Coastal Texas Protection and Restoration Feasibility Study

Final Feasibility Report

# Appendix D – Annex 23:

## *Cost Appendix*

**August 2021**

(This page left intentionally blank.)

# Coastal Texas Protection and Restoration Feasibility Study
# (Coastal Texas Study)
# Feasibility Report
# Cost Appendix

This MII estimate was prepared for the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) initiated in 2014 to evaluate large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternatives aimed at providing the coastal communities of Texas with multiple lines of defense from a wide array of coastal hazards.

The study area includes the entire Texas coastline extending from the mouth of the Sabine River at the Texas/Louisiana border to the mouth of the Rio Grande near Brownsville, Texas. This includes all 18 of Texas coastal counties. The study area was subdivided into 4 regions: the upper Texas coast, the mid to upper Texas coast, the mid Texas coast, and the lower Texas coast.

CSRM features are located in the upper Texas coast and in South Padre Island (SPI) which is located in lower Texas coast.

The Recommended Plan was formulated as a system and includes several features that provide risk reduction through a line of engineered features along the gulf, other features to provide resiliency along the bay and future adaptations to sea level change. The plan features are described below.

- Bolivar Roads Gate System between Bolivar Peninsula and Galveston Island is the largest feature of the Coastal Barrier system. It includes surge barrier gates that are made up of navigable floating sector gates and environmental lift gates and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap.

- The Galveston Ring Barrier System (GRBS) feature is a system of floodwalls, gates, pump stations, levees which connect to existing levee and seawall. In addition, there are combi-wall, environmental lift gates and vertical lift gates at Offatts Bayou. Seawall Elevation is a future adaptation to provide for a continuous barrier for storm surge reduction along the coast.

- Bolivar and West Galveston Beach and Dune System are a critical component of the comprehensive plan for CSRM along the Texas Coast, and they tie into the storm surge gate and ensure its function over time.

- Clear Lake and Dickinson Bay Gates and Pump Stations on the mainland reduce residual risk from bay flooding.

- SPI Beach Nourishment and Sediment Management includes 2.9 miles of beach nourishment and sediment management, with beach nourishment recurring on a 10-year cycle for the authorized project life of 50 years.

- Ecosystem Restoration measures are proposed at eight (8) locations along the coast and include the following: 114 miles of breakwaters, 15.2 miles of bird rookery islands, 2,052 acres of marsh, 12.32 miles of oyster reef, and 19.5 miles of beach and dune.

- Mitigation will be required for 1,577.6 acres of direct and indirect impacts to wetlands and oyster reefs. Over 1,378 acres of habitat will be created or restored in order to offset the direct and indirect impacts of the proposed plan.

Engineering design work is premised on feasibility-level detail and analyses, consistent with the SMART planning process that is necessary to substantiate the Recommended Plan baseline cost estimate. Another key concept is to utilize existing information where applicable. Quantities and design features were developed by the Galveston District (SWG) Engineering Branch and the New Orleans Structural Branch.

The estimates were based on standard operating practices for the Galveston District which assumed conventional contracting practices of large business Invitations for Bids. For CSRM features, sub-contractors have been potentially identified as the following: concrete, landscaping, electrical, mechanical, piles, pumps, and traffic control. For NER features, sub-contractors have been identified as the following: dredging for breakwater foundation, island restoration earthwork, and marsh creation. It was assumed that no overtime would be required beyond reduced productivity and any proposed acceleration of work schedule during design, fabrication, and installation of major gates. The risk register does account for unusual weather delays, e.g. hurricanes, which could result in an indirect overtime to accelerate work to meet schedule; but it does not directly include an additional amount of overtime.

This estimate was prepared using MII ver. 4.4.2, Unit Price Book, National labor Library, and equipment rates for Region 6 (per EP 1110-1-8), and fiscal year 2021 (October 2020). The Mii was organized into three areas. Each area was subdivided into the features, and each feature was subdivided into Non-Federal and Federal Costs and then into the work breakdown structure. The midpoint date of each account code for each of the construction contracts was used to develop the fully funded costs. The estimate was prepared in accordance with ER 1110-2-1302.

Stagging and access areas were identified along the features alignment approximately every quarter mile (Ref: Engineering Appendix: Map Book). Any further environmental concerns will be identified during the development of plans and specifications and will be mitigated for at that

time. Construction methodology is standard construction, except for the Bolivar Road Gates; the gates will start as a design competition (unique for USACE) potentially leading to novel construction methodologies, which are captured as unknown, but likely, risks in the risk register.

Mark Ups will vary by feature and contract. For prime contractors, markups generally consist of the following: JOOH – 10.0%; HOOH – 15%; Profit – 10%, and Bond – 1.5%. For sub-contractors, markups generally consist of the following: JOOH – 5.0%; HOOH – 10%; Profit – 10%. The assumption is sub-contractors will piggyback off prime contractors' JOOH, e.g. field office.

Environmental concerns are captured under ecosystem restoration, mitigation, and through the deployment of environmental surveyors and species spotters during construction. In addition, the estimate and risk register account for minor to potentially devastating rainfall events, tropical storms, and hurricanes. It also accounts for reduced productivity in popular, touristy areas, such as the Galveston Seawall on peak summer days.

**Contingencies**

A formal Cost and Schedule Risk Analyses was performed with the cooperation of the PDT and Cost Engineering Mandatory Center of Expertise for Civil Works (MCX located in Walla Walla District). The risks were quantified, and a cost risk model developed to determine a contingency at 80% confidence level. The contingencies along with the estimates were input into the Total Project Cost Summary (TPCS). An ATR Certification for the cost estimate was provided by Walla Walla District.

The costs were escalated in accordance with the Engineering Regulation and EM 1110-2-1304 to mid-point of construction.

**ACCOUNT CODE 01 -- LANDS AND DAMAGES:** The Galveston District Real Estate Division developed costs for Lands and Damages.

**ACCOUNT CODE 02 – RELOCATION:** This account was separated into three different subgroups:

**Utilities:** Consisted of an assortment of water lines, sewer lines, underground electrical lines, and overhead electrical lines.

**Pipelines:** This item refers to pipelines that require relocation. It was assumed that the relocation of the pipelines would be performed by directional drilling. Those costs were based on quotes from pipe suppliers: hydrostatic testing, welding, and layout, and making tie-ins.

**Structures:** This is a catch-all category used when the items did not fall into one of the above mention categories**.** This category includes pedestrian walkovers (as permitted), drive-overs where appropriate, and boat ramps.

**ACCOUNT CODE 06 – FISH AND WILDLIFE FACILITIES (MITIGATION):**

Three different mitigation types were costed for the Upper Texas Coast. They were the following:

**Estuarine Wetland:** There are a total of seven (7) locations ranging in size from 4- to 667-acre sites (1302 acres total). The sites would be constructed with dredge material from the Bolivar Roads crossing. Included in the cost estimate are the following: temporary containment berms and drainage structures to reach a final elevation of +0.7 to +1.1 NAVD 88, with 20% open water and initial spartina seeding. In Target Year (TY) 4-5, re-seeding Spartina; TY 5 creating sinuous circulation channels and ponds using marsh buggies to compress soil; and TY6 re-seeding/planting 10% of spartina.

**Palustrine (freshwater) Wetland:** The site is located on Galveston Island and consists of restoring dunal swale wetlands by excavating material where necessary to bring it within 1-foot of the winter water table (162 acres of freshwater wetlands comprised of 34.4 acres of wetland and 127.6 acres of prairie buffer). The site would need piezometers installed and monitored for a minimum of two (2) years to establish seasonal water tables. The area would be treated with prescribed burns to remove invasive vegetation and would be replanted with locally sourced wetland and prairie plant species.

**Oyster Reefs**: Three (3) location were identified for the creation of reefs (130.5 acres total). Reef construction would consist of the following: initial /final hydrographic surveys used for quality control; and ½" to 3" gradation crushed limestone that would be used for 9" of settlement at 6" minimum above bay bottom.

The design features were provided by SWF Planning and & Environmental Branch. Quantities were developed by SWG. Yearly monitoring and report of the overall condition of plantings and the marsh will be done every ten (10) years after construction for the duration of the project life and captured within operations and maintenance considerations

**ACCOUNT CODE 10 – BREAKWATER AND SEAWALL:** This code is found in the Galveston Ring Barrier System (GRBS) feature**.** SWG General Engineering and Structural Sections provided all quantities for the work.

**Breakwater:** It was assumed the contractor would need to dredge an access channel in order to place the riprap, which ultimately creates an offshore breakwater to mitigate the wave impacts along the residential area and industrial area of Galveston Island.

**Seawall:** The proposed Seawall raising is an extension of the north sheet-pile cutoff wall located at the north edge of the north sidewalk. This extension is an approximate 3' vertical wall that would have openings for vehicle and pedestrian access. The extension would go from Ferry Road to the west tie-in of the GRBS with a road raising at 89th Street to allow for continued access to the west end of the Island.

**ACCOUNT CODE 11 – LEVEES and FLOODWALLS**. SWG General Engineering and Structural Sections provided all quantities for the work.

**Levees:** It was assumed that material for construction of the earthen levees would be provided from commercial borrow pits. Quotes for delivery to the jobsite were obtained for each of the geographic locations. The Bolivar levee would have a 30-mile haul. An assumed 20% swell factor was used for hauling. Other miscellaneous items include clearing, grubbing, and stripping the area, as well as hydro seeding with mulch and fertilizer. The levee will consist of a 1V:3H slope on the protected side and a 1V:6H slope on the unprotected side. The unprotected side of the levee will be armored with stone protection and the reminder of the levee will be turfed.

**Floodwalls:** Work for this feature is found in Galveston Ring Barrier and Clear Creek features. It was assumed that backfill for construction of the floodwall would be provided from commercial borrow pits 20 miles away. The material would require moisture control and the majority of this processing would be done at the borrow site area prior to bringing to the levee. A dozer and tractor would process/perform moisture control work. Trucks will haul the material to the construction area. Dozers and rollers will be used to spread and compact.

Backfill - Spread and Compact Fill Material Assumption: backfill, additional 4'., over wall heel and toe, levee -spread and compact, levee fill material, 95% compaction standard, 12" lift. In this folder it also, includes the following items:: Sheet Pile Cutoff using PZ-22 steel sheet piles, 22'; Structure Concrete Piles: using 16" square prestressed concrete piles (PCP), 64' long, with 3 piles every 5'; and concrete. The concrete folder includes reinforced slabs, reinforced walls, and stabilization slab (4"). Other miscellaneous items included clearing, grubbing, and stripping the area, as well as hydro seeding with mulch and fertilizer and scour protection of 6" reinforced concrete slab (3,000 psi).

**ACCOUNT CODE 12 – NAVIGATION PORTS and HARBORS**: SWG Engineering Branch provided all quantities and soil characteristics for this work. Included are costs for dredging new work material. Also included under this account code is the cost of Navigation Aids that the Coast

Guard will need for the new alignment. This code of account is found in Bolivar Road Crossing and Galveston Ring Barrier.

At Bolivar Road Crossing 14.8 MCY of new work material will be dredged. Most of this material is associated with access channel, gate foundation/sill, and new channel. The majority of the dredging (14.4 MCY) will be done by hopper dredge. In addition, Anchorage Basins A and D will require 12 MCY to be dredged. Approximately 6 MCY of Anchorage Basin D will be hydraulically dredged, pumped into scow barges, and transported to specify location for Measure G-28. Only the dredging of this material will be included as a CSRM cost. The remaining 6 MCY of Anchorage Basin D will be dredged using one large-sized hopper dredge with disposal in the ODMDS 1 placement area. All turtle protection features (trawlers, endangered species observers, and monitoring surveys) for hopper dredging of Anchorage Basin D is included in this account code.

Galveston Ring Barrier includes costs for pipeline dredging of access channel for the break water and Offatts and Crash Basin access channels. Dredging costs were based on CEDEP estimates.

Also included under this account code is the cost of 12 fixed mooring systems at Anchorage Basin D.

**ACCOUNT CODE 13 – PUMP STATIONS**: Costs are found in Galveston Ring Barrier, Dickinson Bayou, and Clear Creek. Costs for Galveston Island and Dickinson Bayou pumps were developed by Mott MacDonald (A-E) and quality assured by the Government. The pump design for Clear Creek was developed by the Structural Section in Galveston District. In addition, dredging an access channel is included for the Clear Creek and Dickinson Bayou.

**ACCOUNT CODE 15 – FLOODWAY CONTROL-DIVERSION STRUCTURE**: These costs are found in Bolivar Road Crossing, Galveston Ring Barrier, Clear Creek and Dickenson Bayou. The cost for the Dickenson Bayou, and the Offatts Bayou Vertical Lift Gates were developed by Mott MacDonald and quality assured by the Government. Cost for Clear Creek, the remaining gates and combi-wall at Offatts Bayou, and the Bolivar Road Gates were based on designs from New Orleans District: Structural Engineering Section. This is the most complex feature to design and build. Much of the construction will be done from the water and will require cofferdams, temporary channels for ship traffic, specialized equipment, and shipment of fabricated item. (Ref: Engineering Appendix: Construction Schedule).

Cost were derived from similar work by the New Orleans District with the dimensions and quantities adjusted to align with the width and size prescribed for this study. Different structures found in this code of accounts are the following: combi-walls; shallow water environmental gate;

vertical lift gates at minus 20' sill elevation; vertical lift gate at minus 40'sill elevation; 125' sector gate with sill at minus 40'; and a 650' opening floating sector gate.

In addition, the cost includes a central control/visitor center on the Galveston side of the barrier. The 5,000 square foot building would be located on Government owned lands and would be accessible via the construction of a 0.32-mile all-weather concrete road. To assure redundancy in the operation of the gates, a 3,500 square foot auxiliary operations center would be located on the Bolivar side.

**ACCOUNT CODE 17 – BEACH REPLACEMENT**: This code of account is found in the Bolivar Island and West Galveston Island features.

**Beach and Dune placement:** Costs in this account code include all labor and equipment to construct beach and dune features using beach quality sand obtained from the Sabine and Heald Bank offshore sand source. This source is approximately 40 miles offshore with a water depth of 40-50'and will be used for both initial construction operations and renourishment activities. Dredging is assumed to be performed by one large-sized hopper dredge and one medium-sized hopper dredge with hookup to barge-mounted booster pump and pumped to shoreline. As material is pumped, a combination of track dozers and excavators on beach will move pipe and shape material into required construction template. All turtle protection features (trawlers, endangered species observers, and monitoring surveys) for all hopper dredging is included in this account code. Quantities were provided by SWG H&H Branch.

**Beach Ancillary Measures.** The cost was subdivided by Coastal Barrier Resources Act (CBRA) and Non-CBRA Zones. Included in the cost are the following: dune vegetation, sand fencing, dune walkovers (pedestrian walkovers), ramps, and drainage structures (these quantities were provided by SWG H&H Branch). A further description of these features may be found in the Appendix D, Section 5.0 Civil Design.

**ACCOUNT CODE 18 -- CULTURAL RESOURCES PRESERVATION:** Cost for this account code was developed by the archeologist in SWF, Environmental Section, Planning and Environmental Branch it includes cost for the following: survey, mitigation, and National Register of Historic Places.

**ACCOUNT CODE 19 – BUILDINGS, GROUNDS & UTILITIES**: This code of account is found in the West Galveston Bay Non-Structural features. It is the cost associated with raising certain structures situated East of Highway 146 from San Leon, North to Morgan's Point. Quantities and type of structure were provided by the economist.

**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. Costs are based on historical workload patterns and internal charges for SWG.

**ACCOUNT CODE 31 -- CONSTRUCTION MANAGEMENT:** Costs for this account code were developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager. Costs are based on historical workload patterns and internal charges for SWG.

**NER FEATURES**

**ACCOUNT CODE 01 -- LANDS AND DAMAGES:** The Galveston District Real Estate Division developed costs for Lands and Damages.

**ACCOUNT CODE 06 – FISH AND WILDLIFE FACILITIES:** Costs in this account code include all labor, equipment, and material costs associated with the construction, delivery, and installation of reef balls revetment for Measures G-28, B-12, CA-5, M-8, and SP-1.

**ACCOUNT CODE 10 – BREAKWATERS AND SEAWALLS:** Costs in this account code include all labor, equipment, and material costs to procure and install blanket stone, rip-rap, and geotextile base fabric, as well as mining of the GIWW using a pipeline dredge for creation of earthwork breakwater foundation. All earthwork (dredging, transporting, placing, shaping, and compacting) for breakwater foundation assumed to be completed by sub-contractor. Design of breakwater assumes inclusion of type class-C riprap with a gradation of 50 – 1000 LBS and median size of 250 LBS. Cost estimate assumes delivery of riprap and blanket stone from a rock quarry in Missouri with transportation by barge. Breakwater construction is included in Measures G-28, B-12, CA-5, CA-6, M-8, SP-1, and W-3.

**ACCOUNT CODE 11 – LEVEES AND FLOODWALLS:** Costs in this account code include all labor, equipment, and material costs for construction of island restoration features for Measures G-28, M-8, and SP-1. For Measure G-28, all required material will be dredged from Anchorage Area D, as mentioned above, with only the transportation and placement of material included as NER costs. Material will be transported via scow barges, excavated using barge-mounted excavators, and shaped into design template by track dozers.

For Measure M-8, material will be excavated via pipeline dredge from PA 8 by breaching the containment levee, moving dredge along inside of PA, and mining available material. Material will then be pumped via pipelines and shaped into design template by track dozers.

For Measure SP-1, assumed one-third of required material will be obtained from beneficial use of shoaling in the Corpus Christi Ship Channel and LaQuinta Channel with the remaining two-thirds obtained from mining the aforementioned ship channels. Dredging of shoaled material to be performed by pipeline dredges and multiple booster pumps with an assumed maximum pumping distance of 10 miles and average pumping of at least 6 miles required. Costs to dredge shoaled material and pump to nearby placement area was removed from total costs as this is an O&M USACE function. Dredging of the remaining two-thirds to be performed by a pipeline dredge and booster pump with an assumed maximum pump distance of 5 miles and average pumping of at least 3 miles. Assuming mined material from the aforementioned channels will largely consist of compacted sands and stiff clays with minimal loose silty-sandy material expected. Material will be hydraulically pumped to island restoration sites and placed and shaped into design template by dozers and excavators on pontoons and from barges as required.

For Measure W-3, material will be hydraulically dredged from the Lower Laguna Madre and pumped a maximum of 5 miles with average of 3.5 miles to specified island restoration site.

Additionally, costs to deliver and place Articulated Concrete Block Mats on slope-shore face are included for each aforementioned measure. Quantities were provided by SWG Engineering Branch.

**ACCOUNT CODE 12 – NAVIGATION PORTS AND HARBORS**: Costs in this account code include all labor, equipment, and material costs for construction of proposed marsh restoration sites by hydraulically dredging and pumping shoaled material from federal navigation channels. The estimated Operation & Maintenance cost to dispose of this dredge material in typical upland disposal areas was subtracted from the total cost to represent the incremental costs to pump material to the marsh cells. Additionally, costs to create containment dikes via barge-mounted clamshell draglines by excavating in-situ was included. For Measures G-28, B-12, and M-8, marsh fill material will be obtained from dredging shoaled GIWW material, while fill for CA-6 will be obtained from dredging shoaled Matagorda Ship Channel material.

**ACCOUNT CODE 17 – BEACH REPLACEMENT**: Costs in this account code include all labor and equipment to construct beach and dune features using beach quality sand. For Measure B-2, Follets Island, sand will be obtained from the Sabine and Heald Bank off-shore sand source, approximately 40 miles offshore with a water depth of 40-50 feet, using one large-sized hopper dredge. As material is pumped, a combination of track dozers and excavators on beach will move pipe and shape material into required construction template. All turtle protection features (trawlers, endangered species observers, and monitoring surveys) for all hopper dredging is included in this account code.

For Measure W-3, Mansfield Island, sand will be obtained from the Lower Laguna Madre via one 24” pipeline dredge and pumped to beach using a minimally-shaped swash zone placement.

**ACCOUNT CODE 18 -- CULTURAL RESOURCES PRESERVATION:** Cost for this account code was developed by the archeologist in SWF, Environmental Section, Planning and Environmental Branch.

**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. Costs are based on historical workload patterns and internal charges for SWG.

**ACCOUNT CODE 31 -- CONSTRUCTION MANAGEMENT:** Costs for this account code were developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager. Costs are based on historical workload patterns and internal charges for SWG.

**Operation and Maintenance, Repair, Rehabilitation and Replacement**

The purpose of operation and maintenance, repair, rehabilitation, and replacement (OMRR&R) is to sustain the constructed project. O&M cost estimates are for a 50-year period. The estimate was prepared with an effective pricing date of October 2020.

Coastal Texas, Texas

NOTE: The costs for work breakdown Accounts 01, 30, and 31 were developed and found in the TPCS only to prevent errors. The escalation percentage is developed from the construction schedule and included in the TPCS. Contingences were developed in the Risk Analysis and were included in the TPCS. Due to the breakout of Federal and Non-Federal Sponsor costs rounding errors do occur, but they tally correctly.

| | |
|---|---|
| Estimated by | CESWG-EC-PS |
| Designed by | CESWG-E |
| Prepared by | Jackie Lockhart/ Adam Tallman |
| Preparation Date | 3/31/2021 |
| Effective Date of Pricing | 3/31/2021 |
| Estimated Construction Time | 5,475 Days |

**Description** **Page**

| Description | Quantity | UOM | ProjectCost |
|---|---|---|---|
| **Project Cost Summary Report** | | | **16,672,433,902** |
| **01 Upper Texas Coast** | **1.00** | **LS** | **15,098,348,154** |
| **01 Bolivar Island Ancillary Measures** | **1.00** | **JOB** | **1,209,526,345** |
| **01 01 CBRA Zones** | **1.00** | **JOB** | **10,917,084** |
| **0101-01 Non-Fed** | **1.00** | **JOB** | **426,113** |
| **0101-02 Fed** | **1.00** | **JOB** | **10,490,971** |
| **01 05 Non-CBRA Zone** | **1.00** | **EA** | **1,198,609,261** |
| **0105-01 Non-Fed** | **1.00** | **JOB** | **1,276,989** |
| **0105-02 Fed** | **1.00** | **JOB** | **1,197,332,272** |
| **05 Bolivar Roads Gate System:** | **1.00** | **JOB** | **9,392,242,231** |
| **05 01 Non-Fed** | **1.00** | **JOB** | **616,955** |
| **0101-02 Relocations** | **1.00** | **JOB** | **616,955** |
| **05 02 Federal** | **1.00** | **JOB** | **9,391,625,276** |
| **0502-11 Levees and Floodwalls** | **1.00** | **JOB** | **48,550,289** |
| **0502-12 Navigation Ports & Harbors** | **1.00** | **JOB** | **170,290,645** |
| **0502-15 Floodway Control-Diversion Struc** | **1.00** | **JOB** | **9,171,982,780** |
| **0502-18 Cultural Resource Preservation** | **1.00** | **EA** | **801,562** |
| **10 Galveston Ring Barrier System** | **1.00** | **JOB** | **1,926,439,012** |
| **1001 Non-Fed** | **1.00** | **JOB** | **13,757,937** |
| **1001-02 Relocations** | **1.00** | **JOB** | **13,757,937** |
| **1002 Fed** | **1.00** | **JOB** | **1,912,681,076** |
| **1002-06 Induced Damages Mitigation** | **1.00** | **JOB** | **1,745,418** |
| **1002-10 Breakwaters and Seawalls** | **1.00** | **JOB** | **60,086,034** |
| **1002-11 Levees and Floodwalls** | **1.00** | **JOB** | **552,827,505** |
| **1002-12 Navigation Ports & Harbors** | **1.00** | **JOB** | **266,838** |
| **1002-13 Pumping Plant** | **1.00** | **JOB** | **411,724,480** |

Labor ID: NLS2016 EQ ID: EP18R06 Currency in US dollars TRACES MII Version 4.4

| Description | Quantity | UOM | ProjectCost |
|---|---|---|---|
| 1002-15 Floodway Control-Diversion Struc | 1.00 | JOB | 883,668,300 |
| 1002-18 Cultural Resource Preservation | 1.00 | JOB | 2,362,500 |
| 15 West Galveston Ancillary Measures | 1.00 | JOB | 853,323,949 |
| 15 01 CBRA WG TX-05P | 1.00 | JOB | 1,291,904 |
| 1501-01 Non-Fed | 1.00 | JOB | 123,430 |
| 1501-02 Fed | 1.00 | JOB | 1,168,474 |
| 15 05 Non-CBRA Zone | 1.00 | JOB | 852,032,045 |
| 1505-01 Non-Fed | 1.00 | JOB | 6,830,359 |
| 1505-02 Fed | 1.00 | JOB | 845,201,686 |
| 20 Clear Lake Gate System Pump Station | 1.00 | JOB | 913,654,128 |
| 20 01 Non-Federal Costs | 1.00 | JOB | 33,867,819 |
| 20 01 02 Relocations | 1.00 | JOB | 33,867,819 |
| 20 02 Federal Costs | 1.00 | JOB | 879,786,309 |
| 20 02 11 Levees and Floodwalls | 1.00 | JOB | 96,346,492 |
| 20 02 13 Pumping Plant | 1.00 | JOB | 550,201,990 |
| 20 02 15 Floodway Control - Diversion Structure | 1.00 | JOB | 232,623,576 |
| 20 02 18 Cultural Resource Preservation | 1.00 | JOB | 614,250 |
| 25 Dickenson Bay Gate System Pump Station | 1.00 | JOB | 520,340,499 |
| 25 01 Non-Federal Costs | 1.00 | JOB | 6,308,794 |
| 25 01 02 Relocations | 1.00 | JOB | 6,308,794 |
| 25 02 Federal Costs | 1.00 | JOB | 514,031,706 |
| 25 02 11 Levees and Floodwalls | 1.00 | JOB | 44,295,948 |
| 25 02 13 Pumping Plant | 1.00 | JOB | 433,840,026 |
| 25 02 15 Floodway Control - Diversion Structure | 1.00 | JOB | 35,281,482 |
| 25 02 18 Cultural Resource Preservation | 1.00 | EA | 614,250 |
| 30 Mitigation - CSRM | 1.00 | JOB | 60,825,073 |

Labor ID: NLS2016 EQ ID: EP18R06 Currency in US dollars TRACES MII Version 4.4

| Description | Quantity | UOM | ProjectCost |
|---|---|---|---|
| 30 02 Federal Costs | 1.00 | JOB | 60,825,073 |
| 3002 06 Fish and Wildlife Facilities | 1.00 | JOB | 60,825,073 |
| 35 Non-Structural Improvements - West Shore of Galveston Bay | 1.00 | JOB | 221,996,916 |
| 35 02 Federal Costs | 1.00 | JOB | 221,996,916 |
| 35 02 19 Buildings, Grounds, & Utilities | 1.00 | JOB | 221,551,666 |
| 35 02 18 Cultural Resource Preservation | 1.00 | JOB | 445,250 |
| Lower Texas Coast | 1.00 | EA | 40,211,692 |
| CSRM SPI | 1.00 | EA | 40,211,692 |
| Federal | 1.00 | EA | 40,211,692 |
| 17 Beach Replenishment | 1.00 | EA | 40,079,661 |
| 18 Cultural Resources | 1.00 | EA | 132,031 |
| NER Features | 1.00 | EA | 1,533,874,056 |
| G-28 | 1.00 | EA | 523,434,670 |
| Federal | 1.00 | EA | 523,434,670 |
| 06 Fish and Wildlife Facilities | 1.00 | EA | 5,844,869 |
| 10 Breakwaters and Seawalls | 1.00 | EA | 432,216,959 |
| 11 Levees and Floodwalls | 1.00 | EA | 74,040,883 |
| 12 Navigation, Ports, & Harbors | 1.00 | EA | 10,821,959 |
| 18 Cultural Resources | 1.00 | EA | 510,000 |
| B-2 | 1.00 | EA | 28,440,355 |
| Federal | 1.00 | EA | 28,440,355 |
| 17 Beach Replenishment | 1.00 | EA | 28,086,999 |
| 18 Cultural Resources | 1.00 | EA | 353,356 |
| B-12 | 1.00 | EA | 474,709,191 |
| Federal | 1.00 | EA | 474,709,191 |
| 06 Fish and Wildlife Facilities | 1.00 | EA | 1,254,139 |

Labor ID: NLS2016 EQ ID: EP18R06 Currency in US dollars TRACES MII Version 4.4

| Description | Quantity | UOM | ProjectCost |
|---|---|---|---|
| 10 Breakwaters and Seawalls | 1.00 | EA | 462,273,352 |
| 12 Navigation, Ports, & Harbors | 1.00 | EA | 10,897,169 |
| 18 Cultural Resources | 1.00 | EA | 284,531 |
| CA-5 | 1.00 | EA | 45,654,731 |
| Federal | 1.00 | EA | 45,654,731 |
| 06 Fish and Wildlife Facilities | 1.00 | EA | 2,983,900 |
| 10 Breakwaters and Seawalls | 1.00 | EA | 42,665,519 |
| 18 Cultural Resources | 1.00 | EA | 5,313 |
| CA-6 | 1.00 | EA | 59,113,900 |
| Federal | 1.00 | EA | 59,113,900 |
| 10 Breakwaters and Seawalls | 1.00 | EA | 55,384,960 |
| 12 Navigation, Ports, & Harbors | 1.00 | EA | 3,727,453 |
| 18 Cultural Resources | 1.00 | EA | 1,488 |
| M-8 | 1.00 | EA | 167,334,640 |
| Federal | 1.00 | EA | 167,334,640 |
| 06 Fish and Wildlife Facilities | 1.00 | EA | 4,472,654 |
| 10 Breakwaters and Seawalls | 1.00 | EA | 136,918,276 |
| 11 Levees and Floodwalls | 1.00 | EA | 21,778,147 |
| 12 Navigation, Ports, & Harbors | 1.00 | EA | 3,995,251 |
| 18 Cultural Resources | 1.00 | EA | 170,313 |
| SP-1 | 1.00 | EA | 203,480,239 |
| Federal | 1.00 | EA | 203,480,239 |
| 10 Breakwaters and Seawalls | 1.00 | EA | 81,687,606 |
| 11 Levees and Floodwalls | 1.00 | EA | 121,758,102 |
| 18 Cultural Resources | 1.00 | EA | 34,531 |
| W-3 | 1.00 | EA | 31,706,330 |

Labor ID: NLS2016 EQ ID: EP18R06 Currency in US dollars TRACES MII Version 4.4

| Description | Quantity | UOM | ProjectCost |
|---|---|---|---|
| **Federal** | **1.00** | **EA** | **31,706,330** |
| **10 Breakwaters and Seawalls** | **1.00** | **EA** | **8,019,856** |
| **11 Levees and Floodwalls** | **1.00** | **EA** | **8,654,616** |
| **17 Beach Replenishment** | **1.00** | **EA** | **14,778,983** |
| **18 Cultural Resources** | **1.00** | **EA** | **252,875** |

Labor ID: NLS2016 EQ ID: EP18R06 Currency in US dollars TRACES MII Version 4.4

US Army Corps
of Engineers®

# Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study)

# Project Cost and Schedule Risk Analysis Report

*Prepared for:*

U.S. Army Corps of Engineers,
Galveston District

*Prepared by:*

U.S. Army Corps of Engineers
Cost Engineering Technical Center of Expertise, Walla Walla, WA

March 26, 2021

## TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES



## LIST OF APPENDICES

# EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE), Galveston District, presents this cost and schedule risk analysis (CSRA) report regarding the risk findings and recommended contingencies for the Coastal Texas Protection and Restoration Feasibility Study. In compliance with Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008, a *Monte-Carlo* based risk analysis was conducted by the Project Development Team (PDT) on remaining costs. The purpose of this risk analysis study is to present the cost and schedule risks considered, those determined and respective project contingencies at a recommended 80% confidence level of successful execution to project completion.

The Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) which was initiated in 2014 to evaluate large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternatives aimed at providing the coastal communities of Texas with multiple lines of defense from a wide array of coastal hazards.

The study area includes the entire Texas coastline extending from the mouth of the Sabine River at the Texas/Louisiana border to the mouth of the Rio Grande near Brownsville, Texas. This includes all 18 of Texas coastal counties. The study area was subdivided into 3 areas: the Upper Texas Coast, the Lower Texas Coast, and a coast-wide ER Plan.

All CSRM features are found in in the Upper Texas Coast, except for one located in South Padre Island (SPI) which is located in Lower Texas Coast.

The Recommended Plan was formulated as a system and includes several features that provide risk reduction through a line of engineered features along the gulf, other features to provide resiliency along the bay and future adaptations to sea level change. The plan features are described below.

- Bolivar Roads Gates System between Bolivar Peninsula and Galveston Island is the largest feature of the Coastal Barrier system. It includes surge barrier gates that are made up of navigable floating sector gates and environmental lift gates and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap.

- The Galveston Ring Barrier System (GRBS) feature is a system of floodwalls, gates, pump stations, levees which connect to existing levee and seawall. In addition, there are combi-wall, environmental lift gates and vertical lift gates at Offatts Bayou. Seawall Elevation is a future adaptation to provide for a continuous barrier for storm surge reduction along the gulf coast.

- Bolivar and West Galveston Beach and Dune System and Renourishment are a critical component of the comprehensive plan for coastal storm risk reduction along the Texas Coast, and they tie into the storm surge gate and ensure its function over time.

- Clear Lake and Dickinson Gate Systems and Pump Stations on the mainland reduce residual risk from bay flooding.

- SPI Beach Nourishment and Sediment Management.

- Ecosystem Restoration measures are proposed at eight (8) locations along the coast and include the following: 114 miles of breakwaters, 15.2 miles of bird rookery islands, 2,052 acres of marsh, 12.32 miles of oyster reef, and 19.5 miles of beach and dune.

- Mitigation will be required for 1,577.6 acres of direct and indirect impacts to wetlands and oyster reefs. Over 1,378 acres of habitat will be created or restored in order to offset the direct and indirect impacts of the proposed plan.

The current project base construction cost for the Texas Coastal Study is approximately $16.662 Billion excluding contingency and Real Estate and expressed in FY 2021 dollars. This CSRA study included all estimated construction costs, Planning, Engineering, Design and Construction Management costs. Based on the results of the analysis, the Cost Engineering Mandatory Center of Expertise for Civil Works (MCX located in Walla Walla District) recommends a contingency value of $6.3 Billion or approximately 38% of base project cost at an 80% confidence level of successful execution.

Cost estimates fluctuate over time. During this period of study, minor cost fluctuations can and have occurred. For this reason, contingency reporting is based in cost and per cent values. Should cost vary to a slight degree with similar scope and risks, contingency percent values will be reported, cost values rounded.

**Table ES-1. Construction Contingency Results**

| Base Case Construction Cost Estimate | $16,662,228,000 | | |
|---|---|---|---|
| Confidence Level | Construction Value ($$) w/ Contingencies | Contingency (%) | Contingency $ |
| 50% | $21,994,140,960 | 32% | $5,331,912,960 |
| 80% | $22,993,874,640 | 38% | $6,331,646,640 |
| 90% | $23,660,363,760 | 42% | $6,998,135,760 |

## KEY FINDINGS/OBSERVATIONS/ASSUMPTIONS & RECOMMENDATIONS

The PDT worked through the risk register in June 2020. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $6.3Billion and schedule risks adding a potential 135 months; all at an 80% confidence level.

**Cost Risks**: From the CSRA, the key or greater Cost Risk items of include:

- EX4 – Market Conditions – Bidder competition may be limited. Limited number of construction firms are available to construct or bond many of the larger multi-billion contracts. Local infrastructure/capacity does exist to produce the large sector gates. Pipeline and Hopper dredging contractor competition has been limited in the SWG area and nationally. NER and Beach and Dune Nourishment contracts could require four additional large/medium dredges per year for the next eight years. The sheer volume of work may exceed the local and even regional capacity.
- CV3 – Geotechnical Level of Design – Geotechnical Engineers have much of the original Galveston boring data and are comfortable with the overall level of detail. Geotechnical design evaluated a potential range of design values and usually selected the lower bound (more conservative numbers) in developing designs/quantities. Geotechnical Design refinements will be developed during PED. Geotechnical Engineers overall feel: Dune: Low Level Risk, Ecosystem Restoration: Low Risk, Ring Barrier: Medium Level Risk, Closure Structure and Islands: Medium Level Risk, Pump Station: Medium Level Risk, Clear Lake: Medium Level Risk (historical information from TXDOT), and Dickinson: Medium Level Risk (historical information from TXDOT).
- SD4 – Galveston Bay Closure Structure, Large Sector Gate – Design based on Similar St Petersburg, Russia Gates. This is a highly unique design. Some level of study (~30%) has been completed, but much design development and refinement remains. A design competition (working within the operations constraints and using the existing modeling) will be initiated in an effort to develop the best possible design and select the A/E designer of record. Uncertainty remains. Physical modeling and High end modeling for the gate will be required. Just given the complexity of the design, HIGH Cost risk.

Moderate risks, when combined, can also become a cost impact.

- ES2 – Estimate Development – CSRM Estimates are developed to Class 3 estimates and are based on Sabine to Galveston budgetary estimates. NER features are Class 3 estimates based on recent historical bid data. USACE Cost Engineers judgment estimates are conservative and based on other recent budgetary estimates and recent historical NER information.

- SD5 – Galveston Bay Closure Structures, Vertical Lift Gates – Design based on Similar Hartel Barrier (same widths with largest gate being similar to this projects shallow gate). Smaller gate based on Hartel Barrier larger gate. Deeper gate for this project was scaled up version of Hartel Barrier gate.
- PM10 – Pressure to Deliver on an Accelerated Schedule – Project Study has already experienced outside pressure from public and others to accelerate study and project implementation. Hurricanes Ike and Harvey lead to outcries for immediate results. Many large complicated features cannot be accelerated. Baseline schedule reflects realistic and reasonableness implementation of schedule. There is a very high likelihood schedule is accelerated and USACE would pay a premium for that schedule acceleration. Assume a potential cost increase of 3% to 10% of construction costs for schedule acceleration.

**Schedule Risks**: From the CSRA, the key or greater Schedule Risk items include:

- LD4 – Property Acquisition - Non-Federal sponsors for all areas have not been surveyed. Quick take authority is unknown. Without quick take authority condemnation actions could take significant periods of time. DOJ is heavily engaged with border acquisitions so Federal timelines are equally impacted. GLO has experienced up to 24-month delays for individual property acquisitions in the past.
- EX1 – Public Engagement - Public is strongly polarized for both the project as a whole and even specific features. Overall project and even priority of features all have varying degrees of support. Project has already undergone multiple study updates, FOIAs, and public hearings to address the various groups concerns. Legal action is an almost certainty with likely schedule delays.
- PM8 – Multiple Agency Coordination - This is a large project involving multiple agencies. Project spans 18 counties, engages multiple organizations (including Coast Guard), multiple municipalities and environmental groups. Mitigation versus avoidance will likely determine level of coordination required. Project has experienced schedule delays and given the number of stakeholders continued delay is very likely.
- PM11 – Plan Formulation and Public Sponsors - Many features do not currently have sponsors. Public Sponsors, once identified and engaged, may not have same plan formulation goals. Sabine to Galveston is currently experiencing issues with plan refinements and sponsor identification. Designs are conceptual and refinements to meet sponsor priorities can be accommodated. Ring Barrier and its alignment is the only large refinement that a future sponsor may want to change. There is a high likelihood this risk will be addressed in next Texas legislative session. Texas Legislature meets every two years (2021, 2023, etc.). At this point, schedule risk if sponsors are not identified in a timely manner.

Worst case schedule may be delayed two years waiting for next Texas Legislative Session and sponsor identification.

**Recommendations**: The CSRA study serves as a “road map” towards project improvements and reduced risks over time. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

# MAIN REPORT

## 1.0 PURPOSE

Within the authority of the US Army Corps of Engineers (USACE), Galveston District, this report presents the efforts and results of the cost and schedule risk analysis for the Coastal Texas Protection and Restoration Feasibility Study. The report includes risk methodology, discussions, findings and recommendations regarding the identified risks and the necessary contingencies to confidently administer the project, presenting a cost and schedule contingency value with an 80% confidence level of successful execution.

## 2.0 BACKGROUND

The Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) which was initiated in 2014 to evaluate large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternatives aimed at providing the coastal communities of Texas with multiple lines of defense from a wide array of coastal hazards.

The study area includes the entire Texas coastline extending from the mouth of the Sabine River at the Texas/Louisiana border to the mouth of the Rio Grande near Brownsville, Texas. This includes all 18 of Texas coastal counties. The study area was subdivided into 4 regions: the upper Texas coast, the mid to upper Texas coast, the mid Texas coast, and the lower Texas coast.

All CSRM features are found in in the Upper Texas Coast, except for one located in South Padre Island (SPI) which is located in Lower Texas Coast.

The Recommended Plan was formulated as a system and includes several features that provide risk reduction through a line of engineered features along the Gulf of Mexico, other features to provide resiliency along the bay and future adaptations to sea level change. The plan features are described below.

- Bolivar Roads Gate System between Bolivar Peninsula and Galveston Island is the largest feature of the Coastal Barrier system. It includes surge barrier gates that are made up of navigable floating sector gates, vertical lift gates, and environmental lift gates and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap.

- The Galveston Ring Barrier System (GRBS) feature is a system of floodwalls, gates, pump stations, levees which connect to existing levee and seawall. In addition there are combi-wall, environmental lift gate and vertical lift gates at Offatts Bayou. Seawall Elevation is a future adaptation to provide for a continuous barrier for storm surge reduction along the gulf coast.

- Bolivar and West Galveston Beach and Dune System are a critical component of the comprehensive plan for coastal storm risk reduction along the Texas Coast, and they tie into the storm surge gate and ensure its function over time.

- Clear Lake and Dickinson Bay Gate Systems and Pump Stations on the mainland reduce residual risk from bay flooding.

- SPI Beach Nourishment and Sediment Management includes 2.9 miles of beach nourishment and sediment management, with beach nourishment recurring on a 10-year cycle for the authorized project life of 50 years.

- Ecosystem Restoration measures are proposed at eight (8) locations along the coast and include the following: 114 miles of breakwaters, 15.2 miles of bird rookery islands, 2,052 acres of marsh, 12.32 miles of oyster reef, and 19.5 miles of beach and dune.

- Mitigation will be required for 1,577.6 acres of direct and indirect impacts to wetlands and oyster reefs. Over 1,378 acres of habitat will be created or restored in order to offset the direct and indirect impacts of the proposed plan.

## 3.0 REPORT SCOPE

The scope of the risk analysis report is to identify cost and schedule risks with a resulting recommendation for contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The report presents the contingency results for cost risks for construction features. The CSRA does not include consideration for life cycle costs.

### 3.1 Project Scope

The formal process included extensive involvement of the PDT for risk identification and the development of the risk register. The analysis process evaluated the Micro Computer Aided Cost Estimating System (MCACES) cost estimate, project schedule, and funding profiles using Crystal Ball software to conduct a *Monte Carlo* simulation and statistical sensitivity analysis, per the guidance in Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

The project technical scope, estimates and schedules were developed and presented by the District. Consequently, these documents serve as the basis for the risk analysis.

The scope of this study addresses the identification of concerns, needs, opportunities and potential solutions that are viable from an economic, environmental, and engineering viewpoint.

### 3.2 USACE Risk Analysis Process

The risk analysis process for this study follows the USACE Headquarters requirements as well as the guidance provided by the Cost Engineering MCX. The risk analysis process reflected within this report uses probabilistic cost and schedule risk analysis methods within the framework of the Crystal Ball software. Furthermore, the scope of the report includes the identification and communication of important steps, logic, key assumptions, limitations, and decisions to help ensure that risk analysis results can be appropriately interpreted.

Risk analysis results are also intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as the project progresses through planning and implementation. To fully recognize its benefits, cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, cost estimating, budgeting and scheduling.

In addition to broadly defined risk analysis standards and recommended practices, this risk analysis was performed to meet the requirements and recommendations of the following documents and sources:

- Cost and Schedule Risk Analysis Process guidance prepared by the USACE Cost Engineering MCX.

- Engineer Regulation (ER) 1110-2-1302 CIVIL WORKS COST ENGINEERING, dated September 15, 2008.

- Engineer Technical Letter (ETL) CONSTRUCTION COST ESTIMATING GUIDE FOR CIVIL WORKS, dated September 30, 2008.

## 4.0 METHODOLOGY / PROCESS

The Cost Engineering MCX performed the Cost and Schedule Risk Analysis, relying on local District staff to provide expertise and information gathering. The District PDT conducted initial risk identification via meetings with the Walla Walla Cost Engineering MCX facilitator in June 2020. The initial risk identification meeting also included qualitative analysis to produce a risk register that served as the draft framework for the risk analysis.

Participants in the risk identification meeting in June 22-26, 2020 included:

| Name | Office | Representing |
|---|---|---|
| Himangshu Das | SWG | Lead Engineer |
| Paul Hamilton | SWG | |
| Mike Diaz | SWG | |
| Scott Leimer | SWG | Chief Construction Management Section |
| Jose Nazario-Salas | SWG | Contracting |
| Jackie Lockhart | SWG | Cost Engineer |
| Adam Tallman | SWG | Cost Engineer |
| Kenny Pablo | SWG | Real Estate |
| Kelly Burks-Copes | SWG | Project Manager |
| Travis Creel | MVN | Lead Planner |
| Tony Williams | GLO (Sponsor) | Deputy of Coastal Resources |
| Carla Kartman | GLO (Sponsor) | Project Manager |
| Dianna Ramirez | GLO (Sponsor) | Coastal Biologist |
| Jeff Pinsky | RPEC | Chief, Environmental Compliance Branch |
| Carrie McCabe | RPEC | Planner |

The risk analysis process for this study is intended to determine the probability of various cost outcomes and quantify the required contingency needed in the cost estimate to achieve the desired level of cost confidence. Per regulation and guidance, the P80 confidence level (80% confidence level) is the normal and accepted cost confidence level. District Management has the prerogative to select different confidence levels, pending approval from Headquarters, USACE.

In simple terms, contingency is an amount added to an estimate to allow for items, conditions or events for which the occurrence or impact is uncertain and that experience suggests will likely result in additional costs being incurred or additional time being required. The amount of contingency included in project control plans depends, at least in part, on the project leadership's willingness to accept risk of project overruns. The less risk that project leadership is willing to accept the more contingency should be applied in the project control plans. The risk of overrun is expressed, in a probabilistic context, using confidence levels.

The Cost MCX guidance for cost and schedule risk analysis generally focuses on the 80-percent level of confidence (P80) for cost contingency calculation. It should be noted that use of P80 as a decision criteria is a risk averse approach (whereas the use of P50 would be a risk neutral approach, and use of levels less than 50 percent would be risk seeking). Thus, a P80 confidence level results in greater contingency as compared to a P50 confidence level. The selection of contingency at a particular confidence level is ultimately the decision and responsibility of the project's District and/or Division management.

The risk analysis process uses *Monte Carlo* techniques to determine probabilities and contingency. The *Monte Carlo* techniques are facilitated computationally by a commercially available risk analysis software package (Crystal Ball) that is an add-in to Microsoft Excel. Cost estimates are packaged into an Excel format and used directly for cost risk analysis purposes. The level of detail recreated in the Excel-format schedule is sufficient for risk analysis purposes that reflect the established risk register, but generally less than that of the native format.

The primary steps, in functional terms, of the risk analysis process are described in the following subsections. Risk analysis results are provided in Section 6.

### 4.1 Identify and Assess Risk Factors

Identifying the risk factors via the PDT is considered a qualitative process that results in establishing a risk register that serves as the document for the quantitative study using the Crystal Ball risk software. Risk factors are events and conditions that may influence or drive uncertainty in project performance. They may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risk factors may have either favorable or unfavorable impacts on project cost and schedule.

A formal PDT meeting was held with the District office and project owners for the purposes of identifying and assessing risk factors. The meeting included capable and qualified representatives from multiple project team disciplines and functions, including project management, cost engineering, design, environmental compliance, real estate, construction, contracting and representatives of the sponsoring agencies.

The initial formal meetings focused primarily on risk factor identification using brainstorming techniques, but also included some facilitated discussions based on risk factors common to projects of similar scope and geographic location. Additionally, numerous conference calls and informal meetings were conducted throughout the risk analysis process on an as-needed basis to further facilitate risk factor identification, market analysis, and risk assessment.

### 4.2 Quantify Risk Factor Impacts

The quantitative impacts (putting it to numbers of cost and time) of risk factors on project plans were analyzed using a combination of professional judgment, empirical data and analytical techniques. Risk factor impacts were quantified using probability distributions (density functions) because risk factors are entered into the Crystal Ball software in the form of probability density functions.

Similar to the identification and assessment process, risk factor quantification involved multiple project team disciplines and functions. However, the quantification process relied more extensively on collaboration between cost engineering and risk analysis team members with lesser inputs from other functions and disciplines. This process used an iterative approach to estimate the following elements of each risk factor:

- Maximum possible value for the risk factor
- Minimum possible value for the risk factor
- Most likely value (the statistical mode), if applicable
- Nature of the probability density function used to approximate risk factor uncertainty
- Mathematical correlations between risk factors
- Affected cost estimate and schedule elements

The resulting product from the PDT discussions is captured within a risk register as presented in section 6 for both cost and schedule risk concerns. Note that the risk register records the PDT's risk concerns, discussions related to those concerns, and potential impacts to the current cost and schedule estimates. The concerns and discussions support the team's decisions related to event likelihood, impact, and the resulting risk levels for each risk event.

### 4.3 Analyze Cost Estimate and Schedule Contingency

Contingency is analyzed using the Crystal Ball software, an add-in to the Microsoft Excel format of the cost estimate and schedule. *Monte Carlo* simulations are performed by applying the risk factors (quantified as probability density functions) to the appropriate estimated cost and schedule elements identified by the PDT. Contingencies are calculated by applying only the moderate and high level risks identified for each option (i.e., low-level risks are typically not considered, but remain within the risk register to serve historical purposes as well as support follow-on risk studies as the project and risks evolve).

For the cost estimate, the contingency is calculated as the difference between the P80 cost forecast and the baseline cost estimate. Each option-specific contingency is then allocated on a civil works feature level based on the dollar-weighted relative risk of each feature as quantified by *Monte Carlo* simulation. Standard deviation is used as the feature-specific measure of risk for contingency allocation purposes. This approach results in a relatively larger portion of all the project feature cost contingency being allocated to features with relatively higher estimated cost uncertainty.

## 5.0 PROJECT ASSUMPTIONS

The following data sources and assumptions were used in quantifying the costs associated with the project.

a. The District provided estimate files electronically. The files transmitted and resulting independent review, served as the basis for the final cost and schedule risk analyses.

b. The cost comparisons and risk analyses performed and reflected within this report are based on design scope and estimates that are at the feasibility level of design.

c. Schedules are analyzed for impact to the project cost in terms of delayed funding, uncaptured escalation (variance from OMB factors and the local market) and unavoidable fixed contract costs and/or languishing federal administration costs incurred throughout delay.

d. The Cost Engineering MCX guidance generally focuses on the eighty-percent level of confidence (P80) for cost contingency calculation. For this risk analysis, the eighty-percent level of confidence (P80) was used. It should be noted that the use of P80 as a decision criteria is a moderately risk averse approach, generally resulting in higher cost contingencies. However, the P80 level of confidence also assumes a small degree of risk that the recommended contingencies may be inadequate to capture actual project costs.

e. Only high and moderate risk level impacts, as identified in the risk register, were considered for the purposes of calculating cost contingency. Low level risk impacts should be maintained in project management documentation, and reviewed at each project milestone to determine if they should be placed on the risk “watch list”.

## 6.0 RESULTS

The cost and schedule risk analysis results are provided in the following sections. In addition to contingency calculation results, sensitivity analyses are presented to provide decision makers with an understanding of variability and the key contributors to the cause of this variability.

### 6.1 Risk Register

A risk register is a tool commonly used in project planning and risk analysis. The actual risk register is provided in Appendix A. The complete risk register includes low level risks, as well as additional information regarding the nature and impacts of each risk.

It is important to note that a risk register can be an effective tool for managing identified risks throughout the project life cycle. As such, it is generally recommended that risk registers be updated as the designs, cost estimates, and schedule are further refined,

especially on large projects with extended schedules. Recommended uses of the risk register going forward include:

- Documenting risk mitigation strategies being pursued in response to the identified risks and their assessment in terms of probability and impact.
- Providing project sponsors, stakeholders, and leadership/management with a documented framework from which risk status can be reported in the context of project controls.
- Communicating risk management issues.
- Providing a mechanism for eliciting feedback and project control input.
- Identifying risk transfer, elimination, or mitigation actions required for implementation of risk management plans.

### 6.2 Cost Contingency and Sensitivity Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results, as applied to the analysis herein, depict the overall project cost at intervals of confidence (probability).

Table 1 provides the construction cost contingencies calculated for the P80 confidence level and rounded to the nearest thousand. The construction cost contingencies for the P5, P50 and P90 confidence levels are also provided for illustrative purposes only.

**Table 1. Construction Cost Contingency Summary**

| Base Case Construction Cost Estimate | $15,662,228,000 | | |
|---|---|---|---|
| Confidence Level | Construction Value ($$) w/ Contingencies | Contingency (%) | Contingency $ |
| 50% | $21,994,140,960 | 32% | $5,331,912,960 |
| 80% | $22,993,874,640 | 38% | $6,331,646,640 |
| 90% | $23,660,363,760 | 42% | $6,998,135,760 |

#### 6.2.1 Sensitivity Analysis

Sensitivity analysis generally ranks the relative impact of each risk/opportunity as a percentage of total cost uncertainty. The Crystal Ball software uses a statistical measure (contribution to variance) that approximates the impact of each risk/opportunity contributing to variability of cost outcomes during *Monte Carlo* simulation.

Key cost drivers identified in the sensitivity analysis can be used to support development of a risk management plan that will facilitate control of risk factors and their potential impacts throughout the project lifecycle. Together with the risk register,

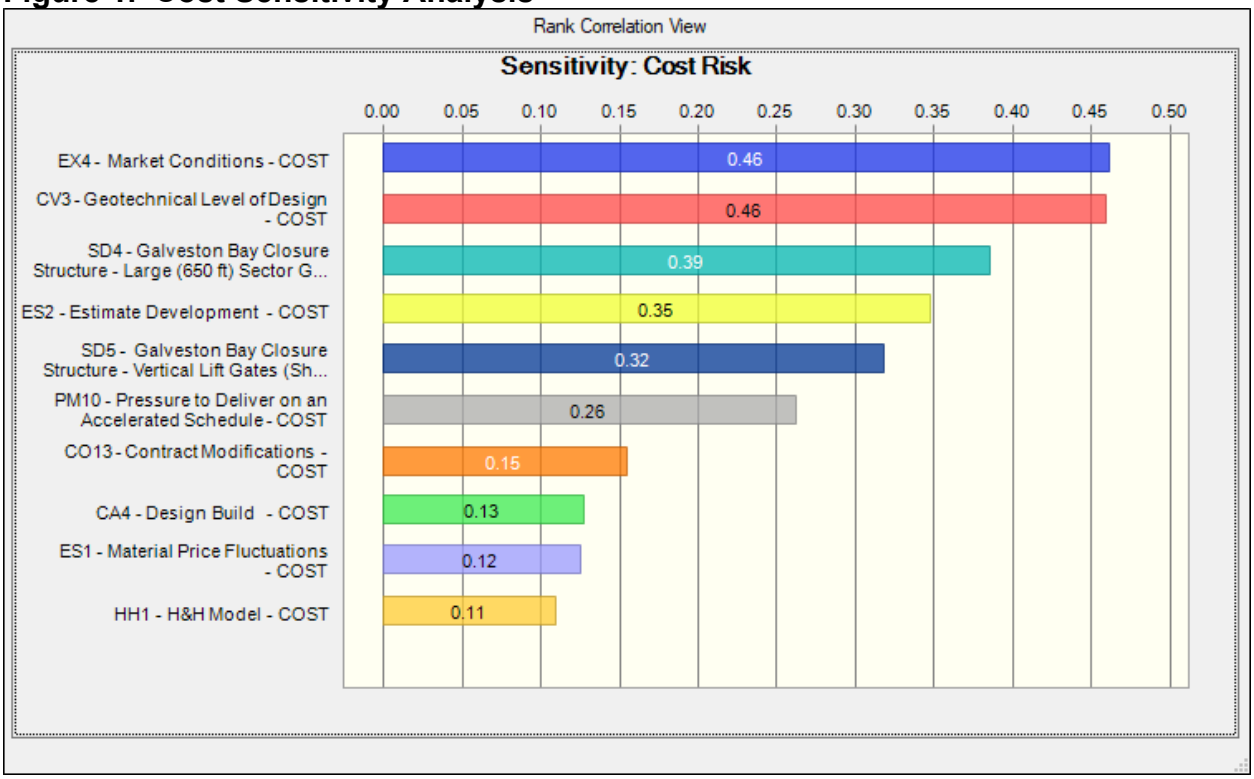
sensitivity analysis results can also be used to support development of strategies to eliminate, mitigate, accept or transfer key risks.

### 6.2.2 Sensitivity Analysis Results

The risks/opportunities considered as key or primary cost drivers and the respective value variance are ranked in order of importance in contribution to variance bar charts. Opportunities that have a potential to reduce project cost and are shown with a negative sign; risks are shown with a positive sign to reflect the potential to increase project cost. A longer bar in the sensitivity analysis chart represents a greater potential impact to project cost.

Figure 1 presents a sensitivity analysis for cost growth risk from the high level cost risks identified in the risk register. Likewise, Figure 2 presents a sensitivity analysis for schedule growth risk from the high level schedule risks identified in the risk register.

**Figure 1. Cost Sensitivity Analysis**




### 6.3 Schedule and Contingency Risk Analysis

The result of risk or uncertainty analysis is quantification of the cumulative impact of all analyzed risks or uncertainties as compared to probability of occurrence. These results,

as applied to the analysis herein, depict the overall project duration at intervals of confidence (probability).

Table 2 provides the schedule duration contingencies calculated for the P80 confidence level. The schedule duration contingencies for the P50 and P90 confidence levels are also provided for illustrative purposes.

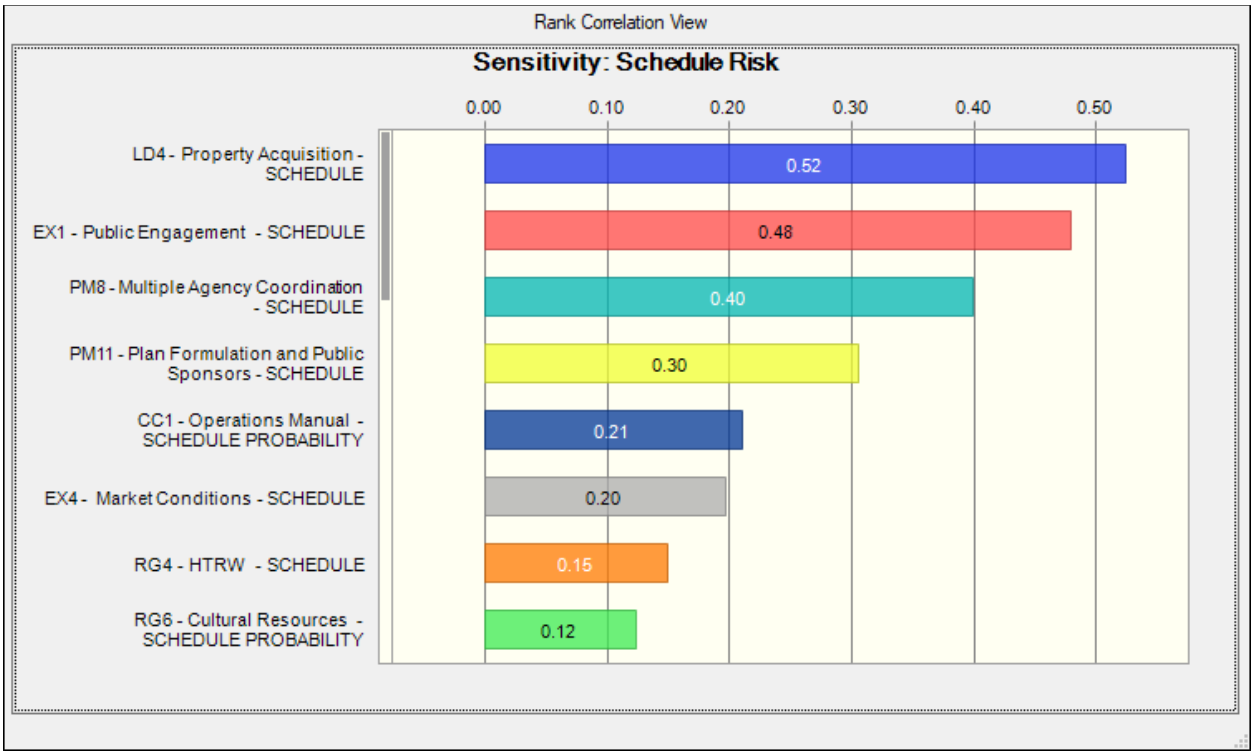
These contingencies were used to calculate the projected residual fixed cost impact of project delays that are included in the Table 1 presentation of total cost contingency. The schedule contingencies were calculated by applying the high level schedule risks identified in the risk register for each option to the durations of critical path and near critical path tasks.

The schedule was not resource loaded and contained open-ended tasks and non-zero lags (gaps in the logic between tasks) that limit the overall utility of the schedule risk analysis. These issues should be considered as limitations in the utility of the schedule contingency data presented. Schedule contingency impacts presented in this analysis are based solely on projected residual fixed costs.

**Table 2. Schedule Duration Contingency Summary**

| Risk Analysis Forecast (base schedule of 264 months) | Duration w/ Contingencies (months) | Contingency (months) |
|---|---|---|
| 50% Confidence | 386 | 122 |
| 80% Confidence | 399 | 135 |
| 90% Confidence | 407 | 143 |

**Figure 2. Schedule Sensitivity Analysis**




## 7.0 MAJOR FINDINGS/OBSERVATIONS/RECOMMENDATIONS

This section provides a summary of significant risk analysis results that are identified in the preceding sections of the report. Risk analysis results are intended to provide project leadership with contingency information for scheduling, budgeting, and project control purposes, as well as to provide tools to support decision making and risk management as projects progress through planning and implementation. Because of the potential for use of risk analysis results for such diverse purposes, this section also reiterates and highlights important steps, logic, key assumptions, limitations, and decisions to help ensure that the risk analysis results are appropriately interpreted.

### 7.1 Major Findings/Observations

Project cost and schedule comparison summaries are provided in Table 3 and Table 4 respectively. Additional major findings and observations of the risk analysis are listed below.

The PDT worked through the risk register in June 2020. The key risk drivers identified through sensitivity analysis suggest a cost contingency of $6.3 Billion and schedule risks adding a potential 135 months; all at an 80% confidence level.

**Cost Risks**: From the CSRA, the key or greater Cost Risk items of include:

- EX4 – Market Conditions – Bidder competition may be limited. Limited number of construction firms are available to construct or bond many of the larger multi-billion contracts. Local infrastructure/capacity does exist to produce the large sector gates. Pipeline and Hopper dredging contractor competition has been limited in the SWG area and nationally. NER and Beach and Dune Nourishment contracts could require four additional large/medium dredges per year for the next eight years. The sheer volume of work may exceed the local and even regional capacity.
- CV3 – Geotechnical Level of Design – Geotechnical Engineers have much of the original Galveston boring data and are comfortable with the overall level of detail. Geotechnical design evaluated a potential range of design values and usually selected the lower bound (more conservative numbers) in developing designs/quantities. Geotechnical Design refinements will be developed during PED. Geotechnical Engineers overall feel: Dune: Low Level Risk, Ecosystem Restoration: Low Risk, Ring Barrier: Medium Level Risk, Closure Structure and Islands: Medium Level Risk, Pump Station: Medium Level Risk, Clear Lake: Medium Level Risk (historical information from TXDOT), and Dickinson: Medium Level Risk (historical information from TXDOT).
- SD4 – Galveston Bay Closure Structure, Large Sector Gate – Design based on Similar St Petersburg, Russia Gates. This is a highly unique design. Some level of study (~30%) has been completed, but much design development and refinement remains. A design competition (working within the operations constraints and using the existing modeling) will be initiated in an effort to develop the best possible design and select the A/E designer of record. Uncertainty remains. Physical modeling and High end modeling for the gate will be required. Just given the complexity of the design, HIGH Cost risk.

Moderate risks, when combined, can also become a cost impact.

- ES2 – Estimate Development – CSRM Estimates are developed to Class 3 estimates and are based on Sabine to Galveston budgetary estimates. NER features are Class 3 estimates based on recent historical bid data. USACE Cost Engineers judgment estimates are conservative and based on other recent budgetary estimates and recent historical NER information.
- SD5 – Galveston Bay Closure Structures, Vertical Lift Gates – Design based on Similar Hartel Barrier (same widths with largest gate being similar to this projects shallow gate). Smaller gate based on Hartel Barrier larger gate. Deeper gate for this project was scaled up version of Hartel Barrier gate.
- PM10 – Pressure to Deliver on an Accelerated Schedule – Project Study has already experienced outside pressure from public and others to accelerate study and project implementation. Hurricanes Ike and Harvey lead to outcries for immediate results. Many large complicated features cannot be accelerated. Baseline schedule reflects realistic and reasonableness implementation of schedule. There is a very high likelihood schedule is accelerated and USACE

would pay a premium for that schedule acceleration. Assume a potential cost increase of 3% to 10% of construction costs for schedule acceleration.

**Schedule Risks**: From the CSRA, the key or greater Schedule Risk items include:

- LD4 – Property Acquisition - Non-Federal sponsors for all areas have not been surveyed. Quick take authority is unknown. Without quick take authority condemnation actions could take significant periods of time. DOJ is heavily engaged with border acquisitions so Federal timelines are equally impacted. GLO has experienced up to 24-month delays for individual property acquisitions in the past.
- EX1 – Public Engagement - Public is strongly polarized for both the project as a whole and even specific features. Overall project and even priority of features all have varying degrees of support. Project has already undergone multiple study updates, FOIAs, and public hearings to address the various groups concerns. Legal action is an almost certainty with likely schedule delays.
- PM8 – Multiple Agency Coordination - This is a large project involving multiple agencies. Project spans 18 counties, engages multiple organizations (including Coast Guard), multiple municipalities and environmental groups. Mitigation versus avoidance will likely determine level of coordination required. Project has experienced schedule delays and given the number of stakeholders continued delay is very likely.
- PM11 – Plan Formulation and Public Sponsors - Many features do not currently have sponsors. Public Sponsors, once identified and engaged, may not have same plan formulation goals. Sabine to Galveston is currently experiencing issues with plan refinements and sponsor identification. Designs are conceptual and refinements to meet sponsor priorities can be accommodated. Ring Barrier and its alignment is the only large refinement that a future sponsor may want to change. There is a high likelihood this risk will be addressed in next Texas legislative session. Texas Legislature meets every two years (2021, 2023, etc.). At this point, schedule risk if sponsors are not identified in a timely manner. Worst case schedule may be delayed two years waiting for next Texas Legislative Session and sponsor identification.

**Recommendations**: The CSRA study serves as a “road map” towards project improvements and reduced risks over time. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

**Table 3. Construction Cost Comparison Summary (Uncertainty Analysis)**

| Base Case Estimate (Excluding 01) | $16,662,228,000 | |
|---|---|---|
| | | |
| **Confidence Level** | **Contingency Value** | **Contingency** |
| 0% | **1,499,600,520** | **9%** |
| 10% | **3,665,690,160** | **22%** |
| 20% | **4,165,557,000** | **25%** |
| 30% | **4,665,423,840** | **28%** |
| 40% | **4,998,668,400** | **30%** |
| 50% | **5,331,912,960** | **32%** |
| 60% | **5,665,157,520** | **34%** |
| 70% | **5,998,402,080** | **36%** |
| **80%** | **6,331,646,640** | **38%** |
| 90% | **6,998,135,760** | **42%** |
| 100% | **10,663,825,920** | **64%** |

**Table 4. Construction Schedule Comparison Summary (Uncertainty Analysis)**

| Base Case Schedule | 264.2 Months | |
|---|---|---|
| | | |
| **Confidence Level** | **Contingency Value** | **Contingency** |
| 0% | **66 Months** | **25%** |
| 10% | **98 Months** | **37%** |
| 20% | **106 Months** | **40%** |
| 30% | **111 Months** | **42%** |
| 40% | **116 Months** | **44%** |
| 50% | **122 Months** | **46%** |
| 60% | **124 Months** | **47%** |
| 70% | **129 Months** | **49%** |
| **80%** | **135 Months** | **51%** |
| 90% | **143 Months** | **54%** |
| 100% | **185 Months** | **70%** |

## 7.2 Recommendations

Risk Management is an all-encompassing, iterative, and life-cycle process of project management. The Project Management Institute's (PMI) *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, *4th edition*, states that "project risk management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project." Risk identification and analysis are processes within the knowledge area of risk management. Its outputs pertinent to this effort include the risk register, risk quantification (risk analysis model), contingency report, and the sensitivity analysis.

The intended use of these outputs is implementation by the project leadership with respect to risk responses (such as mitigation) and risk monitoring and control. In short, the effectiveness of the project risk management effort requires that the proactive management of risks not conclude with the study completed in this report.

The Cost and Schedule Risk Analysis (CSRA) produced by the PDT identifies issues that require the development of subsequent risk response and mitigation plans. This section provides a list of recommendations for continued management of the risks identified and analyzed in this study. Note that this list is not all inclusive and should not substitute a formal risk management and response plan.

The CSRA study serves as a "road map" towards project improvements and reduced risks over time. The PDT must include the recommended cost and schedule contingencies and incorporate risk monitoring and mitigation on those identified risks. Further iterative study and update of the risk analysis throughout the project life-cycle is important in support of remaining within an approved budget and appropriation.

Risk Management: Project leadership should use of the outputs created during the risk analysis effort as tools in future risk management processes. The risk register should be updated at each major project milestone. The results of the sensitivity analysis may also be used for response planning strategy and development. These tools should be used in conjunction with regular risk review meetings.

Risk Analysis Updates: Project leadership should review risk items identified in the original risk register and add others, as required, throughout the project life-cycle. Risks should be reviewed for status and reevaluation (using qualitative measure, at a minimum) and placed on risk management watch lists if any risk's likelihood or impact significantly increases. Project leadership should also be mindful of the potential for secondary (new risks created specifically by the response to an original risk) and residual risks (risks that remain and have unintended impact following response).

# APPENDIX A

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| **Organizational and Project Management Risks (PM)** | | | | | | | | | |
| PM1 | Implementation Schedule | Baseline Schedule assumes 2025 funding start and 2027 construction start. Construction to be complete 2037 to 2043. | For Marsh Shoal construction more local sources have been found from the anchorage basin material.<br><br>There is the opportunity for ER and dredging synergy with the Houston Ship Channel in the future.<br><br>It is acknowledged the potential for savings, but until detailed schedules have been developed and without better projections for funding exact schedule compression is unknown. | Unlikely | Negligible | Low | Very Likely | Negligible | Low |
| PM2 | Funding - Federal | A +/-$20Billion project executed over roughly 20 years would require some $650M/year in Federal Funding with some years far exceeding $1B/year. | Project will request large funding for gates first. Large increment funding is likely to eventually be provided, potentially triggered large storm event (i.e. Hurricane Ike or Harvey).<br><br>Barrier Gate and to a lesser extent Ring Barrier (including Dickenson and Clear Creek) CAN NOT be incrementally funded.<br><br>Federal funding will likely incrementally fund project with smaller pieces likely being funded first. Limited PED funding for gates may also be forthcoming.<br><br>Sabine to Galveston (S2G) $4B project can be viewed as a litmus test for the Texas Coastal project and has been progressing to date with issues remaining to be addressed. S2G may serve as a path for Texas Coastal.<br><br>Project may need to be funded as a completely separate funding stream.<br><br>Project schedule, and ultimately project success are entirely dependent on efficient funding. Instruction to the proejct directs to assume efficient implementation (ie funding). | Unlikely | Negligible | Low | Very Likely | Negligible | Low |
| PM3 | Funding - Sponsor | A +/-$20Billion project executed over roughly 20 years would require some $350M/year in Federal Funding with some years far exceeding $1B/year total. | Nonfederal Sponsor was provided some $200M in State Legislation to fund Sabine to Galveston (S2G) project in FY20 and FY21. Additional future year funding is likely. S2G will likely be completed prior to large Nonfederal financial commitments for this project.<br><br>Sponsor is optimistic and feels State funding is more certain than Federal Funding. | Unlikely | Negligible | Low | Very Likely | Negligible | Low |
| PM4 | Design Staffing | Beach Nourishments, Berm, Ring Barrier and Ecosystem Restoration will likely be designed by Regional and National USACE teams.<br><br>Pump Stations and Closure Gates will be designed by A/E Firm. | Galveston has direct hire authority to begin adding additional staff for this effort. Virtual USACE teams will be utilized to supplemental SWG staff and expertise.<br><br>A/E firms will be utilized for all specialty features (i.e. Gates and Pump Stations).<br><br>S2G staff may role over from that project as completed.<br><br>Given the 15year baseline construction, If project is optimally funded SWG could likely design staff the project with the support of other districts and with A/E augmentation.<br><br>Baseline PED estimate assumes 15%. Rate of 15% is likely good, EBR an Comite have been averaging 10% and Westshore even lower. Overall LOW risk of Cost increases. | Unlikely | Negligible | Low | Very Likely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| PM5 | Construction Management Staffing | SWG will likely staff Construction Management. | Based on staffing approach of S2G, Resident Offices are likely to be established for the various reaches/features. SWG has begun adding multiple Resident Offices for S2G projects. As those projects are completed staff could transition to Coastal Texas.<br><br>To date SWG has been able to meet S2G staffing requirements.<br><br>CM staffing risk is considered LOW. | Unlikely | Negligible | Low | Very Likely | Negligible | Low |
| PM6 | Staff Turnover | Staff turnover for projects extending decades will certainly occur. | Staff turnover can result in loss of institutional knowledge, disjointed decision making and inefficiencies.<br><br>Staff turnover will happen with varying degrees of impact. Closure structures will be design build and not likely to be impacted by USACE turnover. Other 50% project could be impacted by USACE turnover. Closure structures are critical path 15year duration. Other features are 10 year duration. Staff turnover delays for non-closure structures is not likely to impact critical path schedule. | Unlikely | Negligible | Low | Likely | Negligible | Low |
| PM7 | Continuing Contracts Clause | Continuing Contracts Clause will be required to funding several of the larger construction features including Barrier Gates and Ring Barrier. | SWG has experience with Continuing Contracts Clause. Option items (separable elements) are not likely. Approval is likely. Schedule risk is low. | Unlikely | Negligible | Low | Unlikely | Moderate | Low |
| PM8 | Multiple Agency Coordination | This is a large project involving multiple agencies. | Project spans 18 counties, engages multiple organizations (including Coast Guard), multiple municipalities and environmental groups.<br><br>Mitigation versus avoidance will likely determine level of coordination required.<br><br>Project has experienced schedule delays and given the number of stakeholders continued delay is very likely. Schedule could be delayed most likely 24months and worst case 36months.<br><br>Project scope has been expanded to address other agency concerns and additional cost growth is unlikely. | Unlikely | Negligible | Low | Very Likely | Moderate | High |
| PM9 | Project Turnover Plan | Each section will get turned over at completion. | Only feature that may be in question is turnover of the large Barrier Gates. Large Barrier Gate will require a maintenance entity that Texas State Legislature is working to create (likely O&M of $150M/year).<br><br>Until more is known about Texas Legislature intended plan risk is very uncertain. Project Authorization is likely dependent on state legislation. GLO is likely to sign Letter of Intent to continue the study but likely cannot sign PPA without Texas Legislation.<br><br>Historically USACE will not move forward with construction of a project until a long term maintenance partner has been established. Risk is a Black Swan project killer and not modeled. Base assumption project maintenance will be conducted by a sponsor. No CG funds or contingency added for project maintenance. | Unlikely | Negligible | Low | Very Likely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| PM10 | Pressure to Deliver on an Accelerated Schedule | Project Study has already experienced outside pressure from public and others to accelerate study and project implementation. | Hurricanes Ike and Harvey lead to outcries for immediate results. Many large complicated features can not be accelerated.<br><br>Opportunity if funds were made available. If project was funded for gate design and construction immediately project could advance faster. Baseline schedule reflects realistic and reasonableness implementation of schedule.<br><br>There is a very high likelihood schedule is accelerated and USACE would pay a premium for that schedule acceleration. Assume a potential cost increase of 3% to 10% of construction costs for schedule acceleration.<br><br>For large sector gates night work will likely not be permissible for safety reasons.<br><br>Given project, there is some minimal schedule duration the project can not physically be designed/constructed faster.<br><br>See further discussions for Contract Design Build discussions along with External Risks/Opportunities for Public Engagements and Natural Disasters. | Likely | Significant | High | Very Likely | Negligible | Low |
| PM11 | Plan Formulation and Public Sponsors | Many features do not currently have sponsors. | Public Sponsors, once identified and engaged, may not have same plan formulation goals.<br><br>S2G is currently experiencing issues with plan refinements and sponsor identification.<br><br>Designs are conceptual and refinements to meet sponsor priorities can be accommodated. Ring Barrier and it's alignment is the only large refinement that a future sponsor may want to change.<br><br>There is a high likelihood this risk will be addressed in next Texas legislative session. Texas Legislature meets ever two years (2021, 2023, etc.).<br><br>At this point, schedule risk if sponsor's are not identified in a timely manner. Worst case schedule may be delayed two years waiting for next Texas Legislative Session and sponsor identification. | Very Likely | Negligible | Low | Possible | Significant | Medium |
| PM12 | Smart Planning Process Extension | Project has requested a waiver for schedule extension. | Exemption of 14weeks abd $450k has been granted. No additional schedule risk. | Very Likely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| **Contract Acquisition Risks (CA)** | | | | | | | | | |
| CA1 | Low Price Technically Acceptable and Best Value | LPTA is likely contracting vehicle unless Best Value can provide benefit. | LPTA is likely to result in lower bid prices. Technically Acceptable must be clearly defined for all requirements to define basis of pass/fail. Best Value Tradeoff may be considered for phases (say schedule or other value). | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CA2 | Number of contracts | Numerous contracts will be required to execute the projects. | Industry has suggested contracts not extend beyond three years to not tie-up contractor bonding capacity. Bonding beyond 5years is typically not possible. Contractors typically don't have capacity to execute projects with capacity greater than 3 years.<br><br>Project has been divided into manageable contract sizes with 15years for Bolivar Roads crossing and 10years for all other work.<br><br>Early year contracts will be pursued. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CA3 | A/E Design Contracts | Large A/E Contracts are being developed for design support and expertise. | A/E design contracts will likely be base period (say 4yrs) plus option years. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CA4 | Design Build | SWG has used Design Build for other projects and programs. | All potential contracting vehicles will be considered (design-build, LPTA, Best Value) and the best vehicle selected.<br><br>Design Build must have carefully defined performance requirements and budgets. Real Estate footprints, Environmental Impacts and mitigation requirements could change with Design Build process. USACE review and oversight could result in cost increases after contract award.<br><br>If funds/schedule are accelerated Design Build may be a viable approach. S2G has used Design Build vehicle to meet schedule.<br><br>It's almost certain some portions of this project will be Design Build, especially if program scheduled is accelerated.<br><br>SWG and Local Sponsor are not advocates for design build but schedule may dictate.<br><br>Design build could add additional worst case 3% in project cost. | Likely | Moderate | Medium | Unlikely | Negligible | Low |
| CA5 | Small Business Goals | Small Business set-asides are likely for this program. | Acquisition Planning and market research will be conducted to determine the small business capacity and goals. Not all work will be available for small business but small business goals will be pursued.<br><br>Baseline estimate has assumed multiple prime and subcontractor assignments and markups to address small business goals. Some residual risk remains for additional small business expenses. | Possible | Moderate | Medium | Unlikely | Negligible | Low |
| CA6 | Contracting Staff | Additional SWG contracting staff will be required to execute +$15Billion in contracts. | SWG has historically awarded IFB contracts. LPTA/Design Build and other contracts will require additional SWG contract administration.<br><br>SWG has requested approval for additional SWG contract administration staff. SWG was able to eventually staff to meet S2G workload. Additional senior experienced staff will be required likely at higher Grade positions.<br><br>Cost Risk if outside support or higher grade positions. Early on initial contracts may experience delays but overall project will not be delayed as SWG increases and right-sizes staff. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CA7 | Acquisition Plan | Decisions must be made for programmatic or individual Acquisition Plans. | S2G has been pursuing an acquisition plan for over 12months and has yet to be completed.<br><br>Acquisition Plan will need to begin concurrent with start of PED to insure sufficient time. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| **General Technical Risks (TR)** | | | | | | | | | |
| TR1 | Houston Ship Channel | Houston Ship Channel will be under construction during this project and dredge material may be available for Beach Nourishments or Environmental Restorations.<br><br>Texas Coastal Quantities are also based on existing Ship Channel. Houston Ship Channel project may potentially already dredge Texas Coastal Area reducing this projects required volume. | For Marsh Shoal construction more local sources have been found from the anchorage basin material.<br><br>There is the opportunity for ER and dredging synergy with the Houston Ship Channel in the future.<br><br>It is acknowledged the potential for savings, but it's best to not link the two projects given schedule timeline uncertainties. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| TR2 | Future Studies | There is the potential for a new study further deepening the Houston Ship Channel and potentially impacting the gate sill depth. | During design ship simulation will further define gate design and dimensions. Current opening size may slightly increased based on expansion of Houston Ship Channel.<br><br>Currently assumed 60' depth is likely deepest feasible depth given continental shelf and channel geography.<br><br>Any future authorization changes would cover the cost increases to a deeper sill. No cost risk to this project. | Unlikely | Marginal | Low | Unlikely | Negligible | Low |
| TR3 | Site Accessibility | Surge Gates are operated from an artificial island. Access to the gates via boat during a storm event could be compromised. | Office and living facility may be required for personnel operations during a storm event.<br><br>Cost risk is likely LOW relative to total project cost. | Very Likely | Negligible | Low | Unlikely | Negligible | Low |
| TR4 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Architectural and Interior (AI)** | | | | | | | | | |
| AI1 | Ring Barrier, Pump Station and Seawall | Ring Barrier, Pump Station and Seawall must all synergize with the local surroundings | Exterior facades for Galveston Ring Barrier, Seawall, Clear Creek Pump Station, and Offatts Bayou Pump Station must be architecturally appealing for the surrounding community. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| AI2 | Visitor/Operations Center | Cost Estimate includes cost for Visitor/Operations center in Galveston and Auxiliary Control Center in Bolivar | No additional scope is likely. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| AI3 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| AI4 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| **Ecosystem Restoration** | | | | | | | | | |
| ER1 | Ecosystem Restoration Level of Design | Ecosystem features were developed with minimal analysis and no investigation. | Ecosystem Restoration features are fairly standard and the team has historical experience with other projects across the Texas Coast. Specific refinements will occur pending additional geotechnical information.<br><br>Overall level of ER design refinement will result in cost variations of +/-5% for ER features ($1Billion in breakwaters, Island Restoration, Marsh Creation for a total $1.4Billion).<br><br>UPDATE 2021-02-24: Based on other similar work and features, team now feels confident NER features are likely conservative and only likely to decrease 5%, increase is unlikely. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| ER2 | Final Site Selection | Future conditions prior to construction could be different then currently assumed. | Some sites may be completed prior to this project. Other sites may become some degraded that restoration is not possible. There is the potential for future site reductions if projects are completed by others. Project will authorized for regional based restoration, not for specific habitat units.<br><br>Selection will be dependent on final site conditions. ER features allow flexibility and if sites have been completed or are no longer feasibly they will not be pursued with this project. LOW cost risk. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| ER3 | Future Studies | There is the potential for new study (GIWW Resiliency) | May provide opportunity to integrate future design and implementation into current design. Overall relative cost of Marsh Creation is negligible in comparison to total construction cost. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Nonstructural** | | | | | | | | | |
| NS1 | Level of Design | Quantities have been sorted into Residential and commercial sites. | Nonstructural remediation has been developed by facility type. Estimates have been developed for each type of raise.<br><br>Design is very conceptual. Potential estimate variation of -5% to +30% of $50M baseline cost. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| NS2 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| **Geotechnical/Civil/Site Design (CV)** | | | | | | | | | |
| CV1 | Initial Sand Sediment Source | GLO and other agencies are studying available sand sources. | Good quality source material is available. Specifics of avoidance/exclusion areas, existing utility pipelines and overburden may not have been included in the estimate.<br><br>Additional inefficiencies or dredge mob/demobs may be required to acquire sufficient sand.<br><br>Estimate has assumed single further offshore source (Heald Bank area). GLO is doing multiple surveys, both near shore and offshore. There is a likelihood closer sources may be found but available quantity volumes are uncertain. Estimate currently includes multiple mobs/demobs (one per year). Estimate has assumed reuse of material dredged from the barrier gate navigation channel and anchorage basin.<br><br>Beach Nourishment is likely conservative and opportunity cost savings potentially exists but are not modeled at this time in this CSRA. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CV2 | Bolivar Roads Anchorage Areas | Due to gate crossing, 45% of current anchorage area will be unusable which will need to look for alternate anchorage areas. | Coast Guard, Pilots and Ships Captains had opinions on locations. USACE has purposed fixed mooring anchors with tugs to guide and align ships. Coast Guard, Pilots and Captains currently are not supportive for the current USACE purposed solution. User requested sites have been evaluated and were not found to be economically viable (e.g., 87M CY initial dredging with regular maintenance will be needed to a proposed site). Number of users has also been questioned. Tug operation costs for mooring and anchoring have been included in O&M costs.<br><br>Cost and Schedule Risk exists until an Anchorage Area and gate crossing alignment can be agreed upon with the Coast Guard. Project schedule could be delayed multiple years, both for USACE and Coast Guard to reach agreement and also for Coast Guard to conduct their own public hearings and approval process for changing anchorage areas.<br><br>The estimated amount of dredging for USACE proposed anchorage Area is 9,344,000 CY with a 2-year maintenance dredging cycle of 91,830 CY. Currently project costs assume double mooring anchors for each circle for a total of 12 mooring anchors to anchor the bow and stern of a vessel. Estimated cost for a double anchoring system is $5.1M. It is expected that PDT will revisit this subject during PED phase to model the currents and winds for further refinement in the anchoring system. This is likely a critical path item. Design must be developed to a point that anchorage areas can be purposed/studied and then an agreement must be reached with the Coast Guard. Assume 6 to 12month schedule delay. | Unlikely | Negligible | Low | Likely | Significant | High |
| CV3 | Geotechnical Level of Design | Geotechnical Engineers have much of the original Galveston boring data and are comfortable with the overall level of detail. | Geotechnical design evaluated a potential range of design values and usually selected the lower bound (more conservative numbers) in developing designs/quantities. Geotechnical Design refinements will be developed during PED.<br><br>Geotechnical Engineers overall feel:<br>Dune: Low Level Risk<br>Ecosystem Restoration: Low Risk (see Risk ER1)<br>Ring Barrier: Medium Level Risk<br>Closure Structure and Islands: Medium Level Risk<br>Pump Station: Medium Level Risk<br>Clear Creek: Medium Level Risk (historical information from TXDOT)<br>Dickenson: Medium Level Risk (historical information from TXDOT)<br><br>Overall Geotechnical comfort level is Medium Level risk. Assume -5% / +10% for Closure Structure and -/+5% for the Ring Barrier and Pump Stations. | Likely | Moderate | Medium | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| CV4 | Interior Drainage Dune | Interior Drainage in the past has been study for re-routing drainage back into the bay. | The study seeks to route existing beach discharge through proposed dune features via culvert(s) while maintaining the same general footprint and flow pattern. Hard drainage features in the soft dune features may require frequent O&M repairs.<br><br>The verbiage within Federal, State, County, and Municipal beach drainage regulations are generally oriented towards protection of the dunes and beach, which aligns well with the spirit of the proposed project. The most restrictive language is found in Municipal Ordinance 84-40, passed by the City of Galveston in 1984, which states that "… no drainage will be permitted into the Gulf of Mexico or onto the adjacent beach." The City drainage plan clarifies that preexisting developments with beach drainage are exempt under a "grandfather clause". State and county effective beach drainage regulations for the Bolivar Peninsula study area are outlined in the Galveston County Dune Protection and Beach Access Plan (2006), which is generally intended to provide protections to beach and dune systems. There are provisions within the protection plan that offer allowable mitigation measures to offset adverse impacts of beach drainage, which align with the nature of the beach nourishment and dune construction project. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CV5 | Interior Drainage Ring Barrier | Interior Drainage in the study has been studied but additional analysis remains. | Interior drainage mitigation features are purposed to tie existing features into the Ring Barrier pumping system. The specifics are to be developed. Costs have been included in the estimate. Galveston City is currently proposing a new pump station along Harbor site which needs to be accounted in future drainage analyses.<br><br>Additional analysis will be required to confirm no induced damages and refine final alignments. Overall cost exposure relative to total project is low. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CV6 | Levee Borrow Sources | Levee Borrow Sources have assumed commercial borrow sources. | Commercial borrow may become limited in the future. Estimate assumes significant haul distance. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CV7 | Aggregate sources | There is a large volume of concrete requiring sand and gravel. | There is sufficient aggregate sources along the Texas Coast to supply the project. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Structural (SD)** | | | | | | | | | |
| SD1 | Seawall Gates | Scope includes swing gates. | Swing gates may be replaced with either roller gates or even stop logs. Swing gates is the most costly assumption are likely to only become cheaper as design is refined. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| SD2 | Galveston Bay Closure Structure - Combi Wall | Primary Level of Protection. Most well developed design. | Most Robust design similar to IHNC New Orleans closure structure. Design is likely to a 30% level of design.<br><br>Structural design is based on conservative assumptions and team is confident/comfortable with design. Overall Medium Cost Risk variation of -/+ 5% for the Combi-Wall. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| SD3 | Galveston Bay Closure Structure - Small (125 ft) Sector Gates (2) | Design based on Similar Recently Awarded New Orleans Gates. | Shallow water gates have been correlated to the deeper water gates. Limited analysis has been completed. Separate cofferdams have been assumed for each gate (conservative as cofferdam could be sized to accommodate multiple gates).<br><br>Designer is comfortable/confident with design and sufficient quantities. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| SD4 | Galveston Bay Closure Structure - Large (650 ft) Sector Gates (2) | Design based on Similar St Petersburg, Russia Gates. | This is a highly unique design. Some level of study (~30%) has been completed, but much design development and refinement remains. A design competition (working within the operations constraints and using the existing modeling) will be initiated in an effort to develop the best possible design and select the A/E designer of record. Uncertainty remains.<br><br>Physical modeling and High end modeling for the gate will be required. Just given the complexity of the design, HIGH Cost risk. Cost variations of -5% to +25% for the large sector gates is possible. | Likely | Significant | High | Possible | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| SD5 | Galveston Bay Closure Structure - Vertical Lift Gates (Shallow and Deep) | Design based on Similar Hartel Barrier (same widths with largest gate being similar to this projects shallow gate). | Smaller gate based on Hartel Barrier larger gate. Deeper gate for this project was scaled up version of Hartel Barrier gate.<br><br>Similar design level of effort with major items has been investigated. Structural engineer feels remaining cost uncertainty of -5% to +20%. | Likely | Moderate | Medium | Unlikely | Negligible | Low |
| SD6 | Floodwall/Combi Wall/T-Wall | Worst Case Cross section has been developed with highest hydraulic head and weakest geotechnical foundations. | That Worst Case Cross section has been applied for all areas in the system, just with a reduced stem wall height. Design refinement will likely result in reduced foundation and cross section sizes.<br><br>Overall Floodwall costs are likely conservative. There is a minimal risk that additional seepage concerns could be discovered resulting in greater foundation requirements, but worst case cross section already considered seepage. Overall risk is similar to Galveston Bay. Less design has been done, but assumed cross section is like more conservative. Overall Medium Cost Risk variation of -/+ 5% | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| SD7 | Offatts Bayou - Sector Gates | Based on New Orleans Sector Gates | Design has been developed well beyond 30%. Gate and foundation are well developed and within USACE typical project features. 125' sector gate. Feeling is lower risk (+/-5%). | Possible | Moderate | Medium | Unlikely | Negligible | Low |
| SD8 | Alignment | An alignment has studied but changes are likely as final alignment is not agreed to with the various impact groups. | Schedule risk as final alignment is agreed upon. Cost increase is likely negligible but moderate schedule risk. Assume worst case 6 month overall schedule delay to reach agreement on final alignments. | Unlikely | Negligible | Low | Likely | Marginal | Medium |
| SD9 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Electrical (EE)** | | | | | | | | | |
| EE1 | Backup Power | Redundant diesel backup power has been assumed for all pump stations and sector gates. | Urban area. Gird power is readily available in the vicinity. Estimate includes auxiliary and permanent power. It is a whole extra project. They will likely need to build a substation, and who knows how much length of line with potential ROW, NEPA, road replacement, etc. It should be done well before the gate is completed, but they will need to know how much power up front so there will be a slight delay while that is figured out from the gate designers | Unlikely | Negligible | Low | Possible | Negligible | Low |
| EE2 | Level of Detail | Detailed Electrical Estimates have been developed but level of design is very preliminary. | Limited electrical design has been developed to date. Schedule risk is low (time exists to develop design). Cost uncertainty is HIGH electrical features. 0% to 35% cost growth possible. | Very Likely | Moderate | High | Unlikely | Negligible | Low |
| **Mechanical (ME)** | | | | | | | | | |
| ME1 | Level of Design | There are multiple large and highly complex mechanical features (sector gates, pump stations, lift gates, etc.). | Limited mechanical design has been developed to date. Schedule risk is low (time exists to develop design). Cost uncertainty is HIGH mechanical features. 0% to 35% cost growth possible. | Very Likely | Moderate | High | Unlikely | Negligible | Low |
| ME2 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Hydraulics and Hydrology** | | | | | | | | | |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| HH1 | H&H Model | Sediment Modeling, Shoaling, hydraulic load and Channel Stabilization have yet to be modeled. | H&H large scale storm model is reasonably developed and overall water surface profile is defined reasonably and unlikely to change significantly. Slight revisions and refinements are likely but changes will not be significant. Local scale modeling to understand hydraulic load will be critical in PED phase.<br><br>Sediment and Shoaling modeling will have impacts on long term O&M but not an issue for initial authorized project.<br><br>Increased Shoaling during construction would be an authorized project responsibility. There is potential for additional cost but likely negligible.<br><br>Limited ship simulations have been completed. Additional ship simulation modeling will be required. Quantities are currently considered neutral with refinement and optimization remaining. Assume potential +/-5% quantity variation for dredging. Assume +/-2% for Large Sector impacts due to H&H uncertainty. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| HH2 | Clear Creek, Dickenson Bayou and Offatts Bayou and Water Quality | Water quality and dissolved oxygen H&H model and environmental assessment may require additional circulation gates to address water quality concerns | H&H model has not been completed and will provide additional information if additional gates are needed. Current design has combi-walls with gates. If more gates are required that would be in place of combi-walls. Cost Risk likely a tradeoff between circulation gates ($232k/ft) and combi-wall ($41k/ft). Additional gates are not likely required.<br><br>Water quality and circulation gates may be required to prevent stagnation. H&H model/solutions will be required prior to Tier 2 EIS and NEPA compliance required for construction of the Ring Barrier.<br><br>**Until schedule is better understood this may be a critical path item but time exists to develop understanding and resources could be allocated to meet schedule.** | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| HH3 | Pump Station Capacity | Pump station sizes need to be further refined. | Real Estate requirements for pump stations may change. Pump station sites are in densely congested areas. Designers opinion is pump stations are conservatively sized and real estate footprint and capacity sizing will not increase.<br><br>Study is not authorized to improve interior drainage. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| HH4 | H&H Level of Design | H&H level of design is fairly well advanced for a Feasibility study but areas of refinement remain. | Large scale results are well understood, but local scale features works remain. Physical model coupled with high end CFD analyses will be needed in PED phase to understand design loading. Gate and pump operation with sequence of gate operation will be critical tasks in PED phase. Drainage, overtopping and height optimization remains. Overall cost impact for H&H refinement is likely neutral, say +/-2% (Pumping Plant, Dunes, Diversion Structure). Overall designers feel they've been reasonable in assumptions. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| HH6 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Equipment (EQ)** | | | | | | | | | |
| EQ1 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| EQ2 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| EQ3 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| EQ4 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Commissioning/Certification (CC)** | | | | | | | | | |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| CC1 | Operations Manual | An operations manual will be required. | Additional H&H modeling will be required to define gate operations for the surge gates, all other closure gates, pump station operations, etc. Ships putting out to sea and time to deploy surge gates must all be taken into account. Complex system operations must be considered throughout the design process.<br><br>LOW cost risk for authorized costs. Schedule risk exists for final operations manual to be agreed upon by all parties. Assume 15% chance project could be delayed one year. MVN has experienced similar delays in post Katrina operations manual agreement. Construction/design is not likely to be impacted. | Unlikely | Negligible | Low | Possible | Moderate | Medium |
| CC2 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Lands and Damages (LD)** | | | | | | | | | |
| LD1 | Final Alignment | Alignment at 30% design, additional design activities pushed to PED deviation to design may increase cost in PED; | Alignment refinements are likely. Refinements are likely. General Footprint included flexibility. Dune drainage are could require additional real estate footprints. Current Real Estate estimate assumes $100M+ for Galveston Dunes and $90M+ for Bolivar Dunes.<br><br>Alignment area variations of +5% Real Estate are likely. | Likely | Moderate | Medium | Unlikely | Negligible | Low |
| LD2 | Temporary Easements and Site Access | Temporary easements and Site Access will be needed. | Temporary easements and site access have been included for high visibility features (Ring Barrier, Clear Creek, Dickenson, Galveston and Bolivar Beaches) but have not been included for other features of construction.<br><br>Most ER can be constructed from barge. B2 and W3 ER sites have not included temporary access. Cost is negligible, primarily minimal administration costs. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| LD3 | CBRA Zones | CBRA Zone exemption may not be obtained for Bolivar tie-in structures. | If exemption is not obtained an additional 950acre mitigation may need to be acquired.<br><br>UPDATE 2021-03-16: Since this risk was entered into the register the likelihood has decreased dramatically. First, the USFWS concurred with our determination that if the NFS paid for all of the work required to construct the Bolivar Tie in feature that a CBRA exception would not be required because federal funds would not be expended within the zone. Both the USFWS and HQ suggest that acquisition of property is a way to demonstrate compliance with the 3 purposes of CBRA, however if no federal expenditures are made within the CBRA zone, there would be no requirement for additional acquisitions. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| LD4 | Property Acquisition | Non-Federal sponsors for all areas have not been surveyed. Quick take authority is unknown. | Without quick take authority condemnation actions could take significant periods of time. DOJ is heavily engaged with border acquisitions so Federal timelines are equally impacted.<br><br>GLO has experienced up to 24 delays for individual property acquisitions in the past.<br><br>Schedule risk exists for property acquisitions. Property acquisitions can proceed at about 65% design. Overall schedule best case is no impact, most likely is 24months delay and worst case schedule could be cumulatively delayed 48months (worst case). | Unlikely | Negligible | Low | Likely | Significant | High |
| LD5 | Non-Standard Estates | Deviations from Standard Estates would require 8-12months HQ review | Non-Standard Estates are likely given the magnitude of the footprint and the variety of properties involved. Multiple Non-Standard Estates are likely. Cumulatively a 6 to 8month delay is likely. Tiered Structure can help expedite the process. | Unlikely | Negligible | Low | Possible | Moderate | Medium |
| LD6 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Regulatory, Cultural, Environmental Risks (RG)** | | | | | | | | | |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| RG1 | NEPA Compliance | Feasibility Study NEPA document will be a tiered NEPA document with future NEPA review needed for all the CSRM measures. | Tiered NEPA document could result in mitigation changes with subsequent NEPA reviews. Tier 1 Analysis has attempted to capture top end (worst case) mitigation requirements. It is hoped that mitigation requirements will be reduced as design becomes better developed.<br><br>For the larger features (barrier gate, ring barrier, clear creek, Dickenson) individual Supplemental NEPA reports will be required. Supplemental NEPA reviews will each take three years but likely can be concurrent with design and not impact project schedule.<br><br>Construction can not begin until final full EIS has been completed for each reach/feature. Surveys and sampling can be completed prior to final EIS with best management practices.<br><br>ER measures and South Padre Island CSRM will have full Environmental compliance at the end of this study. Beach nourishments and B2 will require some additional study to acquire full environmental compliance. CSRM measures will require separate NEPA reports.<br><br>Offatts Bayou could become a critical path for Supplemental NEPA review for the Ring Barriers. H&H 35% model and footprint for Offatts Bayou gate structures must be established prior to Supplemental NEPA.<br><br>Careful Coordination will be required between Environmental and Engineering to insure timely and potential incremental delivery of information.<br><br>Sequencing of Ring Barrier design, environmental compliance and construction must be further investigated if project is efficiently funded. Risk is concurrent with PM2 - Funding and not modeled. | Unlikely | Negligible | Low | Possible | Moderate | Medium |
| RG2 | Endangered Species Act | Consultations will be required with both Natural Marine Fisheries and US Fish & Wildlife Services. | Consultations have been progressing for currently listed endangered species (piping plover and red knot), Current endangered species share similar habitat. Any change in species or habitat listings would result in the additional consideration and consultations will be required.<br><br>SWG has experienced multiple projects requiring additional consultations. To date projects have not been delayed. Additional consultation costs are Very Likely but also negligible (say $200k ea.) relative to total project costs (multiple billions). | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| RG3 | Mitigation Requirements | PDT has assumed worst case mitigation requirements. | Unless additional endangered species are added or changes in regulation or footprint, mitigation requirements are likely to only decrease (opportunity).<br><br>Mitigation requirements do not include costs for IF additional habitat or areas receive protections beyond what is currently known/defined.<br><br>Best Case cost savings of 5% of assumed mitigation (opportunity), most likely is cost neutral and worst case is 5% cost increase in mitigation costs if additional species/habitat are added to protections. | Likely | Moderate | Medium | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood © | Impact © | Risk Level © | Likelihood (S) | Impact (S) | Risk Level (S) |
| RG4 | HTRW | Industrial areas on the backside of Galveston Island may have HTRW risks for construction of the barrier walls. | Sponsor is responsible for providing clean site. Galveston Island has been occupied since 1830's. To date alignments have been move to avoid the few known areas.<br><br>Cost Risk to the project is LOW. Backside Ring Barrier will be concurrent with Gate Construction and is not a critical path schedule. Any schedule impacts would be contract specific and not impact overall project. Sponsor is responsible for cost of clean. USACE could be responsible for construction contract delay impacts if discovered during construction. Construction impacts relative to overall project cost is negligible.<br><br>S2G delayed Level 1 HTRW survey to PED. There were known areas and significant HTRW has been discovered during PED and has lead to significant schedule delays and cost increases for additional design work/reconnaissance costs (HTRW Cleanup is the responsibility of the sponsor). Issues have had to be elevated to the state.<br><br>Schedule delays may be possible for this project as well if HTRW is encountered. There is some 2 to 7miles of Ring Barrier Floodwalls in which HTRW may encountered. Potential HTRW Risk is significantly smaller than S2G. Assume worst case schedule could be delayed 12months for additional HTRW investigation and re-design. | Unlikely | Negligible | Low | Likely | Moderate | Medium |
| RG5 | Coastal Barrier Resource Act | Work will occur in Seven CBRA Zones and exemptions will be required. | Bolivar CBRA zone with Tie-In's and Beach and Dune Nourishment will have the most impacted area.<br><br>All of the ecosystem restoration areas will meet the requirements for exemptions. CSRM Tie-In is only area of true concern for CBRA Zone exemptions.<br><br>A conservation easement may be required for CBRA Zones.<br><br>The Cost Risk to the project is low, while real estate instruments represent a method for demonstrating consistency with the three purposes of CBRA, other acceptable practices have been identified and coordinated for this project. The USFWS concurred with our determination that all the ER measures meet the requirements for exemption to the CBRA. The USFWS also concurred with our determination that the Beach and Dune measures meet Specific Exception §3505(a)(6)(G), Nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore a natural stabilization system. The USFWS recommended but did not require acquisitions or real estate protections (i.e. conservation easements) for the portions of the Bolivar Peninsula Beach and Dune Measure that cross CBRA zones. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| RG6 | Cultural Resources | There is a high likelihood cultural resources could encountered. | Cultural Mitigation estimates have been provided for likely resources to be encountered. Sites will surveyed prior to construction. If shipwrecks are uncovered excavation and removal would likely be required. Every effort has been made change alignment to work around known areas.<br><br>Uncertainty exists on cultural resources that could be encountered. There is a small likelihood (say 5%) a significant feature is discovered at significant cost ($10M) and schedule (12months). | Unlikely | Negligible | Low | Unlikely | Significant | Medium |
| RG7 | Clean Air Act | Two counties in the study area have been outside allowable thresholds. | Program has been coordinated with local air quality board. Uncertainty exists for conformity with levels. Schedule is not likely to be impacted due to study or limited equipment. Instead, additional costs may be required for mitigation to offset impacts. Minimal Air Quality Mitigation Bank costs have been included in MII estimate. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| RG8 | Marine Mammals | There is an incidental take permit issued by NOAA | Permit will be required. Cost of permitting has been included in Tier 2 EIS. Cost and/or schedule risk impacts are unlikely.<br><br>Pile driving noise, aquatic footprint, and dewatering will be required for permit application.<br><br>Contractors are currently performing similar work in the project areas. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| RG9 | Environmental Windows | Environmental nesting windows for Piping Plover, Red Knott and Sea turtles must be taken into consideration | Baseline estimate productivity rates have been adjusted to Reflect Construction windows.<br><br>Biggest impact would be beach and dune placements around turtle windows. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| RG10 | SHIPO | Seawall and Historic Downtown Galveston will likely be all considered SHIPO features. | Viewshed studies will be required for multiple SHIPO structures. Documentation will be required for the historic properties.<br><br>Design cost changes for SHIPO considerations are likely negligible. Documentation Studies of historic features will likely require time and could have schedule impact.<br><br>Budget includes costs to complete the cultural surveys. A/E support could be utilized to meet schedule. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Construction Risks (CO)** | | | | | | | | | |
| CO1 | Construction Sequencing for Large Sector Gates | Given the complexity and cost magnitude, the Large Sector Gate Construction Sequence has been developed with Structural and Cost Engineers | One Way Navigation must be maintained for the Houston Ship Channel at all times. Sequence of construction has been developed to accommodate navigation requirements, confined site constraints and number of contracts (currently assumed 9 contracts for the entire Galveston Bay Closure Structure). Continuous funding WILL BE REQUIRED for the Large Sector Gate Funding. Incremental construction for the Sector Gates is not feasible. Overall 15year schedule duration is based on input from experts and industry. Schedule optimization may be possible but at potentially additional cost. Construction staging (barges, etc.) for the gates must be coordinated with local navigation.<br><br>Center Island, Bolivar Side Island and Bolivar side gate completed with ship traffic through Galveston side. After Bolivar side is completed traffic would routed through Bolivar side and Galveston side construction completed.<br><br>A refined construction schedule has been developed. Means and methods are likely to vary with final design and construction contractor. Risk covered in SD4. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| CO2 | Unknown Utilities | Galveston Ring Barrier, Clear Creek and Dickenson are likely to have unknown or unlocated utilities | Galveston area has been in development since the 1830's and before. It is very likely unknown utilities will be encountered during construction of the Galveston Ring Barriers. Assume 2% to 4% cost growth to Galveston Ring Barrier Project for unknown utilities. Individual contracts will be delayed for unknown utilities but overall schedule (critical path) is not likely to be impacted. Estimate currently includes $14M for known utility relocations.<br><br>Known utility corridors exist in the Clear Creek and Dickenson projects that have yet to be inventoried. Clear Creek and Dickenson are lesser risk areas. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| CO3 | Concurrent Contracts and Contractor Conflicts | At any given time there could be 5 to 10 concurrent contracts. | Contractors working the same physical spaces could result in interferences.<br><br>There is likely sufficient time, space and number of contracts that contractor interferences can be kept to a minimum for most of the project. Bolivar Road crossing is the only area that multiple contractors may be an in conflict. Estimate includes productivity factor reduction for Bolivar Road inefficiencies and conflicts. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO4 | Laydown Areas | Staging and Laydown areas have been identified for the most complex and most congested sites. | Contracts should have sufficient space for staging areas. Contractor inefficiencies for double handling and offsite storage will likely not be a concern.<br><br>Staging areas have been included for Clear Creek and Dickenson. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO5 | Vibration/seismic monitoring | Much of the floodwall/closure structures are near existing structures | Pile driving activities will require vibration monitoring and concern of noise complaints. Marine Mammal protection will require bubble curtain for noise mitigation during pile driving. Estimate has a small allowance for monitoring and assumes 10hrs/day, Monday to Friday work schedule to minimize noise impacts to the public. Cost threshold may not exceed marginal as it was added to the estimate. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| CO6 | Traffic Control | Traffic control may be an issue | Especially in urban/downtown areas traffic controls could cause issues with construction. Estimate includes traffic controls for Galveston Ring Barrier. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO7 | Road Repair | Construction traffic may damage roads and require repairs. | Cost estimate has anticipated length of road repairs. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO8 | Public Interactions | The Seawall and Beaches are popular public locations. | Temporary fencing and even temporary police routing may be required to interact with and direct traffic. Estimate includes flaggers, temporary fencing, and signage. Construction may need to be sequenced during offseason (winter) months. Hand work rather than large construction for the Seawall may need be required. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO9 | Weather Impacts | USACE Construction contracts have assumed number of weather days. | Storm events and wind/tidal events at times are likely to exceed allowable weather days.<br><br>Assume 1 to 2weeks of normal weather impacts per year for 15year duration of project (4 to 8months delay) with an additional one to two hurricane impacts of 1 month each (5 to 10 months cumulative delay). | Unlikely | Negligible | Low | Likely | Moderate | Medium |
| CO10 | Specialized Equipment | Contracts include SIGNIFICANT number of highly specialized and extreme size items | Project has significant amounts of Gates, Pumps, Motors, Actuators, etc. that will all require sufficient lead time for contractor procurement and manufacturing time.<br><br>This is an acknowledgement of the coordination and lead time required for specialized equipment.<br><br>Current uncertainty with specific items and lead teams results in some schedule uncertainty. Individual contracts may require longer durations for completion, but overall project schedule is not likely to be delayed. Additional interim contractor O&M waiting for long lead equipment may not be included in current estimate but cost is likely. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO11 | Warranty Periods | Warranty periods for Large/Complex facilities can be problematic | Warranty Periods have resulted in cost increases for project turnover. Assume worst case 0.5% cost increase for specialty structures extended warranties. | Likely | Marginal | Medium | Unlikely | Negligible | Low |
| CO12 | Interim O&M / Design Deficiencies | Projects the extended lifecycles can experience cost growth for interim O&M/Design Deficiency Repair after project turnover. | Future follow on construction contracts may have interim O&M/design deficiency repairs added to scopes of work to address issues with other previously completed features from other contracts.<br><br>Overall cost growth relative to overall $15Billion project is likely negligible. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| CO13 | Contract Modifications | Contract Modifications are inherent with any construction contract | Beyond risk already discussed in the CSRA, Mods, Claims and Differing Site Conditions could add an additional 2% to 6% in construction costs. | Very Likely | Significant | High | Unlikely | Negligible | Low |
| CO13 | | | | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **Estimate and Schedule Risks (ES)** | | | | | | | | | |
| ES1 | Material Price Fluctuations | Several Features will be highly dependent on material pricing. | Steel (sector gates), concrete (combi-wall, floodwall), fuel (dredging) and stone (breakwaters) price variations could all have large impacts on project costs. Overall, material price fluctuations carry a MEDIUM cost risk. | Possible | Moderate | Medium | Unlikely | Negligible | Low |
| ES2 | Estimate Development | CSRM Estimates, Class 3 estimates based on S2G budgetary estimates.<br><br>NER, Class 3 estimates based on recent historical bid data. | USACE Cost Engineers judgment estimates are conservative and based on other recent budgetary estimates and recent historical NER information.<br><br>Overall budget is felt to be neutral to even conservative. Assume potential variations of +/- 5% variation. | Very Likely | Marginal | Medium | Unlikely | Negligible | Low |

| | | | | Project Cost | | | Project Schedule | | |
|---|---|---|---|---|---|---|---|---|---|
| CREF | Risk/Opportunity Event | Risk Event Description | PDT Discussions on Impact and Likelihood | Likelihood (C) | Impact (C) | Risk Level (C) | Likelihood (S) | Impact (S) | Risk Level (S) |
| ES3 | Large Quantities | Much of the estimates bid data is based on local quotes. | If quantities become so large that material must be sourced regionally and not locally costs could increase.<br><br>Local aggregate vendors have been consulted and it is anticipated that local suppliers can accommodate. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| ES4 | Schedule | Project Schedule has been developed based on organization of individual feature schedules | Feature schedules have been consider and Bolivar Road Crossing schedule has been evaluated by engineering PDT. A sequence of contract construction has been considered and incorporated into the schedule.<br><br>Overall 15year schedule for Bolivar Road Large Sector gates and some 10year schedule for all other features appears reasonable. Overall Project schedule uncertainty due to schedule level of development is LOW. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| **External Risks (EX)** | | | | | | | | | |
| EX1 | Public Engagement | Public is strongly polarized for both the project as a whole and even specific features. | Overall project and even priority of features all have varying degrees of support.<br><br>Project has already undergone multiple study updates, FOIAs, and public hearings to address the various groups concerns.<br><br>Legal action is an almost certainty with likely schedule delays. Schedule could be delayed best case 6months, most likely 18months and worst case 48months. Authorized Project Cost is not to include budget for potential litigation. | Unlikely | Negligible | Low | Very Likely | Significant | High |
| EX2 | Storm Event and Natural Disasters - Level of Support | Storm Event may lead to public/political desire to complete project. | Increased public awareness could lead to schedule acceleration (schedule opportunity). See Risk PM10 - Accelerated Schedule.<br><br>Actual storm event and weather delays are covered in CO9.<br><br>Comment for Observation, actual risk impacts modeled elsewhere. | Possible | Moderate | Medium | Possible | Moderate | Medium |
| EX3 | Sea Level Rise | Sea Level Rise has been recommended for future study. | The expected average annual damages that are likely in the FWOP are summarized in Table 2-X. This analysis was undertaken considering an intermediate rate of relative sea level rise in the future (approximately X ft. over 50 years, from 20XX to 20XX). This analysis shows that there is a potential for significant damages along the Gulf shorefront and in and around Galveston Bay. A range of RSLC projections were considered in project evaluation, and the effect of these different projections is addressed in the section that describes project performance. | Unlikely | Negligible | Low | Unlikely | Negligible | Low |
| EX4 | Market Conditions | Bidder competition may be limited. | Pipeline and Hopper dredging contractor competition has been limited in the SWG area and nationally. NER and Beach and Dune Nourishment contracts could require four additional large/medium dredges per year for the next eight years. Jones Act waiver may be required to allow outside European dredgers.<br><br>Limited number of construction firms are available to construct or bond many of the larger multi-billion contracts. Local infrastructure/capacity does exist to produce the large sector gates.<br><br>The sheer volume of work may exceed the local and even regional capacity.<br><br>Overall project cost risk is HIGH. Market variability could result in total construction cost variation of -2% to +10%. Schedule could be delayed 12 - 24 months to reflect local market conditions. | Likely | Significant | High | Likely | Moderate | Medium |