal area. However, where unsuitable soil material only cosmetically covers areas of the more suitable soils within borrow sites, it is anticipated that these unsuitable soils will be either (1) moved and placed out of the way in a designated spoil area; or (2) mixed appropriately with the suitable materials such that the final product is suitable for use in the construction of dikes. Existing access ramps at disposal areas 12A and 14B will be maintained and upgraded if needed.

## 7.2. Long Term Dredged Material Management Plan for Expansion

### 7.2.1. Continued Use of Disposal Areas

Several environmental requirements have to be met for continued operation of the confined disposal areas and the ocean dredged material disposal sites. Effluent limits, water quality monitoring requirements, limitations on dike mowing, water level management and bird islands inside the confined areas are detailed in Reference 2.9. Monitoring requirements for the use of the ocean dredged material disposal site are also described in Reference 2.9.

### 7.2.2. Disposal Area Capacity After Expansion

The estimated construction duration is approximately 2 years. The maintenance material for that time period will be removed with the new work dredging contracts.

Table 6-28 lists the anticipated remaining capacity the upland disposal areas will have at the completion of expansion dredging, assuming the dike raisings for 12A, 14B, and 14B Jones/Oysterbed Island are completed as described in paragraph "Dike Construction Required for Expansion". After the expansion project is completed, disposal areas 12BA, 14B, and 14A Jones/Oysterbed Island will be filled to capacity. There will be remaining capacity in 12B, 13A, 13B and Jones/Oysterbed Island. Dike raisings will be required to be performed in areas 12A, 14B, and 14BJones/Oysterbed Island before they can be used again for disposal of maintenance material.

**Table 7-28 Projected Capacity of Upland Disposal Areas at the Completion of Expansion**

| Disposal Area | 46′ Project | 47′ Project | 48′ Project | 50′ Project |
|---|---|---|---|---|
| 12A | Full | Full | Full | Full |
| 12B | 3,313,400 | 2,896,900 | 2,541,100 | 1,804,000 |
| 13A | 2,956,490 | 2,440,690 | 2,200,390 | 1,491,890 |
| 13B | 7,635,000* | 7,635,000 | 7,635,000* | 7,635,000* |
| 14B | Full | Full | Full | Full |
| Jones/Oysterbed | Full | | Full | Full |

* Projected capacity estimated based on an average 6-foot raising.

As discussed in paragraph "Ocean Dredged Material Disposal Site", the ocean disposal area site is dispersive and has sufficient capacity. The maximum volume of material that would be placed in the area is 14,981,700 cubic yards for a 50′ project. This volume, if spread over the entire area would only require a lift thickness of less than 3 feet. This material is also anticipated to be dispersive from the site. Sufficient depth will be available after construction for future maintenance dredging. Therefore, the site will have sufficient capacity for continued maintenance dredging and the expansion project will have no impact to ocean disposal operations.

### 7.2.3. With and Without Project Shoaling Conditions

#### 7.2.3.1. Analysis of Existing Shoaling Patterns, 1995-1997

The shoaling distribution for the inner harbor between Stations 112+500 to 0+000 has been plotted in Figure 79. Shoaling records from the past three years of maintenance dredging since deepening was completed in 1994 have been used. Based on the three years of record, the trend appears that the majority of the shoaling occurs between Stations 70+000 and 41+000. The flow from Back River enters Front River between approximately Stations 60+000 and 58+000. It appears that this junction interferes with the shoaling pattern between Station 50+000 and 61+000 which results in that portion of the channel having a lower shoaling rate than the areas immediately upstream and downstream. Generally, since New Cut was closed, and the last deepening project was completed, the reach of channel between Stations 50+000 and 61+000 has been self-maintaining. Overall, the shoaling is centered on either side of Station 55+000.

The second area with the largest percent of the total channel shoaling is located between Stations approximately Station 100+000 and 97+000. This is due to the shoaling that occurs in the Kings Island turning basin. Any bed load moving downstream tends to settle in this area. As shoal material moves down the Savannah River, the Kings Island turning basin is the first sudden enlargement to the channel cross section. The resulting decrease in velocity causes this area to collect large volumes of shoal material.

The three years of data used to plot Figure 79 should be sufficient to determine trends. It is not a sufficient length of record, however, to reflect all the various conditions of river flows, tides, and storm events that can be expected to occur. However, this is the most current information regarding shoaling distribution. The magnitude of shoaling in the inner harbor for the past three years (approximately 6 million CY per year) has been less than the normal observed shoaling rate. The long-term shoaling is anticipated to be the more normal rate of 7.2 million CY per year. A typical average annual shoaling rate was developed using these shoaling distribution percentages but with a total average annual shoaling rate of 7.2 million CY per year.

The shoaling patterns for the entrance channel since the last deepening were also analyzed and are plotted in Figure 80. The dredging records from 1995 to 1997 were reviewed and the shoaling distribution plotted as shown. The extension of the bar channel from the last deepening has not required dredging since the initial construction. Two surveys taken approximately three years apart were used to analyze the shoaling rate for the outer end of the entrance channel. Based on these surveys the shoaling rate between Stations –60+000B and –85+000B is approximately 60,000 CY/YR. It is anticipated that the outer end of the entrance channel will not require annual dredging but will require occasional dredging.

#### 7.2.3.2. Analysis of Shoaling Patterns, 1972-1981

A similar shoaling distribution graph was plotted in Figure 81 for data available covering the time period from 1972 to 1981. This period reflects the time the tide gate was in operation. The sediment basin was constructed during this time period so a portion of this record does not reflect the effects of the sediment basin. The navigation project depth was –38 feet, MLW. A channel widening was performed after this time period.

Again, the majority of the channel shoaling is centered around approximately Station 55+000. Because the tide gate was operating and ebb flows from Back River into the Front River were null, the interruption to shoaling is not observed between approximate Stations 60+000 and 50+000 as is seen in the 1995-1997 data.

Another major difference is found at the Kings Island turning basin. The additional shoaling in the basin is still evident but not to such a significant extent as on Figure 79.

Also different is the quantity of shoal material between Stations 26+000 and 0+000. During the 1972-1981 time period, approximately 11% of the total channel shoaling occurred in this reach. However, between 1995 and 1997, this quantity was reduced to approximately 3% of the total channel shoaling. Some of this difference could be due to the shorter period of record for the 1995-1997 time period. Offshore wave conditions have been relatively quiet for the past few years and this may have reduced the quantity of sediment moving into the lower reaches of the channel from offshore. Analysis of future dredging records will be required to determine if the relative shoaling in this reach has been reduced.

### 7.2.3.3. Analysis of Shoaling Patterns, 1953-1954

#### 7.2.3.3.1. Shoaling Distribution

A model study of Savannah Harbor was performed prior to construction of the tide gate to determine the impacts to shoaling and salinity. Reference 2.11 discusses the transition zone that occurs in a partially-mixed estuary with vertical mixing of salt and fresh water. The surface salinity is appreciably less than the bottom salinity. A significant portion of the vertical salinity difference occurs within a few feet of depth. The transition zone is similar to an interface but it is not well defined. The study determined flow distribution to evaluate the direction of net bottom flow. At today’s channel Station 70+000 in the report (which was equivalent to Station 125+000 in 1965) for what the report considered a normal freshwater inflow of 7,000 cubic feet per second, CFS, the upstream and downstream flows are in balance. Therefore, upstream of Station 70+000, downstream flow predominates. Downstream of Station 70+000, upstream flow predominates. Because the sediments which deposit in Savannah Harbor are lightweight silts and flocculated clays, their movement is greatly influenced by these flow distributions. For example, a sediment particle entering the upper half of the project would tend to settle and be resuspended with varying current strength and moved progressively downstream to Station 70+000. At that point the net flow is upstream so no further downstream movement would be anticipated. Similarly, sediment deposited downstream of Station 70+000 would be resuspended and continually moved upstream by the net upstream bottom flow. In both cases, there is a net force tending to concentrate sediments in the vicinity of Station 70+000.

Reference 2.12 continues the analysis with a distribution of shoaling by location. The average annual distribution of shoaling for 1953 and 1954 shows that the majority of the shoaling occurred between Stations 75+000 and 65+000. Figure 82 shows the shoaling distribution provided in the report with the old channel stationing converted to the present day stationing. This analysis was performed with pre-tide gate conditions.

7.2.3.3.2. Residual Flow Analysis

Figure 82 also shows the location of the 50% bottom flow predominance at 100% of the channel depth. It is interesting to note that the 50% bottom flow predominance is located at approximately Station 70+000 which falls at the center of the shoaling distribution graph. This agrees well with the discussion of sediment transport in the report. The vertical distribution of flow discussed in Reference 2.11 is for conditions of mean tide and what the report classified as a normal freshwater inflow of about 7,000 CFS. It appears that the data was collected only for a day or two.

For the 1995-1997 time period, velocity and salinity data were collected and analyzed by Applied Technology and Management (ATM) Inc. and are summarized in Reference 2.13. Data was collected for approximately 3 months. The freshwater inflow conditions are different from those in Reference 2.11. Also, the time period for data collection is significantly longer for the more recent data. A residual flow analysis was performed on the 1997 data that would be equivalent to the bottom flow predominance analysis performed in the 1965 study. For this analysis, a residual flow of zero would occur when the upstream and downstream flows are equal. A residual flow of zero is equivalent to a bottom flow predominance of 50%. For the 1997 data, the bottom residual flow of zero no longer falls in the center of the shoaling distribution. Figure 79 also shows the approximate location of the zero bottom residual flow based on the data analysis.

It appears the location for the zero residual velocity has moved upstream by approximately 20,000 feet. This could be partly due to the fact that as the channel has been deepened higher salinity levels have moved upstream. The authorized project depth for the inner harbor at the time Reference 2.11 was prepared was 34 feet with an entrance channel depth of 36 feet. Deepening the channel to its current 42-foot authorized depth for the inner harbor and 44-foot authorized depth for the entrance channel has moved the salinity further upstream and the bottom residual of zero would be expected to move upstream also.

7.2.3.3.3. Salinity and Flocculation

Some of the supporting documentation for a 1961 model study as provided in Reference 2.11 discusses the salinity and flocculation conditions in the harbor. Laboratory test data at that time showed that sediment samples from the Savannah River flocculated totally in 3-12 hours in column settling tests when salinity levels were 5.0 ppt. The report generally uses 5.0 ppt as the level for the salinity interface with regards to flocculation. This report discusses that under normal conditions the saltwater wedge extends to approximately Station 94+000 and retreats to approximately Station 54+000.

The mean bottom salinity levels observed near the Kings Island turning basin (approximately Station 100+000) during the 1997 monitoring averaged from 2.2 ppt to 4.7 ppt. This portion of the channel would be at salinity levels conducive to flocculation occurring at the same time that the channel cross section changes significantly resulting in reduced velocities.

The location of the majority of the shoaling in the harbor for the existing conditions had an average bottom salinity range of about 15-19 ppt (approximately Station 55+000) during the data collection period. The freshwater inflow ranged from 5,900 CFS to 9,500 CFS during this same data collection period. When these flows are averaged they agree fairly well with the freshwater inflow conditions used for the shoaling distribution analysis of the 1953-1954 data. This salinity level is well above the flocculation level of 1-5 ppt. There will be some variation in the salinity levels with the variation of freshwater inflow. Normal freshwater inflow ranges from approximately 11,000 cfs to 12,000 cfs. However, the salinity levels immediately upstream and downstream of Station 55+000 are still anticipated to average well above the 5 ppt flocculation threshold.

Reference 2.14 states that a significant amount of shoal material for the Savannah Harbor enters the river from the ocean and is transported upstream. This conclusion was based on the various sediment samples that were collected for this report. The report states that ocean born sediments have been found as far upstream as locations where the salinity is as low as 5.0 PPT which can be as far upstream as approximately the Kings Island turning basin. Based on this report, the majority of the shoal material that settles upstream and downstream of Station 55+000 is probably moving into the channel from the ocean and is carried upstream by the bottom currents until velocity conditions are suitable for deposition. If this material is being carried in from the ocean, then the saltwater-freshwater interface is not controlling the majority of the sedimentation. River hydrodynamics appear to be the controlling factor for shoaling distribution as least at far upstream as Station 80+000.

Reference 2.14 is also supported by Reference 2.11. Long term suspended sediment data was collected at Clyo and the results of the analysis were included in this report. Based on sediment data collected from 1949 to 1957, it was estimated that only approximately 1,861,600 CY of shoal material was carried downstream annually into Savannah Harbor by the Savannah River out of a total of 7,000,000 CY/YR dredged.

#### 7.2.3.4. Estimated Shoaling for With Project Conditions

7.2.3.4.1. Inner Harbor

Based on changes to the shoaling distribution patterns caused by previous channel modifications, some slight changes are anticipated again in the shoaling distribution after the expansion project is completed. The total shoaling volume for the inner harbor is not anticipated to go above 7.2 million cubic yards annually. This was the prediction in Reference 2.12 and it has continued to hold true after all subsequent changes to the harbor. Also, the shoaling rate for Savannah Harbor in Reference 2.11 was listed as 7,000,000 CY annually for the 1953-1954 time period.

Material that would have previously traveled further downstream is now expected to be trapped by the Kings Island turning basin. The basin will be enlarged again for this project. The cross-section area of the basin will further reduce the velocities allowing additional deposition. A slight upstream shift of the major shoaling area around Station 55+000 is anticipated due to the slight upstream shift of salinity. Theoretically, this will change the bottom flow predominance node to a point further upstream which would allow sediments moving in from the ocean to be carried further upstream. The low shoaling levels between approximately Stations 60+000 and 50+000 are expected to continue. The total average annual shoaling rate for the inner harbor is expected to remain at about 7.2 million cubic yards. This rate has remained constant during previous harbor deepenings. Figures 83 through 86 show cross section plots from selected locations of after dredging surveys taken after the previous deepening project and again taken approximately 5 years later in the same locations. These cross sections show that there has been no significant lower of the side slopes due to the previous deepening. No change in expected in the angle of the side slope with the expansion project.

The volume of shoal material in the sediment basin is expected to also remain fairly constant. No significant change to the flood or ebb velocity is anticipated resulting in no change to sediment transport. Based on previous sediment basin shoaling analysis, there are two significant controlling factors of the efficiency of the sediment basin. These are the amount of material stored in the basin and the depth of the throat. As the storage area that is the sediment basin fills the trapping rate of the basin is reduced. Also, when the depth of the shoaling in the throat increases the trapping efficiency is also reduced. When the expansion project is completed the depth of the channel will be deeper than the depth of the throat. This was also the case from the previous deepening project and the shoaling rate for the sediment basin has continued at approximately 2.4 million CY annually. The storage volume available for the sediment basin will not be changed by the expansion project. In addition, one problem that used to occur frequently for the efficiency of the basin was a significant depth of shoaling in the throat. The required depth for the throat is 38′ and the required depth for the basin is 40′. Since the tide gate has been locked open the throat has been self-maintaining. Based on exam surveys performed in March 1997 and February 1998 it appears that no significant shoaling has occurred and some areas are about one-half a foot deeper now. It is reasonable to assume that the throat will continue to be self-maintaining. This will allow the same volume of water to enter the basin. The majority of the sediment trapped in the basin is not bed load material.

Table 6-29 summarizes the anticipated average annual maintenance dredging volumes. Figure 87 shows the anticipated shoaling distribution for the with project conditions.

According to Reference 2.11, the shoaling rate for the entrance channel was reported as 700,000 CY annually for the 1953-1954 time period. More recently, since the last harbor deepening, the shoaling rate for the entrance channel has been approximately 750,000 CY per year to Station –60+000B.

With the harbor expansion, the entrance channel will be required to be extended. For the 50′ project depth (52′ required depth for the entrance channel) the entrance channel will be extended 25,000 feet. To estimate if additional maintenance dredging will be required in the new channel extension, the shoaling rate was computed for the entrance channel extension which was dredged for the last harbor deepening. No maintenance dredging has been required in this extension. The shoaling rate in this reach was computed using hydrographic surveys taken in March 1994 and August 1997. The shoaling rate for this 10,000 feet of the channel has been approximately 22,000 CY per year. No significant change is expected to this shoaling rate with the proposed expansion project. Based on the shoaling rate for Stations -50+000B to -60+000B, the annual shoaling rate for the 25,000 foot extension is estimated to be 60,000 CY per year.

**Table 7-29 Average Annual Maintenance Dredging Volumes**

| Savannah Harbor Station (cont'd) | Prior to Expansion, 1995-1997 Average Annual Volume (CY) | Prior to Expansion, Typical Annual Volume (CY) | After Expansion, Anticipated Average Annual Volume (CY) | Anticipated Change Due to Expansion (CY) |
|---|---|---|---|---|
| 112+500 | | | | |
| | 156,400 | 213,600 | 182,000 | 0 |
| 105+000 | | | | |
| | 100,400 | 137,300 | 110,000 | 0 |
| 100+000 | | | | |
| | 565,700 | 772,300 | 864,000 | +60,000 |
| 97+000 | | | | |
| | 142,500 | 194,400 | 96,000 | -60,000 |
| 80+000 | | | | |
| | 255,400 | 348,500 | 240,000 | 0 |
| 70+000 | | | | |
| | 834,700 | 1,1,39,500 | 1,152,000 | +29,000 |
| 61+000 | | | | |
| | 215,000 | 293,300 | 293,300 | 0 |
| 50+000 | | | | |
| | 728,900 | 995,000 | 966,000 | -29,000 |
| 41+000 | | | | |
| | 342,600 | 467,500 | 467,500 | 0 |
| | | | | |
| 30+000 | | | | |

| Savannah Harbor Station (cont'd) | Prior to Expansion, 1995-1997 Average Annual Volume (CY) | Prior to Expansion, Typical Annual Volume (CY) | After Expansion, Anticipated Average Annual Volume (CY) | Anticipated Change Due to Expansion (CY) |
|---|---|---|---|---|
| 30+000 | | | | |
| | 79,700 | 109,000 | 109,000 | 0 |
| 26+000 | | | | |
| | 94,800 | 129,600 | 129,600 | 0 |
| 0+000 | | | | |
| | 750,000 | 750,000 | 750,000 | 0 |
| -60+000B | | | | |
| | N.A. | N.A. | 36,000 | 36,000 |
| -75+000B | | | | |
| | N.A. | N.A. | 14,400 | 14,400 |
| -81+000B | | | | |
| | N.A. | N.A. | 2,400 | 2,400 |
| -82+000B | | | | |
| | N.A. | N.A. | 7,200 | 7,200 |
| -85+000B | | | | |
| | | | | |
| Sediment Basin | 2,392,300 | 2,400,000 | 2,400,000 | 0 |
| | | | | |
| Total | 6,658,400 | 7,950,000 | 8,010,000 | 60,000 |

### 7.2.4. Impact of Expansion on the Long Term Dredged Material Management Plan

#### 7.2.4.1. Upland Disposal Areas

A long term analysis is needed to compare the impact of the with project conditions on the existing project. For the 50 year analysis of the disposal areas, it was assumed that

12A, 12B, 13A, 13B, 14B, and Jones/Oysterbed Island would continue to be available for disposal of dredged material. At some time in the future, it is assumed that 14A will be diked to meet requirements as stated in Reference 2.9 and will then be available for disposal of dredged material.

7.2.4.1.1. Differential Maintenance

For the inner harbor no change is expected in the total annual shoaling volume. The shoaling distribution is anticipated to have only minor changes. The largest expected change in shoaling distribution is anticipated at the Kings Island turning basin. Approximately 60,000 CY that would have shoaled downstream between Stations 97+000 and 80+000 are now anticipated to shoal between 103+000 and 97+000 due to the enlargement of the turning basin. This does not affect disposal locations for the dredged material because all future O&M material between 103+000 and 79+000 will be placed into disposal area 12A. The expansion project has caused essentially no change to the volume of dredged material placed into each disposal area annually.

7.2.4.1.2. Impact to Dike Raising Schedules

To determine the impact of the expansion project, the with project condition was compared to the without project condition. To compare, a disposal area rotation schedule was determined based on the assumption that disposal area 2A would not be available. Recommendations in Reference 2.9. Generally, material between Station 103+000 and 79+000 will be placed into disposal area 12A or 12B. For this analysis, it was assumed that material from 103+000 to 79+000 would not be placed into disposal area 13A because of the long pumping distance. Material from 24+000 to 0+000 is expected to be placed into Jones/Oysterbed Island disposal area every 2 or 3 years. This rotation plan is different from the recommended plan in Reference 2.9.

An average annual lift thickness was determined for every disposal area once the rotation scheme was established. The volumes from Table 6-29 were used for the rotation plan and a bulking factor was applied to the shoaling rates. Reference 2.15 was used to estimate the consolidation of the dredged fill layers.

For the without project condition, generally 6 foot dike raisings are required at the frequency listed in Table 6-30.

**Table 7-30 Long Term Dike Raising Frequency**

| Disposal Area | 46′ Project | 47′ Project | 48′ Project | 50′ Project |
|---|---|---|---|---|
| 12A | | | | |
| Before Expansion | 4.4′ | 5.0′ | 5.5′ | 4.4′ |
| After Expansion | 6′ every 7 yrs | 6′ every 7 yrs | 6′ every 7 yrs | 6′ every 7 yrs |
| 12B | | | | |
| Before Expansion | None | None | None | None |
| After Expansion | 6′ every 8 yrs | 6′ every 8 yrs | 6′ every 8 yrs | 6′ every 8 yrs |
| 13A | | | | |
| Before Expansion | None | None | None | None |
| After Expansion | 6′ every 8 yrs | 6′ every 8 yrs | 6′ every 8 yrs | 6′ every 8 yrs |
| 13B | | | | |
| Before Expansion | None | None | None | None |
| After Expansion | 6′ every 18 yrs | 6′ every 18 yrs | 6′ every 18 yrs | 6′ every 18 yrs |
| 14A | | | | |
| Before Expansion | None | None | None | None |
| After Expansion | 6′ every 18 yrs | 6′ every 18 yrs | 6′ every 18 yrs | 6′ every 18 yrs |
| 14B | | | | |
| Before Expansion | 3.4 | 4.0 | 4.1 | 5.0 |
| After Expansion | 6′ every 16 yrs | 6′ every 16 yrs | 6′ every 16 yrs | 6′ every 16 yrs |
| Jones/Oysterbed Island | | | | |
| Before Expansion | 2.0 | 2.3 | 2.6 | 3.0 |

| | | | | |
|---|---|---|---|---|
| After Expansion | 6′ every >50 years | 6′ every >50 years | 6′ every >50 years | 6′ every >50 years |

For the with project conditions, the dike raisings are required with the same frequency. However, the dike raisings will take place earlier due to the expansion material occupying storage capacity in the disposal areas.

To account for the increased disposal costs of the deepening project, a 50 year evaluation was performed of the dike raisings required for the without project conditions and the with project conditions for 46 ′, 47, 48′ and 50′ projects. The difference in present worth was computed for the 50 years of dike raisings for the with and without project conditions and this cost is the increased disposal cost due to expansion. Those costs are presented in Table 6-31.

**Table 7-31 Differential Dike Raising Costs**

| | **Total Net Present Value** | **Differential Dike Raising Cost** |
|---|---|---|
| Without Project | $19,246,825 | |
| 46 Ft. Project | $28,046,379 | $8,799,553 |
| 48 Ft. Project | $28,737,557 | $9,490,732 |
| 50 Ft. Project | $29,474,729 | $10,227,903 |

**7.2.4.2. Ocean Dredged Material Disposal Site**

For future maintenance dredging, material from the entrance channel will continue to be placed in the ocean dredged material disposal site. Because the site is dispersive, it will have capacity to be used continuously for the lifetime of the project and no analysis is required for the impact due to expansion on the ocean disposal area.

**7.2.4.3. Dike Construction for Future Dredged Material**

7.2.4.3.1. Selection of Dike Raising Height

The dikes of the Savannah Harbor disposal areas are proposed to be raised periodically to increase the storage capacity of the disposal areas. Dike heights are typically selected based on the ability of foundation materials to support a given weight or height of soils without excessively displacing foundation materials or causing embankment failure(s). A height of 6 feet has been determined to be the maximum practical height to raise at one time due to the soft nature of the soils inside the area. An exception to the typical dike raising height is that it may be feasible to place dredged material from harbor expansion around the perimeter of the disposal area(s), which could add several years of consolidation time prior to new dike construction. By placing the dredged material around the perimeter to the maximum extent possible, good borrow material for future dike raisings will be available in addition to possible higher future dike raisings in those areas. Other considerations which can effect dike raising height include availability of suitable construction material, possible use of soil reinforcement materials, excavation of unsatisfactory soils, and environmental encroachment into wetlands.

7.2.4.3.2. Dike Alignments

As discussed in paragraph "Dike Raising – Alignment", all dike alignments for proposed dike raisings are typically to the inside of the existing disposal area. This approach reduces the amount of construction material required to achieve a given dike height, eliminates encroachment upon wetlands, and maximizes possible dike heights by performing construction away from the softer foundation conditions identified to the outside of the existing dikes. All proposed dikes alignments should be tied to the existing dike alignment and identified by an elevation and offset from the existing dike alignment for each project condition.

7.2.4.3.3. Slope Stability

The dikes forming the Savannah Harbor disposal areas are typically built over relatively soft soils. Early dike construction generally consisted of a trial and error method; if the dike failed or collapsed, more soil was piled up until the desired height was reached. The two modes of embankment failure which are discussed in paragraph "Dike Raising – Slope Stability" are shown on Figure 90. Analysis of the failure modes determines the combination of side slopes, berms, and/or reinforcements possible for a particular site.

7.2.4.3.4. Dike Construction

Disposal areas 2A, 12A, 12B, 13A, 13B, 14A, 14B, and Jones/Oysterbed Island will all require periodic raising to contain future dredged material. A typical disposal area dike raising cross-section showing multiple raisings is shown in Figure 91. Dike raisings are typically assumed to be completed using conventional means and equipment. Typical dike configurations consist of a 10 to 20 foot top width and 1V on 3H side slopes. A typical O&M type dike raising over dike locations raised for the harbor expansion project is shown on Figure 92. Dike construction is discussed in more detail in paragraph "Dike Raising – Construction

# 8. COST ENGINEERING

## 8.1. Engineering Guidelines

Cost estimates were developed in accordance with the requirements of References 2.16 through 2.18.

## 8.2. Project Costs

Construction feature costs were developed using the Microcomputer Aided Cost Engineering System (MCACES) and the Cost Engineering Dredge Estimating Program (CEDEP). They were formatted in accordance with the Civil Works Breakdown Structure (CWBS). The estimates were prepared using a team approach in which the cost engineer receives input from design team members. The MCACES estimates were developed for labor, equipment, and materials with related productivity that is commensurate with the level of detailed information provided. The complete MCACES project cost estimates and associated databases, including Summary for Owner, Indirect, and Direct Cost and Detail and Link Listing Reports, are available at the Savannah District office with the supplemental documentation for the project.

Detailed estimates were developed for the 45-, 46-, 47-, 48-, and 50-foot alternatives. The detail sheets contain dredging costs, mobilization costs, debris removal, disposal area improvements, implementation of the Old Fort Jackson protection plan, removal of the *CSS Georgia*, and contingencies associated with each of these elements. Estimates also include the costs for lands and damages, relocations, cultural resource preservation, CED, construction management, and navigation aids.

## 8.3. Dredging Costs

### 8.3.1. New Work Dredging Costs

All dredging costs were developed using CEDEP. The dredging estimates assume that all maintenance material, all new work material including advance maintenance, and all allowable overdepth will be removed. It is also assumed that the working plant will remove 0.2 feet of excess material to below the pay prism. Due to time constraints, large portions of the allowable overdepth will not be dredged. However, for cost and scheduling purposes it is assumed that all allowable overdepth and 0.2 feet of excess material will be removed.

The amount of material in the entrance channel dictates the use of a large class hopper dredge and two 26 cubic yard clamshell dredges for the 46- through 48-foot projects in order to excavate the material within the environmental windows and to keep the construction duration from exceeding 30 months. The amount of material is so great that for the 50-foot project, a medium class hopper will be needed for both dredging windows in conjunction with the large class hopper and three 26-yard clamshell dredges.

The estimate is based on clamshell dredges removing material oceanward from Station 0+000 to -14+000B for the 45- and 46- foot projects and remove material from Stations 0+000 to -38+500B for projects whose depths are greater than 46 feet, MLW. An additional medium class hopper will be needed for the 50-foot project and will remove material from Stations -60+000B to -85+000B.

The dredging of the harbor's interior, from Station 103+000 to 0+000, will be done by a pair of 30-inch hydraulic dredges for all plans except the 50-foot which will require a supplemental 22-inch hydraulic dredge. The supplemental dredge is necessary to reduce the construction period and will perform work simultaneously with the larger dredges. This 22-inch dredge will tentatively remove materials between Stations 24+000 and 40+000. The 30-inch dredge in the upper harbor will require 2 booster pumps to enable it to reach disposal areas some 45,000 feet away. The 30-inch dredge in the lower end of the harbor should not require boosters since the pumping distance should not exceed 20,000 feet.

All mobilization distances are assumed to be 1,000 miles. Hopper dredges will be mobilized during two dredging windows for all plans.

#### 8.3.2. Differential Maintenance Costs

The differential maintenance costs for this project are based on unit prices developed for the government estimates for the most recent harbor maintenance dredging projects. Unit prices for reaches of the inner harbor were developed for the contract advertised for bids as DACW21-98-B-0008, while unit prices for the entrance channel were developed for the contract advertised under DACW21-97-B-0115. The quantities of differential maintenance are discussed in section "Estimated Shoaling for With Project Conditions" in this appendix. Cost for this work are included in the summary sheets in the "Alternative Projects First Cost Estimates."

#### 8.3.3. Berthing Area Dredging

The costs for dredging the required berthing area, CB-7, was calculated by multiplying by the cost of removing the material between Stations 103+000 and 102+000 by the quantity of material in the berth for each project depth. The berth will be dredged and maintained to the same depth as the navigation channel adjacent to the berth. It is assumed that this material will be pumped to disposal area 12A with the same equipment that was used to dredge material from the channel. Cost for this work are included in the summary sheets in the "Alternative Projects First Cost Estimates."

#### 8.3.4. Character of Materials

Types and percentages of new work material range from silty sand to stiff rock/hard material.

**8.3.5. Debris Removal and Disposal**

Visual surveys of debris on the river banks was performed to quantify debris which required removal prior to commencement of dredging. Identified debris includes trees (standing and fallen), shrubbery, miscellaneous debris (cables, flotsam, pipes, etc.), old abandoned watercraft, riprap, ballast rock, piling, and various shore protection systems. Attachment 2 contains a summary of the debris used in preparing the estimate

All removed debris, except rock debris, will be transported to Station 111+750. An access ramp and burn area will be constructed at this location prior to commencement of dredging operations. Disposal of non-burnable material from the burn site will be in a commercial landfill. Rock debris will be transported to the north abutment of the tidegate and offloaded for future use. The burn site will be restored at the completion of the project.

The estimate assumes that the debris will be removed by mechanical equipment operating from shore and/or barges. Equipment utilized in preparation of the cost estimate consisted of cranes, front-end loaders, bulldozers, off-road dump trucks, medium size barges, and small tugboats. The estimate also assumes the prime contractor is a dredging contractor with this equipment inventory.

Mobilization/demobilization costs are based upon mobilization within a 600-mile radius of the project site. The equipment will be transported to the site on the barges.

Contingencies are based upon the contingency factors outlined in Reference 2.18.

Construction duration for debris removal is equivalent to the project construction period.

**8.3.6. Environmental Restrictions**

A number of environmental restrictions apply to construction dredging operations. Hopper dredging activities for the expansion project will be limited to operating between 01 December and 15 April of each year.. Vessel speeds will be restricted during this period speeds to less than 5 knots or less during night (sunset to sunrise) unless information from the Right Whale Early Warning System (RWEWS) or any other observation/information reveal there are no right whales within 15 nautical miles of the project area. If no right whales are sighted during the day’s surveillance, the vessel speeds will not be restricted. Contractors will provide personnel on all marine equipment operating between landings and the worksite(s), trained endangered species observers during daytime operations to watch for endangered species during the period 01 December through 31 March. In addition to the endangered species observers, two turtle observers will be provided between 01 April and 15 April. The turtle observers will be on-board the hopper dredge(s) 100 percent of the time the contractor will be dredging and transiting to and from the disposal site. The trained observers will document any turtle or turtle parts retained in the screens. The cost estimates have taken into account all environmental considerations concerning right whales and sea turtles.

#### 8.3.7. Dredging Assumptions

It is assumed that all maintenance, new work, and excess materials will be removed at the same time. All equipment costs are in accordance with the databases in the predefined CEDEP program with labor rates updated to 1998 specs. All estimates assume large and/or medium class hopper dredges, 30- and 22-inch pipeline dredges, and 26 CY clamshell dredges in order to meet time constraints.

### 8.4. Disposal Area Improvements

This section contains the cost estimates for constructing improvements to disposal areas 12A and 14B prior to the harbor expansion project, and constructing improvements to disposal areas 12A, 12B, 13A, 14B, and Jones/Oysterbed Island. Prior to commencement of dredging, dike improvements consisting clearing and grubbing, dike raising, raising existing weirs, and grassing will be completed. Costs of future dike raisings have also been included for the fifty year project life for the without and with project conditions.

### 8.5. Sequence of Construction

The estimates are based on the sequence of construction as described in section "Construction Phasing for the Selected Plan". Separate construction contracts will be required for the improvements to the disposal areas that should be completed prior to the award of related dredging contracts.

### 8.6. Construction Performance Periods

Computations have been based on the assumption that all materials from Station 0+000 to -85+000B will be removed by hopper and clamshell dredges. All materials from Station 103+000 to 0+0000 will be removed by hydraulic pipeline dredges.

## 9. NAVIGATION AIDS

When dredging is completed, existing aids to navigation will be relocated and additional aids placed to properly mark the location of the channel. The number and position of additional aids was coordinated with the U.S. Coast Guard's Office for Aids to Navigation in Miami, Florida.

In the inner harbor, Beacons 12, 14, and 16 in the Kings Island turning basin will be repositioned as a result of enlargement of the basin. City Front Channel Beacon 62 and Fig Island Beacon 57 will also be repositioned as a result of dredging new channel wideners. Seven pairs of range markers will be repositioned as a result of the channel modifications. The ranges which will require new aids are Fort Jackson Upper and Lower Ranges, Upper and Lower Flats Ranges, Elba Island Range, New Channel Range, and Jones Island Range.

Additional aids will be required in the extension of the entrance channel and the sea buoy will be relocated to mark the seaward end of the channel. One pair of new buoys will be required for each one-mile extension of the entrance channel. In addition to the initial placement costs, annual maintenance of the buoys will be required. The Coast Guard also recommends that the dayboards on the Tybee Range be replaced with day/night lights. This is necessary because the dayboards become impractical and difficult to see in the entrance channel extension.

Table 9-1 lists the costs for navigation aids for each project alternative. The results of the ship simulator study may recommend additional navigation aids to assist the pilots in transit or docking maneuvers.

**Table 9-1 Costs for Navigation Aids**

| Nav Aid | 44-foot Project | 46-foot Project | 47-foot Project | 48-foot Project | 50-foot Project |
|---|---|---|---|---|---|
| Relocate Lights (5) | $ 6,900 | $ 6,900 | $ 6,900 | $ 6,900 | $ 6,900 |
| New Ranges (7) | 509,800 | 509,800 | 509,800 | 509,800 | 509,800 |
| Light Tybee Range | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 |
| Ent. Channel Buoys | $ 31,000 | $ 93,000 | $124,000 | $124,000 | $155,000 |
| Total | $555,700 | $617,700 | $648,700 | $648,700 | $679,700 |
| Annual Maintenance (Buoys) | N/A | $ 3,100 | $ 12,400 | $ 12,400 | $ 15,500 |

## 10. REAL ESTATE REQUIREMENTS

Construction of the bend wideners and improvements to the Kings Island turning basin will require the removal of land above the mean high water elevation. These areas are located on the north bank of the river. No easements or land acquisitions will be acquired to accommodate land-based construction activities for this project. The acquisitions will include the rights to remove land, timber, trees, piling, structures and/or buildings, and for sloughing of the land which may occur as a result of construction activities for this project.

## 11. COST ALLOCATIONS

Costs for dike construction and activities required to dredge this project will be allocated in accordance with Reference 2.8. For the initial expansion dredging, Operation and Maintenance funds will pay for the removal of material from the existing authorized project including advance maintenance and allowable overdepth material. The O&M appropriation will also provide funds to pay for a portion of the mobilization/demobilization (mob/demob) costs for the expansion project. This cost will be limited to the mob/demob cost of the most recent maintenance dredging contract which was awarded for similar work in Savannah Harbor. Dredging of the remainder of the material will be cost shared.

Cost sharing formulas for navigation projects change at a depth of 45 feet. Projects 45 feet or less are shared at 75% Federal costs and 25% non-Federal costs. Non-Federal costs for projects deeper than 45 feet are 50% of the increment below a 45-foot project and the 25% of the cost of a theoretical 45-foot project.

Costs for construction of the disposal area dikes required to accommodate the dredged material from the expansion project are considered a general navigation feature and are cost shared the same as dredging. The disposal area evaluation performed for this project concluded that there is not sufficient capacity in all of the existing confined disposal sites to contain maintenance material dredged from the present time through the completion of expansion dredging. Disposal areas 12A, 14B, and Jones/Oysterbed Island will require dike improvements prior to commencement of dredging. Costs for these improvements will be shared in accordance with Reference 2.8. Disposal areas 12B and 13A do not require improvements prior to commencement of dredging for the expansion project.

## 12. ENVIRONMENTAL FEATURES

Each of the project alternatives includes features which result from environmental impact study findings. These features include closing the upstream and downstream ends of the oxbow at Drakies Cut, dredging a habitat improvement feature for shortnose sturgeon in the Port Wentworth turning basin, closing Middle River at its confluence of the Front River and re-establishing flows between Middle and Little Back Rivers, and construction a steel pile sheet wall around a portion of the moat wall at Old Fort Jackson. Closing the cuts would isolate the Middle and Little Back River marsh areas from salt water which presently flows through these cuts.

The proposed location of the closures in the oxbow at Drakies Cut are shown on Figure 91. These closures could be constructed using the material dredged from the expansion project dredging. Approximately 134,500 CY of material will be required for these closures

A habitat improvement feature for the shortnose sturgeon is planned for the Port Wentworth turning basin but could be relocated if environmental research indicates a more suitable location. If constructed at the Port Wentworth turning basin, the area will be approximately 1,000 feet long, 500 feet wide, and 8 feet deep. Approximately 175,000 CY of material will be removed from this area. The location and limits of the habitat area are shown on Figure 92.

The location of the closure in Middle River is shown on Figure 93 and the connecting channel to Little Back River is shown on Figure 94. The connecting channel, which requires the removal of approximately 20 acres of land above mean high water, will be dredged first and material will be placed in disposal area 2A. Approximately 800,000 CY of material will be dredged to re-establish flows between the Middle and Little Back Rivers. After the connector is dredged, material will be borrowed from disposal area 2A for construction of the closure structure. Approximately 1,050,000 CY will be required to construct the closure.

The proposed protection at Old Fort Jackson is construction of a steel sheet pile wall consisting of interlocking steel sheet piling along the outside face of the moat. Pile tops will be elevation +0.5 feet, MLW, and pile tips will be driven to a minimum elevation of -44.5 feet, MLW. Each wall end will be anchored to a HP12x53 pile, 4 required, driven to the same top and tip elevations. Whalers (top) will be included in the design. A top seal will also be included consisting of a 2.5-foot thickness of reinforced concrete. Backfill between the installed sheet piles and the existing structure will consist of pumped grout and/or concrete. The steel sheet pile wall will be constructed to protect the entire length of the moat along the river with tie-ins to the adjacent high ground on each end to prevent flanking.

# 13. CONSTRUCTION PHASING FOR THE SELECTED PLAN

The selected plan for the expansion project is a 48-foot deep navigation channel in the inner harbor and a 50-foot deep channel in the entrance channel. The construction sequencing for the selected plan will require the advertisement and award of five construction contracts. One contract will be for dike improvements, one for protection at Old Fort Jackson, and three dredging contracts. Maintenance material will be removed concurrently with the expansion dredging. A separate maintenance dredging contract will not be required in Savannah Harbor between Stations 103+000 and -60+000B during the period of expansion dredging.

## 13.1. Dike Improvements

Prior to commencement of dredging for the expansion project, a contract to raise the dike in disposal areas 12A and 14B will be awarded. The dikes in disposal areas 12A and 14B will be raised using material borrowed from within each respective disposal area. It is estimated that 46,800 CY will be required to improve the dikes in disposal area 12A and 73,600 CY of material will be required for disposal area 14B improvements. The weir risers will require vertical extensions and the catwalks will have to be repositioned. Modifications to the outfall pipes will not be required. It is anticipated that this work will require approximately 6 months to complete. A reach of the front dike in disposal area 2A will also require moving as a result of enlarging of the Kings Island turning basin. This work will be included in the dike improvement contract.

## 13.2. Old Fort Jackson Protection

A separate contract will be awarded for construction of the sheet pile wall at the moat structure of Old Fort Jackson. It is estimated that this work will take approximately 9 months to complete. This work would be completed prior to commencement of expansion dredging between Stations 59+500 and 57+500.

## 13.3. Dredging

Three contracts will be awarded to perform the dredging. The first contract will be for deepening and extending the entrance channel and can be awarded at the same time the dike improvement contract is awarded. Approximately 10,302,500 CY of new work material will be removed between Stations 0+000 and –82+000B. This material will be placed in the EPA approved ocean disposal site. It is anticipated that dredging will be performed using clamshell or mechanical dredges and hopper dredges. Hopper dredges will be limited to working between December and March because of environmental restrictions. It is anticipated that it will take approximately 20 months to complete dredging the entrance channel. Multiple pieces of equipment working simultaneously will be required to complete this work within the specified time.

Two contracts will be awarded for dredging the inner harbor. One contract will be for the removal of approximately 11,123,000 CY of material from the reach between Stations 70+000 and 0+000. The contract for this reach will also be awarded at approximately the same time the contract for the entrance channel is awarded. A short reach of the back dike in Jones/Oysterbed Island disposal area will be raised and this work will be performed by the dredging contractor since it is less than 500 feet in length. More than one dredge can work in this reach since several disposal areas will be used. Dredging will commence at Station 70+000 and dredged material will be placed in disposal area 12B. Placement of material in disposal area 14B cannot commence until improvements to the weirs and dikes are completed. Dredging between Stations 63+360 and 0+000 may not commence until 15 March unless all other dredging between Station 70+000 and 63+360 is completed prior to that date. It is anticipated that it will require 36 months to complete this contract.

A second inner harbor contract for dredging between Stations 103+000 and 70+000 will be awarded prior to completion of the dike improvement contract. Dredged material will be placed in disposal area 12A. Dredging cannot commence until the dike and weir improvements are completed in disposal area 12A. Approximately 5,844,600 CY of material will be dredged in this reach and it is anticipated that it will take approximately 28 months to complete. Construction of the closures in the oxbow at Drakies Cut and the Middle River at the confluence of Front River, creation of the habitat improvement area for shortnose sturgeon area, and re-establishing flows between Middle and Little Back Rivers will also be included in this contract.

The dredging contractors will encounter debris on the riverbanks, on the existing river bottom, and in the new work prism. The dredging contractors will be required to remove and dispose any debris encountered. A separate contract for debris removal will not be awarded.

## 14. OPERATION AND MAINTENANCE REQUIREMENTS

Upon completion of dredging for the expansion project, annual maintenance dredging will be required to maintain the authorized project dimensions. Increases in the total average annual quantity of material dredged from the inner harbor are not anticipated. Approximately 2.4 million CY of material will be dredged from the sediment basin annually and approximately 4.8 million CY will be dredged from the navigation channel and turning basins between Stations 112+500 and 0+000. This material will be placed in the existing confined dredged material disposal areas. The only impact the expansion project will have on the shoaling locations is a slight upstream shift of approximately 60,000 CY of material into the Kings Island turning basin and approximately 29,000 CY between Stations 79+000 and 60+000. Material shifting to the turning basin is presently dredged between Stations 97+000 and 79+000 and the material shifting to Stations 79+000 and 60+000 presently shoals between Stations 50+000 and 40+000. This shift in shoaling locations results in a longer pumping distance and a slight increase in the cost of maintaining the improved project. If the habitat improvement area is dredged in the Port Wentworth turning basin, it will be maintained as part of the continuing O&M dredging activities in the navigation channel.

Periodic dike improvements and maintenance activities on the disposal areas will be cost shared in accordance with the provisions contained in the Water Resources Act which authorizes this expansion project. These activities include dike raising, weir replacement and maintenance, dike repairs, mowing the grass on the dike slopes, and removing vegetation from inside the disposal areas. Dewatering activities will also be performed to utilize dredged material for dike improvements and maintenance.

It is anticipated that an additional 52,800 CY of maintenance material will be dredged annually from the entrance channel as a result of the deepening and seaward extension of the channel. Annual maintenance of approximately 802,800 CY will be performed and the dredged material will be placed in the EPA approved ocean disposal site and/or in the nearshore and feeder berms which were approved in Reference 2.9.

The anticipated cost increase in O&M dredging as a result of the dredging the selected plan approximately $ 149,300, including contingencies.

## 15. CONTINUING ENGINEERING AND DESIGN ACTIVITIES

Additional detailed engineering analyses will be performed during the Continuing Engineering and Design (CED) phase of this expansion project. Activities performed in this phase will be detailed project designs, cost estimates, and construction plans and specifications for the selected plan. Engineering studies scheduled are a ship simulator study to be performed by the WES, additional subsurface investigations and laboratory analyses to characterize the materials to be dredged, evaluation of the suitability of material in the entrance channel for placement in a nearshore disposal site or on Tybee Island, magnetometer and side scan sonar surveys, hydrographic and topographic surveys, sedimentation modeling, and detailed designs of environmental features. Changes in the project design resulting from detailed studies performed in CED will be documented.

The ship simulator study will be used to verify the proposed wideners and channel alignment. If it is determined during this study that modifications are required, the channel configuration will be revised.

Additional subsurface investigations will be needed prior to completing an assessment of the materials to be dredged within the project area for plans and specifications and for final design of the dike improvements to disposal areas 12A and 14B. Laboratory analyses and material classification information from the channel borings will be used to refine the dredging cost estimates. Information from these investigations and analysis will also be used to the extent possible to analyze the suitability of the material from the entrance channel for placement in a nearshore/feeder berm disposal area or directly on the beach on Tybee Island. If the material is suitable for placement in these alternative sites, disposal of dredged material in these areas will be analyzed to determine the least costly disposal alternative. The purpose of the subsurface investigations on the dikes will be to identify soil properties of the existing dike, foundation soils, and dredged materials.

A sedimentation model will be developed for the recommended plan. The purpose of the model will be to determine if the existing advance maintenance locations and depths require modification as a result of the expansion project.

Detailed designs for the proposed environmental features will also be performed in CED. The proposed features include closing Middle River between disposal areas 1S and 2A, re-establishing flows between Middle and Little Back Rivers in the vicinity of New Cut closure, creation of a habitat improvement area, and closing the oxbow at Drakies Cut. Drakies Cut is located upstream of the Houlihan Bridge.

Plans and specifications for five construction contracts will be prepared. The contracts will be for dike improvements to disposal areas 12A and 14B, structural protection for Old Fort Jackson, dredging the inner harbor channel between Stations 103+000 and

70+000, dredging Stations 70+000 to 0+000 in the inner harbor, and dredging the entrance channel between Stations 0+000 and –82+000B. Construction of the environmental features in Drakies Cut, Port Wentworth turning basin, and Middle River will be included in the inner harbor contract to dredge Stations 103+000 and 70+000. Hydrographic and topographic surveys will be performed for preparation of the detailed designs and construction plans and specifications.

Table 15-1 summarizes the engineering activities and costs for work to be performed in CED.

**Table 15-1 Continuing Engineering and Design Activities**

| Activity | Cost |
|---|---|
| Ship Simulator Study | $ 237,600 |
| Geotechnical Investigations | 414,500 |
| Sediment Model | 21,400 |
| P/S - Dike Improvements | 222,000 |
| P/S - Old Ft. Jackson | 104,800 |
| Engr. Support - *CSS Georgia* | 87,200 |
| P/S – Dredging (3 contracts) | 1,747,000 |
| Engr. Management | 111,700 |
| Total | $ 2,944,200 |

## 16. FIGURES

**Figure 1 Disposal Areas for the Existing Project**

**Figure 2 Whitehall – Kings Island Examination Survey**

**Figure 3 Whitehall Examination Survey**

**Figure 4 Marsh Island Examination Survey**

**Figure 5 Marsh Island Examination Survey**

**Figure 6 Marsh Island Examination Survey**

**Figure 7 City Front Examination Survey**

**Figure 8 Wrecks Channel Examination Survey**

**Figure 9 Wrecks – Oglethorpe Examination Survey**

**Figure 10 Oglethorpe – Fort Jackson Examination Survey**

**Figure 11 The Bight Examination Survey**

**Figure 12 Bight – Upper Flats Examination Survey**

**Figure 13 Upper Flats – Lower Flats Examination Survey**

**Figure 14 Lower Flats Examination Survey**

**Figure 15 Long Island Crossing Examination Survey**

**Figure 16 Long Island Crossing Examination Survey**

**Figure 17 Long Island Crossing Examination Survey**

**Figure 18 New Channel Range Examination Survey**

**Figure 19 New Channel Range Examination Survey**

**Figure 20 Tybee Knoll Examination Survey**

**Figure 21 Tybee Knoll Examination Survey**

**Figure 22 Tybee Knoll Examination Survey**

**Figure 23 Tybee Knoll Examination Survey**

**Figure 24 Tybee Roads Examination Survey**

**Figure 25 Tybee Roads Examination Survey**

**Figure 26 Tybee Roads Examination Survey**

**Figure 27 Tybee Roads Examination Survey**

**Figure 28 Tybee Roads Examination Survey**

**Figure 29 Tybee Roads Examination Survey**

**Figure 30 Tybee Roads Examination Survey**

**Figure 31 Tybee Roads Examination Survey**

**Figure 32 Tybee Roads Examination Survey**

**Figure 33 Tybee Roads Examination Survey**

**Figure 34 Channel Typical Sections**

**Figure 35 Channel Typical Sections**

**Figure 36 Channel Typical Sections**

**Figure 37 Channel Typical Sections**

**Figure 38 Channel Typical Sections**

**Figure 39 Top of Slope Channel Stations 101+000 to 103+000**

**Figure 40 Top of Slope Channel Stations 98+000 to 101+000**

**Figure 41 Top of Slope Channel Stations 96+000 to 97+500**

**Figure 42 Top of Slope Channel Stations 93+500 to 95+500**

**Figure 43 Top of Slope Channel Stations 92+000 to 93+500**

**Figure 44 Top of Slope Channel Stations 85+500 to 87+500**

**Figure 45 Top of Slope Channel Stations 87+000 to 88+500**

**Figure 46 Top of Slope Channel Stations 77+500 to 79+000**

**Figure 47 Top of Slope Channel Stations 75+000 to 76+500**

**Figure 48 Top of Slope Channel Stations 69+500 to 71+700**

**Figure 49 Cross Section Station 101+887**

**Figure 50 Cross Section Station 99+144**

**Figure 51 Cross Section Station 98+605**

**Figure 52 Cross Section Station 77+500**

**Figure 53 Cross Section Station 88+000**

**Figure 54 Old Fort Jackson Section Plan**

**Figure 55 Cross Section Station 58+357**

**Figure 56 Cross Section Station58+500**

**Figure 57 Cross Section Station58+580**

**Figure 58 Cross Section Station 58+642**

**Figure 59 Cross Section Station 58+650**

**Figure 60 Old Fort Jackson Section 160**

**Figure 61 Old Fort Jackson Section 130**

**Figure 62 Old Fort Jackson Possible Slope Protection**

**Figure 63 SNG Pipeline Cross Section Station 51+500**

**Figure 64 Typical Channel Templates**

**Figure 65 Debris Offloading Site DA 12A/12B**

**Figure 66 Debris Offloading Site DA 1N**

**Figure 67 1997 Aerial Photograph of Disposal Area 12A**

**Figure 68 1997 Aerial Photograph of Disposal Area 12B**

**Figure 69 1997 Aerial Photograph of Disposal Area 13A**

**Figure 70 1997 Aerial Photograph of Disposal Area 13B**

**Figure 71 1997 Aerial Photograph of Disposal Area 14B**

**Figure 72 1997 Aerial of Jones/Oysterbed Island Disposal Area Part 1**

**Figure 73 1997 Aerial of Jones/Oysterbed Island Disposal Area Part 2**

**Figure 74 1997 Aerial of Jones/Oysterbed Island Disposal Area Part 3**

**Figure 75 Disposal Areas for the Expansion Project**

**Figure 76 Disposal Area 12A Location of Dike Raising**

**Figure 77 Disposal Area 14B Location of Dike Raising**

**Figure 78 Disposal Area 12A and 14B Typical Dike Raising Design Section Required for Harbor Expansion**

**Figure 79 Inner Harbor Shoaling Distribution 1995-1997**

**Figure 80 Entrance Channel Shoaling Distribution 1995-1997**

**Figure 81 Inner Harbor Shoaling Distribution 1972-1981**

**Figure 82 Inner Harbor Shoaling Distribution 1953-1954**

**Figure 83 Historical Sideslope Comparison**

**Figure 84 Historical Sideslope Comparison**

**Figure 85 Historical Sideslope Comparison**

**Figure 86 Historical Sideslope Comparison**

**Figure 87 Anticipated Inner Harbor Shoaling After Expansion**

**Figure 88 Typical Failure Modes for Disposal Area Dikes**

**Figure 89 Typical Disposal Area Dike Plan**

**Figure 90 Disposal Area 12A and 14B Typical Dike Raising Design Section for Future O&M Work**

**Figure 91 Closures at Drakies Cut Oxbow**

**Figure 92 Habitat Improvement Site**

**Figure 93 Middle River Closure**

**Figure 94 New Cut Channel**

# 17. ALTERNATIVE PROJECTS FIRST COST ESTIMATES

## 17.1. 45 ft. Project First Cost Estimate

| 45 ft. Alternative Project Cost Summary | | | | | |
|---|---|---|---|---|---|
| Account Code | Item | Estimated Cost | % | Contingency | Total Cost |
| 12 | **Navigation, Ports and Harbors** | | | | |
| 120201 | Mobilization | $2,365,200 | | $591,300 | $2,956,500 |
| | Dredging | | | | |
| 120216 | Pipeline Dredging | $37,939,000 | | $9,484,900 | $47,423,900 |
| 120217 | Hopper Dredging | $7,248,200 | | $1,812,100 | $9,060,300 |
| 120215 | Mechanical Dredging | $7,616,300 | | $1,904,100 | $9,520,400 |
| | Debris Removal | $1,891,324 | | $387,481 | $2,278,805 |
| 120220 | Disposal Area Improvements | $8,742,000 | | $2,185,500 | $10,927,500 |
| 12021603 | Aids to Navigation | $555,700 | | $138,925 | $694,625 |
| | **Subtotal** | **$66,357,724** | | **$16,504,306** | **$82,862,030** |
| | | | | | |
| 1 | **Land, Easements, Relocations & Rights of Way** | | | | |
| | Acquisition | $1,641,000 | 25 | $410,300 | $2,051,300 |
| | Administration | $134,000 | 0 | $0 | $134,000 |
| 6 | **Fish and Wildlife Features** | | | | |
| 6019903 | Environmental Mitigation Plan | $8,010,400 | | $1,602,080 | $9,612,480 |
| 6039901 | Chloride Mitigation | $46,000,000 | | $0 | $46,000,000 |
| 6019902 | Dissolved Oxygen Mitigation | $24,000,000 | | $0 | $24,000,000 |
| 18 | **Cultural Resource Preservation** | $9,740,190 | | $4,608,135 | $14,348,325 |
| 30 | **Continuing Engineering and Design** | $7,500,000 | 12 | $900,000 | $8,400,000 |
| 31 | **Supervision & Administration** | $3,100,000 | 24 | $744,000 | $3,844,000 |
| | **Dredging Non-Federal Berth** | $277,000 | 0 | $0 | $277,000 |
| | **Total** | **$166,760,314** | | **$24,768,821** | **$191,529,135** |
| | **Average Contingency Percentage** | | 15% | | |

**17.2. 46 ft. Project First Cost Estimate**

| 46 ft. Alternative Project Cost Summary | | | | | |
|---|---|---|---|---|---|
| Account Code | Item | Estimated Cost | % | Contingency | Total Cost |
| 12 | **Navigation, Ports and Harbors** | | | | |
| 120201 | Mobilization | $2,496,600 | | $624,200 | $3,120,800 |
| | Dredging | | | | |
| 120216 | Pipeline Dredging | $43,799,900 | | $10,950,100 | $54,750,000 |
| 120217 | Hopper Dredging | $9,864,500 | | $2,466,100 | $12,330,600 |
| 120215 | Mechanical Dredging | $8,667,800 | | $2,167,000 | $10,834,800 |
| | Debris Removal | $1,891,324 | | $387,481 | $2,278,805 |
| 120220 | Disposal Area Improvements | $8,780,000 | | $2,195,000 | $10,975,000 |
| 12021603 | Aids to Navigation | $617,700 | | $154,425 | $772,125 |
| | **Subtotal** | **$76,117,824** | | **$18,944,306** | **$95,062,130** |
| | | | | | |
| 1 | **Land, Easements, Relocations & Rights of Way** | | | | |
| | Acquisition | $1,641,000 | 25 | $410,300 | $2,051,300 |
| | Administration | $134,000 | 0 | $0 | $134,000 |
| 6 | **Fish and Wildlife Features** | | | | |
| 6019903 | Environmental Mitigation Plan | $8,010,400 | | $1,602,080 | $9,612,480 |
| 6039901 | Chloride Mitigation | $46,000,000 | | $0 | $46,000,000 |
| 6019902 | Dissolved Oxygen Mitigation | $24,000,000 | | $0 | $24,000,000 |
| 18 | **Cultural Resource Preservation** | $9,740,190 | | $4,608,135 | $14,348,325 |
| 30 | **Continuing Engineering and Design** | $7,500,000 | 12 | $900,000 | $8,400,000 |
| 31 | **Supervision & Administration** | $3,100,000 | 24 | $744,000 | $3,844,000 |
| | **Dredging Non-Federal Berth** | $334,000 | 0 | $0 | $334,000 |
| | **Total** | **$176,577,414** | | **$27,208,821** | **$203,786,235** |
| | **Average Contingency Percentage** | | 15% | | |

**17.3. 47 ft. Project First Cost Estimate**

## 47 ft. Alternative Project Cost Summary

| Account Code | Item | Estimated Cost | % | Contingency | Total Cost |
|---|---|---|---|---|---|
| 12 | **Navigation, Ports and Harbors** | | | | |
| 120201 | Mobilization | $2,693,700 | | $673,400 | $3,367,100 |
| | Dredging | | | | |
| 120216 | Pipeline Dredging | $49,597,800 | | $12,399,500 | $61,997,300 |
| 120217 | Hopper Dredging | $9,307,200 | | $2,326,800 | $11,634,000 |
| 120215 | Mechanical Dredging | $9,223,200 | | $2,305,800 | $11,529,000 |
| | Debris Removal | $1,891,324 | | $387,481 | $2,278,805 |
| 120220 | Disposal Area Improvements | $9,145,000 | | $2,286,300 | $11,431,300 |
| 12021603 | Aids to Navigation | $648,700 | | $162,175 | $810,875 |
| | **Subtotal** | **$82,506,924** | | **$20,541,456** | **$103,048,380** |
| | | | | | |
| 1 | **Land, Easements, Relocations & Rights of Way** | | | | |
| | Acquisition | $1,641,000 | 25 | $410,300 | $2,051,300 |
| | Administration | $134,000 | 0 | $0 | $134,000 |
| 6 | **Fish and Wildlife Features** | | | | |
| 6019903 | Environmental Mitigation Plan | $8,010,400 | | $1,602,080 | $9,612,480 |
| 6039901 | Chloride Mitigation | $46,000,000 | | $0 | $46,000,000 |
| 6019902 | Dissolved Oxygen Mitigation | $24,000,000 | | $0 | $24,000,000 |
| 18 | **Cultural Resource Preservation** | $9,740,190 | | $4,608,135 | $14,348,325 |
| 30 | **Continuing Engineering and Design** | $7,500,000 | 12 | $900,000 | $8,400,000 |
| 31 | **Supervision & Administration** | $3,100,000 | 24 | $744,000 | $3,844,000 |
| | **Dredging Non-Federal Berth** | $389,000 | 0 | $0 | $389,000 |
| | **Total** | **$183,021,514** | | **$28,805,971** | **$211,827,485** |
| | **Average Contingency Percentage** | | 16% | | |

**17.4. 48 ft. Project First Cost Estimate**

## 48 ft. Alternative Project Cost Summary

| Account Code | Item | Estimated Cost | % | Contingency | Total Cost |
|---|---|---|---|---|---|
| 12 | **Navigation, Ports and Harbors** | | | | |
| 120201 | Mobilization | $2,693,700 | | $673,400 | $3,367,100 |
| | Dredging | | | | |
| 120216 | Pipeline Dredging | $55,776,500 | | $13,944,300 | $69,720,800 |
| 120217 | Hopper Dredging | $11,796,000 | | $2,949,000 | $14,745,000 |
| 120215 | Mechanical Dredging | $9,805,000 | | $2,451,300 | $12,256,300 |
| | Debris Removal | $1,891,324 | | $387,481 | $2,278,805 |
| 120220 | Disposal Area Improvements | $9,491,000 | | $2,372,800 | $11,863,800 |
| 12021603 | Aids to Navigation | $648,700 | | $162,175 | $810,875 |
| | **Subtotal** | **$92,102,224** | | **$22,940,456** | **$115,042,680** |
| | | | | | |
| 1 | **Land, Easements, Relocations & Rights of Way** | | | | |
| | Acquisition | $1,641,000 | 25 | $410,300 | $2,051,300 |
| | Administration | $134,000 | 0 | $0 | $134,000 |
| 6 | **Fish and Wildlife Features** | | | | |
| 6019903 | Environmental Mitigation Plan | $8,010,400 | | $1,602,080 | $9,612,480 |
| 6039901 | Chloride Mitigation | $46,000,000 | | $0 | $46,000,000 |
| 6019902 | Dissolved Oxygen Mitigation | $24,000,000 | | $0 | $24,000,000 |
| 18 | **Cultural Resource Preservation** | $9,740,190 | | $4,608,135 | $14,348,325 |
| 30 | **Continuing Engineering and Design** | $7,500,000 | 12 | $900,000 | $8,400,000 |
| 31 | **Supervision & Administration** | $3,100,000 | 24 | $744,000 | $3,844,000 |
| | **Dredging Non-Federal Berth** | $454,000 | 0 | $0 | $454,000 |
| | **Total** | **$192,681,814** | | **$31,204,971** | **$223,886,785** |
| | **Average Contingency Percentage** | | **16%** | | |

**17.5. 50 ft. Project First Cost Estimate**

| 50 ft. Alternative Project Cost Summary | | | | | |
|---|---|---|---|---|---|
| **Account Code** | **Item** | **Estimated Cost** | **%** | **Contingency** | **Total Cost** |
| 12 | **Navigation, Ports and Harbors** | | | | |
| 120201 | Mobilization | $4,014,000 | | $1,003,500 | $5,017,500 |
| | Dredging | | | | |
| 120216 | Pipeline Dredging | $74,878,100 | | $18,719,700 | $93,597,800 |
| 120217 | Hopper Dredging | $19,825,100 | | $4,956,300 | $24,781,400 |
| 120215 | Mechanical Dredging | $14,143,600 | | $3,535,900 | $17,679,500 |
| | Debris Removal | $1,891,324 | | $387,481 | $2,278,805 |
| 120220 | Disposal Area Improvements | $10,227,900 | | $2,557,000 | $12,784,900 |
| 12021603 | Aids to Navigation | $679,700 | | $169,925 | $849,625 |
| | **Subtotal** | **$125,659,724** | | **$31,329,806** | **$156,989,530** |
| | | | | | |
| 1 | **Land, Easements, Relocations & Rights of Way** | | | | |
| | Acquisition | $1,641,000 | 25 | $410,300 | $2,051,300 |
| | Administration | $134,000 | 0 | $0 | $134,000 |
| 6 | **Fish and Wildlife Features** | | | | |
| 6019903 | Environmental Mitigation Plan | $8,010,400 | | $1,602,080 | $9,612,480 |
| 6039901 | Chloride Mitigation | $46,000,000 | | $0 | $46,000,000 |
| 6019902 | Dissolved Oxygen Mitigation | $24,000,000 | | $0 | $24,000,000 |
| 18 | **Cultural Resource Preservation** | $9,740,190 | | $4,608,135 | $14,348,325 |
| 30 | **Continuing Engineering and Design** | $7,500,000 | 12 | $900,000 | $8,400,000 |
| 31 | **Supervision & Administration** | $3,100,000 | 24 | $744,000 | $3,844,000 |
| | **Dredging Non-Federal Berth** | $530,000 | 0 | $0 | $530,000 |
| | **Total** | **$226,315,314** | | **$39,594,321** | **$265,909,635** |
| | **Average Contingency Percentage** | | 17% | | |