Appendix A – Engineering

Galveston Harbor Channel Extension, TX

Section 216

Draft Validation Report

October 2023

US Army Corps of Engineers

Galveston District

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EXECUTIVE SUMMARY

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1 GENERAL

Recommended Plan:

Engineering studies for the Galveston Harbor Channel (GHC) Extension Section 216 Feasibility Study Report (GHCE Feasibility Report) included: preliminary geotechnical investigations (sampling and laboratory analysis); preparation of a preliminary dredged material management plan (DMMP); beneficial use concept studies; in-house hydrographic surveys of the channel; and land surveys. Other engineering and design surveying and mapping, environmental quality features, civil design, geotechnical design, structural design, access roads, operations and maintenance (O&M), cost estimates, data management and schedules.

Additional Channel:

During PED the design team was tasked with adding an additional channel to the Galveston Harbor Channel Extension. In 2019, the Board of Trustees of the Galveston Wharves, the Non-Federal Sponsor for the project, requested an adjustment in channel design to allow for increased safety as ships maneuvered into the docks on the far western end of the channel. This additional channel was coordinated with both terminal owners and the Galveston/Texas City Pilots Association. Deepening of the GHC additional channel consists of 505 feet of the Galveston Harbor Channel (from Station 22+571 to Station 23+076.21).

The Galveston District converted the vertical datum for all navigation projects from Mean Low Tide (MLT) to Mean Lower Low Water (MLLW) in accordance with US Army Corps of Engineers Headquarters memorandum directing conversion (USACE 2014). For the HGNC Galveston Channel Extension (GHCE) Entrance Channel the conversion from MLT to MLLW is one foot deeper, for example where prior reports reference deepening to 45 feet MLT this report referenced 46 feet MLLW.

1.1 Project Description

Recommended Plan:

The study produced a National Economic Development (NED) Plan consisting of deepening the western most portion of the currently authorized 41-foot deep GHC, resulting in a 2,571-foot extension of the existing 46-foot channel. The plan includes keeping the width of the channel extension equal to the existing 46-foot channel at 1,075 feet. The NED Plan includes using the existing Pelican Island upland confined PA for containment of the resulting dredged new work materials from the channel deepening and the future dredged maintenance material for the 50-year period of analysis.

Additional Channel:
The change is the addition of 505 foot channel that is deepened to match the 46-foot channel.

2 CIVIL ENGINEERING

The plan of improvement with additional channel described in this document pertains to the Galveston Harbor Channel, Texas. A study area map and pertinent channel design information are shown on Drawing Nos. C-101 through C-501 attached to this appendix.

2.1 Galveston Harbor Channel

Recommended Plan:

The GHC is subdivided into two reaches: Station 0+000 to Station 20+000 and Station 20+000 to Station 22+571. The existing 41-foot GHC reach extends from Station 20+000 to Station 22+571. The Extended Entrance, Entrance, Outer and Inner Bar Channels (Stations 0+000 to 20+000) were deepened to their existing depths during the recent Houston-Galveston 46-foot Widening and Deepening Project for the Houston Ship Channel (HSC). Refer to Drawing C-101 for a plan view of the GHC.

Within the proposed GHC Extension reach (Station 20+00 to Station 22+571) the proposed 46-foot channel footprint replaces the 41-foot footprint, and thus the 41-foot channel will not be maintained after construction of the 46-ft channel. The proposed 46-foot extension would have a design width of 1,075 feet, thus matching the width of the existing 46-foot GHC at Station 20+000.

Additional Channel:

The proposed GHC additional channel (Station 22+571 to 23+076.27) has not previously been dredged and has been designed to meet the 46-foot Galveston Channel. The proposed additional channel would have varied design width to facilitate the egress and ingress of the TXIT traffic. This area will be maintained to the 46-ft along with the existing GHC and proposed GHC Extension.

2.2 Site Selection and Project Development

2.2.1 Proposed Extension Channel and Additional Channel

Recommended Plan:

The proposed channel centerline alignment extends westward from Station 20+000 to the end of the existing 41-foot channel at Station 22+571. The channel would have side slopes of 1V:3H and a bottom width of 1,075 feet. The template depths were updated to Figure 1 and 2 based on the memo titled “District policy on setting dredging templates for studies, new work

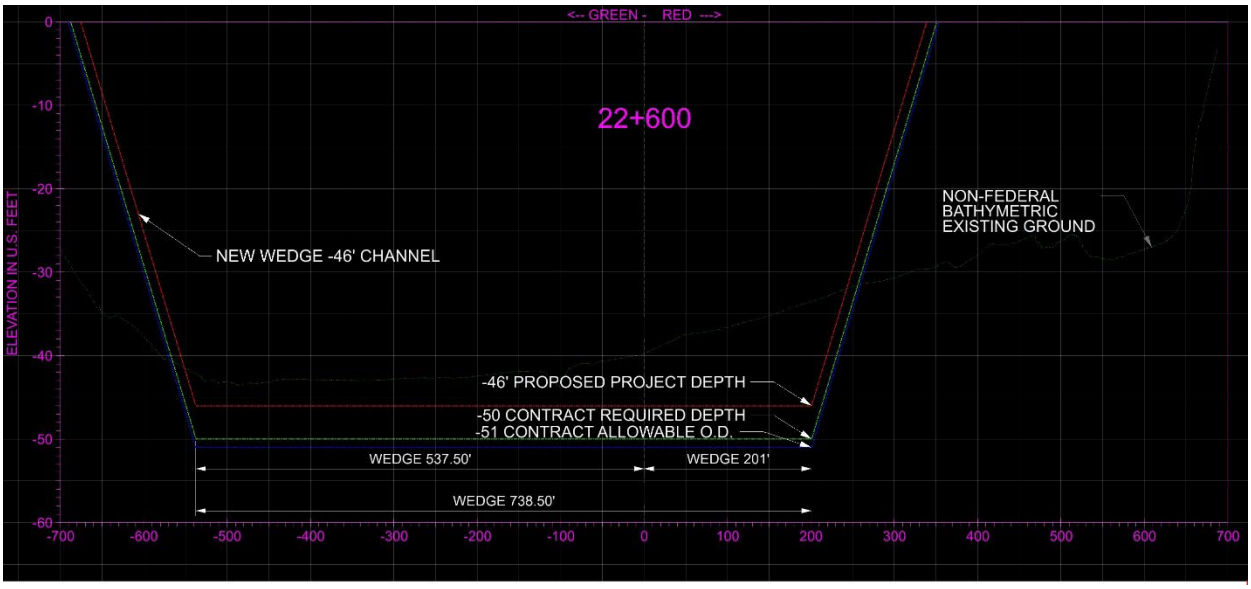
construction projects, and channel maintenance" dated April 2019. The memo is included in Attachment C and further explained below in "New Work Dredging".

Additional Channel:

The proposed channel centerline alignment would continue to extend from Station 20+000 to Station 23+076.27. The additional channel would also have the side slopes of 1V:3H with varying bottom widths from 744.45 feet to 384.50 feet. At the westerly limit of dredging for the additional channel there is an additional 150-foot end slope to facilitate dredging operations. The templates show 46-foot proposed project depth, 3-foot advanced maintenance, 1-foot additional over depth and 1-foot allowable overdepth.

See Figure 1 and 2 for the proposed channel cross sections.

1 Cross-Section Template Sample of Recommended Plan



2 Cross-section Template Sample of Additional Channel

2.3 Real Estate

No additional land will be required for the selected plan.

2.4 Relocations and Removals

Relocations and removals associated with the project and considered for this analysis included aids to navigation, structures, pipelines and utilities. There were no changes to requirements as stated in the feasibility study.

2.4.1 Structures

Additional Channel:

Information was received from Texas A&M at Galveston, located on the north side and at the west end of the proposed GHC Extension of their fishing dock so that the dredging safety envelope could be calculated. This is discussed more in Section 7 of this appendix.

2.5 Maintenance Dredging Frequency and Shoaling Rate

The dredging frequency will remain the same (four years) as the existing 46-foot channel. Pelican Island Placement area should be able to accept all new work material for the extension and additional channel as well as 50 years of maintenance material. The current operation of this area will remain with every other dredging cycle being a hopper dredging contract with placement at a near ODMDS. As a contingency, if additional capacity needs arise, San Jacinto Placement area could be used or additional hopper dredging may be performed.

2.6 Design Considerations

Additional Channel:

Several design assumptions were made in conjunction with this study. Hydrographic survey data provided by the area office were utilized in defining new work volumes. The most recent surveys were collected March 11, 2022 collected with a single-beam scan sonar in 500 feet grid pattern. A bathymetric survey of the additional channel was performed by the Non-Federal Sponsor on November 3, 2021. The material shown in the surveys were identified as new-work material. Quantities were calculated as material in template including advance maintenance and allowable overdepth.

The additional channel design used the TXIT Suezmax Expansion Simulation Report to prepare the needed footprint. After scouring analysis of the structures within or close to the footprint identified in the report showed that 150' envelope of safety was adequate to reduce the risk to the structures. This factor shortened the bottom width at Station 22+5741.34 from 1075 feet (Main Channel) to 886.38 feet (Additional Channel).

2.7 New Work Dredging

The term "new work" refers to the material below the existing channel template which will be removed to increase the channel depth to the new project depth and the additional channel. The additional channel has proposed templates which are trapezoidal shapes, defined by bottom width and side slopes. Those templates were used to model the channel and calculate new work volumes. The proposed template includes the current advance maintenance and allowable overdepth values of four feet and one foot, respectively.

According to the memo titled "District policy on setting dredging templates for studies, new work construction projects, and channel maintenance" dated April 2019 references ER 1130-2-520 and EP 1130-2-520 and states the policy is for "standardizing new work dredging templates is to ensure that all new work material be removed from the future Operations and Maintenance (OM) template where no new work material will be encountered during OM dredging activities. The ER makes specific reference that "…dense clays, rock, or manmade materials" be removed to ensure future maintenance of the project to the authorized dimensions." Refer to Attachment C for the memo which indicates that in areas where hard new work material exists the dredging will be performed one foot deeper than required for O&M contracts. The document later indicates that the PDT will

perform a geotechnical analysis to identify dense clays and other hard materials. Galveston Harbor Channel contains clays identified in the boring as stiff, soft, and very soft within the dredging template as shown in Attachment A. The stiff clay is expected to be considerable harder to dredge than the silty material that will be encounter in O&M contracts, while very soft clay should be similar as O&M material. Based on the analysis of anticipated soil conditions at the channel bottom, one foot of additional overdepth is recommended below the required 3-foot of advanced maintenance to ensure removal of all hard materials from the future maintenance template. See Table 2.2 for a breakdown of required advanced maintenance, additional overdepth and allowable overdepth.

New work material volumes are shown in Table 2.1.

Table 2.1: Dredging Quantity Summary Table

Appendix 1-Quantity Summary Table									
SECTIONS				QUANTITIES					
Section No.	From Station	To Station	Length of Station (Feet)	Required Depth 46' (CY)	Advanced Maintenance (CY)	Additional Allowable Overdepth (CY)	Total Estimated 51' (CY)		Placement Area Distribution
Galveston Harbor Ship Channel									
1	20+000.00	22+571.34	2,571	44,000	343,000	114,000	501,000		Pelican Island
		Subtotal Galveston Harbor Channel (New Work)		44,000	343,000	114,000	501,000		
SECTIONS				QUANTITIES					
Section No.	From Station	To Station	Length of Station (Feet)	Required Depth 46' (CY)	Advanced Maintenance (CY)	Additional Allowable Overdepth (CY)	Total Estimated 51' (CY)		Placement Area Distribution
Galveston Harbor Turning Area									
2	22+571.34	22+926.27	355	64,000	35,000	9,000	108,000		Pelican Island
3	22+926.27	23+076.27	150	12,000	5,000	1,000	18,000		Pelican Island
		Subtotal Galveston Harbor Turning Area (New Work)		76,000	40,000	10,000	126,000		
Total Galveston Harbor Channel and Turning Area				120,000	383,000	124,000	627,000		
Notes:	1.) May 2022 Surveys								
	2.) Authorized Project Depth (46'), Advanced Maintenance (50'), Overdepth (1')								
		AM=4'							
		OD=1'							
	3) Contract Required Depth=Authorized Project Depth +Advanced Maintenance								

2.7.1 Third-Party Portside Facilities Dredging

Third-party (non-Federal) portside facilities new work dredging volume is not included in the additional channel design.

2.7.2 Allowable Overdepth

Additional depth outside the required channel template would be permitted to allow for inaccuracies in the dredging process. Per Engineering Regulation (ER) 1130-2-520, *Navigation and Dredging Operations and Maintenance Policies,* "District Commanders may dredge a maximum of two feet of allowable overdepth in coastal regions…, and inland navigation channels." This additional dredging allowance would be referred to as a dredging tolerance, or allowable overdepth. The Galveston Channel extension and additional channel have a one-foot allowable overdepth.

2.7.3 Advance Maintenance

Advance maintenance consists of dredging deeper than the authorized channel template to provide for the accumulation and storage of sediment. In critical and fast-shoaling areas advance maintenance would be required to avoid frequent re-dredging and to ensure the most reliability for

navigation within the channel and the least overall cost for operating and maintaining the project authorized dimensions. ER 1130-2-520 authorizes Major Subordinate Command (MSC) Commanders to approve advance maintenance. Advance maintenance for the proposed 46-foot GHCE and additional channel would be three feet. This would allow the GHCE and additional channel to be maintained at the same frequency (4-year cycle) as the existing adjacent 46-foot channel, thus operations and maintenance cost over the 50-year project life would be optimized because of the reduction in the number of required maintenance dredging contracts (and mobilization costs).

Table 2.2: Channel Dimensions

STARTING STATION	ENDING STATION	CHANNEL BOTTOM WIDTH	CONTRACTOR ADVANCED MAINTENACE	ADDITIONAL OVERDEPTH	CONTRACTOR ALLOWABLE OVER DEPTH
20+000	22+571.34	1075’	3’	1’	1’
22+571.34	23+076.21	VARIES	3’	1’	1’

2.8 Beneficial Use of Dredged Material

Beneficial use of the dredged material for the GHCE and additional channel are not included in current design.

3 Surveying, Mapping, and Other Geospatial Data Requirements

There have been no changes to the surveying, mapping or geospatial data requirements. There is also no change to the datum used from the feasibility study.

4 Project Site Access

The Pelican Island PA has existing access roads available. No public roads will require improvement for access to the project site.

5 Geotechnical Engineering

5.1 Existing Soils Data-Channel

The geotechnical design for the deepening of the GHCE and the additional channel was completed using historical geotechnical investigations (1965 and 2008). The summary of the potential new work dredging material within the project segments is presented in Table 5.1.

Table 5.1: Potential New Work Dredging Materials

From Sta.	To Sta.	Length of Station (Feet)	Quantity (cy)	to PA	Will the new work material be more challenging to dredge compared with the dredging of the O&M material based on Available Geotechnical Data? Yes/No[1]	Approximate New Work Material Ratio Between Sand (%): Soft Clay/Silt (%): M. Stiff to Hard Clay (%) (Based on Recent Channel Borings)	Soil Types	Reference Borings	Remarks SPT, Undrained Shear Strength (ksf)
20+000.00	22+571.34	2,571.34	333,072	**Pelican Island**	Yes	Sand (10%): Soft Clay/Silt (0%): M. Stiff to Hard Clay (90%)	Soft CL/CH and Hard CL/CH	3ST-81, 07-240, 3ST-82, 07-241	0 to 4.5 ksf
22+571.34	23+076.27	504.93	143,100	**Pelican Island**	Yes	Sand (10%): Soft Clay/Silt (0%): M. Stiff to Hard Clay (90%)	Medium CL/CH and Stiff CL/CH	07-241	0.45 to 1.39 ksf

Table 5.1 provides an approximate soil classification of the new work dredged material and summary of the new work placement plan. The soil classifications include medium stiff to hard clay materials, requiring the need for the over depth and advance maintenance dredging. Between boring locations in the existing information, it is assumed that the depths of material layers changed linearly. The assumption is that the last shown material layer continued to the proposed depth. The fence diagram/subsurface profiles from the 1965 and 2008 geotechnical data are presented in Attachment A. The distribution of blow counts (SPT N values) and Unconfined Compression Test results (UC) for clayey soils will be presented on the fence diagrams to understand potential dredged materials' engineering properties.

5.2 Channel Slope Stability

A geotechnical engineering evaluation of the slope stability of the channel cut was conducted based on available geotechnical data from 2021 Geotechnical Investigation. Total of two (2) sections were identified as critical and were analyzed for slope stability as part of this design.

The channel slopes were analyzed for both undrained Construction and drained conditions. Safety factors (associated with slope stability analyses) specified in the Engineering Manuals EM 1110-2-5025 and EM 1110-2-1902. Considering the relatively low consequences of failure of a channel slope compared to a dam's failure, a minimum factor of safety of 1.3 for end-of-construction (undrained) and for long-term (drained) conditions were selected for this analysis. The minimum slope stability analysis resulted in minimum factors of safety of 1.89 and 2.4 for the end-of-construction and the long-term conditions, respectively. See Attachment B for slope stability models.

5.3 Placement Areas

There is no change to expected use of Placement Areas. Pelican Island Placement Area will be utilized for this project.

6 Operation and Maintenance

The addition of the additional channel in the O&M phase of the project is the only change to the O&M plan.

7 Hydrology and Hydraulics

Additional Channel:

The shoaling analysis showed an average shoaling rate of 1.15 ft per year averaged over the entire area of the previously dredge area. This rate is multiplied over the entire area of the new wedge for the total expected quantity of new maintenance material per year. Those quantities are displayed in the geotechnical section of the DDR. Updates to the channel shoaling analysis are ongoing. The update will utilize the Corps Shoaling Analysis Tool (CSAT) that was previously unavailable. The CSAT calculates channel shoaling volumes using historical channel surveys and uses the shoaling rates to predict future dredging volumes. CSAT results may differ from the original analysis and may result in changes to the predicted volumes of future maintenance material. Any changes to these volumes will be provided when the ongoing H&H update to the shoaling and scour analysis is completed.

Prop-wash jet streams are one of many flow types that present a risk to quay structures. That said, it is certainly not the most dominate flow mode concerning the Pelican Island bridge. Nor'easters, tropical storms, and the sediment transport associated with such events pose a much greater risk to the bridge columns. In the design of bridge piers, these extreme flow velocities at the bed must be considered in design. A potential scour increase on the order of 2-10 inches is negligible considering the rather extreme modes the bridge has experienced in its lifetime. Scour in the marine environment is also a cyclical process where the bed is constantly renourished, as opposed to a riverine environment. Suffice to say, the scour increase shown here has been accounted for in the design of the bridge. TXDOT does label this particular structure as "scour critical" and the piers should be closely monitored in the aftermath of extreme events. Updates to the bridge pile scour analysis are ongoing. The scour analysis was performed using the "German" approach which can be found in the guidance document from the Maritime Navigation Commission of the World Association for Waterborne Transport Infrastructure (PIANC Marcom). It is currently being updated using the Coastal Engineering Manual's Equation VI-5-265 (Engineer Manual (EM) 1110-2-1100; Colorado State University Equation). Preliminary results from the updated analysis are comparable to the original. Final values will be provided up on completion of the analysis.

Climate: Future relative sea level change (RSLC) was not addressed per ER ER 1100-2-8162 in the 2017 Feasibility Study and Chief's Report as the ER was not issued until 2019. Project features that may be affected by RSLC include shoreline change, dredged material placement area dikes, channel shoaling and water quality.

8 Cost Engineering

8.1 Background

Galveston Harbor Channel Extension (GHCE) Feasibility Study was first certified by Walla Walla District 14 February 2017, and included associated costs. The Chief's Report was signed 8 August 2017, and the project was authorized by Congress in the Water Resources Development Act of 2018.

The PED phase for the authorized project began in 2019. Since then, the Texas International Terminals Facility (TXIT) was expanded to add another dock to the west of their existing docks.

A 2019 Ship Simulation study was performed and demonstrated that an additional 500 feet of channel length (additional channel) was necessary to allow the pilots to maneuver the terminal end of the channel and enter or exit the TXIT docks safely and efficiently. The Project Partnership agreement for the A was signed between USACE SWG and the Wharves Board of the City of Galveston as the non-Federal Sponsor on 13 July 2022.

8.2 Last Estimate

GHCE Feasibility Study was re-certified by Cost MCX 22 May 2022. GHCE Feasibility Study and additional channel was conditionally certified by Cost MCX 22 May 2022, because the additional channel was outside the original authorization. The associated cost was not included at that time.

8.3 Current Estimate

The current estimate was created as a part of the FY24 Validation Report for HGNC Galveston Channel Extension with the use of the most recent costs for labor, equipment, and materials.

The channel was assumed to be dredged using a cutter-head 30" pipeline dredge with the material discharge into existing Pelican Island PA located upland. The project does not include PA work. The PA dikes are currently being raised under O&M contract and the PA will have sufficient capacity to contain new work material. Cell AB in Pelican Island is being raised to 33 feet with 5 foot of freeboard and expected capacity of 4.2 million CY.

The cost for mobilization and demobilization and the dredging costs were developed using CEDEP, assuming the dredge was based in New Orleans, LA. The dredging assumptions were based on standard operating practices for SWG.

The project is estimated less than $40M and an Abbreviated Risk Analysis (ARA) was developed to determine project contingencies. The midpoint date of the account code for the construction contract was determined by CEDEP and confirmed with PDT. This information was utilized to develop the fully funded cost that is reflected in the Total Project Cost Summary Sheet (TPCS), providing a comprehensive view of the overall project cost.

8.4 The changes between last and current estimates

ACCOUNT CODE 12 -- NAVIGATION PORTS AND HARBORS:

The cost for this account was developed in CEDEP and the MII v4.4.3 following the guidelines of ER 1110-2-1302 and EM 1110-2-1304. The following changes were applied:

- Labor rates in CEDEPs were adjusted (decreased) to the local level, using historical data from RMS.
- Fuel price was decreased from $5.34 (May 2022) to $4.50 (Oct 2023).
- Mobilization and demobilization cost was increased, considering the historical costs that the district has incurred on similar projects. Estimate assumes a full demobilization rather than a partial (50%) demobilization.
- Dredging quantities were increased due to the addition of the additional channel, based on the surveys conducted in September 2023.
- Associated costs for dredging third-party facilities (TXIT berth and Gulf Sulphur berth) were added to the total project cost.

ACCOUNT CODE 30 -- ENGINEERING AND DESIGN:

The cost for this account was developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager. Approximately the same percentages were used for Feasibility, less spent thru.

ACCOUNT CODE 31 -- CONSTRUCTION MANAGEMENT:

The cost for this account was developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager. Approximately the same percentages were used for Feasibility, less spent thru.

See Table 8.1 below summering cost change.

Table 8.1 Comparison of Project First Costs ($1,000s)

Between Feasibility Study NED (FY17), and Authorized Plan (FY22), and Modified Plan (FY24)

Cost Account	Description	Feasibility Project First Cost[1]	Feasibility Project Recertified First Cost (Includes $756 spent cost)[2, 5]	Recommended Plan First Cost (Includes $756 spent cost)[3, 5]	Cost Difference between Recertified Cost and Recommended Plan	% Difference between the Recertified Cost and Recommended Plan	Current Estimate for Authorized Plan First Cost (Includes $2,050 spent cost)[4, 5]	Current Estimate for Modified Plan First Cost (Includes $2,050 spent cost)[4, 5]	Cost Difference between Current Estimates for Authorized Plan and Modified Plan	% Difference between Current Estimates for Authorized Plan and Modified Plan
		Oct-16	Oct-21	Oct-21	Oct-21	Oct-21	Oct-23	Oct-23	Oct-23	Oct-23
12	*Navigation, Ports & Harbors Federal Cost Channel*	*$11,490*	*$12,728*	*$16,225*			*$12,211*	*$12,211*		
12	*Navigation, Ports & Harbors Federal Cost Turning Area*	*$0*	*$0*	*$0*			*$0*	*$1,554*		
12	*Navigation, Ports & Harbors non-Federal Cost*	*$1,938*	*$0*	*$0*			*$3,250*	*$3,250*		
12	Navigation, Ports & Harbors Subtotal	$13,428	$12,728	$16,225	$3,497	22%	$15,461	$17,015	$1,554	9%
30	Planning, Engineering & Design	$1,504	$1,404	$1,404	$0	0%	$2,787	$2,861	$74	3%
31	Construction Management	$401	$392	$393	$1	0%	$747	$822	$75	9%
TOTALS		**$15,333**	**$14,523**	**$18,021**	**$3,498**	**19%**	**$18,995**	**$20,699**	**$1,704**	**13%**

9 Channel Construction

There is no expected change in the planned channel construction. The project will be dredged in one contract. All material will be excavated with a hydraulic pipeline dredge, and placed into the confined upland Pelican Island PA.