ENGINEERING APPENDIX A

GULF INTRACOASTAL WATERWAY BRAZOS RIVER FLOODGATES AND COLORADO RIVER LOCKS SYSTEMS FEASIBILITY STUDY

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1 INTRODUCTION

1.1 PROJECT LOCATION

The study area (Figure 1) encompasses approximately 40 miles of the GIWW in Texas, at the intersections of the Brazos and Colorado Rivers along the Gulf Coast and covers two counties, Brazoria and Matagorda. The Brazos floodgates are 7 miles southwest of Freeport, Texas in Brazoria County and are accessible via Floodgate Road, 3.5 miles south of State Highway 36. The Colorado locks are located near Matagorda, Texas in Matagorda County. The East Lock is located on Matagorda Street approximately 0.25 miles west of the FM 2031 Bridge over the GIWW. The West Lock is not accessible by road.

Figure 1 Location Map

1.2 EXISTING CONDITIONS

1.2.1 BRAZOS RIVER CROSSING

The Brazos River flows into the Gulf of Mexico, crossing the GIWW near Freeport, TX. In 1929, the Brazos River was diverted 8 miles south of its mouth at Freeport to reduce flooding and shoaling in the Port of Freeport. The Brazos River Floodgates were constructed in July 1941. Two 75 foot floodgates, one on each side of the Brazos River crossing of the GIWW, are provided to control flood flows from the Brazos River into the GIWW and to control sand and silt deposition from the Brazos River into the GIWW. The authorized channel in the GIWW is 125 feet wide and is typically about 12 feet deep. The floodgates were installed at a time when most tug boats pulled barges behind them instead of using the modern pushing method. The current angled approaches to each floodgate is not conducive to the pushing method with the limited forebay and narrow gate openings. The cross current and through gate flows cause eddies to form unstable approach conditions. When the floodgates were built in 1943, barges were typically 26 feet to 35 feet wide. The floodgate chamber is 75 feet wide, and the maximum width of the barge it can accommodate is 55 feet. Today, it is common for towboat operators to push two 35 feet dry cargo barges side by side, for a total width of 70 feet. A typical tank barge measures 54 feet across, so tank barges must transit singly. The necessity to break the tow to pass individual barges through the Floodgates causes time delays. Also, shoaling issues have occurred causing periodic grounding of vessels. This has increased the difficulties faced by pilots navigating between the floodgates. Frequent accidents occur when tows strike the facilities while trying to line up to enter the floodgates after crossing the Brazos River. The floodgates are only approximately 600 feet from the river. When crossing the river, towboat operators do not have enough time to recover their course after struggling with the river currents. As a result, an average of 36 accidents occurs per year, causing damages to the facility and to the barges. When these accidents involve tank barges, there is also a risk for hazardous material spills.

Tidal effects are present at the project location. Combined with the Brazos River flood stage, this can cause flow both into and out of the GIWW. In addition, the flow velocities through the west floodgate are greatly affected by the San Bernard River. The outlet dredging for the San Bernard River within the last decade has silted in due to low flow and the GIWW has become its outlet partly through the west gate structure. This has increased the difficultly on pilots to navigate the structures.

Restrictions are placed on the tows allowed to cross the Brazos River during high flow events by the USACE in accordance with 33CFR 207.187 (Table 1). Long periods of high flow through the Brazos River that require “tripping” barges through places a serious economic impact on operation of tows through the reach.

Condition	River Velocity	Head Differential	Restriction
1	Over 2 mph	0.7 to 1.8 ft	• Single vessel passage • Tows with single loaded barges • Tows with two empty barges • Velocity reaches 1.7 mph, tows with two empty barges only
2	-	Over 1.8 ft	Closed
3	Over 5 mph	-	• Single vessel passage • Tows with one barge only loaded or empty • Operation during daylight hours only
4	Over 7 mph	-	Closed

Table 1 Existing Navigation Restrictions – Brazos River Crossing

Due to the well-known navigation issues associated with these floodgates, individual companies have instituted additional self-imposed regulation on their pilots above and beyond the USACE restrictions in order to minimize risks.

Currently, the project has multiple documented maintenance/operational issues outlined in the 2017 Operational Condition Assessment (OCA). Because of the low elevation of the top of the wall of the gate structure, barges routinely hit the walls and gates damaging the steel railing, concrete walls and machinery pit. There are up to 8 feet deep scour holes along the steel sheet pile guide walls on the West and East gates which extend towards the middle of the channel, exceeding the design elevations of the guidewalls. The steel sheet piling for the guidewalls is exhibiting corrosion at the waterline and the bolts for the wale beams are heavily corroded. The guidewall timber bumpers and steel tangent plates are missing or damaged from constant barge impact. Additionally, the existing design of the guidewall is not resilient to barge impact, requiring repairs to the guidewall for most barge impacts. The existing plumbing system (water and septic) and emergency generator/fuel systems are significantly deteriorated with no dependable backup power. The existing electrical power cables within the chamber crossovers are extremely deteriorated. The existing paint system has been ineffective preventing marine growth (particularly gulf oysters) on the structure. This growth has been substantial and adds significant weight causing damage to the hinges/machinery. Also, the gates have been binding during operation; this is speculated to be caused by the movement of the non-pile founded 2 feet thick slabs. The lock buildings continue to deteriorate with missing roof shingles, asbestos siding, leaking windows and doors, inadequate lighting, no GFI receptacles required by NEC, and panel boards that have deteriorated to the point of exposed wiring.

However, the most eminent of concerns is the ongoing high river silt deposits that form on the east and west side of the Brazos. These shoals are developing in the area required for vessel entry. In past years, barges have unexpectedly grounded on these shoals and dredging was required to maintain an open path to the gates.

1.2.2 COLORADO RIVER CROSSING

The Colorado River flows into West Matagorda Bay, crossing the GIWW near Matagorda, TX. Two 1,200 foot by 75 foot locks, one on each side of the Colorado River crossing of the GIWW, are provided to control flood flows from the Colorado River to the GIWW, improve navigation safety by controlling traffic flow and currents at the intersection of the Colorado River's connection with the GIWW and to control sand and silt deposition from the Colorado River into the GIWW. The authorized channel in the GIWW is 125 feet wide and is typically about 12 feet deep. The original course of the Colorado River southward of the GIWW was south-southwesterly through the Matagorda Peninsula into the Gulf of Mexico. In the early 1990s, a diversion channel was dredged from the intersection of the Colorado River and GIWW southwesterly to West Matagorda Bay. Diversion of flow into Matagorda Bay was performed to route the heavy sediment load into the bay to create shallow wetlands for environmental improvements of biologic productivity. When the original floodgates for the lock were built in 1943, barges were typically 26 feet to 35 feet wide. The lock chamber is 75 feet wide, and the maximum width of the barge it can accommodate is 55 feet. Today, it is common for towboat operators to push two 35 feet dry cargo barges side by side, for a total width of 70 feet. A typical tank barge measures 54 feet across, so tank barges must transit singly. The necessity to break the tow to pass individual barges through the locks causes time delays.

USACE restrictions are placed on the size of a tow that can cross the Colorado River when current speed in the river immediately upstream of the intersection exceeds 2.0 mph or 3.0 fps (Table 2). Long periods of high flow through the Colorado River that require "tripping" place a serious economic impact on operation of tows through the reach.

Condition	River Velocity	Restriction
1	2 mph (3.0 fps) or higher	• Single vessel passage • Tows with one loaded barge or two empty barges
2	Over 7 mph	• Closed

Table 2 Existing Navigation Restrictions – Colorado River Crossing

The original Colorado River Floodgates were constructed in September 1943 with the conversion to locks in 1954.The locks are 75 feet wide with sills at El. -17.0 MLLW (NAD88: El. -15.2) and a top of monolith at El. 20.0 MLLW (17.8 top of wall). The locks are quite atypical compared to modern standards.

Currently, the project has multiple documented maintenance/operational issues outlined in the 2017 Operational Condition Assessment (OCA). There are 5 feet deep scour holes along the tie-back sheet pile guide walls on both the East and West locks, exceeding the design elevations of the guidewalls. There are up to 15 feet deep scour holes along the steel sheet pile guide walls and concrete gravity walls on the West and East gates which extend towards the middle of the channel. Wall timbers are missing or damaged. Additionally, the existing design of the guidewall is not resilient to barge impact, requiring repairs to the guidewall for most barge impacts. The existing plumbing system (water and septic) and emergency generator/fuel systems are significantly deteriorated. The existing gate controls, switchgears and transformers are very old and show signs of significant deterioration. The controls houses are in poor condition and do not meet modern codes. The existing electrical conduit running underneath the lock structure is damaged and has rendered the West gates inoperable. The existing paint system has been ineffective preventing marine growth (particularly gulf oysters) on the structure. This growth has been substantial and adds significant weight causing damage to the hinges/machinery.

1.2.3 GIWW DREDGING

Currently, the GIWW in the vicinity of the river crossings is dredged on a 2 year cycle. There is a finite amount of adjacent disposal area capacity remaining as no new disposal areas are currently identified. Future disposal may need to shift to the considerably more expensive offshore disposal option if additional disposal areas are not identified. Refer to Paragraph 3.2 for assumptions made to develop the project dredging disposal cost estimate for the selection of the TSP. Refer to Paragraph 4.4 and **Appendix 9, O&M DMMP – Comparison and Review for Beneficial Use** for the final project dredging disposal plan.

1.3 DESCRIPTION OF ALTERNATIVES

The following are the alternatives that were investigated past the AMM.

1.3.1 BRAZOS RIVER CROSSING ALTERNATIVES

1.3.1.1 Alternative 2A – Major Rehabilitation of Existing Structure

Key Features	• Remove, repair, sand blast, paint, and reinstall Sector Gates • Raise gate operating machinery and control house to avoid flooding • Add alignment dolphins • Rehabilitate and modify existing sheet pile guidewalls to better handle impacts

This alternative consists of a refurbishment of the existing 75 foot flood gate complex on both sides of the river. Some of the issues that cause delays and shutdowns of the existing gate structures include vessel impact damage to the existing anchored sheet pile guide walls, a low machinery pit elevation that makes equipment susceptible to flooding, and the accumulation of large amounts of crustacean life on the steel gate members which add a substantial amount of operating weight burden to the machinery. The rehabilitation focuses on addressing these items. The rehabilitation would be conducted without a navigation bypass. Rehabilitation efforts would be coordinated to minimize disruption to navigation. A composite panel system called UHMW (Ultra High Molecular Weight Polyethylene) backed by steel plating is proposed to be installed on the river side of the anchored sheet pile guide walls. These panels have a dampening effect from the vessel impacts and can be changed out by panel instead of a full sheet pile replacement, minimizing delays to navigation from allisions and subsequent lengthy repairs. The GIWW guide wall approach side does not experience the same frequency and magnitude of allisions as the river side guidewalls; therefore, they will were not included in the rehabilitation alternative. The Brazos River Floodgates are minimally higher than the mean high water elevation of the Brazos River, resulting in frequent flooding of the machinery pits as they are below the top of the skin plate on the river side. This causes additional shutdown and delays to navigation. This alternative proposes to relocate the machinery in the pit to a higher elevation (minimum 4 feet) and raise the operator buildings. A raised new foundation floor slab is required. The gates will be modified to accept the machinery drive at the higher elevation. Electrical work would consist of new power and controls for the machinery. The sector gates would be rehabilitated including replacement of damaged steel members such as on the fender rack and skin plate and repainting the gates with coal tar epoxy or similar upgraded coating system capable of reducing crustacean growth. The improved sector gates with upgraded coating system may reduce delays to navigation from gate shutdown and maintenance. Finally, a dolphin alignment structure on the river side would be provided to assist navigation and reduce impact to the guidewall structure. Reduced impacts as a result of the dolphin structure were not quantified because ship simulation was not performed to quantify the accident reduction.

1.3.1.2 Alternative 3A – Move Gates Farther Back in Existing Channel With New 125’ Gates on East and West Sides

Key Features	• Demolish existing gate structures • Construct new 125’ wide gate structures set back further from river • Construct new guidewalls • Construct new and improved dewatering system

This alternative consists of construction of new 125 foot flood gates along the existing alignment, set back approximately 1300 feet from the river from the existing gate structure (See Figure 2). This setback allows the full length of a tow protection from the river’s cross currents enabling an easier, more efficient and safer approach. This increased length of fore bay is estimated to provide an overall safer transit and potentially fully eliminate allisions. The first phase of the construction of the alternative would be the creation of a temporary by-pass channel to run along the south side of the existing channel routing traffic around both existing flood gates and new flood gate locations. The temporary by-pass channel would be constructed to the authorized channel width of 125 feet and was assumed to not change delays or safety risks when compared to the existing river crossing. Excavation material was assumed to be disposed in adjacent placement areas along the GIWW. Demolition of the existing flood gates is required. This will include removal of sector gates, vertical masonry walls, buildings, and anchored sheet pile guide walls. The existing base slab is to remain in place. Once the guide walls are removed, the remaining fill is to be excavated and sloped to accommodate a new 125 foot channel to pass through the site. The channel is also to be excavated for a new pile founded base slab with a sill elevation of EL. -16.0. The new wall and gate height is to match that of the Colorado Locks, approximately EL 16.0. The foundation slab is estimated to be 9 foot thick and the walls have an estimated 6 foot thickness. The sector gate layout has an upper, center, and lower frame with two outside trusses and one in the middle. The new sector gates are to have new control houses that house hydraulic power unit, panels, control hub, and personnel. The drive system is a Hagglund or Eaton motor splined into a gear rack along the skin plate of the gate. A dewatering system that allows for unwatering of the gate bays to service the gates while keeping the channel open through the structure for navigation would be provided. In order to construct the sector gate in the existing channel, a full Temporary Retaining Structure (TRS) is required. This is likely to be a rectangular sheet pile enclosure with upper and lower whales braced with interior struts. A connection of the main structure to dry land on the channel edges is to be accomplished with a build out of embankment and use of a retaining wall similar to the existing configuration. Other features are to include a guide wall with impact dolphins, a storage platform for dewatering materials, and placement of 3 foot thick rip rap adjacent to the structures for erosion control. Operator buildings are located in the vicinity of the bank area to house maintenance equipment. After completion of the new structures, the temporary bypass channel will be filled in as necessary to prevent flow, with the remaining excavated channel turned into a barge mooring/storage channel after construction.

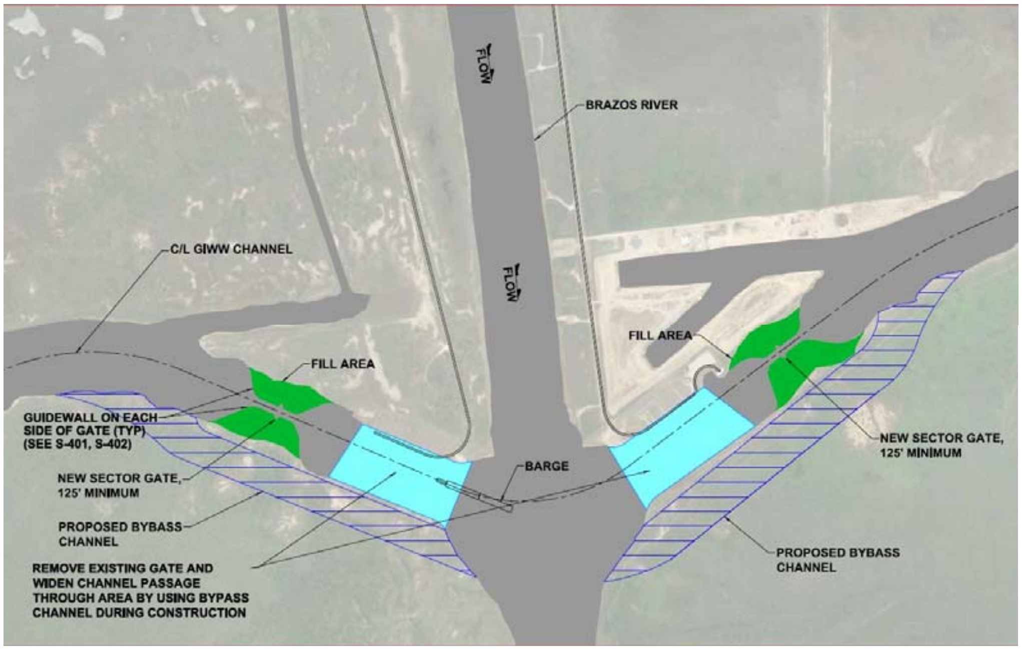


Figure 2 Brazos River Crossing – Alt 3a

1.3.1.3 Alternative 3A.1 – Remove Existing Gates, Open Channel West Side and New 125’ Gate Further Back in GIWW on East Side

Key Features	• Demolish existing gate structures • Construct new 125’ opening gate structures set back further from river on the east side • Construct new guidewalls • Construct new and improved dewatering system • No structure, full open channel on the west side

This alternative consists of construction of a new 125 foot flood gates along the existing alignment, set back approximately 1300 feet from the river from the existing gate structure on the east side, and a minimum 125 foot open channel on the west side of the river crossing (See Figure 3). The increased fore bay is to assist with an overall more safe and efficient vessel operation through the system, reducing allisions. The open channel will have a bottom depth of -12 ft NAVD88 and a bank-to-bank width of approximately 500 feet. The first phase of the construction of the alternative would be the creation of a temporary by-pass channel to run along the south side of the existing channel routing traffic around both existing flood gates and new flood gate locations. The temporary by-pass channel would be constructed to the authorized channel width of 125 feet and would not be expected to increase any delays or safety risks from the existing structures. Demolition of the existing flood gates is required. This will include removal of sector gates, vertical masonry walls, buildings, and anchored sheet pile guide walls. The existing base slab is to remain in place. Once the guide walls are removed, the remaining fill is to be excavated and sloped to accommodate a new 125 foot channel to pass through the site. Sector gate design and features for the new 125 foot gate on the east side will be the same as described for Alternative 3a above.

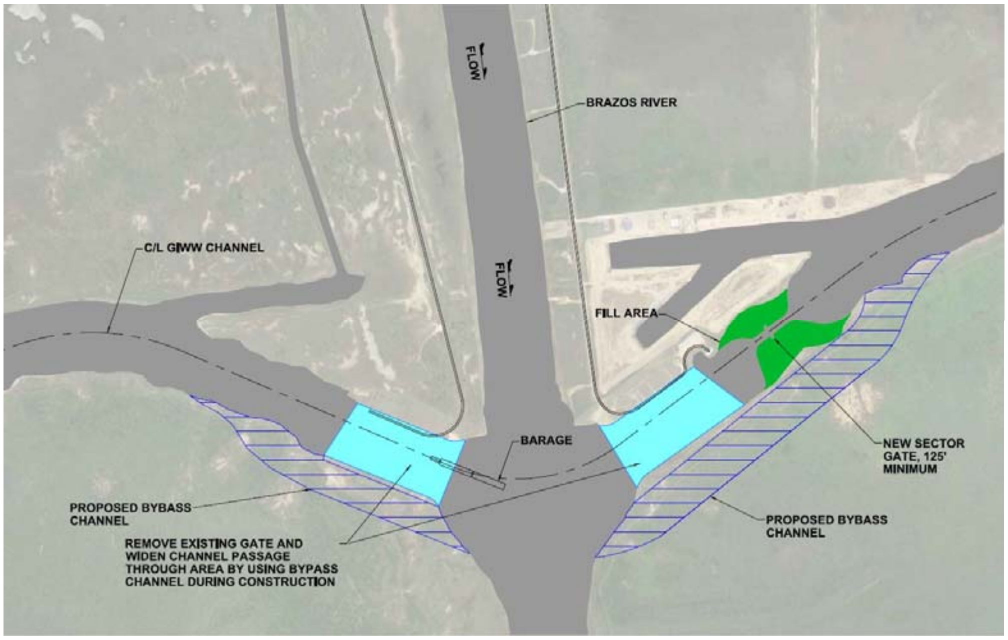


Figure 3 Brazos River Crossing – Alt 3a.1

1.3.1.4 Alternative 9a – Open Channel on Straight Alignment North of Existing Gates

Key Features	• Demolish existing gate structures • Open channel on new alignment north of Texas Boat and Barge facility

This alternative consists of a new authorized 125 foot wide open channel alignment placed on an optimized straight line across the Brazos River north of the existing channel where the gates are currently located (See Figure 4). This allows navigation to pass through the existing alignment while the new open channel is under construction. The open channel will have a bottom depth of -12 ft NAVD88 and a bank-to-bank width of approximately 500 feet. A temporary by-pass channel is not required. Construction in the new alignment requires the relocation of one business and the roadway that provides access to existing flood gates. Once the new channel is established, demolition operations are to begin on the existing flood gates. Demolition includes the removal of sector gates, vertical masonry walls, buildings, and anchored sheet pile guide walls. The existing base slabs are to remain in place. Once structure removal is complete, the existing channel can be closed off.

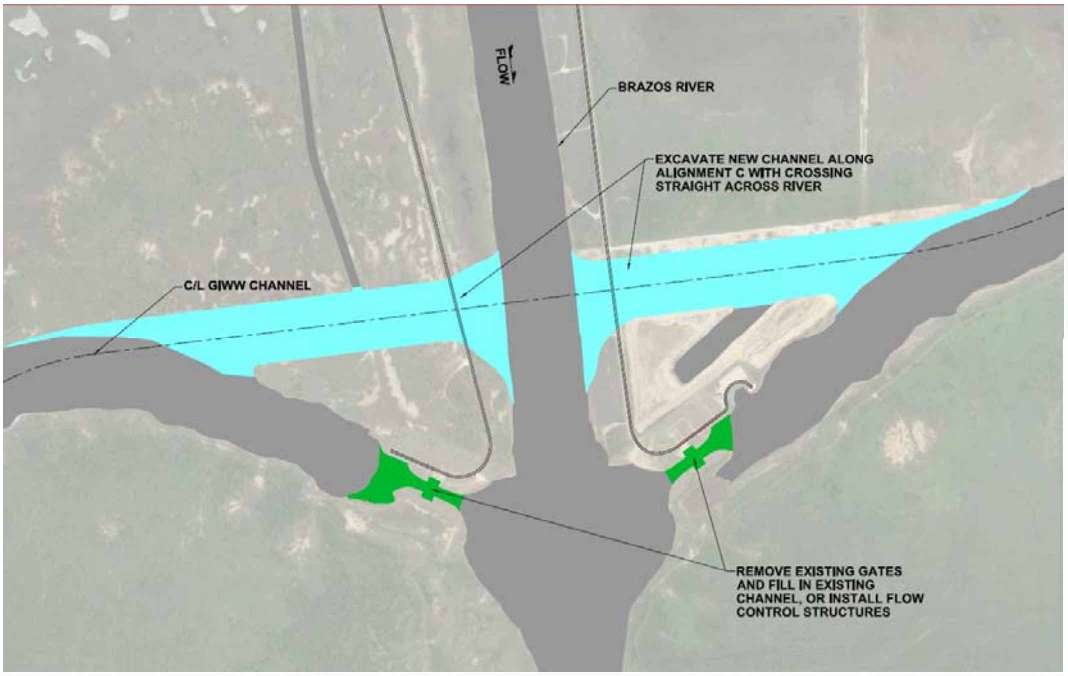


Figure 4 Brazos River Crossing – Alt 9a

1.3.1.5 Alternative 9b – New 125’ Gates on Straight Alignment North of Existing Gates

Key Features	- Demolish existing gate structures - Construct new 125’ opening gate structures on new alignment north of Texas Boat and Barge facility - Construct new guidewalls - Construct new and improved dewatering system

This alternative consists of construction of new 125 foot flood gates placed in an optimized straight line channel alignment across the Brazos River north of the existing channel where the gates are currently located (See Figure 5). This allows navigation to pass through the existing alignment while the new channel and gates are under construction. A temporary by-pass channel is not required. Construction in the new alignment requires the relocation of one business and the roadway that provides access to existing flood gates. Once the new channel and flood gates are installed, demolition operations are to begin on the existing flood gates. Demolition includes the removal of sector gates, vertical masonry walls, buildings, and anchored sheet pile guide walls. The existing base slabs are to remain in place. Once structure removal is complete, the existing channel can be closed off. Sector gate design and features for the new 125 foot gate on the east side will be the same as described for Alternative 3a above. Additionally, a connection of the main structure to dry land on the channel edges is to be accomplished with a build out of embankment and use of a retaining wall similar to the existing configuration.

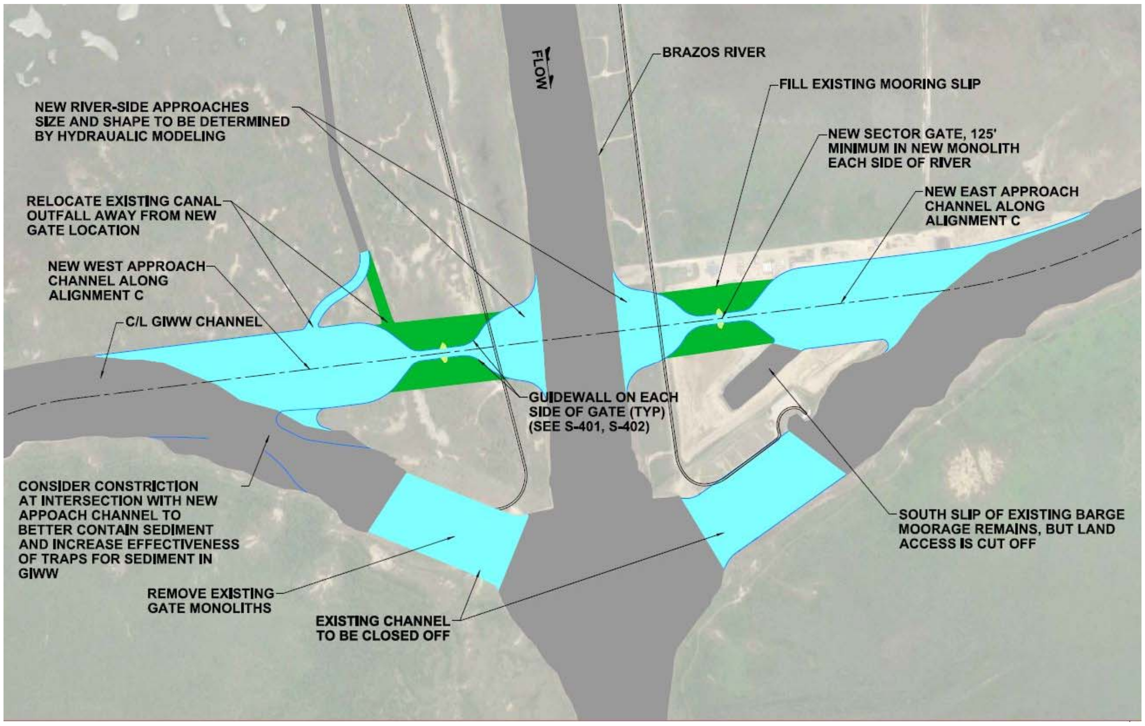


Figure 5 Brazos River Crossing – Alt 9b

1.3.1.6 Alternative 9c – New 125' Gates on Straight Alignment North of Existing Gates With Flow Control Structure

	• Demolish existing gate structures • Construct new 125' opening gate structures on new alignment north of Texas Boat and Barge facility

Key Features	• Construct new guidewalls • Construct new and improved dewatering system • An addition of a flow control structure on the west side existing alignment

This alternative incorporates all the features of work describe in Alternative 9b with the addition of a flow control structure in the existing west side channel on the river side of flood gate foundation (See Figure 6). The purpose of this flow control structure is to regulate input into the GIWW coming from the San Bernard River. The structure is to be located to the river side of the existing flood gate foundation. It consists of a sluice gate structure including a pile foundation, base slab, inlet walls/towers, 3 vertical sluice gates, Rodney hunt type lifting system, dewatering bulkheads, scour control riprap, and a tie-in to land by either floodwall or embankment. The base slab is 7 foot thick and 50 foot wide. The pier wall thickness is 3 feet. The wall height is approximately 31 feet. The sluice gate is approximately 16 foot high. The layer or riprap is 3 foot thick. The bulkheads consist of a skin plate with horizontal support members and vertical stiffeners.

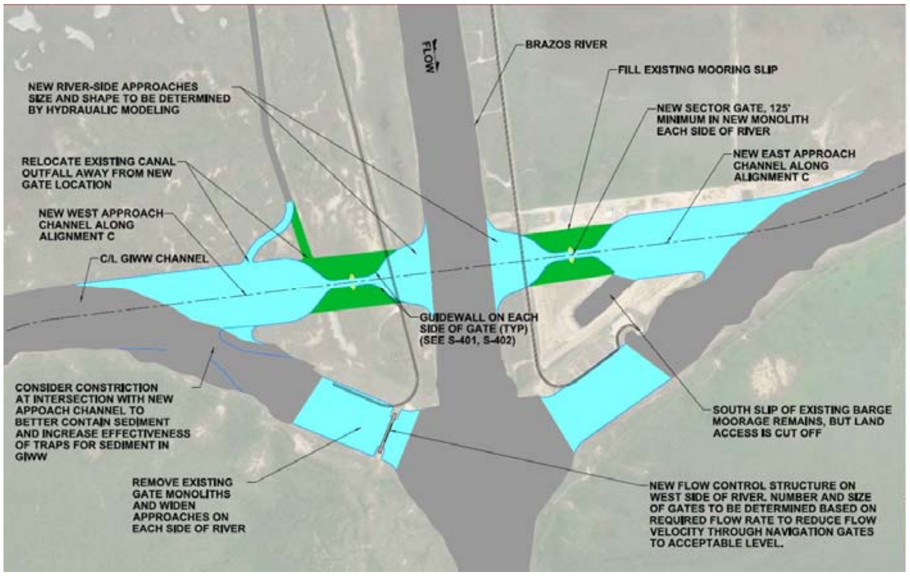


Figure 6 Brazos River Crossing – Alt 9c

1.3.2 COLORADO RIVER ALTERNATIVES

1.3.2.1 Alternative 2B – Major Rehabilitation of Existing Lock

Key Features	• Remove, repair, sand blast, paint, and reinstall Sector Gates • Replace and update machinery

	• Rehabilitate and modify existing sheet pile guidewalls to better handle impacts • Installing new machinery houses

This alternative consists of a refurbishment of the existing 75 foot lock complex on both sides of the river. Some of the issues that cause delays and shutdowns of the existing lock structures include vessel impact damage to the existing anchored sheet pile guide walls, outdated machinery, and the accumulation of large amounts of crustacean life on the steel gate members which add a substantial amount of operating weight burden to the machinery. The rehabilitation focuses on addressing these items. The rehabilitation would be conducted without a navigation bypass. Rehabilitation efforts would be coordinated to minimize disruption to navigation. A composite panel system called UHMW (Ultra High Molecular Weight Polyethylene) backed by steel plating is proposed to be installed on the river side of the anchored sheet pile guide walls. These panels have a dampening effect from the vessel impacts and can be changed out by panel instead of a full sheet pile replacement, minimizing delays to navigation from allisions and subsequent lengthy repairs. The GIWW guide wall approach side does not experience the same frequency and magnitude of allisions as the river side guidewalls; therefore, they will were not included in the rehabilitation alternative. The machinery is to be replaced with a new Hagglund or Eaton Motor/Hydraulic Power Unit (HPU) system. New machinery houses are to be constructed with slabs on grade to house the new HPU units. Hydraulic lines are run from the motor to HPU. The gates are to be modified with a gear rack to spline into the motor. Electrical work consist of new power and controls for the machinery. The sector gates would be rehabilitated including replacement of damaged steel members such as on the fender rack and skin plate and repainting the gates with coal tar epoxy or similar upgraded coating system capable of reducing crustacean growth. The improved sector gates with upgraded coating system may reduce delays to navigation from gate shutdown and maintenance.

1.3.2.2 Alternative 3B – Open Channel

Key Features	• Demolish existing locks • Construct new open channel through lock alignment

This alternative consists of the removal of both locks on either side of the river crossing and creation of a 125 foot wide open channel crossing in the existing alignment (See Figure

7). A temporary 125 foot by-pass channel would be provided to the south of the existing alignment while the existing locks were removed. This allows navigation to pass through the existing alignment while the new open channel is under construction. Demolition includes the removal of sector gates, vertical masonry walls, buildings, and anchored sheet pile guide walls. The existing base slabs are to remain in place. Once structure removal is complete, the bypass channel would be filled in as necessary to prevent flow with the original material that was stockpiled nearby.

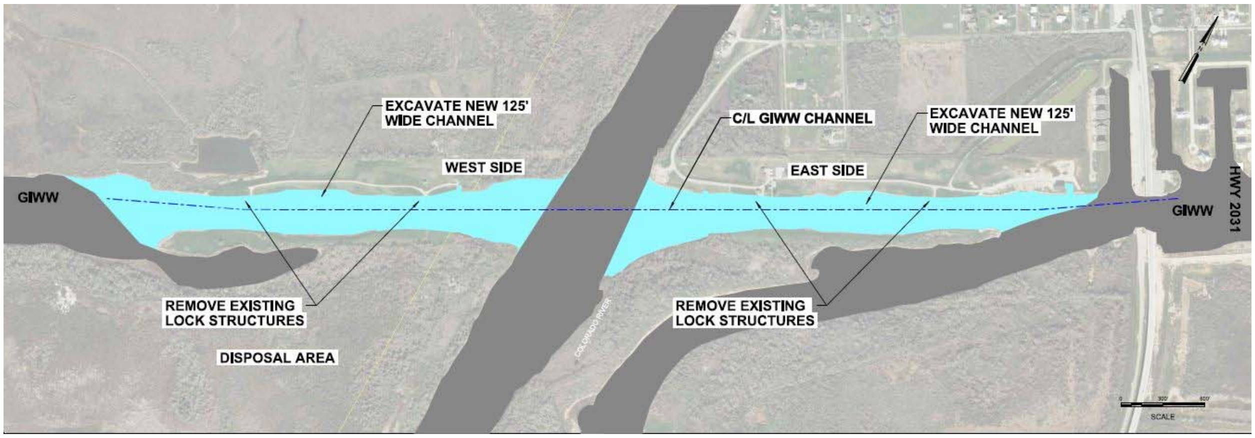


Figure 7 Colorado River Crossing – Alt 3b

1.3.2.3 Alternative 4b.1 – Riverside Gate Removal

Key Features	• Demolish lock gates closest to river • Construct 125 ft channel from original forebay to the remaining gates • Update remaining gate machinery • Install new machinery house, control house, and equipment buildings

This alternative consists of the removal of the existing river side sector gate structures (See Figure 8). The existing 75 foot lock complex on both sides of the river cause considerable delays in barge traffic due to the proximity of the river side gate structures to the river. Substantial benefits of decreased tripping delays and additional fore bay before the river crossing are realized with the removal of the river side gates on both sides. The removal would include the removal of the anchored sheet pile guide walls, vertical structure walls, sector gates, control houses, and equipment buildings. The land area behind the anchored sheet pile retaining walls would be excavated in order to accommodate a new 125 channel up to the remaining sector gate structure on the GIWW side of the lock. The interior guide wall in the lock chamber would also be removed. Because of the increased demand on the remaining GIWW side sector gate structures because of the reduction in delays, similar rehabilitation would be performed on the remaining sector gates as described in Alternative 2B above to accommodate the greater demand on the features to remain for this alternative. Additionally, this alternative reduces the redundancy of having 2 sets of gates to prevent sediment transport into the GIWW. In the current FWOP condition, if one sets of gates becomes inoperable, the other set of gates can still pass navigation traffic and prevent significant sediment transport into the GIWW, Rehabilitation of the remaining set of gates is necessary to maintain reliability to open and close when needed to limit sediment transport into the GIWW,

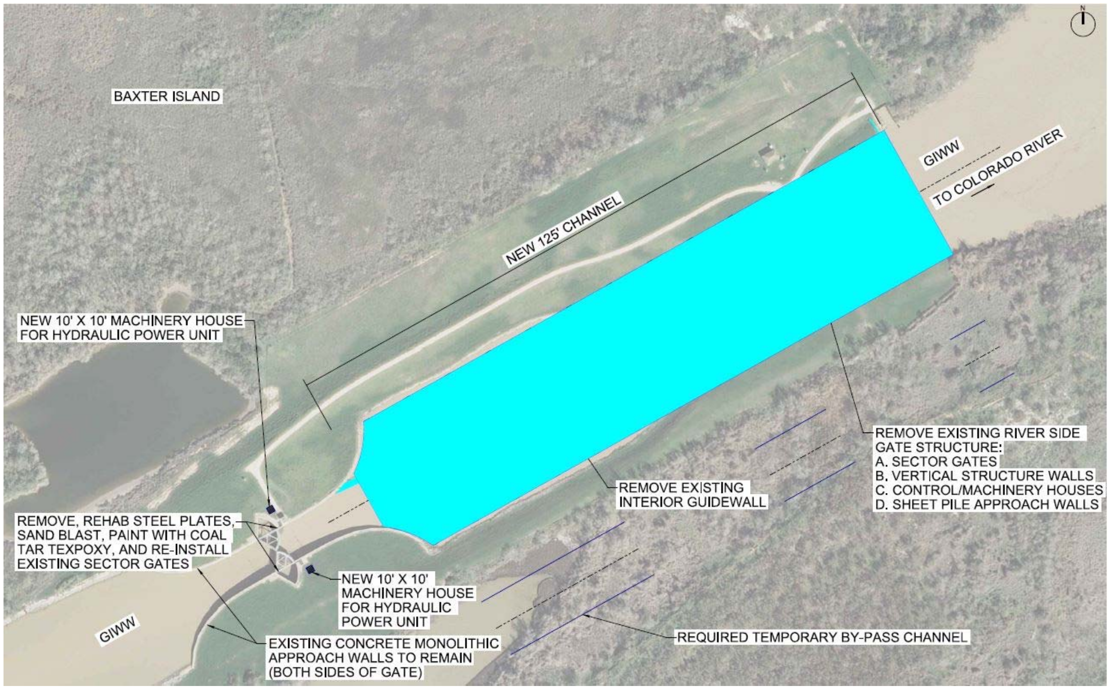


Figure 8 Colorado River Crossing – Alt 4b.1

1.4 SELECTED TSP ALTERNATIVES

Based on the economic analysis and cost estimates developed, the highest net benefits were found in Alternative 9a at Brazos and Alternative 4b.1 at Colorado. Potential risk and uncertainty of environmental, navigation, and system impacts led to the selection of Alternative 3a.1 at Brazos and Alternative 4b.1 at Colorado as the TSP.

1.5 REFINEMENTS POST PUBLIC REVIEW AND ADM MILESTONE

The Recommended Plan for navigation improvements for BRFG-CRL has to be responsive to local needs and desires as well as the economic and environmental criteria established by Federal and State law. Significant comments were raised during the public review period that resulted in additional analysis and refinement of the final plans. The comments concerned: 1) impacts to the San Bernard River; 2) navigation impacts at Port Freeport; 3) a narrow 75-foot gate opening at CRL; and 4) increased sedimentation due to temporary construction bypasses.

1.5.1 San Bernard River Impacts

Public comments indicated that a project was underway by local organizations for the dredged opening of the mouth of the San Bernard River. Hydraulic modeling conducted up to the TSP was performed for the existing condition with the San Bernard mouth closed due to siltation. Public comments focused on the negative effects that the open channel on the west side of the GIWW at the Brazos River would have on the mouth of the San Bernard River if plans to open the mouth were implemented. To address the aforementioned public comments, additional modeling was conducted. The existing AdH model was modified to include an open connection between the San Bernard River and the Gulf of Mexico. Qualitative comparisons were made to analyze the general impact of the proposed TSP on sedimentation within the GIWW and the inlet stability of the San Bernard mouth when compared to existing conditions.

When the San Bernard is open, the TSP showed an increase in sedimentation of approximately 9,700 cy/year in the San Bernard Gulf Channel when compared to existing conditions. Overall, model results show that opening the San Bernard mouth causes additional sedimentation in the West GIWW, approximately 134,800 cy/year for existing conditions, and 114,900 cy/year for BRFG alternative 3a.1. The inlet stability analysis indicated that the San Bernard has poor stability during existing conditions as well as for the proposed TSP. Any changes in the inlet stability due to the proposed TSP are expected to be minor, and do not change the stability regime of the San Bernard Inlet. Detailed information on the modeling performed is available in the **Appendix 1 Hydraulic Engineering Appendix – Brazos River Floodgates.**

1.5.2 Port Freeport Impacts

Another major concerned raised during the public review period dealt with the velocity impacts of the proposed TSP on velocities at the crossing of the Freeport Channel at the GIWW. Affected industries along Port Freeport questioned whether the increase from a 75-foot gate opening to a 125-foot gate opening would cause velocities at the crossing that would require additional tug assistance when the 125-foot gate was opened. Velocity data was extracted at the GIWW crossing at the Freeport Channel and along various points along the Freeport Channel. The velocity data indicated minimal changes in velocity for the recommended plan with a 125-foot wide gate at the east side of the Brazos River crossing. Detailed information on the velocity data extracted from the AdH model and analyzed is available in the **Appendix 1 Hydraulic Engineering Appendix – Brazos River Floodgates.** In addition to the concerns over the 125-foot wide gate, Port Freeport users also expressed concerns over sedimentation and current flows due to the temporary bypass channel proposed as part of the TSP. These concerns led to a refinement of the TSP.

1.5.3 Brazos River TSP (3a.1) Refinements

In response to comments received during public review and subsequent meetings held with Industry, the team refined the BRFG TSP (3a.1) (**Figure 9**) to address those concerns. By offsetting the channel alignment to the south, dredging of a new bypass channel during the construction period is eliminated. Thus, the concerns cited by Port Freeport during the public review period about additional sedimentation and current flows to their harbor during the 2-year construction period are fully addressed. The existing floodgates on the east and west side of the Brazos River would remain fully operational during the two-year construction period. At the end of the construction period, the plug at the edge of the river would be excavate on both the east and west sides. Note that the north edge of the plug excavation is shaved to be more perpendicular to the river for improved navigation safety. Then the navigation traffic is transferred to the new alignment and the new floodgate. Once the new alignment and floodgate become operational, the old floodgate facilities on the east and west side of the river would be decommissioned and left in place. The existing south guidewalls and south monoliths for the existing floodgates are to be removed for additional navigation clearance. An additional refinement was the elimination of the build out of embankment to the water’s edge using tie-back retaining walls similar to the existing configuration. Instead, timber guidewalls with end cells will be provided to facilitate safe navigation through the structure. The embankment will be built out to the land side edge of the sector gate monolith and sloped to match existing grades.

This refinement saves a significant amount on construction costs: 1) eliminating demolition costs (leaving existing floodgate facilities in place); 2) eliminating bypass channel excavation; and 3) savings on road and utility infrastructure costs.

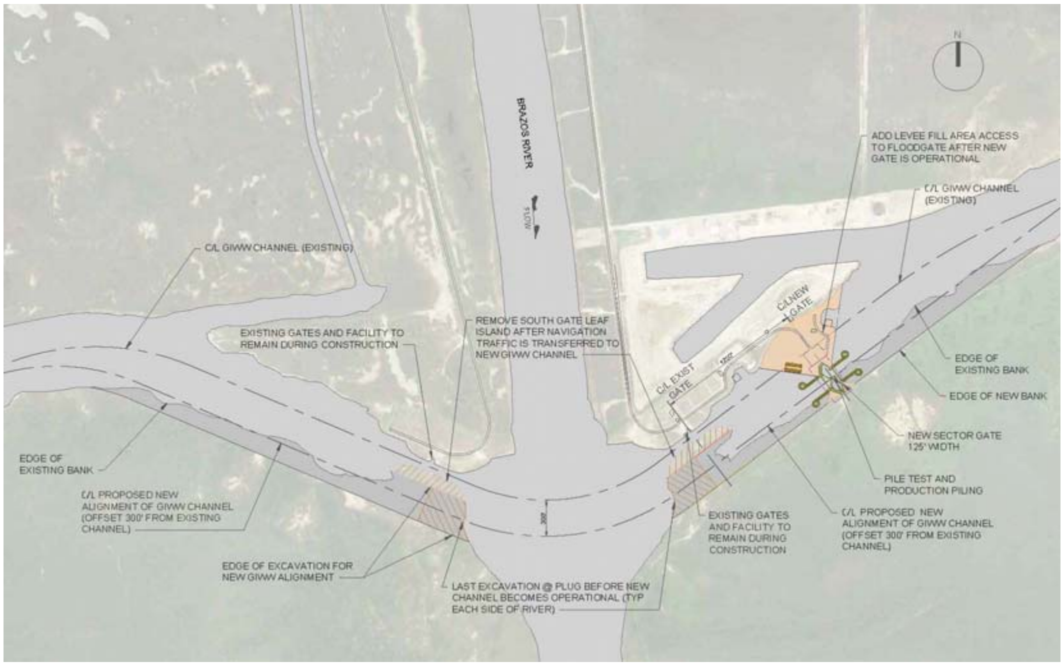


Figure 9 Brazos River TSP Refinements

1.5.4 Colorado River TSP (4b.1) Refinements

During the public review period, industry raised concerns over the potential bottleneck that the 75-foot gate proposed in the TSP would be along the Texas GIWW. Industry comments pointed out that the CRL gate structure would be the only 75-foot constriction along the Texas GIWW. Additionally, the conversion from locks to floodgates as proposed would eliminate the ability to lock in high river velocity conditions, causing additional delays. Industry representatives and lock personnel also noted degradation of the Colorado River outlet, which has resulted in increased differential heads between the GIWW and Colorado River for lower river velocities. While additional survey data was not available to validate the degradation of the river outlet in Matagorda Bay, measured velocities and stages corroborate a degradation in the outlet is occurring, which would result in additional delays not accounted for in the original assessment of the TSP. Detailed information on the analysis performed on the outlet degradation is available in the **Appendix 2 Hydraulic Engineering Appendix – Colorado River Locks.** In response to the aforementioned concerns, the team refined the CRL TSP (4b.1) to address those concerns (**Figure 10**). Instead of rehab of the existing 75-foot sector gate, a new 125-foot gate would be constructed on both the east and west sides of the river crossing. The new gate structures would be offset to an alignment to the south, eliminating the need for a new bypass channel during the construction period, resulting in significant savings in maintenance dredging of the GIWW during construction. The wider 125-foot sector gates result in a significant reduction in velocity through the gate structures. Discussions with navigation industry representatives indicated that velocities through the gate opening would dictate navigability through the gate structure and that vessels can operate through a 5mph current in typical conditions. Modeling indicates that the 5mph would be exceeded 6% of the time, potentially resulting in shutdown of the gate structure. While the 125' gate structure may result in total shutdown of navigation more than the existing lock structure, daily required lockages during tidal events for the 75' lock structure would be eliminated. The reduction in accidents and lockages associated with the wider 125' gate structures result in net benefits over the life of the project. The assumed navigation restrictions developed as a result of industry input will be validated during PED through the use of Ship Simulation modeling. The existing locks on the east and west side of the Colorado River would remain fully operational during the two-year construction period. At the end of the construction period, final dredging would be performed to complete the new alignment. Then the navigation traffic is transferred to the new alignment and the new floodgates. Once the new alignment and floodgates become operational, the old lock facilities on the east and west side of the river would be decommissioned and left in place. The existing south guide walls and south monolith for the existing east GIWW floodgate are to be removed for additional navigation clearance.

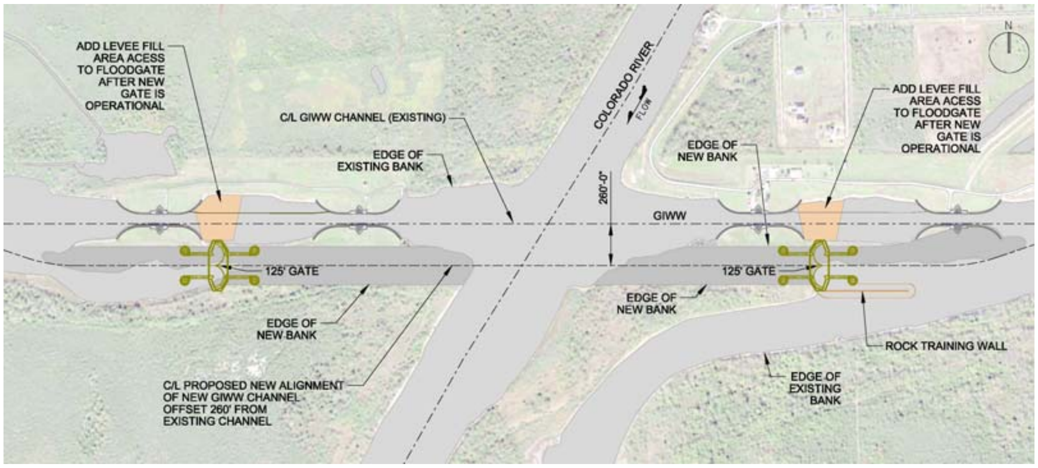


Figure 10 Colorado River TSP Refinements

1.6 RECOMMENDED PLAN

The Recommended Plan for the BRFG-CRL System is alternative (3a.1) for BRFG and alternative (4b.1) for CRL. The BRFG component of the Recommended Plan consists of constructing a new 125-foot sector gate structure approximately 300-feet south of the existing alignment, set back approximately 1,200 feet from the river on the east side, and a minimum 125-foot open channel on the west side of the river crossing. The CRL component of the Recommended Plan consist of constructing new 125-foot sector gate structures approximately 260-feet south of the existing alignment, set approximately mid-way between the existing lock gates.

1.6.1 Brazos River Floodgates

At BRFG, the main features of the Recommended Plan are the removal of the existing gates on both sides of the river crossing, the construction of a 125-foot wide open channel on the west side and a new 125-foot wide sector gate structure on the east side. The open channel would have a bottom depth of -12 feet NAVD88 with a bank-to-bank width of approximately 500 feet. The new sector gate on the east side would be set back approximately 1,200 feet from the existing gate structure, providing increased safety and efficient vessel operation through the system, reducing allisions. The gate would be constructed to a top elevation (El.) of 16-feet NAVD88 with a sill at El. -16 feet NAVD88. The gate machinery will consist of a hydraulically powered rack and pinion system. Riprap will be provided 250 ft outward from either side of the sector gate structure to protect against scour due to flow velocity through the structure along with prop wash from vessels transiting along the GIWW. Timber guidewalls will be provided at all four corners of the sector gate structure to facilitate safe navigation through the structures. Sheet pile dolphin cellular structures will be provided at the end of the timber guidewalls to guard against head-on collisions from oncoming tows. New control houses, an administrative office building, a generator building, a warehouse and a boat house will be constructed to support the maintenance and operation of the new gate structure. A steel needle girder and needle system will be fabricated to permit dewatering of the gatebay structure to perform maintenance. A pile founded concrete storage platform will be constructed on the north side of the gate structure for storage of the needle girder dewatering system. During PED, the needle girder system will be designed to dewater both the entire gate structure and individual gatebays, allowing passage of tows when work is not ongoing within the dewatered gatebay. Finally, embankment will be constructed to El 12.0 from the existing northern bank to the structure to permit an area to perform maintenance on the gate structure. An elevated roadway and parking structure will be constructed to El 16.0.

The construction of the open channel and new sector gate would take approximately two years to complete, assuming an adequate funding stream. Assuming one contract, construction would be sequenced as follows:

- An access channel would be dredged on the GIWW side of the east gate structure to permit floating plant access for construction of the structure. Advanced dredging of the new west channel would be performed with the exception of a small plug on the river side of the new channel. Disposal of excavated material from the bypass would be placed in the adjacent placement areas. Suitable material would be re-used for backfill for the new 125-foot sector gates.

- Once dredging for floating access is completed, the production piling for the gate structure would be driven in the wet. Foundation pilings would consist of approximately 246 steel pipe piles measuring 30-inch in diameter and driven to a depth of 125 feet below grade.

- The internally braced cofferdam would then be constructed and the gate structure completed. Concrete pours for the sector gate monolith would occur first. Machinery, electrical, and mechanical connections would all be installed after completion of concrete placement. Concurrent with the construction of the gate structure, portions of the guidewalls and end cells not within the footprint of the cofferdam could also be constructed. Construction of the new buildings on the reservation would also be constructed concurrently.

- The cofferdam would then be removed and the remaining ancillary features completed.

- The remaining portion of the new channel would be dredged and navigation transferred to the new structure.

- The existing gate structures would then be decommissioned and the southern half of both gate structures would be removed.

- The final grading and construction of the access levee would then be completed.

1.6.2 Colorado River Locks

At CRL, the main features of the TSP are the construction of new 125-foot sector gate structures on the east and west sides of the river crossing. The new sector gates would be set back approximately 1,000 feet from the river crossing. The gates would be constructed to a top El. Of 16-feet NAVD88 with a sill at EL. -16 feet NAVD88. The gate machinery will consist of a hydraulically powered rack and pinion system. Riprap will be provided 250 ft outward from either side of the sector gate structures to protect against scour due to flow velocity through the structure along with prop wash from vessels transiting along the GIWW. Due to the tidal effects of the old Colorado River mouth on the east side of the east Colorado gate, a training berm will be provided to minimize cross currents of vessels transiting through the gate structure. Timber guidewalls will be provided at all four corners of the sector gate structures to facilitate safe navigation through the structures. Sheet pile dolphin cellular structures will be provided at the end of the timber guidewalls to guard against head-on collisions from oncoming tows. New control houses, an administrative office building, a generator building, a warehouse and a boat house will be constructed to support the maintenance and operation of the new gate structure on the east side of the river crossing. The steel needle girder and needle system stored at the Brazos River be used for maintenance dewatering. During PED, the needle girder system will be designed to dewater both the entire gate structure and individual gatebays, allowing passage of tows when work is not ongoing within the dewatered gatebay. Finally, embankment will be constructed to El 12.0 from the existing northern bank to the gate structures to permit an area to perform maintenance on the gate structure. An elevated roadway and parking structure will be constructed to El 16.0.

The construction of the new sector gate structures would take approximately two years to complete, assuming an adequate funding stream. Assuming one contract, construction would be sequenced as follows:

- An access channel would be dredged on the GIWW side of each structure to permit floating plant access for construction of the structures. Disposal of excavated material from the bypass will be placed in the adjacent placement areas. Suitable material will be re-used for backfill for the new 125 foot sector gates.

- Once dredging for floating access is completed, the production piling for the gate structure would be driven in the wet. Foundation pilings would consist of approximately 246, 30 inch steel pipe piles, driven to a depth of 125 feet below grade on the east gate and 130 feet below grade on the west gate.

- The cofferdam would then be constructed and the gate structure completed. Concrete pours for the sector gate monolith would occur first. Machinery, electrical, and mechanical connections would all be installed after completion of concrete placement. Concurrently with the construction of the gate structure, portions of the guidewalls, end cells and rock training wall not within the footprint of the cofferdam could also be constructed. Construction of the new buildings on the lock reservation would also be constructed concurrently.

- The cofferdam would then be removed and the remaining ancillary features completed.

- The remaining portion of the new channel would be dredged and navigation transferred to the new structure.

- The existing lock would then be decommissioned and the southern end of the eastern GIWW sector gate would be removed.

- The final grading and construction of the access levee would then be completed.

2 CLIMATOLOGY, HYDROLOGY, HYDRAULICS, AND WATER QUALITY

2.1 BACKGROUND

The engineering team performed a numerical model study of hydrodynamics, including currents, salinity, and sediment changes, associated with the proposed alternatives aimed at improving navigation through the intersection of the Gulf Intracoastal Waterway (GIWW) and the Colorado River and the intersection of the GIWW with the Brazos River. One team, consisting of engineers from Mott Macdonald, was responsible for analysis of the Brazos River, while another team from the New Orleans District (MVN), were responsible for analysis of the Colorado River. The two teams worked closely together to ensure a consistent methodology was followed for both analyses. The purpose of the numerical model study was to evaluate the impacts to currents, water levels, sediment, and salinity associated with proposed alternatives aimed at improving navigations, as well evaluate the potential effects of climate and sea level change. The following chapter describes the various inputs and outputs of the numerical modeling. Further information concerning the hydraulic analysis can be found in the H&H Appendix.

2.2 AdH MODELING

2.2.1 General

Adaptive Hydrology/Hydraulics (AdH) is a modular, parallel, adaptive finite-element model for one-, two- and three-dimensional flow and transport. AdH is a module of the Department of Defense (DoD) Surface-Water Modeling System and Ground-Water Modeling System. AdH simulates groundwater flow, internal flow and open channel flow. The AdH model was developed in the Engineer Research and Development Center's Coastal and Hydraulics Laboratory and is a product of the System-Wide Water Resources Program. AdH was developed to address the environmental concerns of the DoD in estuaries, coastal regions, river basins, reservoirs and groundwater. The general features in AdH that benefit the modeler include:

•Adaptation: The user needs only to generate a general mesh to capture the geometry of the problem. AdH will automatically refine it to provide accurate solutions and more stable and less expensive simulations.

•Portability: AdH can run efficiently on a wide variety of platforms ranging from standard PCs to high-end supercomputers.

2.2.2 GIS and Field Data

GIS data needed for the development of the hydraulic models included bathymetric surveys, pre and post dredge contract bathymetric surveys, land cover surveys, aerial imagery, and levee alignment shapefiles. The channel bathymetry in the project area is highly dynamic due to dredging and floods that remove or deposit sediment. A comprehensive bathymetric survey of the area of interest, including both Colorado and Brazos Rivers and the GIWW was completed in March 2017, providing an estimate of the channel geometry that could be applied to the AdH model for existing conditions.

A large effort was made to collect and process all available gage data, including water levels, velocities, sediment concentrations, salinities, sediment properties. Gages in the area are operated by USACE, NOAA and USGS. All available gage data was downloaded and processed to assist in the assignment of model boundary conditions, and to help assist in the calibration and validation of the models. The gage data is absolutely imperative to ensure the quality and robustness of the hydraulic model results.

In March of 2017, sediment samples were taken at various locations of interest. The properties of the sediment, including the grain size distribution and bulk density, were applied to the AdH model. The sediment data was critical for the modelers to achieve a calibrated model.

2.2.3 Boundary/Initial Parameters

2.2.3.1 Discharge

For the Colorado River, a long term USGS gage near Bay City, TX provided discharges that were used as a boundary condition for the model.
For the Brazos River, a USGS gage near Rosharon, TX was used for boundary condition flows. A USGS gage at Boling, TX was also used for boundary condition flows for the San Bernard River.

2.2.3.2 Stage

A stage boundary condition was assigned at the gulf boundary. The stage hydrograph includes tides. The gulf boundary was assigned sufficiently far from the influence of the river.

2.2.3.3 Sediment

Sediment concentrations are measured by USGS. For the Colorado River, a sediment rating curve was developed based on measurements of sediment concentration and discharge. The rating curve was used to develop sediment concentration time-series that were applied at the river boundary. For the Brazos River, a sediment rating curve was developed for the San Bernard and Brazos River gages and applied at the respective river boundaries.

2.2.3.4 Wind

The offshore boundary was forced with verified tide levels, which include the effects of wind on water surface elevations at each respective project site. By using this methodology, relevant wind-driven processes, such as set-down from northerly winds, are accounted for in the model simulations.

2.2.3.5 Precipitation and Evaporation

Precipitation and evaporation were also assigned to the model based on measurements at local gages. At the BRFG project site, model calibration and investigation of historical data showed that local precipitation and evaporation processes were not controlling factors in model calibration, and therefore were not included in the model simulations. See **APPENDIX 1 - HYDRAULIC ENGINEERING APPENDIX – BRAZOS RIVER FLOODGATES** for further information on model setup.

2.2.3.6 Salinity

A constant salinity time-series of 33 parts per thousand was applied at the gulf boundary and a constant salinity of 0.01 was applied to all freshwater inflows. The initial salinity of the gulf was set to 33, and the initial salinity everywhere else was set to 20, based on observations.

2.2.3.7 Locks/Gates Operation

Locks were simulated using the breach card in AdH. This method effectively raises or lowers the bathymetry during the simulation using a user specified time-series. A time-series of gate operations was developed for the Brazos River floodgates and Colorado River locks.

2.2.3.8 Relative Sea Level Change

This document uses current USACE guidance to assess relative sea level change (RSLC). Current USACE guidance—ER 1100-2-8162, December 2013, and Engineer Technical Letter (ETL) 1100-2-1, June 2014—specifies the procedures for incorporating climate change and RSLC into planning studies and engineering design projects. Projects must consider alternatives that are formulated and evaluated for the entire range of possible future rates of RSLC for both existing and proposed projects. USACE guidance specifies evaluating alternatives using “low,” “intermediate,” and “high” rates of future sea level change.

- Low - Use the historic rate of local mean sea level change as the “low” rate. The guidance further states that historic rates of sea level change are best determined by local tide records (preferably with at least a 40-year data record).
- Intermediate - Estimate the “intermediate” rate of local mean sea level change using the modified NRC Curve I, which is corrected for the local rate of vertical land movement.
- High - Estimate the “high” rate of local mean sea level change using the modified NRC Curve III, which is also corrected for the local rate of vertical land movement.

USACE (ETL 1100-2-1, June 2014) recommends an expansive approach to considering and incorporating RSLC into civil works projects. It is important to understand the difference between the period of analysis (POA) and planning horizon. Initially, USACE projects are justified over a POA, typically 50 years. However, USACE projects can remain in service much longer than the POA. The climate for which the project was designed can change over the full lifetime of a project to the extent that stability, maintenance, and operations may be impacted, possibly with serious consequences, but also potentially with beneficial consequences. Given these factors, the project planning horizon (not to be confused with the economic POA) should be 100 years, consistent with ER 1110-2-8159. Current guidance considers both short- and long-term planning horizons and helps to better quantify RSLC.

2.2.3.8.1 Historical RSLC

Historical rates are taken from the Center for Operational Oceanographic Products and Services (CO-OPS) at NOAA, which has been measuring sea level for over 150 years. Changes in MSL have been computed using a minimum 30-year span of observations at each location. These measurements have been averaged by month to eliminate the effect of higher frequency phenomena such as storm surge, in order to compute an accurate linear sea-level trend.

The MSL trends presented are local relative trends as opposed to the global (eustatic) sea-level trend. Tide gauge measurements are made with respect to a local fixed reference level on land; therefore, if there is some long-term vertical land motion occurring at that location, the relative MSL trend measured there is a combination of the global sea-level rate and the local vertical land motion, also known as RSLC.

Historical rates of local RSLC can be obtained from local tide records. The tide gage with sea level trend information nearest to the Brazos and Colorado River systems, with over 40 years of record, is located at Freeport, TX (NOAA Gage 8772440). The NOAA MSL trend at this site is equal to 4.35 mm/yr (1.47 feet/century) with a 95 percent confidence interval of ± 1.12 mm/yr. NOAA has identified an apparent datum shift that occurred at this tide gauge about 1970. A 2013 NOAA report on estimating vertical land movement (subsidence) using long-term tide gage data estimates that the subsidence rate at the Freeport tide gage was -3.65 ± 0.41 mm/year between 1954 and 2006 (NOAA 2013). A vicinity map for NOAA Gage 8772440 is shown in **Figure 11.**

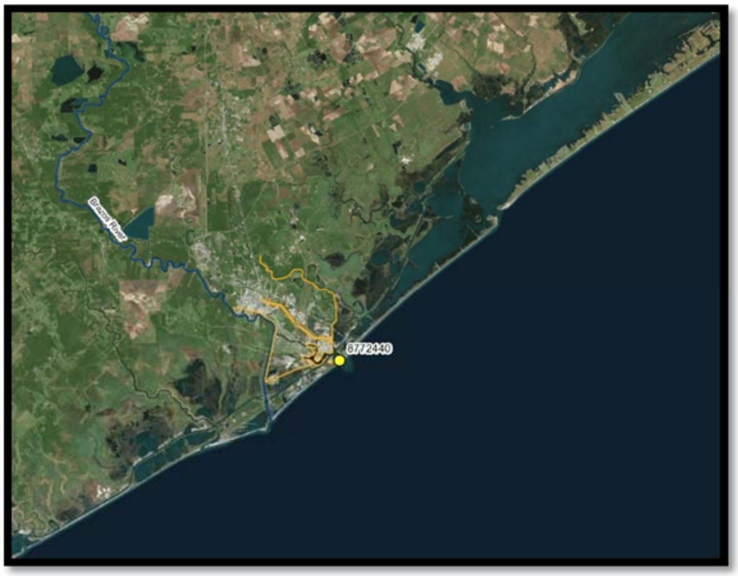


Figure 11 NOAA Gage 8772440 Vicinity Map

2.2.3.8.1 Predicted Future Rates of RSLC for 20-Year Period of Analysis

The computed rate of RSLC in this section gives the expected changes between the years 2025 and 2045 for the Brazos and Colorado River systems. RSLC values for this 20-year period are summarized in **Table 3** and plotted for in **Figure 12**.

Table 3 Estimated RSLC over the First 20 Years of the Project Life (2025-2045)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low	Intermediate	High
		(feet)		
Freeport, TX	4.35 mm/year	0.29	0.44	0.92

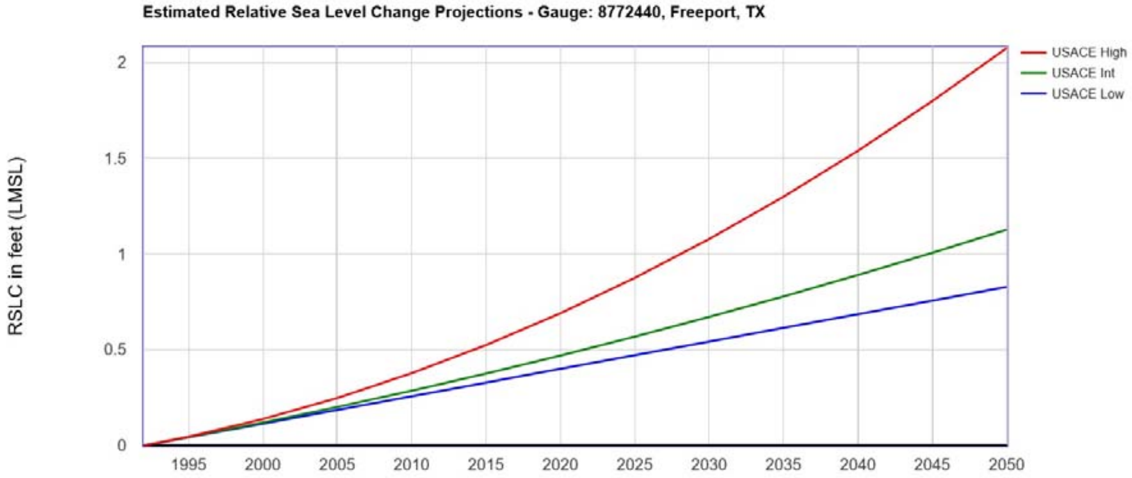


Figure 12 RSLC at Freeport, Texas over 20-Year Period of Analysis (2025 Base Year)

2.2.3.8.2 Predicted Future Rates of RSLC for 50-Year Period of Analysis

The computed rates of RSLC in this section give the expected change between the years 2025 and 2075 for the Brazos and Colorado River systems. **Table 4** summarizes the RSLC values for this 50-year period. **Figure 13** shows the computed sea level change for the Brazos River system based on the current USACE guidance for “low,” “intermediate,” and “high” rates of change.

Table 4 Estimated RSLC over the First 50 Years of the Project Life (2025-2075)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low	Intermediate	High
		(feet)		
Freeport, TX	4.35 mm/year	0.72	1.23	2.86

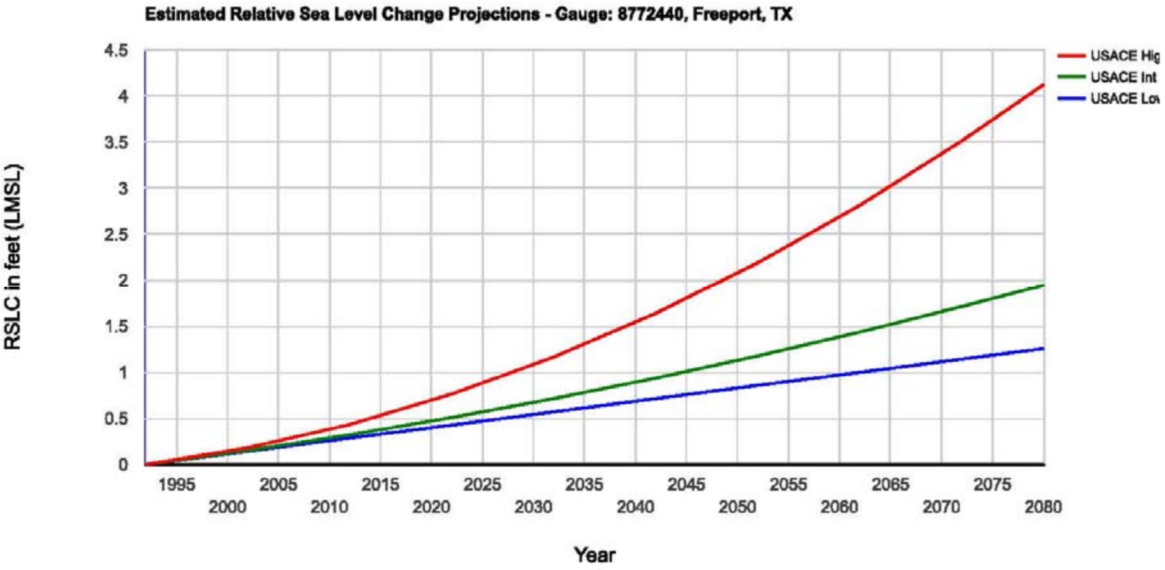


Figure 13 RSLC at Freeport, Texas over 50-Year Period of Analysis (2025 Base Year/2075 End of 50-Year Project Economic Life)

2.2.3.8.3 Predicted Future Rates of RSLC for 100-Year Period of Analysis

The planning, design, and construction of a large water resources infrastructure project can take decades. Though initially justified over a 50-year economic POA, USACE projects often remain in service much longer. The climate for which the project was designed can change over the full lifetime of the project to the extent that stability, maintenance, and operations may be affected. These changes can cause detrimental or beneficial consequences. Given these factors, the project planning horizon (not to be confused with the economic POA) should be 100 years, consistent with ETL-1110-2-1.

The period of economic analysis for USACE projects has generally been limited to 50 years because economic forecasts beyond that time frame were not considered reliable. However, the potential impacts of RSLC over a 100-year period can be used in the formulation of alternatives and for robustness and resiliency comparisons. ETL 1100-2-1 recommends that predictions of how the project or system might perform, as well as its ability to adapt beyond the typical 50-year economic analysis period, be considered in the decision-making process.

The computed rates of RSLC in this section give the expected change between the years 2025 and 2125 for the Brazos and Colorado River systems. **Table 5** summarizes the RSLC values for this 100-year period. **Figure 14** shows the computed sea level change for the

Brazos River system based on the current USACE guidance for “low,” “intermediate,” and “high” rates of change.

Table 5 Estimated RSLC over the First 100 Years of the Project Life (2025-2125)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low	Intermediate	High
		(feet)		
Freeport, TX	4.35 mm/year	1.43	2.9	7.58

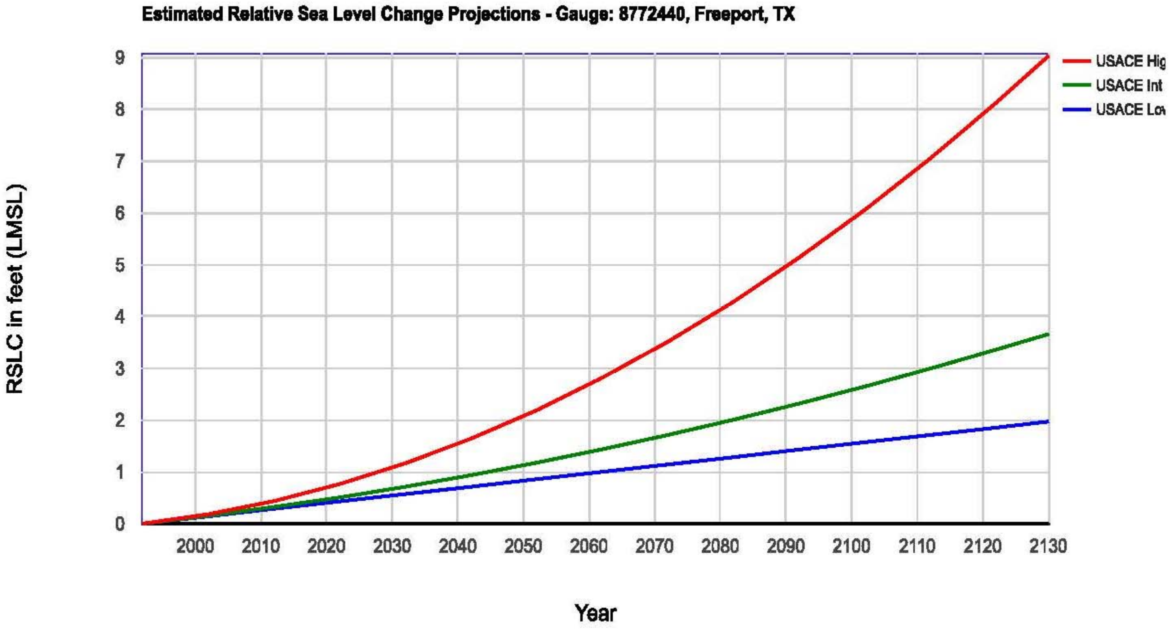


Figure 14 RSLC at Freeport, Texas over 100-Year Period of Analysis (2025 Base Year/2075 End of 50-Year Project Economic Life/2125 End of Project Planning Horizon)

2.2.3.8.4 Incorporation of RSLC into Modeling and Plan Formulation

Future conditions were modeled by adjusting the boundary conditions and re-running the AdH simulations for the alternatives. Given the uncertainty in projected sea level rise and subsidence, a range of relative sea-level change scenarios was quantitatively evaluated. For this project, 1.0ft and 2.0ft RSLC were evaluated. A 2.0ft RSLC from year 2020 is possible by year 2060 in the high scenario, or by year 2100 for the intermediate scenario, or well beyond 2125 for the low scenario. A RSLC higher than 2.0ft is possible, but that scenario was purposefully not evaluated in the hydraulic modeling for two reasons: First, at that level of inundation, the project would no longer function as designed, as the Gulf Intracoastal Waterway would be located seaward of the future coastline and would therefore cease to be "intracoastal." Modeling additional sea level change beyond this level will not inform selection among alternatives. Second, a higher RSLC amount was not evaluated due to limitations of the AdH model – with the entire model domain inundated, the model will not run stably or reliably. In theory the model could be extended to allow additional sea level elevations to be evaluated, but the cost of this extension was not justified by the limited additional knowledge it would yield. Furthermore, the future condition modeling is not able to capture many of the processes that will impact project area hydraulics over the long term, including marsh accretion, coastal erosion, dredging and other anthropogenic effects such as changes to the watershed. If modeling were conducted for higher RSLC amounts, the uncertainty around the results due to these processes would likely dwarf any conclusions drawn from the modeling. Therefore, 2.0ft was selected as the highest RSLC value for which the hydraulic model could provide reliable predictions.

Although not modeled in this study, a higher RSLC scenario would most likely be beneficial to navigation, as channel depths would increase and velocities at the crossings would slow. Sedimentation impacts are less clear but sedimentation could also be reduced as velocities upstream would provide less transport capacity to bring sediment to the project site. The estimated high rate of RSLC over the 100 year planning horizon could result in nearly 7.58 feet of RSLC. Shortly after the end of the 50-year economic life as RSLC approaches 3 feet, inundation maps suggest that additional outlets to the Gulf would develop due to inundation of low lying lands south of the GIWW. Towards the end of the 100-year planning horizon, nearly the entire GIWW would be open to the Gulf. Under these higher RSLC scenarios, structures would be more likely to be removed or bypassed, which is consistent with industry preference for an open channel on both sides of both river crossings. As more structures are removed or spend more time in the open position, the differences between structural alternatives are reduced, further reducing the information to be gained from a higher RSLR modeling exercise. As the GIWW becomes more open to the Gulf due to increasing RSLC, further adaptive measures will need to be investigated to ensure the continued viability of the waterway. Example adaptive measures could include shoreline restoration and raising the natural barrier islands and peninsulas that surround the GIWW and protect it from the Gulf.

2.2.4 Calibration and Validation

The models were simulated for floods occurring in 2015, 2016 and 2017. In general, AdH output compared well with observations at USGS, USACE and NOAA gages. **Figure 15** displays an example of the modeled water levels compared to the observed water levels at the Colorado River locks. **Figure 16** shows an example of the modeled water levels compared to the observed water levels at three gage locations within the Brazos River Floodgates model. The purpose of calibration and validation is to improve the models predictive skill. A calibrated and validated model provides more confidence in the evaluation of project alternatives.

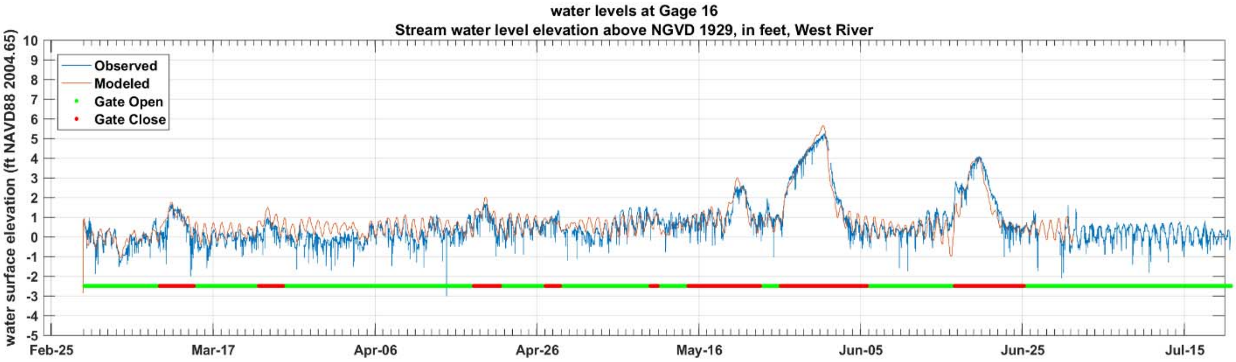


Figure 15 Colorado River Crossing – Gage 16

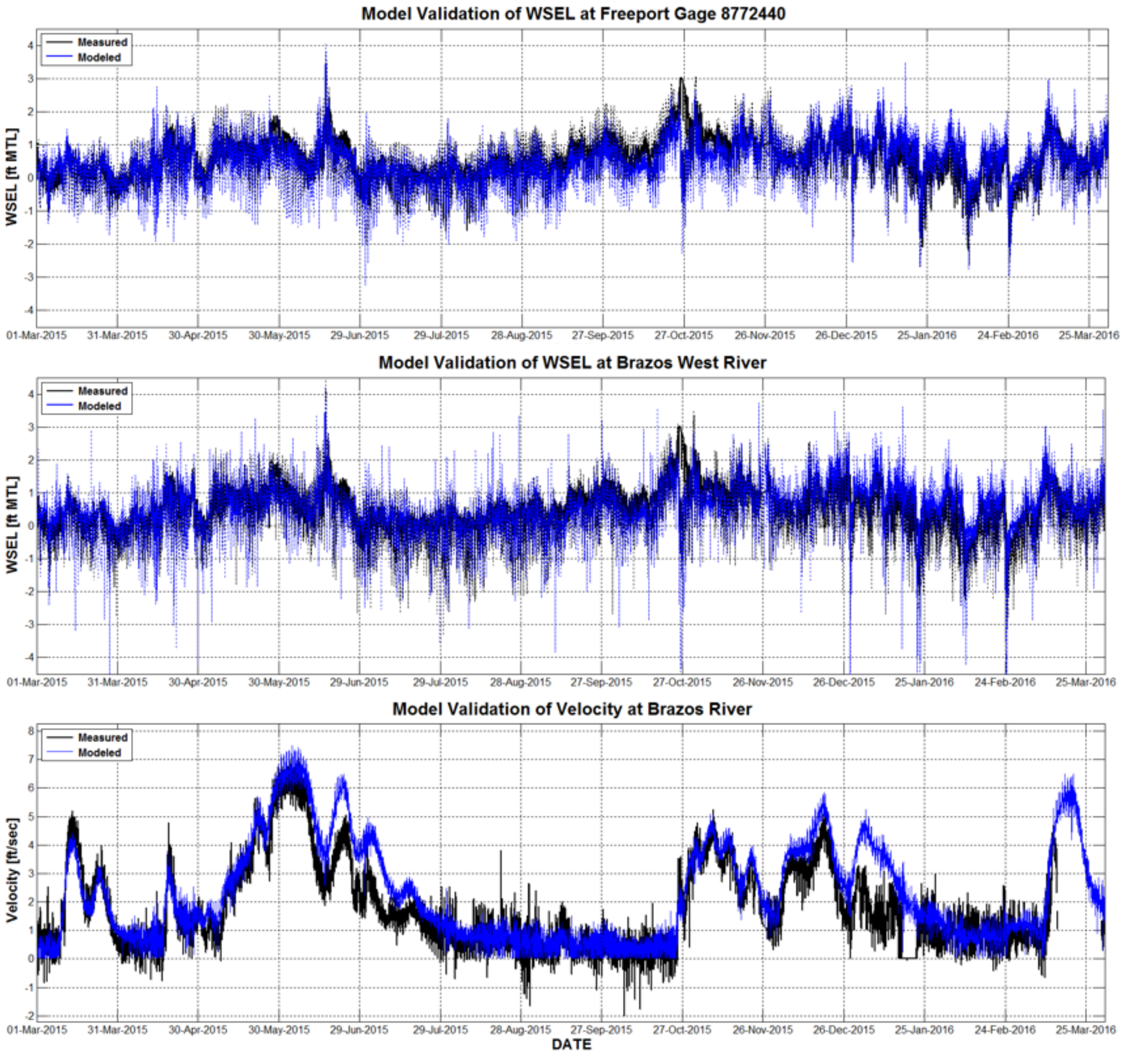


Figure 16 Model Validation of water surface elevations for Brazos model.

During the course of the investigation, Hurricane Harvey made landfall near the project site. The rainfall associated with the storm produced near record discharges for the Colorado River, and record discharges for the Brazos River. The event provided a very beneficial data point for the calibration and validation of the hydraulic models. Detailed information on the Hurricane Harvey analysis is included in the **Hydraulic Engineering Appendix.**

2.2.5 Currents, Water Levels, Salinity and Sediment

AdH was used to evaluate project alternatives in terms of impacts to currents, salinity and sediment. The primary goals of the modeling included:

1. Estimate changes to water levels, velocities and discharges near the project site and within the

GIWW

2. Estimate the expected changes to salinity in the project vicinity.

3. Estimate changes to the sediment budget, and changes to deposition patterns in specific areas of interest.

An example of the output from the AdH model is provided in the following figures. **Figures 17 and 18** display the sediment deposition areas that were delineated in the post-processing of model results. **Tables 6 and 7** contain the average annual sedimentation volumes that were summarized in each of the distinct areas based on the results of the simulations of the 2015 and 2016 floods. For the Colorado River Crossing with the open-channel alternative, the sedimentation rates in the GIWW increase from approximately 150% in the GIWW West, to 300% in the GIWW East. Changes to the sedimentation were also evaluate for future conditions for with and without project. Changes in the sedimentation rates for the proposed Brazos River alternatives are summarized in **Table 7**. Additional information on the sedimentation analysis can be found in Appendices 1 and 2.

The AdH model was also used to evaluate impacts to salinity for the various areas of interest displayed in **Figures 17 and 18**. **Tables 8 and 9** contains the mean salinity values for existing condition and open-channel, and future condition existing condition and open-channel. The results show very modest changes to average salinity within each of the specific geographic areas. For the Colorado River Crossing with the open-channel alternative, salinities are expected to decrease in East Matagorda Bay, and increase slightly in West Matagorda Bay. Both GIWW East and West are expected to have decreased salinities with the open channel alternative. For the Brazos River Crossing minor decreases in salinity are expected in the west GIWW and east GIWW for all alternatives. The only exception is a slight potential increase in salinity in the east GIWW for alternative 3a.1. Additional information on the salinity analysis can be found in Appendices 1 and 2.

For the Colorado River Crossing, a velocity rating curve was developed for the existing and open channel alternatives at the location of gage 14. Using the rating curve, and long term daily discharges presented in **Figure 19**, long term daily velocities were produced for the period 1948 to present for both existing and open channel alternatives. The velocity time-series were provided to the economics team for the navigation analysis.

For the Brazos River Crossing, a hindcast of velocities and head differentials for all alternatives was developed. The hindcast was developed to predict head differentials and velocities at each gate from 1980-2016. The head differential and velocity time-series was provided to the economics team for navigation analysis.

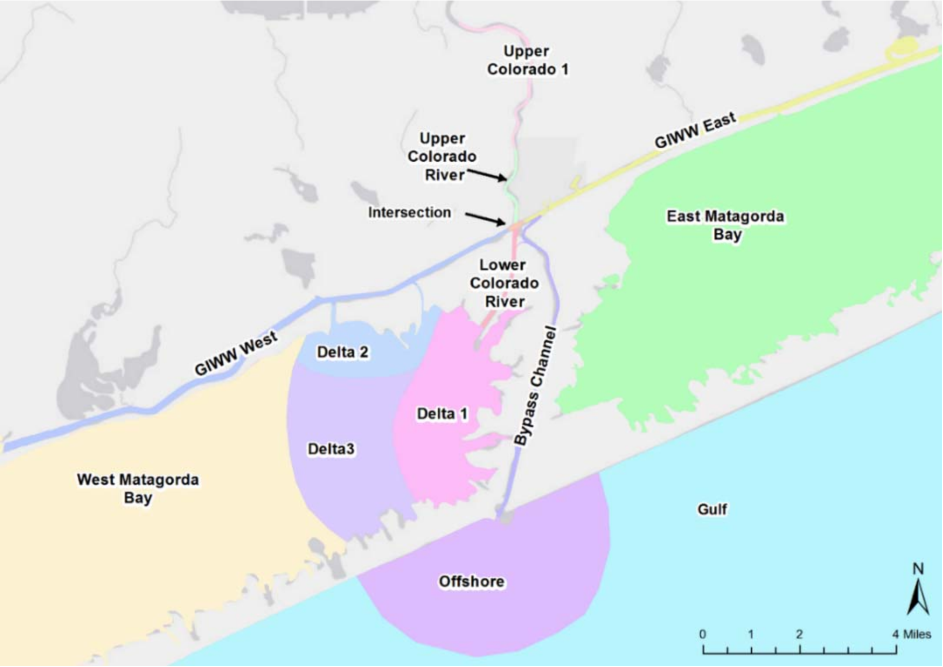


Figure 17 Map Showing the Location of the Assigned Sediment Deposition Areas – Colorado River Crossing

Figure 18 Map Showing the Location of the Assigned Sediment Deposition Areas – Brazos River Crossing

Area of Interest	Results Based on 2016 Simulation Regression Analysis			Results Based on 2015 Simulation Regression Analysis		
	Average Annual deposition Existing (cubic yards)	Average Annual deposition Open Channel (cubic yards)	% difference	Average Annual deposition Existing (cubic yards)	Average Annual deposition Open Channel (cubic yards)	% difference
GIWW East	75,124	285,606	**280**	49,331	193,940	**293**
GIWW West	199,974	492,967	**147**	147,801	324,766	**120**
Bypass Channel	42,509	81,952	**93**	27,290	50,678	**86**
Intersection	7,766	18,207	**134**	12,905	17,053	**32**
Delta 1	1,651,540	1,780,622	**8**	1,409,626	1,533,274	**9**
Delta 2	611,284	723,660	**18**	583,908	728,329	**25**
Delta 3	1,374,640	771,110	**-44**	1,302,189	497,307	**-62**
Offshore	346,021	732,546	**112**	235,308	527,348	**124**

Table 6 Average Annual Deposition Simulations for Existing and Open Channel Scenarios based on 2015 and 2016 Simulation Results – Colorado River Crossing

Alternative	West GIWW	Brazos Basin	East GIWW	Freeport Channel	Brazos Delta	Freeport Offshore	Total in Zones Requiring Maintenance
Existing/2a	554,769	48,000	890,769	295,385	44,382,462	208,726	1,788,923
3a	493,846	59,077	902,769	316,615	44,332,615	190,864	1,772,307
	(-11%)	23%	1%	7%	0%	(-8%)	(-0.1%)
3a.1	653,130	58,332	902,653	326,420	44,000,887	196,239	1,940,535
	18%	22%	1%	11%	(-1%)	(-6%)	8%
9a	781,846	92,308	1,079,077	978,462	42,026,769	854,614	2,931,693
	41%	92%	21%	231%	(-5%)	309%	64%
9b	780,923	96,923	1,044,000	550,154	43,232,308	396,989	2,472,000
	41%	102%	17%	86%	(-3%)	90%	38%
9c	781,846	107,077	1,044,000	550,154	43,218,462	395,887	2,483,077
	41%	123%	17%	86%	(-3%)	90%	39%

Table 7 Average Annual Deposition Simulations for Existing and Alternative Scenarios based on Simulation Results – Brazos River Crossing

Location	Average Salinity Existing RSLR=0 (ppt)	Average Salinity Existing RSLR=1 (ppt)	Average Salinity Existing RSLR=2 (ppt)	Average Salinity Open-Channel RSLR=0 (ppt)	Average Salinity Open-Channel RSLR=1 (ppt)	Average Salinity Open-Channel RSLR=2 (ppt)
West Matagorda Bay	18.0	18.6	19.1	18.2	18.7	19.3
Gulf	32.0	32.1	32.1	31.9	32.0	32.0
East Matagorda Bay	25.2	25.2	25.6	22.3	22.9	23.8
Upper Colorado 1	0.3	0.3	0.4	0.3	0.3	0.4
GIWW East	17.2	17.9	18.8	14.1	15.1	16.1
GIWW West	10.2	11.2	12.1	9.1	10.0	10.9
Bypass Channel	18.3	19.2	20.0	16.4	17.6	18.4
Intersection	7.4	8.6	9.3	7.3	8.2	9.0
Lower Colorado River	11.2	12.0	12.7	11.1	12.1	12.9
Upper Colorado River	0.5	0.6	0.7	0.5	0.6	0.7
Delta 1	11.0	11.4	12.0	11.6	12.4	13.3
Delta 2	10.2	11.0	11.8	10.3	11.3	12.3
Delta3	9.4	9.9	10.5	10.4	11.3	12.3
Offshore	30.1	30.3	30.4	29.7	30.0	30.2

Table 8 Mean Salinity values for 2015 Simulation at specific areas of interest – Colorado River Crossing

Alternative	West GIWW	Brazos Basin	East GIWW	Freeport Channel
Existing	5.6	1.7	5.0	15.6
3a	6.0 (0.4)	2.2 (0.5)	3.9 (-1.1)	15.2 (-0.4)
3a.1	3.8 (-1.8)	2.7 (1.0)	5.8 (0.8)	13.6 (-2.0)
9a	3.7 (-1.9)	2.3 (0.6)	4.0 (-1)	10.3 (-5.3)
9b	4.2 (-1.4)	1.9 (0.2)	3.7 (-1.3)	13.4 (-2.2)
9c	4.0 (-1.6)	2.0 (0.3)	3.5 (-1.5)	13.3 (-2.3)

Table 9 Mean Salinity values at specific areas of interest – Brazos River Crossing

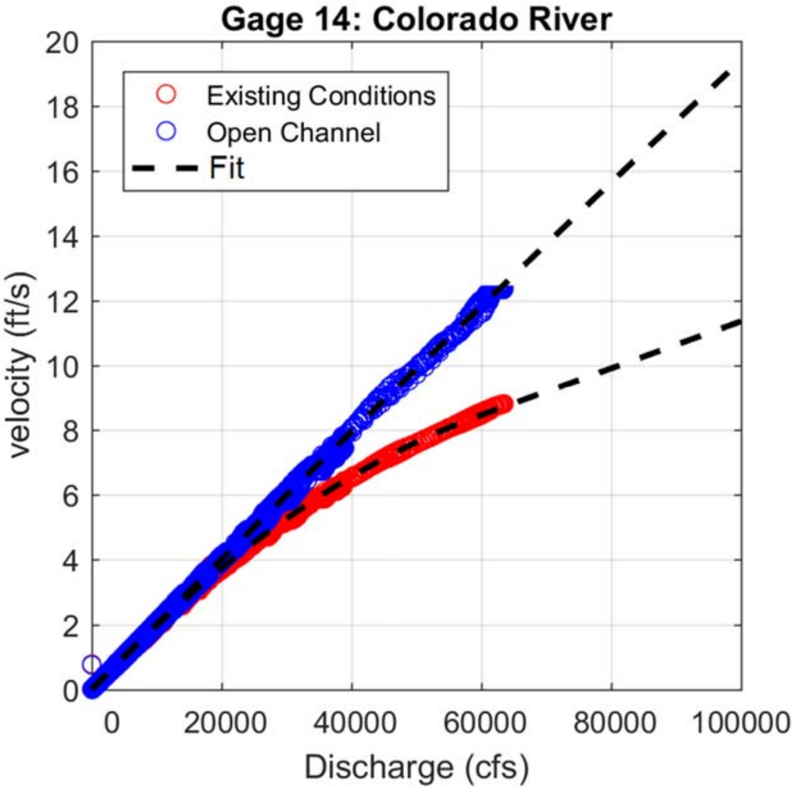


Figure 19 Discharge vs Velocity Rating Curve at Gage 14

2.2.6 Open San Bernard Impacts

Additional sedimentation modeling was conducted after the Tentatively Selected Plan (TSP) milestone to determine the impacts of an open San Bernard mouth on the proposed project. This additional modeling was conducted to examine sedimentation patterns in the GIWW if the San Bernard Inlet were opened. It should be noted that currently, the mouth of the San Bernard is not dredged or maintained, and is only open following large storm events. The existing AdH model was modified to include an open connection between the San Bernard River and the Gulf of Mexico. Wave driven sediment transport was not included in the model, and the results shown only reflect sedimentation due to river deposition. Since much of the morphology of the San Bernard River mouth is governed by the littoral processes, this analysis should not be used to develop quantitative analysis regarding the impact of the proposed TSP on the duration that the San Bernard River mouth will remain open. Instead, qualitative comparisons were made to analyze the general impact of the proposed TSP on the inlet stability of the San Bernard mouth when compared to existing conditions.

Sediment deposition was quantified in three separate areas of impact for the open mouth condition: The San Bernard Gulf Channel, the San Bernard Inlet, and the West GIWW. Modeled sedimentation in these areas was also calculated for the closed mouth condition. **Figure 20** shows the bounds of these impact areas.

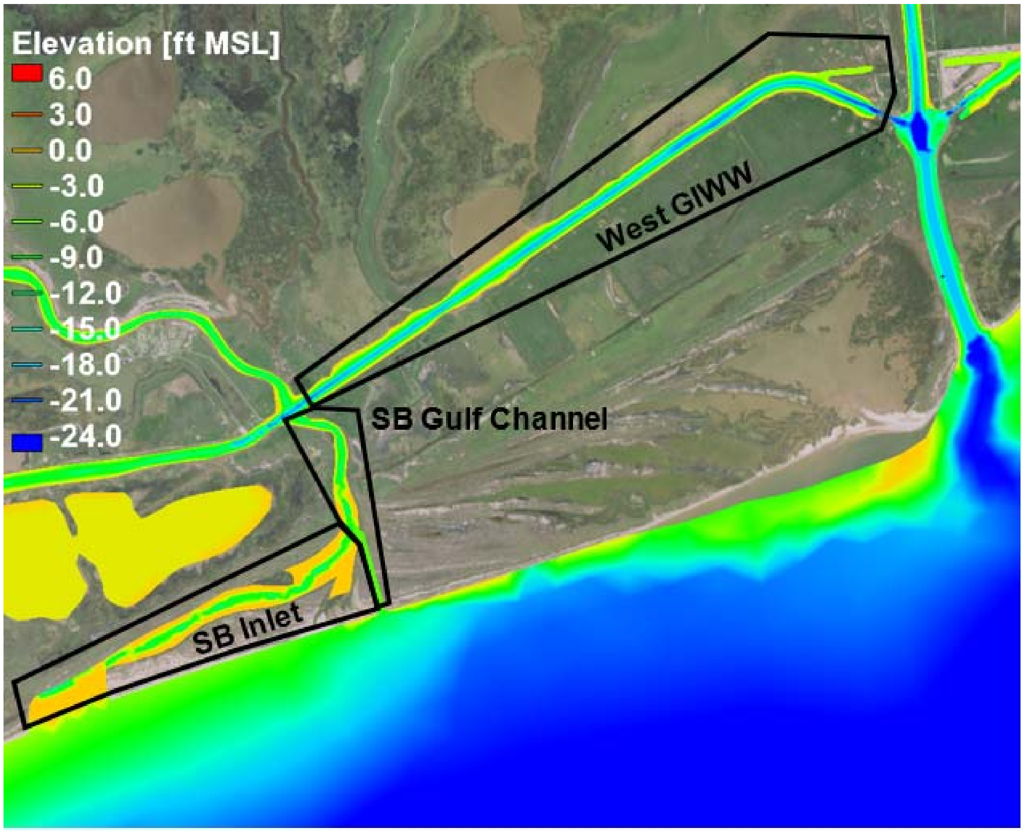


Figure 20 Locations of the West GIWW, San Bernard Gulf Channel, and San Bernard Inlet Zones of Impact

Tables 10 through 12 show the annualized sedimentation rate in the West GIWW, the San Bernard Gulf Channel, and the San Bernard Inlet, respectively.

Alternative	Closed San Bernard	Open San Bernard	Change (open - closed)
Existing	555,000	689,800	+134,800 (+24%)
Alt. 3a.1	653,100	768,000	+114,900 (+18%)
Change (Alt - Existing)	+98,100 (+18%)	+78,200 (+11%)	

Table 10 Annualized Sedimentation Rate in West GIWW [Cubic Yards/Year]

Alternative	Closed San Bernard	Open San Bernard	% Change (open vs closed)
Existing	10,100	1,200	-8,900 (-88%)
Alt. 3a.1	30,600	10,900	-19,700 (-64%)
% Change (Alt vs Existing)	+20,500 (+203%)	+9,700 (+808%)	

Table 11 Annualized Sedimentation Rate in San Bernard Gulf Channel [Cubic Yards/Year]

Alternative	Closed San Bernard	Open San Bernard	% Change (open vs closed)
Existing	13,500	12,000	-1,500 (-11%)
Alt. 3a.1	26,000	24,200	-1,800 (-7%)
% Change (Alt vs Existing)	+12,500 (+93%)	+12,200 (+102%)	

Table 12 Annualized Sedimentation Rate in San Bernard Inlet [Cubic Yards/Year]

In general, the open San Bernard condition results in increased sedimentation in the West GIWW compared to closed conditions. This is true for both existing conditions (24% increase) and Alternative 3a.1 (18% increase). The open San Bernard reduced sedimentation in the San Bernard Gulf Channel when compared to the closed condition, which is to be expected due to increased flowrates and velocities in this area. Based on historical aerial examination, previous dredging attempts, and previous literature, the controlling process for the morphology of the San Bernard mouth was found to be the net westward transport of sediments deposited by the Brazos River into the Gulf of Mexico, and not sediment deposition in the San Bernard channel via the GIWW. Further discussion of the open San Bernard mouth analysis is conducted in **APPENDIX 1** "HYDRAULIC ENGINEERING APPENDIX – BRAZOS RIVER FLOODGATES".

Based on stakeholder concerns over the FWP effects on the San Bernard River and its connection to the Gulf of Mexico, it is recommended that a targeted monitoring program be investigated during PED. The monitoring program could document hydraulic conditions before, during, and after project implementation. The monitoring program could enable USACE to demonstrate to the stakeholders the degree that the implemented FWP condition had not affected the hydraulics of the San Bernard River and its connection to the Gulf of Mexico.

3 CIVIL/STRUCTURE DESIGN ON ALTERNATIVES FOR TSP SELECTION

This section summarizes the work that was performed to develop sufficient quantities for the civil/structural features of the various alternatives investigated following the AMM. No design was performed to develop the cost estimates.

3.1 Alternative Quantity Take-Offs for TSP Selection

Each alternative consists of various features of work that were quantified to support the cost estimate.

3.1.1 Quantity Take-Offs for Rehab Alternatives

For the Rehabilitation alternatives, historical documents were reviewed to determine specifics of the original structures. These historical documents consisted of the original drawings of the two projects and previous rehabilitation contracts that were completed prior to this study. Features such as wall dimensions, sector gate dimensions, foundation dimensions, anchored sheet pile guide walls, concrete guide walls, interior chamber guide walls, machinery, and electrical system were shown in the historical documents. The previous rehabilitation contracts also assisted in pro-rating the cost of gate removal, damaged plate replacement, sand blasting, painting, and re-installation costs.

Anchored sheet pile limits were identified in the original construction drawings in order to determine the quantities for the UHMW (Ultra High Molecular Weight Polyethylene) backed by steel plating proposed to be installed on the river side of the anchored sheet pile guide walls. CADD was utilized to lay out a typical composite UHMW panel size with a steel backing plate to cover the sheet pile area exposed to navigation impacts. A nominal panel size of 4 foot by 4 foot was selected as the main size and a smaller 4 foot by 1 foot, 8 inch panel was to fill in smaller sections. The number of panels, bolts, and steel backing plate surface area was quantified.

For CRL, a Hagglund Viking 63 Series was used for the cost based on machinery used for previous sector gates of this size in the Southeast Louisiana area. The sized motor led to the sizing of a new Hydraulic Power Unit (HPU). Cost data for both the HPU(s) and machinery house(s) was based on similar configurations on sector gate structures in the Southeast Louisiana area. For BRFG, the decision based on discussion with the operators to relocate the existing machinery. The machinery pits are approximately 4 feet lower than the Colorado Locks and experiences frequent flooding. The plan is to raise the operating machinery even with the top of protection height. To accomplish this, a bracket is to be fabricated on the gate to raise the gear rack to accommodate the new machinery height. Additionally the control houses are to be raised

4 feet higher as they are subject to frequent rubbing and scraping by vessels transiting through. New concrete column like piers are to be constructed with a new floor slab on top. The building with controls are to be relocated on top. The concrete and steel for these additions were quantified by the ton. Additionally for Brazos, two 5 pile dolphin structures are to be located on each side of the river to act as a guide into the intersecting GIWW alignment. A typical dolphin consists of 24 inch steel pipe piles with a lower steel bracket for stiffening and a concrete cap at the top. The materials were quantified; cost data was accessible as these are common sector gate features in the recent south Louisiana hurricane protection work.

3.1.2 Quantity Take-Offs for New Structures

For the Brazos alternatives that include a new structure replacement, a 125 foot opening sector gate was quantified. Features of the sector gate structure include sand/gravel bedding, concrete stabilization slab, reinforced concrete foundation slab, reinforced concrete vertical walls, vertical and battered spiral welded pipe piles, steel sheet piling, steel tension connectors, pre-engineered machinery and control houses, miscellaneous metal ladders, railing, corner protection, seal plates steel dewatering bulkheads, hydraulic motors, hydraulic power units, and electrical power/controls. Sector Gate features consist of steel pipe, hinge and pintle, composite protection members, seals, cathodic protection, walkway grating, hand rails, and paint system. All concrete features were measured by the cubic yard along with bedding material. Piling both vertical and battered was measured by the linear foot. Steel cut off sheet piling was measured by the square foot. Steel tension connectors that install on top of selected piles were measured by each. Miscellaneous metal seal plates, walkway rails, corner protection, and ladders was measured by the linear foot. The steel members of the sector gate and dewatering bulkheads were measured by the ton while gate features such as hinge, pintle, seals, and cathodic protection was grouped as lump sum cost. Composite timbers on the gate the fender system was quantified by linear foot. The dewatering storage platform consisting of steel frame work and support piling was measured by the ton and linear foot respectively. All quantities were developed through pro-rating of existing sector gate structures.

The placement of the new structure requires excavation of the existing channel and placement of a temporary retaining structure (TRS). The area excavated was quantified by the cubic yard. A portion of the excavated quantity will be re-used to grade out a new vessel channel and to fill in the temporary by-pass channel once construction is complete. The remaining material is to be placed in adjacent disposal areas south of the GIWW at both projects. The TRS is to be a braced excavation with sheet pile, whale members, and struts. It also utilizes king post piling and support piling. The sheet pile was quantified by the square foot. Steel members were measured by the ton and piling by the linear foot respectively. Costs were also added for a dewatering system and TRS removal.

Additional new structure work includes an anchored sheet pile guidewall system that will be protected by the UHMW Panel system. The existing anchor wall design was used as the basis of the new design and to develop quantities. The guidewall sheet pile was quantified by the square foot with anchor hardware measured by the ton. The UHMW panels were quantified by the number panels over exposed surface area above the normal water line. Steel backing plate corresponds to this surface area.

BRFG Alternative 9c includes the addition of a flow control structure to regulate the San Bernard River contribution into the GIWW. It is to be placed in the existing west side channel on the river side of the demolished structure. The quantities and cost were based on cost estimate prepared for a similar sluice gate structures designed for the Morganza to the Gulf of Mexico PAC. Piling was quantified by linear foot. Concrete foundation, vertical towers, and horizontal slabs was measured by the cubic foot.

3.1.3 Quantity Take-Offs for Demolition

Demolition of the existing 75 foot wide sector gate structure is required on open channel and new structure replacement alternatives at Brazos. This also includes the riverside gates removal alternative 4b.1 at Colorado. The scope involves the removal of the vertical walls, gates, control house, machinery, and anchored sheet pile guidewall. The tonnage of the gates were calculated for removal costs. All concrete demolition was calculated by the cubic yard. Existing construction plans were used to develop the quantities.

3.2 O&M Dredging Assumptions

Anecdotal O&M data was supplied by SWG Operations Division personnel based on historical data including yearly maintenance costs on the structures, major maintenance cost and frequency on the structures, average yearly dredge quantities along the GIWW, estimated dredging costs based on recent dredging contracts, and remaining capacity of the existing disposal sites. Remaining capacities of the disposal sites was based on prior geotechnical analysis conducted for determining current and remaining maximum capacities for GIWW Placement Areas. Nos. 29 through 88. The placement areas considered for capacity for this study were Placement Areas 86/87, 88, 89, 90, 92, 106, 108, 108A, 109, and 110. Estimated dike elevations from the prior geotechnical analysis conducted and past dredging/construction contracts for placement areas not covered by the prior geotechnical analysis were used to calculate future volumes for the placement areas based on 3 foot incremental lifts until the estimated maximum dike elevation was reached.

A comparison of the historical dredge quantities was made versus the sediment deposition predicted by the AdH models. Because the AdH models output total of channel deposition included quantities from top of bank to top of bank and does not account for the consolidation that may occur in the deposited material, the yearly historical dredge quantities were less than those predicted by the AdH model. Therefore, the O&M dredging costs for the various alternatives was developed by pro-rating the quantities predicted by the AdH model by the ratio of the AdH predicted sediment values for the existing condition to the actual historical dredge quantities.

3.2.1 Brazos River Crossing

For dredging costs for Freeport, all dredging was assumed to be disposed offshore as that is the current mode of disposal for dredging in the Freeport Channel. A mobilization cost and unit cost were assumed for the dredge disposal in this area (costs escalated over 50 year project life). The existing dredge frequency of 8 months provided by OD was assumed to stay constant. It was assumed that the volume of dredging in each event would increase based on changes to sedimentation rates computed by the modeling.

For dredging costs for the GIWW from the east gate to the Freeport Harbor, a remaining adjacent disposal quantity of 7,500,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. For dredging costs for the GIWW from the west gate to the San Bernard River, a remaining adjacent disposal quantity of 3,000,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. For dredging costs for the GIWW crossing at the Brazos Floodgates, a remaining adjacent disposal quantity of 8,000,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. The existing dredge frequency of 2 years was provided by OD for the FWOP. The GIWW and Brazos dredging frequencies and associated mobilization costs were scaled from existing O&M frequency based on changes to sedimentation rates computed by the AdH modeling. A cost of $200,000 was assumed every 5 years to complete the permit process to utilize offshore disposal areas once offshore disposal was needed.

3.2.2 Colorado River Crossing

For dredging costs for the GIWW east of the locks, a remaining adjacent disposal quantity of 12,500,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. While there are currently no offshore disposal sites available near the crossing, this study assumes that they will be approved and available. For dredging costs for the GIWW west of the locks, a remaining adjacent disposal quantity of 10,500,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. For dredging costs for the GIWW crossing at the Colorado River, a remaining adjacent disposal quantity of 4,000,000 CY was assumed. After that capacity was exceeded, offshore disposal was assumed. The existing dredge frequency of 2 years was provided by OD for the FWOP. The GIWW and Brazos dredging frequencies and associated mobilization costs were scaled from existing O&M frequency based on changes to sedimentation rates computed by the AdH modeling. A cost of $200,000 was assumed every 5 years to complete the permit process to utilize offshore disposal areas once offshore disposal was needed.

4 CIVIL/STRUCTURE DESIGN ON RECOMMENDED PLAN

4.1 Civil/Structural Project Features

This section summarizes the work that was performed to develop sufficient quantities for the civil/structural features of the recommended plan. Limited design was performed to develop the cost estimates. The majority of the quantities developed for the sector gate monoliths were based off the 125 foot sector gate designed for the Morganza to the Gulf of Mexico Post-Authorization Change Report (MTOG PAC). Those sector gate structures designed for the MTOG PAC had the same sill (El -16.0) and top of structure (El 16.0) as the sector gates at the Brazos and Colorado River Crossings. Other structural features were quantified based on similar features from historical structures constructed with the New Orleans District (MVN), such as timber guidewalls and pile clusters. More critical, costly components such as the pile foundations for the structures were designed and quantified for each structure where adequate geotechnical site data was available.

4.2 General Structural Design Criteria

4.2.1 References

All design is in accordance with applicable Corps engineering guidance and applicable industry standards. Because many of the designs utilized to develop the costs for this study were from the MTOG PAC from the 2012 timeframe, some USACE publications listed are not the latest guidance available. During PED, the designs will be refined with the latest USACE criteria.

4.2.1.1 Technical Publications

- American Concrete Institute, Building Code Requirements for Structural Concrete and Commentary (ACI 318-14).
- American Institute of Steel Construction (AISC), Manual of Steel Construction, Allowable Stress Design, 9th Edition.

4.2.1.2 Corps of Engineers Publications

- Hurricane and Storm Damage Reduction System Design Guidelines, New Orleans District, 12 June 2008.
- EM 1110-2-2000 Standard Practice for Concrete for Civil Works Structures Change 2 (Mar 01).

- EM 1110-2-2104 Strength Design Criteria for Reinforced Concrete Hydraulic Structures (Jun 92, Aug 03).
- EM 1110-2-2105 Design of Hydraulic Steel Structures Change 1 (May 94).
- EM 1110-2-2503 Design of Sheet Pile Cellular Structures Cofferdams & Retaining Structures (Sep 89).
- EM 1110-2-2703 Lock gates and Operating Equipment (Jun 94).
- EM 1110-2-2906 Design of Pile Foundations (Jan 91).
- ER 1110-2-8152 Planning and Design of Temporary Cofferdams and Braced Excavation (Aug 94).

4.2.1.3 Computer Programs

- Structural Analysis and Design Software, “STAAD.Pro 2006”, release 23W, Research Engineers
- CE Pile Group Analysis Program, “CPGA”, CASE Program No. X0080
- “Mathcad”, Version 15, Parametric Technology Corporation
- “Microsoft Excel”, 2013, Microsoft Corporation

4.2.2 General Design Criteria

4.2.2.1 Unit Weights

Unit weights utilized for structural design are summarized in **Table 13**.

Table 13 - Unit Weights

Item	LBS/CF*
Water	62.4
Steel	490
Granular Fill(saturated)	120
Stone	132
Stabilization Slab Concrete	135
Normal Weight Concrete	150

*Unit weights taken from HSDRRS guidelines.

4.2.2.2 Loadings

4.2.2.2.1 Water Elevations

The only component of the sector gate structures specifically designed for the Brazos and Colorado River Crossing sector gates was the pile foundations based on the available boring data available. The water elevations used for the pile foundation design are shown in Table 14.

Table 14 - Water Elevations

High River	High River GIWW Side	Hurricane	Hurricane-GIWW Side	Reverse River Side	Reverse GIWW Side	Maint. Dewat.
8.0	0.0	10	-2	-1	2	5

4.2.2.2.2 Lateral Pressure

Use Unit Weight and K at rest values
Ko = 0.8 for clay
Ko = 0.5 for granular materials
Ko = 0.5 for rip rap

4.2.2.2.3 Wind Pressures

The wind force utilized for design was 50 psf for hurricane conditions and 20 psf for maintenance conditions.

4.2.2.2.4 Wave Loadings

No wave loadings were considered in the design of the pile foundations for the 125 ft sector gates at the Brazos and Colorado River Crossings.

4.2.2.2.5 Boat Impact

4.2.2.2.5.1 Concrete Structures

The 125 ft sector gate structures from the MTOG PAC were designed for the unusual impact force of 200 kips in accordance with the HSDRRS design guidelines.

4.2.2.2.5.2 Sector Gate Channel Truss in Open Position and Sector Gate in Closed Position

The sector gate leaves from the MTOG PAC were designed for a 125 kip impact force applied at each joint along the channel truss/skin plate in accordance with the requirements of EM 1110-2-2703, “Lock gates and Operating Equipment”.

4.2.2.2.6 Uplift Conditions

Uplift conditions utilized for design of the pile foundations were in accordance with Chapter 5 of the HSDRRS design guidelines.

Impervious - Sheet pile cutoff is assumed 100% effective
Pervious - Linearly varying between the F/S and P/S elevations

4.2.3 Concrete Design General Requirements

4.2.3.1 Reinforced Concrete Strength

All reinforced concrete will have a design compressive strength of 4000 psi.

4.2.3.2 Load Factors

Reinforced concrete hydraulic structures were designed in accordance with EM 1110-2-2104. EM 1110-2-2104 procedures are referenced to the load factors and strength reduction factors found in ACI 318-08, Appendix C.

A single load factor of 1.7 was used for dead and live loads in addition to a hydraulic factor of 1.3.

Strength reduction factor for bending = 0.9

Strength reduction factor for shear = 0.85

4.3 Description of Design of Project Features

The physical features associated with the construction of the 125 ft sector gate structures at the Brazos and Colorado River Crossings are as follows:

- Excavation
- Stone
- Access Levee/Gate Reservation Area
- Stone/Sheetpile Training Berm (Colorado East Only)
- Interior Braced Cofferdams
- Sector Gate Concrete Monolith
- Sector Gate Pile Foundation
- Steel Sector Gate

- Needle Girder, Needles and Supports
- Needle Girder Storage Platform
- Guidewalls
- End Cell Dolphins
- Administration Building
- Warehouse Building
- Boat Dock
- Generator Building
- Electrical Controls and Circuitry
- Mechanical Equipment
- Demolition

4.3.1 Excavation

Excavation quantities were developed based on available LIDAR data in the project vicinity along with the hydrographic surveys taken for the hydraulic modeling in 2016. Disposal was assumed to be in adjacent Placement Areas along the GIWW. Suitable material from the excavation may be re-used for construction of the access levee/gate reservation area, but was not assumed for the cost estimate.

4.3.2 Stone

No detailed hydraulic analysis was performed to determine stone sizes in the vicinity of the sector gate. A 42 in layer of 1000lb stone extending 250 ft outward from either side of the sector gate structure was modeled off the stone utilized for the design of the West Closure Complex (WCC) in Southeast Louisiana. WCC experiences high flow through the structure due to 30,000 cfs of interior drainage pumped through the structure in a high rain event along with prop wash from vessels transiting along the GIWW. Similar conditions can be expected for the gates located at the Brazos and Colorado River Crossings. Detailed sizing and limits for the stone will be developed in PED.

4.3.3 Access Levee/Gate Reservation Area

A trapezoidal area built up to El 12.0 will be constructed across the former channel to connect the existing northern bank area to the new gate structures. The trapezoidal area was selected to provide adequate space to operate and maintain the gate structures, including a large enough space to sandblast and paint the steel sector gates during dewatering events. An elevated access levee/road and parking area will be constructed to El 16.0 atop the trapezoidal area to permit access to the sector gate structures. The road and parking areas will consist of a 6" base course and 6" asphalt wearing course. Refer to the civil sheets for dimensions of the access levee/gate reservation area.

4.3.4 Stone Training Berm (Colorado East Only)

Due to the tidal effects of the old Colorado River mouth on the east side of the east Colorado gate, a training berm is being provided to minimize cross currents of vessels transiting through the gate structure. The berm consists of 1000 lb stone with a crown width of 5 ft and 1 vertical on 2 horizontal side slopes. A 30 ft PZ-22 sheetpile cut-off wall is provided to prevent any tidal flow through the stone. The berm extends 500 ft eastward from the structure to allow the majority of vessels to align with the structure before cross currents are encountered. Final design of the stone training berm will be performed in PED with the assistance of SHIPSIM to determine the required limits. For details of the berm, refer to sheets C-104 and C-301.

4.3.5 Interior Braced Cofferdam

A cofferdam will be constructed to permit the construction of the sector gate monoliths in the dry. The cofferdam is an internally braced cofferdam with wide-flange walers and pipe braces supporting PZ sheet piling. Anchor forces, bending moment in the sheet piling, and required sheet piling tip elevation were computed for the Brazos River Crossing and for each side of the Colorado River Crossing. Details of the Phase 2 cofferdam can be found on Sheet S-405.

ER 1110-2-8152 will be followed throughout the project design process, requiring that all cofferdams will be designed by the Government.

4.3.6 Sector Gate Monolith Concrete

Details of the concrete monolith are shown on Sheets S-101 and S-301.

4.3.6.1 Sector Gate Wall

Sector gate walls were designed as a cantilever beam extending from the base slab as part of the MTOG PAC. A constant wall thickness of 4 ft was assumed the full height of the wall.

4.3.6.1 Sector Thrust Block and Machinery Block

Sector gate thrust and machinery blocks were not designed because of their relatively small quantity compared to that of the remainder of the walls. Historical data from previously constructed sector gates was utilized to size the thrust and machinery blocks.

4.3.6.1 Sector Gate Base Slab

The 125' sector gate base slab will measure 310'-6" long by 117'-8" wide. The sector gate base slab thickness used from the MTOG PAC was determined utilizing 2D transverse and longitudinal strips. The transverse strip was taken beneath the thrust block while the longitudinal strip was taken beneath the machine and thrust blocks. The strips were designed as solid beams, given the property of the width of the slab that was examined. All loads acting along the width of the beams were input into STAAD (Structural Analysis and Design) and resolved along the centroid of the beam. Piles were modeled as pinned supports. A 10 ft thick slab was determined.

4.3.7 Sector Gate Pile Foundation

4.3.7.1 General

The pile foundation for the sector gates will include 246 thirty inch pipe piles with 5/8" thick wall thickness battered on 4 vertical to 1 horizontal slope. The design Factors of Safety and allowable deflection utilized for the design comply with EM 1110-2-2906 and the latest requirements Hurricane and Storm Damage Risk Reduction System Design Guidelines. All pile capacities used assumed compression pile testing, but no tension pile testing. Tension hooks are provided on all piles. CPGA analysis was performed for each sector gate. Details for the pile foundation are shown on Sheet S-102. Alternative pile types and arrangements will be investigated during detailed design for each structure to optimize the pile foundation.

4.3.7.1 CPGA Analysis

CPGA was utilized to develop the pile layouts for the gate structures and determine the required tip elevation. The piles were modeled as pinned connections with the piles providing all of the lateral resistance. The horizontal subgrade modulus was based on the soil in the top ten pile diameters. The horizontal subgrade modulus was reduced for group effects in accordance with EM 1110-2-2906.

4.3.7.2 Pile Curves and Horizontal Subgrade Modulus

Pile curves and horizontal subgrade modulus were calculated for the three sector gates.

The resulting pile tips are summarized in **Table 15**.

Table 15 - 125’ Sector Gate Pile Tips

Structure	Pile Tip (ft)
Brazos	-110
Colorado West	-120
Colorado East	-105

4.3.7.3 Cut-off Wall

A cut-off sheetpile wall will be provided to reduce possible seepage, scouring and uplift. A PZC-13 sheetpile meeting the requirements of ASTM A572, Grade 50 was assumed for the cutoff wall. Tip elevations were calculated utilizing Lane’s Weighted Creep Ratio for each structure. Details and tips for the cut-off wall are shown on Sheet S-102.

4.3.8 Steel Sector Gate

4.3.8.1 General

The structural design of the sector gates for the MTOG PAC sector gates used for this study was performed in accordance with Corps engineering guidance and applicable industry standards. The Corps criterion is specified in EM1110-2-2105 and EM 1110-2-2703. The sector gates will consist of structural pipe sections supporting the vertical ribs and skin plate with a central angle of 70. All connections will be welded connections. A rack and pinion gear system will operate the gate. All steel members on the gate will be painted with a coal tar epoxy paint system. Details of the steel sector gate are shown on Sheets S-103 to S-105, S-201 to S-203, S-401, and S-501 to S-502..

4.3.8.2 Skin Plate

The skin plate of the MTOG PAC sector gates used for this study was designed conservatively as a simply supported member by vertical angles, spaced 2' on center. An allowable stress of 0.50 times the yield stress was permitted for basic loading conditions with a permissible increase of one-third for abnormal loading conditions. EM 1110-2-2703 requires that the skin plate be designed with a 1/16” reduction in thickness.

4.3.8.3 Vertical Ribs

The skin plate will be attached to the vertical ribs by continuous welds. The ribs of the MTOG PAC sector gates used for this study were designed as simply supported members between the horizontal built-up plate girders. The skin plate was considered as an effective part of the vertical ribs, with the effective width of skin plate determined according to the AISC specifications for a non-compact flange. A minimum depth of ribs will be required to be 8 in. to facilitate painting and maintenance. The ribs are also constructed from material conforming to ASTM A-588 Grade 50 steel.

4.3.8.1 Horizontal Beams

The gate leaf consists of horizontal beams supporting the vertical ribs and skin plate. The beam of the MTOG PAC sector gates used for this study was designed as a continuous member supported by the horizontal struts and braces at midpoint between the struts. The curve of the beam was neglected, with the length used for design equal to the arc length along the center line of the beam. The beams are constructed from material conforming to ASTM A-572 Grade 50 steel. The dead weight applied to the girders included, where applicable, the walkway weight, the weight of the intercostals and ribs, and the self-weight of the girder.

4.3.8.2 3D Modeling of Gate

The trusses and frames of the MTOG PAC sector gates used for this study were analyzed as a three-dimensional space frame in STAAD Pro 2006. The chords of the trusses were analyzed as fixed members while the minor members of the trusses along with the members of the frames were analyzed as pinned connections.

The hinge was modeled to resist forces in the horizontal plane (F_x, F_y) while the pintle was modeled as a pinned connection to resist forces in both the horizontal and vertical planes (F_x, F_y, F_z). For gate open cases with boat impact, a roller support was added at the location of the gate stop to stabilize the structure during boat impacts while in the gate closed cases with boat impact, a roller support was added to the machinery to resist boat impacts and stabilize the structure. The vertical dead load was carried only by the pintle.

4.3.8.3 Hinge and Pintle

The gate frames will be supported at the top by a hinge and at the bottom by a pintle. In order to assure good pintle and hinge alignment, a spherical pin will be provided in the hinge to compliment the spherical pintle. All vertical loads will be transferred to the concrete base through the pintle. Horizontal reactions will be transferred to the thrust block through bronze bushings. Bearing pressures on the bushings were limited to 2500 psi for operating conditions and 5000psi for maintenance conditions.

4.3.8.4 Fender

A fendering system was provided on the channel side truss of the sector gate to protect the truss from a barge impact of 125 kips. This load corresponds to the load recommended in EM 1110-2-

2703 "Lock Gates and Operating Equipment" for sector gates. The entire fendering system will be removable to permit maintenance and painting of the gate as needed.

The impact load was assumed to be distributed evenly between two 8 in x 12 in composite marine timbers, supported on 5 ft centers by vertical W 10 x 77 sections. The composite marine timbers were designed as continuous members supported by the vertical members. The vertical members were designed as simply supported members between the horizontal members. Two large horizontal W27X146 sections, which are bolted on at panel points on the channel side truss of the gate, transfer the impact load back to the channel side truss and were designed as continuous members.

4.3.8.5 Walkway

The walkway extends around the trusses of the gate leaf as well as along the skin plate. A 4’-6” walkway width was provided, designed for an imposed live load of 200 psf. Aluminum grating with 1 1/4 in by 3/16 in bearing bars was selected to span the 4 ft required width of walkway. Aluminum handrails are provided along the entire walkway to resist a force of 200 lb applied at the top rail in accordance with EM 385-1-1.

4.3.9 Needle Girders, Needles and Supports

The needle girder system arrangement from the MTOG PAC used for this study was designed to dewater the entire gatebay to permit maintenance of the sector gates. The needle girder system was designed for a sill elevation of -16.0 with a water elevation of +5.0. Each gate structure will be provided with 24 steel needles (12 on each side of the structure), measuring 14’-6” in width, used to dewater the concrete gatebay monoliths. The steel needles will consist of vertical WT 8X38.5 members with a 7/16” skin plate. The needles will be supported by the sill of the concrete gatebay and the needle girder at El 5.0. The needle girder was designed as a simply supported, built-up girder, spanning across the 125’ gate opening. The girder will be supported along its weak axis by 3 support towers. The girder at mid-span has a depth of 8’-4” with 3/4” web and 2”x20” flanges. The girder will taper down to a depth of 5’-4” at the ends. The support towers will consist of welded HSS connections, supporting the dead and vertical live loads of the needle girder. Details of the needle girder, needles and support are shown on Sheets S-402 to S-403.

4.3.10 Needle Girders Storage Platform

The needle girder storage platform will be a reinforced concrete structure measuring 71 ft wide by 135 ft long. The structure will consist of an 8” cast in-place slab supported by 40” wide by 30” deep cast in-place beams, spaced 9’ O.C. The storage platform will be supported by 60 twenty-four inch square precast pre-stressed concrete (PPC) piles, 80' long. No design was performed for the storage platform. Quantities were pro-rated based off of similar structure designed in Southeast Louisiana. Details of the needle girder storage platform are shown on Sheet S-302.

4.3.11 Guidewalls

Guidewalls will be provided as aids to navigation and to protect the main flood gate structure from impact. Details were taken from the HNC Lock structure from the MTOG PAC as both structures will see similar vessel traffic. The wall lengths and details on the walls are shown on Sheet S-303.

4.3.12 End Cell Dolphins

End Cell Dolphins will protect the main flood gate structure and guidewalls from head-on impact from errant vessels. The end cell design was mirrored on the Western Closure Complex 225' Sector Gate, where similar vessel traffic is seen along the GIWW. The end cell will consist of a 60' sheet pile cellular structure with a concrete ring in the interior or the cell. The inside of the concrete ring will be in-filled with lightweight fill material. The concrete structure will be supported by 18" diameter pipe piles. Details are shown on Sheet S-404.

4.3.13 Control Houses

A precast 16'x16' two-story concrete control house will be provided on the north gate leaf of each sector gate structure to shelter the gate control systems and machinery and provide space for a gate operator as required. The buildings are considered small and were not designed, so historical dimensions were used for cost estimation purposes. It is assumed that these buildings will be pre-fabricated during construction.

4.3.14 HPU Building

A precast 10'x10' one-story concrete control house will be provided on the south gate leaf of each sector gate structure to shelter the hydraulic power unit (HPU). The buildings are considered small and were not designed, so historical dimensions were used for cost estimation purposes. It is assumed that these buildings will be pre-fabricated during construction.

4.3.15 Administration Building

A 6,000 SF administration building of CMU construction will be provided at both Brazos and Colorado River Crossings with office space, conference room, restrooms, storage, and break rooms. For cost estimation purposes, it was assumed that one third of the building would be unfinished dedicated space for storage. The buildings are considered small and were not designed, so details from a similar administration building constructed for the Port Allen Lock in Southeast Louisiana were used for cost estimation purposes. It is assumed that the building would be founded on concrete grade beams and timber piling. See Sheet S-204 for details.

4.3.16 Warehouse Building

A 20 ft by 40 ft pre-engineered metal building warehouse will be provided at both Brazos and Colorado River Crossings to accommodate additional storage, tool rooms and machinery areas. The buildings are considered small and were not designed, so details from a similar warehouse constructed for the Catfish Point Control Structure in Southeast Louisiana were used for cost estimation purposes. It is assumed that the building would be founded on concrete grade beams and timber piling. See Sheet S-207 for details.

4.3.17 Boat House

A boat house will be provided at both Brazos and Colorado River Crossings to provide shelter for 2 boat slips to accommodate vessels up to a beam length of 15 ft, draft of 6 ft and overall length of 25 ft. Additional storage and deck space will be provided. The buildings are considered small and were not designed, so details from the previously constructed boat houses at the project sites were used to develop the cost estimate. It is assumed that the building would be founded on concrete grade beams and timber piling. See Sheet S-205 for details.

4.3.18 Generator Building

A precast 14’x14’ one-story concrete generator building will be provided at both Colorado and Brazos River Crossings to shelter the generator. The buildings are considered small and were not designed, so historical dimensions were used for cost estimation purposes. It is assumed that the building would be founded on concrete grade beams and timber piling. See Sheet S-206 for details.

4.3.19 Demolition

Required demolition includes the removal of the southern half of both sector gates at the Brazos River including guidewalls. At Colorado River, only the souther half of the east gate and guidewall on the east lock will be removed. All other components of the gate and lock structures will be decommissioned, including the removal of all steel sector gates. The scope involves the removal of the vertical walls, gates, control house, machinery, and anchored sheet pile guidewall. The tonnage of the gates were calculated for removal costs. All concrete demolition was calculated by the cubic yard. Existing construction plans were used to develop the quantities.

4.3.20 Sector Gate Electrical Controls and Circuitry

4.3.20.1 Electrical Service

The Electrical service to the structure will be 480/277 volt, 3 phase, 4 wire grounded secondary service from the local utility company. The service will be sized to support the structure loads including power for Gate machinery, lighting, controls, and any other miscellaneous loads.

4.3.20.2 Emergency Generator

A diesel generator will be provided for back-up power in the case of loss of utility power. The fuel supply for the generator will be provided from a fuel tank to a skid mounted UL-Listed double-walled day tank. Alarms will be locally annunciated on the generator.

4.3.20.3 Grounding System

The structure grounding system will be in accordance with the NFPA 70 - National Electrical Code. The grounding system will consist of copper ground rods interconnected with copper conductors. All jumpers and grounding electrode conductor connections will be done by exothermic weld. All electrical equipment, machinery, and exposed metal will be bonded to the grounding electrode system.

4.3.20.4 Lighting System

All exterior lighting fixtures will be provided with vandal-proof shields. The fixtures will be HPS and shall be controlled by photocells. Fluorescent light fixtures will be provided in the control houses.

4.3.20.1 Conduits and Boxes

All wiring will be installed in rigid metal conduit except that motors and other electrical equipment subject to vibration will be connected with liquid-tight flexible metal conduit. All pull boxes and junction boxes will be of cast metal of sufficient thickness or provided with bosses to accommodate the required threads for the conduit connections of size specified. All outlet boxes for receptacles, switches, and lighting fixtures will be of cast metal with bosses drilled and tapped or with threaded hubs of sizes specified. The edges will be designed to take a heavy cover gasket with four or more screws for attaching covers or fixtures.

4.3.20.2 Controls

A hard wired control system will be installed to operate the Gates. The control consoles will be installed in the control houses.

4.3.20.3 Lightning Protection System

A lightning protection system will be designed to protect the structure from lightning strikes. The system will be designed in accordance with NFPA 780-Installation of Lightning Protection Systems. Surge suppression devices on all incoming power and communication lines will be provided.

4.3.21 Mechanical

4.3.21.1 Gate Operation

Gate operation will be two speeds with a time dependent 1 to 4 second speed ramp at start, stop and speed changes. The dual speed and speed ramp will be accomplished electronically by way of a hydraulic proportional valve. A slow gate speed of 3.5 degrees per minute will be used near the end of gate travel, (1 to 3 feet from fully close or fully open, measured at the skin plate). A higher speed of 30 degrees per minute will be used in between the ends of travel.

4.3.21.2 Gate Operating Loads

The gate operating loads consist of friction from hinge, pintle and seal and hydrodynamic loads. The hydrodynamic loads were based on differential hydrostatic head applied over the gate end beams. Four load cases were considered.

4.3.21.3 Gate Operating Machinery

The gate operating machinery will be a rack and pinion gear drive. The rack will be attached to the gate along the outside radius of the gate's skin plate. A pinion drive gear will be attached to a low speed high torque hydraulic (LSHT) motor mounted on the wall. A Hagglunds Viking Series 84 LSHT hydraulic motor operating at 3600 psi was used for design purposes. Each gate will be equipped with its own hydraulic power unit (HPU). The HPU will include a variable delivery pressure compensated pump driven by an electric motor. The electric motor will be 30 horsepower. Additional HPU items will include valves, manifold, gauges, filters, clean vent, and storage tank. The gate operating machinery is shown on Sheet M-901.

4.3.21.1 Gate Operating Machinery

Hinge and pintle bushings will be split in the vertical plane. Hinge and pintle bushings will be a greaseless/self-lubricating system with an approved composite. The material will have a dynamic coefficient of friction that is less than or equal to 0.08 dry and 0.10 water-lubricated for a bearing pressure load of 2 ksi at surface speed 90 fpm. The ultimate compressive strength of the material will be a minimum of 50 ksi and its water absorption will be less than 0.10 percent by weight. Bushing material and dowels will meet the requirements of ASTM B 148, Alloy C95500, ASTM B 271, Alloy C95500, or ASTM A705, Type 630, minimum hardness 40 Rc. The hinge bushing shall normally be dry but may be exposed to rain water and a marine environment.

5 GEOTECHNICAL DESIGN ON RECOMMENDED PLAN

5.1 General

Geotechnical information is a key component of design details that impacts cost. There was no new field data collected for this study, and therefore no new laboratory testing to determine soil profiles. Soil profiles were determined with the limited data available and limited geotechnical analyses were performed.

Currently, there is no detailed site-specific boring and soils testing data in the area in order to consider the foundation as well-defined and use lower factors of safety in design. Without any new soil boring and testing data beneath the footprint of any proposed structures that would be constructed as part of the TSP, higher safety factors will be used, resulting in more conservative designs, for the feasibility level design following TSP. The PDT has elected to tolerate the risk(s) associated with the lack of geotechnical data and proceed.

5.2 Geotechnical Exploration

Soil boring data used in the design were obtained from the Texas Coastal Sediment Geodatabase (TxSed) compiled by the Texas General Land Office (GLO).

The strength test data for these borings are somewhat adequate for this level of design, consisting mostly of pocket penetrometer tests and torvane tests, with occasional unconfined compression tests. Also accompanying the strength test data is soil classification, Atterberg limits, moisture contents, sieve analyses, and dry unit weight determination. Deeper, site-specific borings and more detailed classification and strength testing is needed in order to well define the foundation conditions.

All data was plotted in charts of Shear Strength vs. Depth and Wet Density vs. Depth. Boring logs were laid out next to each other, from left to right in order to determine stratification lines. These stratification lines were overlaid on the plots of Shear Strength vs. Depth and Wet Density vs. Depth in order to create design lines.

5.2.1 East Brazos River Flood Gate

Six (6) borings were used for design on the east side of the Brazos. Three (3) of those boring locations vary from 1200 feet to 1500 feet away from the new gate. The other three (3) boring locations vary from 2700 feet to 3500 feet away from the new gate. Ground surface elevations of the borings are not known; only the depths are known. The borings extend to depths of approximately 60 feet.

Analysis of the referenced historic boring logs indicates that the foundation materials, in general, consist of sandy, cohesionless material near the surface of the channel bottom of approximately 2 feet in thickness. This material is underlain by clay strata of varying strengths to the end of the borings. Soft clays extend from approximately 2 feet deep to approximately 16 feet deep. Below this depth, the strengths of the clays vary from medium to stiff.

5.2.2 Colorado River East Flood Gate

Two (2) borings were used for design on the east side of the Colorado. The ground surface of these borings are approximately 15 feet below the water surface. Although no ground surface elevation was reported, an assumption was made that the water surface was at approximately zero elevation. Using this assumption and knowing the boring depth below the water surface, the ground surface elevations of the borings were assumed. The borings extend to depths of approximately 52 feet.

Analysis of the referenced historic boring logs indicates that the foundation materials, in general, consist of clay blanket near the surface of the channel bottom of approximately 9 feet in thickness. This material is underlain by a 4 foot thick sand stratum in which the bottom of the sand stratum is at approximately the same elevation as the dredge line of the proposed excavation. The sand stratum is underlain by strata of varying strengths of clay to the end of the borings. The strengths of these clays vary from medium to stiff.

5.2.3 Colorado River West Flood Gate

Three (3) borings were used for design on the west side of the Colorado. The ground surface of these borings are approximately 18 feet below the water surface. Although no ground surface elevation was reported, an assumption was made that the water surface was approximately zero elevation. Using this assumption and knowing the boring depth below the water surface, the ground surface elevations of the borings were assumed. The borings extend to depths of approximately 52 feet.

Analysis of the referenced historic boring logs indicates that the foundation materials, in general, consist of clay blanket near the surface of the channel bottom of approximately 12 feet in thickness. This material is underlain by a 7 foot thick sand stratum. This sand stratum may require specific dewatering efforts during construction, but the sheet pile wall of the TRS will likely reduce much of the flow from this layer. Additional field investigation and analyses would be required to determine the extent. This sand stratum is underlain by stratum of stiff clay to the end of the borings.

5.3 General Structure Design

5.3.1 Geotechnical Analysis of Structures

Feasibility geotechnical design of sector gates, and temporary retaining structures are presented below.

5.3.2 Stability Analyses

No stability analyses were conducted for the sector gates at Brazos or Colorado. Detailed stability analyses to evaluate any unbalanced loads for pile founded structures and to determine factors of safety for levee tie-in embankment slopes will be performed during PED when more reliable site-specific data is available.

5.3.2.1 Temporary Retaining Structure

A Temporary Retaining Structure (TRS) was designed for each sector gate structure for cost estimating purposes. Design of the actual TRS is normally required of the contractor. Results of the TRS design will be furnished upon request. A summary of these results are listed in **Table 16.** The TRS was designed using a combination of CWALSHT and SupportIT. CWALSHT is a CASE software program developed by the USACE for the use in designing and analyzing cantilever and single braced sheet pile structures. SupportIT is a software program developed by GT Soft Ltd. for the use in designing a cantilever, single braced, or multi-braced TRS.

Table 16 Results of Sector Gate TRS Designs

Structure	Tip Elevation (Ft)	Bending Moment (Ft-Kips/ft)	Brace Force @ El -3 (Kips/ft)	Brace Force @ EL -9 (Kips/ft)	Brace Force @ EL -14 (Kips/ft)	Brace Force @ EL -19 (Kips/ft)	* Brace Force @ EL -27 (Kips/ft)
Brazos East	-40.0	100.0	6.9	9.4	14.8	24.4	14.5
Colorado East	-42.0	103.8	7.4	6.5	8.3	14.0	10.8
Colorado West	-48.0	135.3	9.0	8.5	7.9	20.6	15.7

* Lowest brace is assumed to be a tremie slab

5.3.3 Dewatering and Sheet Pile Cutoff Design

Based on the available boring data, consideration was given for the dewatering requirements at each structure. Additionally, it was determined that design needed to be performed for the sheet pile seepage cutoff beneath each structure. Included herein are the results of those analyses and the assumptions that were made.

5.3.3.1 Dewatering

For the Brazos East Structure, based on the available boring data, the foundation at the structure location appears to be clay material throughout the depth of interest. Therefore, it is not likely that any specific dewatering requirements will be necessary for this site other than pumping within the TRS.

For the Colorado East Structure, based on the available boring data, the foundation at the structure location appears to include a shallow sand layer that could possibly be removed via excavation. But without more detailed investigations, this would be difficult to determine. Therefore, based on the current available data, engineering judgment is that it is not likely that any specific dewatering requirements will be necessary for this site other than pumping within the TRS.

For the Colorado West Structure, based on the available boring data, the foundation at the structure location includes a sand layer slightly deeper than the dredge elevation. This sand layer may need specific dewatering, but the sheet pile will likely cut off much of the flow and reduce much of the pressure from within this layer. Without more investigation (additional borings, piezometers, etc.) this would be difficult to determine. Therefore, based on the current available data, engineering judgment is that it is likely that specific dewatering requirements will be necessary for this site in addition to pumping within the TRS.

5.3.3.2 Seepage Cutoff Design

The sheet pile seepage cutoff for each structure was designed using Lane's Weighted Creep Method. Top of wall (TOW) structure elevations and bottom of base slab elevations were provided for each structure. Water elevations used in the analyses were provided. The water head assumed was the difference in elevation from the TOW at elevation +10 feet to the inside side water elevation of -2 feet.

For sheet piling design it was assumed that the soil beneath the pile founded gate will settle and leave a gap between the base and the soil for a flow path. It was also assumed that any soil along the outer edge of the base slab may experience shrinkage and leave a gap between the base and the soil for a flow path. Thus the only seepage cutoff path taken into consideration in the Lane's Weighted Creep Ratio analysis was that of the sheet piling beneath the gate foundation. Sand layers that the sheet piling penetrated were transformed by their corresponding creep ratios to that of a CH layer thickness with an equivalent creep ratio. More details of this analysis will be furnished upon request. A summary of these results are listed in **Table 17**.

Table 17 Results of Sheet Pile Cutoff Designs

Structure	Cutoff Tip Elevation (Ft)	Length of Sheet Pile (Ft)
Brazos East	-46.0	18
Colorado East	-46.0	18
Colorado West	-50.5	22.5

5.3.4 Pile Capacity for Structures

5.3.4.1 Design Methods and Assumptions

Computations were made to estimate the ultimate single pile load capacities for an open-ended 30-inch diameter steel pipe pile with wall thickness of 5/8-in. Capacities were computed for piles driven from assumed ground surfaces of the borings used for various structures. The pile capacities were computed for Q-case and S-case soil parameters in accordance with EM 1110-2-2906.

Q and S-case computations are plotted as ultimate capacity. Due to the lack of proximate geotechnical data, the recommended factors of safety for allowable pile capacity without a pile load test being performed have been modified to 3.5 for the Q-case and 2.0 for the S-case. Once adequate borings and testing are performed in the PED phase of the project, a well-defined foundation can be developed and the factors of safety as defined in EM 1110-2-2906 can be used, which would be 3.0 and 1.5 for the Q-case and S-case, respectively, without a site specific pile load test. If a site specific pile load test is performed, the Q-case factor of safety can be modified to 2.0 and the S-case factor of safety would remain at 1.5. The pile capacity curves will be furnished upon request.

If unbalanced loads are found to exist at the gate structure(s) during the PED phase of design, the axial capacity of the supporting piles above the identified critical depth should be ignored for support of the structure.

5.3.4.2 Pile Group Capacity and Spacing

Piles will derive a majority of their supporting capacity from skin friction. Therefore, it will be necessary to consider the effect of group action.

5.3.4.3 Estimated Settlement

Long-term settlement of individual pile foundations are typically not significant and usually in the range of ½ to ¾ inch. This estimate assumes piles will be driven in rows and does not include the elastic deformation of the piles. Elastic deformation can better be defined during the pile load test.

5.3.4.4 Pile Driving

Close field supervision should be maintained by experienced personnel to ensure proper procedures are followed and accurate records are kept during pile driving operations. The driving record should include the pile type, overall length, tip and butt diameters, embedment length below finished grade, and number of blows per foot of penetration. An accurate driving record is especially important to verify piles are installed to the required tip embedment and to give an indication of any unusual driving characteristics that may indicate pile breakage or overstress. If square precast concrete piles or steel H-Piles were to be considered as a substitute, they should be driven with a single acting air hammer with the hammer manufacturer's recommended rated energy (ft-lbs) per blow for each type (and length) of pile.

5.3.4.5 Test Piles

Test piles should be installed in close proximity to the project site or within the project footprint. The number and location of the test piles will depend on the type and location of the project features. The test pile program will be developed once the project features are finalized.

5.3.4.6 Static Load Tests

A series of load tests will be performed on piles considered for the project. The number of load tests will depend on the project features and will be provided during preparation of the plans and specifications. In general, load tests should be performed in accordance with ASTM D 1143. Project specifications will require load tests to failure or 300 percent of design load, whichever is achieved first. Static load tests will be performed no earlier than 21 days after initial pile installation.

5.3.4.7 Monitoring Considerations

Installation of piles may affect nearby structures. When structures are nearby, vibrations should be monitored during the test pile program, installation of job piles, installation and removal of sheet piles, and any demolition or other construction activities. The monitoring should be performed with a seismograph to evaluate peak particle velocities and frequency at critical structures during pile driving. The record of peak particle velocities should provide information in assessing potential damage and the need for changes in driving operations.

6 Operation and Maintenance for Recommended Plan

6.1 Normal Operation and Maintenance

Currently, normal operation is budgeted for $1.75 million per year for each of the two projects, Brazos River Floodgates and Colorado River Locks. For the purposes of this study, it is assumed that the current operation budget will be maintained for the recommended plan.

6.2 Major Operation and Maintenance

Currently, major maintenance occurs approximately every 10 years for each of the two projects. For Colorado River Locks, the last major maintenance contract was approximately $9.1 million while the last major maintenance contract for the Brazos River Floodgates was $5.6 million. Based off the contract data, it costs the approximately $5 million per gate monolith for major maintenance. For the recommended plan, it is assumed that improvements in the gate design, operating machinery and coating system will reduce major maintenance to a 15 year cycle, which will equate to $333,000 annually for the Brazos River Floodgates and $666,000 annually for the Colorado River Locks. Additionally, the timber guidewalls will require major maintenance every 5 years (estimated at 5% of the first cost) and replacement every 25 years, which will equate to $110,000 annually for the Brazos River Floodgates and $168,000 annually for the Colorado River Locks.

6.3 O&M Dredging

The recommended plan at both the Brazos and Colorado Rivers results in increases in the amount of maintenance dredging that will be required at the river crossings, along the GIWW and in the Freeport Harbor throughout the life of the project. Dredge material is currently disposed of in Placement Areas (PA) along the GIWW for all dredging along the GIWW and at the river crossings. Dredged material in Freeport Harbor is disposed offshore or in nearby Placement Areas. The PAs along the GIWW where additional maintenance dredging will need to be disposed include PAs 86/87, 88, 89, 90, 92, 106, 108, 108A, 109, and 110. **Figures 21 and 22** show the location of the PAs considered in the analysis.

Figure 21 Locations of PAs Considered in Vicinity of Brazos River Floodgates

Figure 22 Locations of PAs Considered in Vicinity of Colorado River Locks

The remaining capacity of the aforementioned PAs was based on past assessments conducted along with recent analysis conducted by the Galveston District. The assessment titled: "Gulf Intracoastal Waterway, Texas, High Island to Brazos River, Dredged Material Management Plan, Final Preliminary Assessment" dated March 2012 (Appendix 9) was used to develop remaining capacities at PAs 86/87 and 88. The assessment titled: "Gulf Intracoastal Waterway, Texas, Brazos River to Port O'Conner, Preliminary Project Assessment" dated March 2000 (Appendix 9) was used to develop remaining capacities at PAs 89, 90, 92, 106, 108, 108A, 109, and 110. Additional geotechnical analysis conducted by the Galveston District Engineering Branch in August of 2018 increased the capacity of PA 88.

The prior assessments were used to calculate future volumes for the placement areas based on 3 foot incremental lifts until the estimated maximum dike elevation was reached. For all adjacent disposal, a mobilization cost was assumed every two years for the dredge disposal. The perimeter of each PA was examined to calculate the cost of a 3 foot dike raise for each PA. Once the future volumes were exhausted for each PA offshore disposal was assumed. Refer to **Table 18** for a summary of the PAs and their remaining capacities and the unit cost for dike raises.

Table 18 Analysis of Remaining Capacity of PAs

Placement Area	Sedimentation Deposition Area (From AdH Model)	Remaining Capacity (CY)	Perimeter of PA (ft)	Cost to Raise PA Dike ($/CY)
86/87	Freeport to Brazos	1,543,040	20,234	$0.72
88	Freeport to Brazos	1,479,056	15,205	$0.68
89	Brazos River Crossing	8,024,720	34,920	$0.36
90	West of Brazos	575,960	11,016	$1.57
92	West of Brazos	2,976,600	17,602	$1.06
106	East of Colorado	6,359,760	54,405	$0.60
108	Colorado River Crossing	2,207,040	17,399	$0.95
108A	Colorado River Crossing	706,640	8,471	$2.39
109	West of Colorado	2,274,800	20,290	$0.98
110	West of Colorado	1,742,400	16,140	$1.17

For dredging costs for Freeport, all dredging was assumed to be disposed offshore as that is the current mode of disposal for dredging in the Freeport Channel. The existing dredge frequency of 8 months provided by OD was assumed to stay constant. It was assumed that the volume of dredging in each event would increase based on changes to sedimentation rates computed by the modeling.

A comparison of the historical dredge quantities was made versus the sediment deposition predicted by the AdH models. Because the AdH models output total of channel deposition included quantities from top of bank to top of bank and do not account for the consolidation that may occur in the deposited material, the yearly historical dredge quantities were less than those predicted by the AdH model. Therefore, the O&M dredging costs for the various alternatives was developed by pro-rating the quantities predicted by the AdH model by the ratio of the AdH predicted sediment values for the existing condition to the actual historical dredge quantities.

The existing dredge frequency of 2 years was provided by OD for the FWOP. The dredging frequencies and associated mobilization costs were scaled from existing O&M frequency based on changes to sedimentation rates computed by the AdH modeling. A cost of $200,000 was assumed every 5 years to complete the permit process to utilize offshore disposal areas once offshore disposal was needed.

6.3.1 Beneficial Use Comparison

Three locations near the Brazos River Crossing were identified as potential Beneficial Use (BU) site alternatives to the recommended plan of upland confined placement and offshore disposal once the upland disposal confined placement was exhausted. The results of the BU comparison are contained in Appendix 9. The BU sites are comparable in cost to offshore disposal, but those costs don't include real estate costs. No BU sites were identified for the Colorado River Crossing. Use of the BU sites is not recommended.

7 COST

7.1 Brazos River Floodgates and Colorado River Locks Systems

7.1.1 General

7.1.1.1 Cost estimate development

The project cost estimate was developed in the latest TRACES MII cost estimating software and used the standard approaches for a feasibility estimate structure regarding labor, equipment, materials, crews, unit prices, quotes, sub- and prime contractor markups. This philosophy was taken wherever practical within the time constraints. It was supplemented with estimating information from other sources where necessary such as quotes, bid data, and A-E estimates. The intent was to provide or convey a "fair and reasonable" estimate that which depicts the local market conditions. The estimates assume a typical application of tiering subcontractors. All of the construction work (e.g., sector gate structures, dredging, excavation, dewatering, pilings, rock, etc.) is common to the gulf coast region. The construction sites are accessible from land and water. Access is easily provided from the Gulf of Mexico, GIWW, or various local highways.

7.1.1.2 Estimate Structure

The estimates are structured to reflect the projects performed. The estimates have been subdivided by alternative and USACE feature codes.

7.1.1.3 Bid Competition

It is assumed that there will not be an economically saturated market and that bidding competition will be present.

7.1.2 Contract Acquisition Strategy

There is no declared contract acquisition plan/types at this time. It is assumed that the contract acquisition strategy will be similar to past projects with large, unrestricted design/bid/build contracts.

7.1.3 Labor Shortages

It is assumed there will be a normal labor market.

7.1.4 Labor Rates

Local labor market wages are above the local Davis-Bacon Wage Determination and actual rates have been used. Local payroll information was not available, therefore regional gulf coast information was used from the New Orleans District Construction Representatives and estimators with experiences in past years.

7.1.5 Materials

Cost quotes are used on major construction items when available. Recent quotes may include concrete, steel and concrete piling, rock, gravel and sand. The assumption is that materials will be purchased as part of the construction contract. The estimate does not anticipate government furnished materials. Prices include delivery of materials.

7.1.6 Quantities

Quantities provided for Colorado River Locks by MVN Structures Branch and for Brazos River Floodgates by TXDOT.

7.1.7 Equipment

Rates used are based from the latest USACE EP-1110-1-8, Region VI. Adjustments are made for fuel and facility capital cost of money (FCCM). Judicious use of owned verses rental rates was considered based on typical contractor usage and local equipment availability. Only a few select pieces of marine \ marsh equipment are considered rental. Full FCCM/Cost of Money rate is latest available; Mii program takes EP recommended discount, no other adjustments have been made to the FCCM. Equipment was chosen based on historical knowledge of similar projects.

7.1.8 Severe Rates

Severe equipment rates were used for various pieces of equipment in the hydraulic dredging crews where they may come in contact with a saltwater environment.

Rental rates were used for various pieces of marine and marsh equipment where rental is typical such as marsh backhoes.

7.1.9 Fuels

Fuels (gasoline, on and off-road diesel) were based on local market averages for on-road and off-road for the Gulf Coast area. The Team found that fuels fluctuate irrationally; thus, used an average.

7.1.10 Crews

Major crew and productivity rates were developed and studied by senior USACE estimators familiar with the type of work. All of the work is typical to the gulf coast area and New Orleans District cost engineers. The crews and productivities were checked by local MVN estimators, discussions with contractors and comparisons with historical cost data. Major crews include haul, earthwork, piling, concrete, and hydraulic dredging.

Most crew work hours are assumed to be 10 hrs 6 days/wk which is typical to the area. Marine based bucket excavation/dredging operations are assumed to work 2-12 hours shifts 7 days / week.

A 10% “markup on labor for weather delay” is selectively applied to the labor in major earthwork placing detail items and associated items that would be affected by small amounts of weather making it unsafe or difficult to place (trying to run dump trucks on a wet levee) or be detrimental/non-compliant to the work being done (trying to place/compact material in the rain). The 10% markup is to cover the common practice of paying for labor “showing up” to the job site and then being sent home due to minor weather which is part of known average weather impacts as reflected within the standard contract specifications. The markup was not applied to small quantities where this can be scheduled around.

7.1.11 Unit Prices

The unit prices found within the various project estimates will fluctuate within a range between similar construction units such as floodwall concrete, earthwork, and piling. Variances are a result of differing haul distances (trucked or barged), small or large business markups, subcontracted items, designs and estimates by others.

7.1.12 Relocation Costs

Relocation costs are defined as the relocation of public roads, bridges, railroads, and utilities required for project purposes. In cases where potential significant impacts were known, costs were included within the cost estimate.

7.1.13 Mobilization

Contractor mobilization and demobilization are based on the assumption that most of the contractors will be coming from within the gulf coast/southern region. Mob/demob costs are based on historical studies of detailed Government estimate mob/demob which are in the range of 5% of the construction costs. With undefined acquisition strategies and assumed individual project limits, the estimate utilizes a slightly more comprehensive approx. 6% value (min) applied at each contract rather than risking minimizing mob/demob costs by detailing costs based on an assumed number of contracts. This value also matches well with values previously prescribed by Walla Walla District, which has studied historical rates.

7.1.14 Field Office Overhead

The estimate used a field office overhead rate of 13%, 12% for the prime contractor’s base operations plus an additional 1% for access support since the project is located on the opposite side of the GIWW from land access. Based on historical studies and experience, Walla Walla District has recommended typical rates ranging from 9% to 11% for large civil works projects; however, the 9-11% rate does not consider possible incentives such as camps, allowances, travel trailers, meals, etc. which have been used previously to facilitate large or remote projects. With undefined acquisition strategies and assumed individual project limits, the estimate utilizes a more comprehensive percentage based approach applied at each contract rather than risking minimizing overhead costs by detailing costs based on an assumed number of contracts. The applied rates were previously discussed among numerous USACE District cost engineers including Walla Walla, Vicksburg, Norfolk, Huntington, St. Paul and New Orleans.

7.1.15 Overhead Assumptions

Overhead assumptions may include superintendent, office manager, pickups, periodic Overhead assumptions may include superintendent, office manager, pickups, periodic travel, costs, communications, temporary offices (contractor and government), office furniture, office supplies, computers and software, as-built drawings and minor designs, tool trailers, staging setup, camp/facility/kitchen maintenance and utilities, utility service, toilets, safety equipment, security and fencing, small hand and power tools, project signs, traffic control, surveys, temp fuel tank station, generators, compressors, lighting, and minor miscellaneous.

7.1.16 Home Office Overhead

Estimate percentages range based upon consideration of 8(a), small business and unrestricted prime contractors. The rates are based upon estimating and negotiating experience, and consultation with local construction representatives. Different percents are used when considering the contract acquisition strategy regarding small business 8(a), competitive small business and large business, high to low respectively. The applied rates were previously discussed among numerous USACE District cost engineers including Walla Walla, Vicksburg, Norfolk, Huntington, St. Paul and New Orleans.

7.1.17 Taxes

Local taxes will be applied based on the counties that contain the work. Reference the tax rate website for Texas: http://www.salestaxstates.com.

7.1.18 Bond

Bond is assumed 1% applied against the prime contractor, assuming large contracts. No differentiation was made between large and small businesses.

7.1.19 Planning, Engineering & Design (PED)

The PED cost includes such costs as project management, engineering, planning, designs, investigations, studies, reviews, value engineering and engineering during construction (EDC). Historically a rate of approximately 12% for E&D plus small percentages for other support features is applied against the estimated construction costs. Other USACE civil works districts such as St. Paul, Memphis, and St. Louis have reported values ranging from 10-15% for E&D. Additional support features might include project management, engineering, planning, designs, investigations, studies, reviews, and value engineering.

7.1.20 Supervision & Administration (S&A)

Historically a range from 5% to 15% depending on project size and type applied against the estimated construction costs. Other USACE civil works districts such as St. Paul, Memphis, and St. Louis report values ranging from 7.5-10%. Consideration includes that a portion of the S&A effort could be performed by contractors. S&A costs are percentage based.

7.1.21 Contingencies

Contingencies at the alternative stage were developed using the USACE Abbreviated Cost Risk Analysis (ARA) program based on cost risks determined by the PDT. A separate ARA was prepared for each alternative to help differentiate between the alternatives. For the TSP, a full Cost and Schedule Risk Analysis (CSRA) was developed on the complete project using the Crystal Ball program. See Cost and Schedule Report for details.

7.1.22 Escalation

Escalation used is based upon the latest version of the US Army Corps of Engineers Engineering Manual (EM) 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS).

7.1.23 HTRW

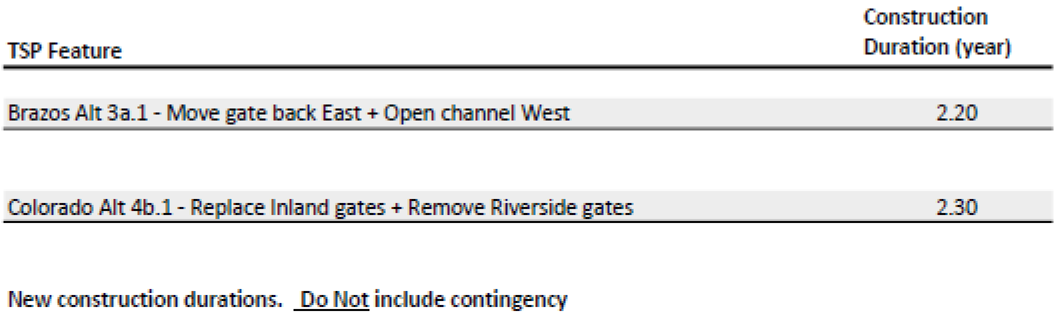
The estimate does not include costs for any potential Hazardous, Toxic, and Radioactive Waste (HTRW) due to lack of any concerns.

7.2 Cost Estimate and Schedule – Recommended Plan

This section summarizes the schedule and cost associated with the recommended plan for the Brazos and Colorado River Crossings. The updated schedule and cost reflect refinements made to the selected alternatives after the TSP Milestone.

7.2.1 Schedule – Recommended Plan

The schedule for each of the project sites was developed based on the construction line items for each feature of work. Detailed schedules are attached at the end of Appendix 10.



TSP Feature	Construction Duration (year)
Brazos Alt 3a.1 - Move gate back East + Open channel West	2.20
Colorado Alt 4b.1 - Replace Inland gates + Remove Riverside gates	2.30

New construction durations. Do Not include contingency

Table 19 Summary of Construction Durations

7.2.2 Cost Estimates – Recommended Plan

Tables 20 and 21 show the baseline project cost for each project site. This information is taken from the Total Project Cost Sheet (TPCS).

Table 20 Brazos River – Recommended Plan Alt 3a.1

Feature	Cost	Contingency	Total
01 Lands & Damages	$159,000	$40,000	$199,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$544,000	$152,000	$696,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str	$91,404,000	$25,593,000	$116,997,000
30 PED	$18,366,000	$5,142,000	$23,508,000
31 Construction Management	$10,054,000	$2,815,000	$12,869,000
TOTAL	$120,527,000	$33,743,000	$154,270,000

Table 21 Colorado River –Recommended Plan Alt 4b.1

Feature	Cost	Contingency	Total
01 Lands & Damages	$36,000	$9,000	$45,000
02 Relocations			
05 Locks	$146,330,000	$40,972,000	$187,302,000
06 Fish & Wildlife Facilities	$29,000	$8,000	$37,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str			
30 PED	$29,272,000	$8,196,000	$37,468,000
31 Construction Management	$16,097,000	$4,507,000	$20,604,000
TOTAL	$191,764,000	$53,693,000	$245,457,000

7.2.3 Cost Estimates – Recommended Plan Mii Summary

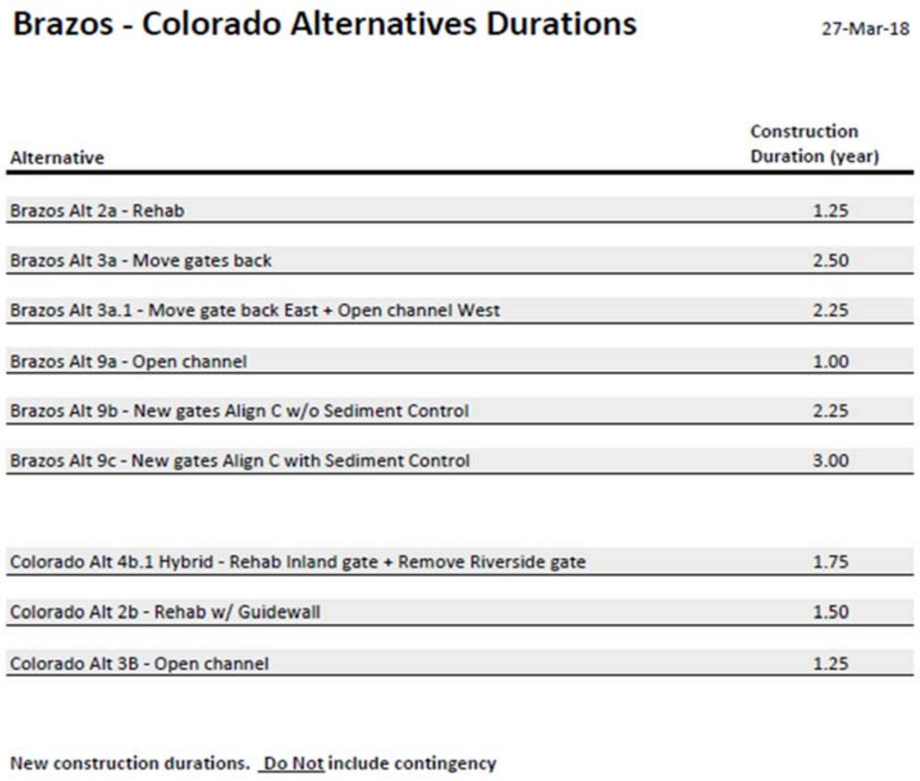
Mii project summary for each project site attached at end of Appendix 10.

7.2.4 Cost Estimates – Recommended Plan CSRA Summary

Cost and Schedule Risk Analysis (CSRA) summary and risk register for the project attached at end of Appendix 10.

7.3 Cost Estimate and Schedule – Alternatives

7.3.1 Schedule – Alternatives



Brazos - Colorado Alternatives Durations

27-Mar-18

Alternative	Construction Duration (year)
Brazos Alt 2a - Rehab	1.25
Brazos Alt 3a - Move gates back	2.50
Brazos Alt 3a.1 - Move gate back East + Open channel West	2.25
Brazos Alt 9a - Open channel	1.00
Brazos Alt 9b - New gates Align C w/o Sediment Control	2.25
Brazos Alt 9c - New gates Align C with Sediment Control	3.00
Colorado Alt 4b.1 Hybrid - Rehab Inland gate + Remove Riverside gate	1.75
Colorado Alt 2b - Rehab w/ Guidewall	1.50
Colorado Alt 3B - Open channel	1.25

New construction durations. Do Not include contingency

Table 22 Summary of Construction Durations

7.3.2 Baseline Project Cost for Each Alternative

Tables 23 through 31 show the baseline project cost for each alternative. This information is taken from the Total Project Cost Sheet (TPCS).

Table 23 Brazos River – Alt 2a Rehab

Feature	Cost	Contingency	Total
01 Lands & Damages	$28,000	$6,000	$33,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities			
11 Levees & Floodwalls			
15 Fldwy Control & Div Str	$24,579,000	$10,323,000	$34,902,000
30 PED	$5,002,000	$2,101,000	$7,102,000
31 Construction Management	$2,751,000	$1,155,000	$3,907,000
TOTAL	$32,359,000	$13,585,000	$45,944,000

Table 24 Brazos River – Alt 3a

Feature	Cost	Contingency	Total
01 Lands & Damages	$28,000	$6,000	$33,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$311,000	$131,000	$442,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str	$161,982,000	$68,033,000	$230,015,000
30 PED	$33,033,000	$13,874,000	$46,907,000
31 Construction Management	$18,169,000	$7,631,000	$25,799,000
TOTAL	$213,523,000	$89,674,000	$303,197,000

Table 25 Brazos River – Alt 3a.1

Feature	Cost	Contingency	Total
01 Lands & Damages	$28,000	$6,000	$33,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$306,000	$122,000	$429,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str	$91,359,000	$36,543,000	$127,902,000
30 PED	$18,657,000	$7,463,000	$26,119,000
31 Construction Management	$10,262,000	$4,105,000	$14,367,000
TOTAL	$120,611,000	$48,239,000	$168,850,000

Table 26 Brazos River – Alt 9a

Feature	Cost	Contingency	Total
01 Lands & Damages	$1,803,000	$448,000	$2,251,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$1,556,000	$591,000	$2,148,000
09 Channels & Canals	$14,220,000	$5,404,000	$19,624,000
15 Fldwy Control & Div Str			
30 PED	$3,211,000	$1,220,000	$4,431,000
31 Construction Management	$1,766,000	$671,000	$2,436,000
TOTAL	$22,556,000	$8,334,000	$30,890,000

Table 27 Brazos River – Alt 9b

Feature	Cost	Contingency	Total
01 Lands & Damages	$1,803,000	$448,000	$2,251,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$1,454,000	$582,000	$2,036,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str	$146,851,000	$58,740,000	$205,592,000
30 PED	$30,188,000	$12,075,000	$42,263,000
31 Construction Management	$16,603,000	$6,641,000	$23,245,000
TOTAL	$196,900,000	$78,487,000	$275,386,000

Table 28 Brazos River – Alt 9c

Feature	Cost	Contingency	Total
01 Lands & Damages	$1,803,000	$448,000	$2,251,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$1,454,000	$596,000	$2,050,000
15 Fldwy Control & Div Str	$145,277,000	$59,563,000	$204,840,000
15 Fldwy Control & Div Str	$8,629,000	$3,538,000	$12,167,000
30 PED	$31,621,000	$12,965,000	$44,586,000
31 Construction Management	$17,393,000	$7,131,000	$24,524,000
TOTAL	$206,176,000	$84,241,000	$290,418,000

Table 29 Colorado River – Alt 2b1 Rehab

Feature	Cost	Contingency	Total
01 Lands & Damages	$16,000	$3,000	$20,000
02 Relocations			
05 Locks	$46,428,000	$20,428,000	$66,856,000
06 Fish & Wildlife Facilities			
11 Levees & Floodwalls			
15 Fldwy Control & Div Str			
30 PED	$9,449,000	$4,157,000	$13,606,000
31 Construction Management	$5,197,000	$2,287,000	$7,484,000
TOTAL	$61,090,000	$26,876,000	$87,966,000

Table 30 Colorado River – Alt 3b Open Channel

Feature	Cost	Contingency	Total
01 Lands & Damages	$16,000	$3,000	$20,000
02 Relocations			
05 Locks			
06 Fish & Wildlife Facilities	$36,000	$15,000	$51,000
09 Channels & Canals	$18,840,000	$8,101,000	$26,941,000
15 Fldwy Control & Div Str			
30 PED	$3,841,000	$1,651,000	$5,492,000
31 Construction Management	$2,112,000	$908,000	$3,021,000
TOTAL	$24,845,000	$10,680,000	$35,524,000

Table 31 Colorado River – Alt 4b.1

Feature	Cost	Contingency	Total
01 Lands & Damages	$16,000	$3,000	$20,000
02 Relocations			
05 Locks	$33,758,000	$14,178,000	$47,936,000
06 Fish & Wildlife Facilities	$36,000	$15,000	$51,000
11 Levees & Floodwalls			
15 Fldwy Control & Div Str			
30 PED	$6,879,000	$2,889,000	$9,769,000
31 Construction Management	$3,785,000	$1,589,000	$5,374,000
TOTAL	$44,474,000	$18,675,000	$63,149,000