BRAZOS ISLAND HARBOR, TX

CHANNEL IMPROVEMENT PROJECT

FINAL ENGINEERING APPENDIX

MAY 2014

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BRAZOS ISLAND HARBOR CHANNEL IMPROVEMENT PROJECT

1.0 GENERAL INFORMATION

The Brazos Island Harbor (BIH) Improvement Feasibility Study (FS) with the Engineering Appendix (EA) was conducted after a Cost Sharing Agreement for the feasibility study was signed on June 28, 2006 with the study officially starting in July of 2006. Congress authorized the U.S. Army Corps of Engineers (USACE) to conduct a study of Brazos Island Harbor, Texas to determine whether the project should be modified in regards to widening and deepening the existing channels pursuant to a resolution of the Committee on Public Works, United States (U.S.) House of Representatives dated May 5, 1966. The Engineering Appendix follows the requirements of Project Management Plan, July 2006, ER 1110-2-1150, Appendix C, and input of the non-Federal Sponsor, the Brownsville Navigation District (BND).

Engineering studies for this deep draft navigation project included Ship Simulation/Navigation Study, HarborSym Modeling, Sediment Study, Hydrodynamic Modeling, Storm Surge Modeling, Habitat Evaluation Procedure/Habitat Suitability Models, Endangered and threatened species assessments, Geometrical analysis of Rig Movement and Oil Rig Analysis investigations by the Corps of Engineers' Engineer Research & Development Center (ERDC); preliminary geotechnical investigations and preparation of a preliminary DMMP by Geotechnical Section, in-house channel surveys; and A-E land surveys. Other engineering and design features considered include surveying and mapping, civil design, geotechnical design, operations and maintenance, cost estimates, and scheduling for construction. Preliminary alternative designs and screening level cost estimates were developed in sufficient detail to substantiate the recommended plan and baseline cost estimate.

1.1 PROJECT LOCATION AND DESCRIPTION

Brazos Island Harbor, Texas is located in Cameron County at the southern coast of Texas about 5 miles from the Mexican border of Brownsville. The Brownsville Ship Channel (BSC) extends approximately 19.4 miles from the turning basin to the entrance reach in the Gulf of Mexico.

Figure 1-1 – Study Area

The Brownsville Ship Channel is shown in the Study Area (Figure 1-1), the Location Plan on Drawing No. C-01 and also on Drawing Nos. C-02 thru C-09. The proposed Tentatively Selected Plan (TSP) is a 52-foot depth dredging plan with no widening from Station 84+200 to Station -17+000. The different channel depths are described in Section 2.2.4 and Table 2.5 lists dimensions for the proposed 52-foot depth plan. The TSP also includes a proposed dike to protect the loma between the cells and erosion protection along the levee toe at PA 4A and PA 4B. These additions are shown on Drawing No. C-06. This plan also includes extending the entrance channel 4000 feet to account for the additional depth of 52 feet MLLW, shown on Drawing No. C-09. This improvement will allow larger and deeper draft ships to navigate the Port of Brownsville. The bottom channel widths for the existing and proposed channel are the same. Refer to the Existing Channel Dimensions Table 2-1 for the depth dimensions of the existing Brownsville Ship Channel. The Brownsville Ship Channel is practically a straight channel without bridge crossings or other known obstructions. The Port Isabel Channel which extends north at approximately Station 18+000 of the Brownsville Ship Channel was not a part of this study.

2.0 BROWNSVILLE SHIP CHANNEL

2.1 EXISTING BROWNSVILLE SHIP CHANNEL

The existing Brownsville Ship Channel consists of the Entrance Channel at 46 feet MLLW deep (including 2 feet of advance maintenance) by 300 feet wide for a distance of 1.3 miles; Jetty Channel at 46 feet MLLW deep (including 2 feet of advance maintenance) by 300 to 400 feet wide for a distance of 1.13 miles; Main Channel at 44 feet MLLW deep (including 2 feet of advance maintenance) by varying widths for a distance of 15 miles; Turning Basin Extension at 44 feet MLLW deep (including 2 feet of advance maintenance) by varying widths for a distance of 1.25 miles; Turning Basin at 38 feet MLLW deep (including 2 feet of advance maintenance) by varying widths for a distance of 3,300 feet.

The existing channel widths were not modified. The majority of the channel is 250 feet but some channel sections vary in widths of 300 feet and above. The historical justification of the need for the widths above 250 is included in the Brazos Island Harbor 1960 Planning Report. Those increased widths are needed for safety and maneuverability in the turning basin and turning basin extension and to provide an adequate width of fairway to the turning basin in the reach of channel just before and adjacent to the oil terminals. Vessels needed additional clearance because they were having difficulty passing the entrance to the Brownsville turning basin extension when vessels were moored at the oil docks. Because of the small cross sectional area of the channel, large vessels must pass at a slow rate of speed to prevent damage to the moored vessels and wharves for surge action. The very slow speed is not sufficient for steerageway and control of the vessel is difficult, especially during rough weather. These existing widths allow a minimum of 125 feet of berthing space between any structure and the Federal Channel Additionally, the 400-foot wide section of channel transitioning to the jetty channel is needed because of the strong southeast winds in the portion of the waterway crossing the Laguna Madre making it difficult for vessel navigation. The improved channel will need the same historical clearances as before to eliminate most of the waiting time encountered by vessels unable to pass in the narrow channel and also to reduce the navigational hazards in these reaches.

2.1.1 Brownsville Entrance Channel Reach

The Brownsville Entrance Channel Reach extends from the Gulf of Mexico to the offshore end of the jetties. It begins just east of the jetty and extends 1.3 miles out to the Gulf of Mexico. The channels width is 300 feet and depth is 46 feet MLLW, including 2 feet of advance maintenance.

2.1.2 Brownsville Jetty Channel Reach

The Brownsville Jetty Channel Reach extends the entire length of the jetties, 1.13 miles at 46 feet MLLW in depth, including 2 feet of advance maintenance. The channels width transitions from 300 feet to 400 feet.

2.1.3 Brownsville Main Channel

The Brownsville Main Channel Reach, approximately 15 miles, extends from the Brownsville Ship Jetty Channel to the Turning Basin Extension at 44 feet MLLW in depth, including 2 feet of advance maintenance. The channel width transitions from 400 feet to 250 feet and ending at 300 feet.

2.1.4 Brownsville Turning Basin Extension

The Brownsville Turning Basin Extension, 1.25 miles, extends from the Main Channel to the Brownsville Turning Basin at a depth of 44 feet MLLW, including 2 feet of advance maintenance. The channel width transitions from 300 feet to 400 feet ending at 325 feet.

2.1.5 Brownsville Turning Basin

The Brownsville Turning Basin Reach, 3,300 feet, extends from Turning Basin Extension to the west end of the channel at a depth of 38 feet MLLW, including 2 feet of advance maintenance. The channel width transitions from 325 feet to 1200 feet.

Table 2-1 Existing Brownsville Ship Channel Dimensions

Reach	Station	to	Station	Bottom Width (FT)	Project Depth (MLLW)	Channel Depth (MLLW)	A.O. (FT)	Side Slope
Entrance Channel	-13+000		-6+000	300	44	46	2	1V:6H
Jetty Channel	-6+000		-1+026	300	44	46	2	1V:6H
Transition	-1+026		-0+826	300-400	44	46	2	1V:6H
Jetty Channel	-0+826		0+000	400	44	46	2	1V:6H
Main Channel	0+000		1+515.3	400	42	44	1	1V:3H
Transition	1+515.3		2+328.82	250	42	44	1	1V:3H
Main Channel	2+328.82		35+000	250	42	44	1	1V:3H
Main Channel	35+000		62+847.26	250	42	44	1	1V:2.5H
Transition	62+847.26		63+769.5	250-300	42	44	1	1V:2.5H
Main Channel	63+769.5		79+415	300	42	44	1	1V:2.5H
Transition	79+415		79+610	300-400	42	44	1	1V:2.5H
Turning Basin Extension	79+610		83+400	400	42	44	1	1V:2.5H
Transition	83+400		83+600	400-325	42	44	1	1V:2.5H
Turning Basin Extension	83+600		85+000	325	42	44	1	1V:2.5H
Turning Basin Extension	85+000		86+215	325	36	38	1	1V:2.5H
Transition	86+215		86+355	325-450	36	38	1	1V:2.5H
Turning Basin	86+355		86+705	450	36	38	1	1V:2.5H
Transition	86+705		86+945	450-690	36	38	1	1V:2.5H
Turning Basin	86+945		88+170	690	36	38	1	1V:2.5H
Transition	88+170		88+600	690-1200	36	38	1	1V:2.5H
Turning Basin	88+600		89+150	1200	36	38	1	1V:2.5H
Transition to End	89+150		89+500	1200-860	36	38	1	1V:2.5H

A.O. = ALLOWABLE OVERDEPTH-Channel Depth includes Advance Maintenance.

2.2 PROJECT DESIGN AND DEVELOPMENT

During the feasibility study, different alternative navigation channel plans were evaluated. The feasibility study consisted of a three phase process: Initial Plan Formulation, Plan Formulation, and Detail design.

2.2.1 Initial Plan Formulation

Nine initial structural alternatives with different iterations are listed in Table 2-2. Several widths were combined with the four depths of 45, 48, 50 and 55 feet including the existing depth. Initial Plan Formulation involved screening initial alternatives and eliminating alternatives that rated low. The remaining alternatives were analyzed in a more detailed manner in the next phase(Table 2-3). Alternatives that did not improve navigation or have support from the non-federal sponsor were not considered in the next screening. The nine structural alternatives were reduced to five after additional screening that included quantities, costs and benefit-to-cost ratios (BCRs) in Table 2-3.

Table 2-2 Initial Alternatives

ITEM	DESCRIPTION
I-1a	Deepen existing channel depth to 45' MLLW
I-1b	Deepen existing channel depth to 48' MLLW
I-1c	Deepen existing channel depth to 50' MLLW
I-1d	Deepen existing channel depth to 55' MLLW
I-2a	Deepen to 45 feet and widen channel bottom by 100 feet
I-2b	Deepen to 50 feet and widen channel bottom by 100 feet
I-2c	Deepen to 55 feet and widen channel bottom by 100 feet
I-3	Widen only "passing areas"
I-4a	Widen channel bottom by 100 feet
I-4b	Widen channel bottom by 200 feet
I-4c	Widen channel bottom by 300 feet
1-4d	Widen channel bottom by 400 feet
1-5	Widen channel only to point where rigs are worked on
1-6	Deepen only up to new turning basin location
1-7	Deepen and widen up to new turning basin location
I-8	Add new turning basin (2000 feet X 2000 feet) with various depths
I-9	Deepen channel to 48 feet MLLW and widen with shelves, each side by 50 feet to 75 feet at 45 foot MLLW depth
I-10a	Utilize another port
I-10b	Alternative modes of commodity transport
I-11	No Action Alternative

Table 2-3 Initial Alternatives After Evaluation Screening

ITEM	DESCRIPTION	QUANTITY CYS
1.a	Deepen existing channel depth to 45 feet	7 Million
1.b	Deepen existing channel depth to 48 feet	12 Million
1.c	Deepen existing channel depth to 50 feet	15 Million
2.a	Deepen to 45 feet and widen channel bottom by 200 feet	26 Million
2.b	Deepen to 48 feet and widen channel bottom by 200 feet	32 Million
2.c	Deepen to 50 feet and widen channel bottom by 200 feet	36 Million
3a	Deepen to 45 feet and widen with 75-foot shelves at 42-foot depth	21 Million
3b	Deepen to 48 feet and widen with 75-foot shelves at 42-foot depth	26 Million
3c	Deepen to 50 feet and widen with 75-foot shelves at 42-foot depth	29 Million
4d	Widen (only) channel bottom by 200 feet	24 Million
1-5	Deepen to 45 feet up to and creation of new turning basin	24 Million
1-6	Deepen to 48 feet up to and creation of new turning basin	26 Million
1-7	Deepen to 50 feet up to and creation of new turning basin	28 Million

2.2.2 Plan Formulation Phase

Plan Formulation phase re-focused on four alternative depths: 45, 48, 50 and 52 feet MLLW. The selective widening with costs are shown below in Table 2-4. The Engineer Research and Development, Coastal and Hydraulics Laboratory (ERDC-CHL) performed ship simulations for BIH for depths of 42, 45 and 48 feet MLLW and various widths. The simulations included a 2-foot allowance and could be applied to a 50-foot MLLW depth. The ERDC-CHL recommendation was to deepen the channel at 50 feet MLLW and widen at 350 feet. Further analysis was done that revealed the alternative plans with widths of 300 and 350 feet would extend top of cut of channel and impact approximately 1 acre of submerged aquatic vegetation. The 52-foot deepening with no widening plan produced the greatest net benefits and was the deepest channel dimension the non-Federal sponsor would support. Therefore the 52-foot deepening with no widening plan was chosen as the TSP.

2.2.3 Value Engineering Study

During the Plan Formulation Phase, the Value Engineering Study Report was done by ARCADIS, a Value Engineering Consultant. They also analyzed the current design which was to deepen the channel at 50 feet MLLW and widen the channel at 350 feet in width. The Value Engineering alternatives recommendations were as follows:

- VE-1 – Only widen the channel to 300 feet from Station 28+000 to Station 79+415 in lieu of 350 feet.
- VE-2 – Only deepen the channel to 48 feet from Station 84+200 to the end of the turning basin.
- VE-3 – Do not deepen the turning basin.

The Project Design Team (PDT) decided to use the recommendation of VE-3 and modifications to VE-2 for the final plan. The channel would be deepened to 42 feet MLLW instead of 48 feet MLLW from Station 84+200 to Station 86+000. The Value Engineering Study Report and Major Subordinate Command (MSC) Acceptance of VE Implementation letter are added as attachments to the Engineering Appendix.

Table 2-4 Plan Formulation Alternatives

ITEM	DESCRIPTION	QUANTITY CYS
F1-a	Deepen entire existing channel to a depth of 45 feet	3,736,000
F1-b	Deepen entire existing channel to a depth of 48 feet	8,274,000
F1-c	Deepen entire existing channel to a depth of 50 feet	11,430,000
F1-d	Deepen entire existing channel to a depth of 52 feet	14,093,000
F2-a	Deepen to 45 feet and widen by 50 feet to a 300-foot width	7,703,000
F2-b	Deepen to 48 feet and widen by 50 feet to a 300-foot width	12,912,000
F2-c	Deepen to 50 feet and widen by 50 feet to a 300-foot width	16,503,000
F2-d	Deepen to 52 feet and widen by 50 feet to a 300-foot width	19,758,000
F3-a	Deepen to 45-feet and widen by 100 feet to a 350-foot width	14,007,000
F3-b	Deepen to 48-feet and widen by 100 feet to a 350-foot width	19,315,000
F3-c	Deepen to 50-feet and widen by 100 feet to a 350-foot width	22,569,000
F3-d	Deepen to 52-feet and widen by 100 feet to a 350-foot width	26,728,000

2.2.4 Detail Design Phase

The detail design phase concentrates on the TSP. The proposed channel is approximately 20 miles with the 4000 feet extension to the entrance channel. After the final screening, which included the economic study, the TSP was identified as being the 52-foot deepening with no widening. Refer to Appendix H for the details of the economic analysis. The 52-foot plan was chosen because it was the most cost effective with the most net benefits. The depths for the Brownsville Entrance and Jetty Channel require an additional 2 feet of depth (54-feet) to allow for the effects of vessel pitch, roll, and heave occurring there as a result of strong currents, waves and wind. The proposed Brownsville Channel is shown on the LOCATION PLAN, Drawing No. C-01. Table 2-5, BSC TSP Dimensions show the new 52-foot depth proposed dimensions for the separate reaches. The channel depth column include the advance maintenance for each reach. Cross sections on Drawing Nos. C-12 thru C-14 show the depths for the existing and proposed channels. Drawing No. C-9 show the proposed 4000 feet extension to the entrance channel. The proposed BSC reaches are described in the paragraphs below.

Table 2-5 Proposed BSC Dimensions For 52 ft MLLW Depth

Reach	Station	To	Station	Bottom Width (FT)	Project Depth (MLLW)	Channel Depth (MLLW)	A.O. (FT)	Side Slope
New Entrance Channel Extension	-17+000		-13+000	300	54	56	2	1V:6H
Entrance Channel	-13+000		-6+000	300	54	56	2	1V:6H
Jetty Channel	-6+000		-1+026	300	54	56	2	1V:6H
Transition	-1+026		-0+826	300-400	54	56	2	1V:6H
Jetty Channel	-0+826		0+000	400	54	56	2	1V:6H
Main Channel	0+000		1+516.3	400	52	54	1	1V:3H
Transition	1+515.3		2+328.82	400-250	52	54	1	1V:3H
Main Channel	2+328.82		35+000	250	52	54	1	1V:3H
Main Channel	35+000		62+847.26	250	52	54	1	1V:2.5H
Transition	62+847.26		63+769.47	250-300	52	54	1	1V:2.5H
Main Channel	63+769.47		79+415	300	52	54	1	1V:2.5H
Transition	79+415		79+610	300-400	52	54	1	1V:2.5H
Turning Basin Extension	79+610		83+400	400	52	54	1	1V:2.5H
Transition	83+400		83+600	400-325	52	54	1	1V:2.5H
Turning Basin Extension	83+600		84+200	325	52	54	1	1V:2.5H
Turning Basin Extension	84+200		85+000	325	42	44	1	1V:2.5H
Turning Basin Extension	85+000		86+000	325	42	44	1	1V:2.5H
Turning Basin Extension	86+000		86+215	325	36	38	1	1V:2.5H
Transition	86+215		86+355	325-450	36	38	1	1V:2.5H
Turning Basin	86+355		86+705	450	36	38	1	1V:2.5H
Transition	86+705		86+945	450-690	36	38	1	1V:2.5H
Turning Basin	86+945		88+170	690	36	38	1	1V:2.5H

Transition	88+170		88+600	690-1200	36	38	1	1V:2.5H
Turning Basin	88+600		89+150	1200	36	38	1	1V:2.5H
Transition to End	89+150		89+500	1200-860	36	38	1	1V:2.5H

A.O. = ALLOWABLE OVERDEPTH

Channel Depth includes Advance Maintenance depth – There is a constant 2’ for the entire waterway.

2.2.4.1 Brownsville Entrance Channel Extension

The new extension to the Entrance Channel begins at existing Sta -13+000 and extends to Sta -17+000. Refer to Drawing No. C-9. The bottom width of 300 feet will remain the same as existing. The depth will be 54 feet MLLW.

2.2.4.2 Brownsville Entrance Channel

The bottom width for the proposed channel from Sta -13+000 to Sta -6+000 was not increased and the existing centerline remains the same. The existing channel depth for this reach increased from 44 feet MLLW to 54 feet MLLW. The depth in this area has historically been an additional 2 feet deeper than the main channel to allow for the effects of vessel pitch, roll and heave occurring there as a result of strong currents, waves and wind. Refer to Drawing No. C-09.

2.2.4.3 Brownsville Jetty Channel

The bottom width for the proposed Jetty Channel from Sta -6+000 to Sta 0+000 was not increased and the existing centerline remains the same. The existing channel depth increased from 44 feet MLLW to 54 feet MLLW. The depth in this area has historically been an additional 2 feet deeper than the main channel to allow for the effects of vessel pitch, roll and heave occurring there as a result of strong currents, waves and wind.

2.2.4.4 Brownsville Main Channel

The bottom width for the proposed Main Channel from Sta 0+000 to Sta 79+610 was not increased and the existing centerline remains the same. The existing channel depth increased from 42 feet MLLW to 52 feet MLLW.

2.2.4.5 Brownsville Turning Basin Extension

The bottom width for the proposed Turning Basin Extension Channel was not increased and the existing centerline remains the same. The existing channel depth of 42 feet MLLW was increased to 52 feet MLLW for Sta 79+610 to Sta 84+200. The existing channel depth of 42 feet MLLW for Sta 84+200 to Sta 85+000 was not increased because it was determined to not be economically viable. The existing depth of 36 feet MLLW for Sta 85+000 to Sta 86+000 was increased to 42 feet MLLW. The existing depth of 36 feet MLLW was not increased but maintained from Sta 86+000 to Sta 86+215.

2.2.4.6 Brownsville Turning Basin

The bottom width for the proposed Turning Basin from Station 86+215 to Sta 89+500 was not increased and the existing centerline remains the same. The existing channel depth of 36 feet MLLW was not increased due to incorporation of Value Engineering Proposal VE-3.

2.3 MITIGATION

There are no significant impacts to the project, therefore mitigation will not be required.

2.4 AIDS TO NAVIGATION

We are assuming there may be existing aids to navigation that are affected by the proposed plan within the channel that may require relocating or removal. There may also be a need for the installation of new aids to navigation. The U.S. Coast Guard (USCG) is responsible for installing, relocating and the removal of aids to navigation. The associated cost for this work is included in the MCACES estimate.

2.5 DREDGING FREQUENCY

The dredging cycle of a channel is defined by the average number of years between the O&M dredging operations for a historical period. Each channel or canal has its own dredging frequency. The District's Dredging Histories Database Management System contains this information, and is the major source for the ERDC's Sediment Study Report. It is assumed for the new project that the dredging frequency will not change and will remain identical to the existing Channel. Frequency can be seen in the Predicted Shoaling Table 2-6 below.

2.6 PREDICTED SHOALING RATES

A desktop study for sediment related problems was performed by ERDC. The study was performed for a 50 feet MLLW depth, and then revised for the proposed 52 feet MLLW depth. The study produced shoaling estimates that are shown in the Predicted 52 ft MLLW Shoaling Quantities Table 2-6.

Table 2-6 Predicted 52 ft MLLW Shoaling Quantities

Channel Reach	O&M Cycle FREQ (YR)	Shoaling CY/Cycle
Sta. 17+000 to 0+000	1.5	706,000
Sta. 0+000 to 11+000	4.5	727,000
Sta. 11+000 to 28+000	4	736,000
Sta. 28+000 to 34+000	4	172,000
Sta. 34+000 to 50+000	4	494,000
Sta. 50+000 to 65+000	5	718,000
Sta. 65+000 to 79+415	6	586,000
Sta. 79+415 to 89+500	7	241,000

NOTE: This Table only shows the estimated shoaling per section.

2.7 NEW WORK DREDGING

New work material volumes can be seen in Table 2-7, the Brownsville Ship Channel New Work Dredging Quantities For 52 ft MLLW Plan. New work material volumes do not contain maintenance material. The new work volumes which total 14,093,000 CYS include Advance Maintenance as well as the recommended Allowable Overdepth.

Table 2-7 Brownsville Ship Channel New Work Dredging Quantities For 52 ft MLLW Plan

Reach	Station	To Station	Total New Work CYS*
New Brownsville Entrance Channel Extension	-17+000	-13+000	232,000
Brownsville Entrance Channel	-13+000	-6+000	872,000
Brownsville Jetty Channel	-6+000	0+000	963,000
Brownsville Main Channel	0+000	79+415	11,212,000
Brownsville Turning Basin Extension	79+415	86+215	748,000
Brownsville Turning Basin	86+215	89+500	66,000
Brownsville Channel Total			14,093,000

2.8 ALLOWABLE OVERDEPTH

An additional depth outside the required template is permitted to allow for inaccuracies in the dredging process. District commanders may dredge a maximum of two feet of Allowable Overdepth in coastal regions, and in inland navigation channels. (ER 1130-2-520 Navigation and Dredging Operations and Maintenance Policies*)* This additional dredging allowance is referred to as Allowable Overdepth (AO). The existing channel varied between 1' to 2' allowable over depth. It is anticipated that large pipeline dredges will be utilized to construct the proposed waterway. District policy recommends 2' allowable overdepth in reaches where large dredges operate. The existing and proposed channel contain the same allowable overdepth for the entire length of the channel.

Table 2.8 Allowable Overdepth

Reach	**Allowable Overdepth FT**
Brownsville Entrance Channel (Sta -17+000 to Sta 6+000)	2
Brownsville Jetty Channel (Sta. -6+000 to Sta 0+000)	2
Brownsville Main Channel (Sta 0+00-Sta 79+415)	1
Brownsville Turning Basin Extension Channel (Sta 79+415-Sta 86+215)	1
Brownsville Turning Basin (Sta 86+215-Sta 89+500)	1

2.9 ADVANCE MAINTENANCE

The existing Brownsville Ship Channel has a constant 2 foot Advance Maintenance depth. This 2 feet remains constant for the proposed channel to reduce maintenance costs.

2.10 REAL ESTATE

Acquisition of real estate was not required for this project. All placement areas are owned by the Port of Brownsville. Navigational servitude takes precedence for the extension of the Brownsville Entrance Channel. Refer to the Real Estate Appendix for more details.

2.11 PLACEMENT AREAS

The proposed Brownsville Channel Project has several existing upland Placement Areas(PA) (2, 4A, 4B, 5A, 5B, 7 and 8), adjacent to the entire reach. There are also three existing open water placement areas; an Ocean Dredge Material Disposal Site (ODMDS) for the Maintenance and New Work PA and a Nearshore Feeder Berm PA 1A, Beneficial Use Site. The existing Maintenance ODMDS PA is not planned to be utilized for placement of maintenance material, but will be available if needed. The existing Feeder Berm PA 1A will be used for placement of maintenance material. Details concerning the Placement Areas can be found in the Geotechnical Section 4.0 of this Engineering Appendix. Proposed placement areas are shown in Drawings F-02 through F-08.

2.12 RELOCATIONS

During the Detail Phase, two pipelines were identified. A 10 inch pipeline is assumed to be abandoned and 75 feet below the authorized depth. A 4 inch pipeline is 54 feet below authorized depth and runs parallel to the channel and is outside of the work vicinity. Neither of these pipelines will be impacted by the proposed work and will not require relocation or removal. Refer to the Real Estate Appendix for additional details on the pipelines. It is assumed that some berthing/dock areas will need to be upgraded due to deepening of the channel. The Port of Brownsville will undertake the responsibility of modifying existing berthing/dock facilities that will need upgrading to receive and accommodate vessel traffic at the new channel depths.

2.13 REFERENCES

ER 1110-2-1150 Engineering and Design for Civil Works Project, August 1999
ER 1130-2-520 Navigation and Dredging Operations and Maintenance Policies, November 1996

3.0 SURVEYING, MAPPING, AND OTHER GEOSPATIAL DATA REQUIREMENTS

3.1 SURVEYS

Hydrographic surveys were performed by the Southern Area Office of the Galveston District. Surveys consisting of cross sections were taken of the Brownsville Ship Channel in March 2012. As the preliminary designs progressed, these surveys were manipulated for volumes to address different depths and channel widths. During the Preconstruction Engineering & Design (PED) phase, updated hydrographic surveys will be done and topographic surveys will be performed to better define the proximity of channel to land, docks and jetties.

3.2 MAPPING

Existing maps, from Galveston District's historical files, of the vicinity were used during the initial and plan formulation phases. Updated mapping was developed for the Detail phase, to include proposed conditions.

3.3 DATUM

3.3.1 Horizontal

The North American Datum of 1983 (NAD 83) Texas State Plane Coordinate System, Texas South Zone was used during all phases of the Feasibility Study for all drawings.

3.3.2 Vertical

The vertical datum of Mean Lower Low Water (MLLW) were used in calculating new work volumes. Land surveys performed for the placement areas used NAVD 88. Refer to Section 6-Hydrology and Hydraulics Section for additional information on the MLLW Datum used.

4.0 GEOTECHNICAL

4.1 SUMMARY

This section is prepared to provide geotechnical information to support the development of the BIH Channel Improvement Project. This includes stability of the channel, stability of the containment dikes around each placement area (PA), selection of the PAs for dredge material distribution, and a preliminary subsurface investigation for the channel improvement. The geotechnical design is consistent with the engineering plan presented in this Feasibility Report. This section presents the following information:

- Description of the geotechnical data obtained for design for this project;
- Preliminary designs;
- Geotechnical considerations for containment dikes and channel slopes;
- Review of construction related issues;
- Description of future operation and maintenance, including placement area utilization and management, as it relates to the geotechnical design of the project and the 50-year dredged material placement plan;
- Recommendations for additional investigations and analysis required for final design for construction of the project.

4.1.1 Regional Geology

The Brownsville Ship Channel is located on alluvial plain of the Rio Grande River which is within the Coastal Plain physiographic province. The area is characterized by seaward sloping of

Quaternary formation which dips gently to the Gulf Mexico. Only two geologic formations are exposed: the Beaumont Formation of Pleistocene age and the overlying sediments of Holocene (recent) age that is in accordance with "Soil Survey of Cameron County, Texas" (1977) from United States Department of Agriculture - USDA. The surface soils at the entrance area are subject tide exchange; it is classified as Barrada series which consist of deep, very poorly drained, calcareous, saline clays. Barrada soils have no use in farming; they are barren and produce no vegetation, when dried out the soil particles become fluffy and easily moved around by the coastal wind; the dredge materials placed in PA4A represent Barrada clay soil characteristic. During the last Pleistocene glacial stage, the sea level was lowered approximately 450 feet; the major streams deepened their channel, flowed across the Continental Shelf, and discharged into the Gulf many miles beyond the present shoreline. During interglacial periods when water from the melting glaciers flowed back into the ocean, the sea level rose, the deepened valleys were drowned and estuary was formed. The estuary has subsequently been filled with river transported sediments. The natural terrain along the south side of the BIH ship channel has been altered by man-made disposal areas with containment dikes. The sediment at the mouth of the channel and along the shoreline is marine or Aeolian in origin while those inlands along the channel are primarily alluvial. The recent deposits consist of inter bedded loose to very dense sands and silty sands and medium to stiff clays, sandy clays, and clayey sands. These deposits range in thickness from approximately 12 feet on the west end of the project to 55 feet on the east end. A few thin layers of soft clays and sandy clays exist in the recent deposits. Beneath the recent sediments lie the stiff to hard Pleistocene clays, sandy clays and clayey sands. The layers and pockets of silty sands which exist within the Pleistocene clays at some locations are thicker and more numerous along the western portion of the channel.

4.1.2 Site Geology

Along BIH ship channel areas are a flat, generally undulating coastal plain ranging in elevation from sea level to 27 feet NAVD 88 at the crown elevation in Placement Area 8 (PA 8) located at the south side of BIH ship channel turning basin. The soils in BIH project areas were formed in Quaternary period and mostly are fluviatile deposits. According to UADA 1977 Soil Survey conducted in Cameron County Texas, the soils in the project area are consist of very young Holocene deposits and the older Beaumont Formation deposits; and it is classified as Sejita-Lomalta-Barrada association, Laredo-Lomalta association, and Beaumont formation. Sejita-Lomalta-Barrada association is the saline, wet soils along BIH entrance and jetty area. Mudflats located along the shores of the Laguna Madre are a unique physiographic feature of the area. These non-vegetated areas are occasionally covered by high tides water and generally have a width of about one-fourth mile in the lower section of the Laguna Madre. Other principle geological features of the area are clay dune formation known locally as lomas. These lomas are numerous in south Texas, and several are located adjacent to the BIH Ship Channel. Along the water way between Port Isabel and the Port of Brownsville, the land is generally undeveloped and in some locations the land has been utilized as placement areas for the dredged materials.

4.2 SUBSURFACE SOIL INVESTIGATIONS

4.2.1 Field Soil Investigations.

Soil core borings (boring numbers 08-102 through 08-235) were taken under Contract No. DACW64-03-D0008, Task Order No. 0081, during Dec 2008 to Feb 2009 by Tolunay-Wong Engineering, Inc. Professional Service Industries, Inc (PSI) obtained underwater channel borings (boring numbers 08-236 through 08-259) under contract to the non-Federal Sponsor (NFS) Brownsville Navigation District in May 2009.

The cohesive subsurface soil samples were collected in accordance with ASTM D 1587 "Standard Practice for Thin-Wall Tube Geotechnical Sampling of Soil." The undisturbed cohesive samples were taken at every two-foot and undrained shear strength were measured with a hand pocket penetrometer for each of the cohesive samples. The field visual classifications were performed and the information was recorded in the field logs for each of the cohesive samples at the site.
The cohesionless soil samples were collected in accordance with ASTM D 1586 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils." The spilt-spoon sampling was primarily employed for the cohesionless to semi-cohesionless soil strata, whereby the disturbed samples were collected in a glass jar at ever five-foot interval if a cohesionless stratum is greater than five-foot. The field visual classifications were conducted and cohesionless sample information was recorded in the field logs for each of the cohesionless samples at the site.
The subsurface soil samples were collected along the existing Brownsville Ship Channel and six of the seven Placement Areas (PA 2, PA4A, PA5A, PA5B, PA7 and PA8). A field assessment was conducted during the site visits to inspect the conditions of the existing containment dikes. The depth of the containment dike borings ranged from 50 to 75 feet below top of existing containment dikes. The depths of the interior borings were approximately 20 feet below the surfaces. PA4B foundation investigation and the borrow site investigation were not included at the time of the subsurface soil exploration. Table 4-1 presents a summary of the geotechnical borings performed.

Table 4-1 Soil Investigation Borings

Location	Number of PA Containment Dike Foundation Borings	Foundation Boring Depth (ft)	Number of PA Interior Borrow Borings	Interior Boring Depth (ft)	Number and Depth of Channel Excavation Borings	Year Drilled
PA 2	8	70	8	20	N/A	2008
PA 4A	16	75	9	20	N/A	2008
PA 4B	NA	NA	NA	NA	N/A	NA
PA 5A	5	50	14	20	N/A	2008
PA 5B	8	50	14	20	N/A	2008

PA 7	9	65	10	20	N/A	2008
PA 8	11	50	10	20	N/A	2008
Main Channel	N/A	NA	N/A	NA	29 @ 75 ft	2009
Jetty and Entrance Channel	N/A	NA	N/A	NA	Historic Borings	1989

The locations of the PA borings are shown on Drawing Nos. F-02, F-03 and F-05 through F-08. The channel boring locations are shown on Drawing Nos. C-02 through C-09. The logs of the borings are shown on Drawing Nos. F-09 through F-22. The jetty channel historical boring plan and soil profiles are shown on Drawing Nos. F-23 and F24.

4.2.2 Laboratory Testing.

Laboratory tests were performed on representative soil samples to measure physical and engineering properties. The following ASTM test methods were performed on the selected soil samples.

ASTM D 2216	Moisture Content
ASTM D 4318	Liquid and Plastic Limit
ASTM D 422	Abbreviated & Completed Mechanical Analysis
ASTM D 2166	Unconfined Compression Test
ASTM D 2487	Engineering Classification of Soil
ASTM D 2850	Unconsolidated Undrained Triaxial Test
ASTM D 3080	Consolidated Drained Direct Shear Test
ASTM D 698	Standard Compaction Test

Individual lab test results are not included in this report due to volume of material; however summaries are included on the boring logs. The results of unconfined compression tests (UC), and unconsolidated undrained triaxial tests (UU) were utilized for the analyses of undrained shear strengths for end-of-construction conditions. In some cases the laboratory results were correlated in conjunction with the field hand penetrometer test readings. The results of the laboratory tests are shown on the boring log profiles on Drawing Nos. F-09 through F-22. The selected soil samples were tested for shear strength along with Atterberg limits. These test results were utilized for the slope stability analyses. The measured liquid limits (LL) ranged from 24 to 76. The plasticity index (PI) of the fine grain soil ranged from 8 to 49. The undrained shear strength from UU and UC ranged from 400 pounds per square foot (psf) to 4000 psf. The effective friction angles (φ) of the lean clay (CL) and high plasticity clay (CH) ranged from 11 degrees to 34 degrees. The effective friction angles were measured using ASTM D3080. Direct shear tests may result in variations of the estimated friction angles; therefore, a 15 percent reduction was applied to the test results. The friction angles shown in Figure 4-2 include this 15 percent reduction.

4.2.3 Additional Investigations.

Additional geotechnical investigations are recommended during the PED phase. The additional investigations would include core drilling, sampling and testing of soils along the channel at a shorter interval between borings which will provide more detailed soil information for dredge excavation. Core drilling, sampling and testing will also be required at PA 4B since no investigations were performed in that PA for this study.

4.3 SELECTIONS OF PRELIMINARY DESIGN PARAMETERS

This project will use only the nine existing PAs (New Work ODMDS, Feeder Berm BU, 2, 4A, 4B, 5A, 5B, 7 and 8) for new work and maintenance material placement for the initial channel improvements and for the 50-year operations and maintenance period. The existing Maintenance ODMDS PA is not planned to be used for maintenance operations; however, would be available should it be needed. No new PAs would be required for the project. New work from the channel improvements would be placed in the open water New Work ODMDS, and the upland confined PAs 2, 4B, 5A, 5B, 7 and 8. PA4A will not be used for placement of new work material because it has been used extensively in the past due to high shoaling in this reach resulting in limited capacity. The open water Feeder Berm BU, and the upland confined PAs 4A, 4B, 5A, 5B, 7 and 8 will be used for maintenance dredging over the 50-year period of analysis.

This project will include construction of one new drop-outlet structure in each of PAs 2, 4B, 5A, 5B, 7, and 8 prior to the proposed channel improvements. Three new drop-outlet structures would be constructed in PA4A for future maintenance dredging. All of these new drop-outlet structures will be installed with one or two 54 inch diameter steel pipes to be determined during PED.

The slopes on the new channel templates will match the existing channel slopes. This was determined after review of historic hydrographic surveys indicated no noticeable channel slope stability problems. Therefore, the slopes of the proposed channel slope will be consistent with the existing channel.

4.4 GEOPHYSICAL INVESTIGATION

A geophysical investigation was not performed for this study. Based on information gathered for this study a geophysical investigation would not be required during the PED phase.

4.5 GROUNDWATER STUDY

A groundwater study was not conducted as part of this study. However, during the geotechnical field investigation, water levels were measured in the open boreholes when encountered, and again 24 hours later. Water levels are shown on the boring logs. The groundwater levels measured in open boreholes may not reflect natural ground water elevations.

4.6 RECOMMENDED INSTRUMENTATION

There is no requirement for geotechnical instrumentation for this project.

4.7 GEO HAZARDOUS

4.7.1 Earthquake.

An earthquake study was not performed for this feasibility study because the ship channel is located in an area that is rated as the lowest earthquake probability (0 – 2%) occurrence region in according to United State Geological Survey (USGS). Figure 4-1 presents a USGS map of Texas earthquake probability statistics. The area of this study lies in the dark blue-shaded areas at the southern tip of Texas. Based on the above referenced published information, the effects of earthquakes on the ship channel would be minimal.

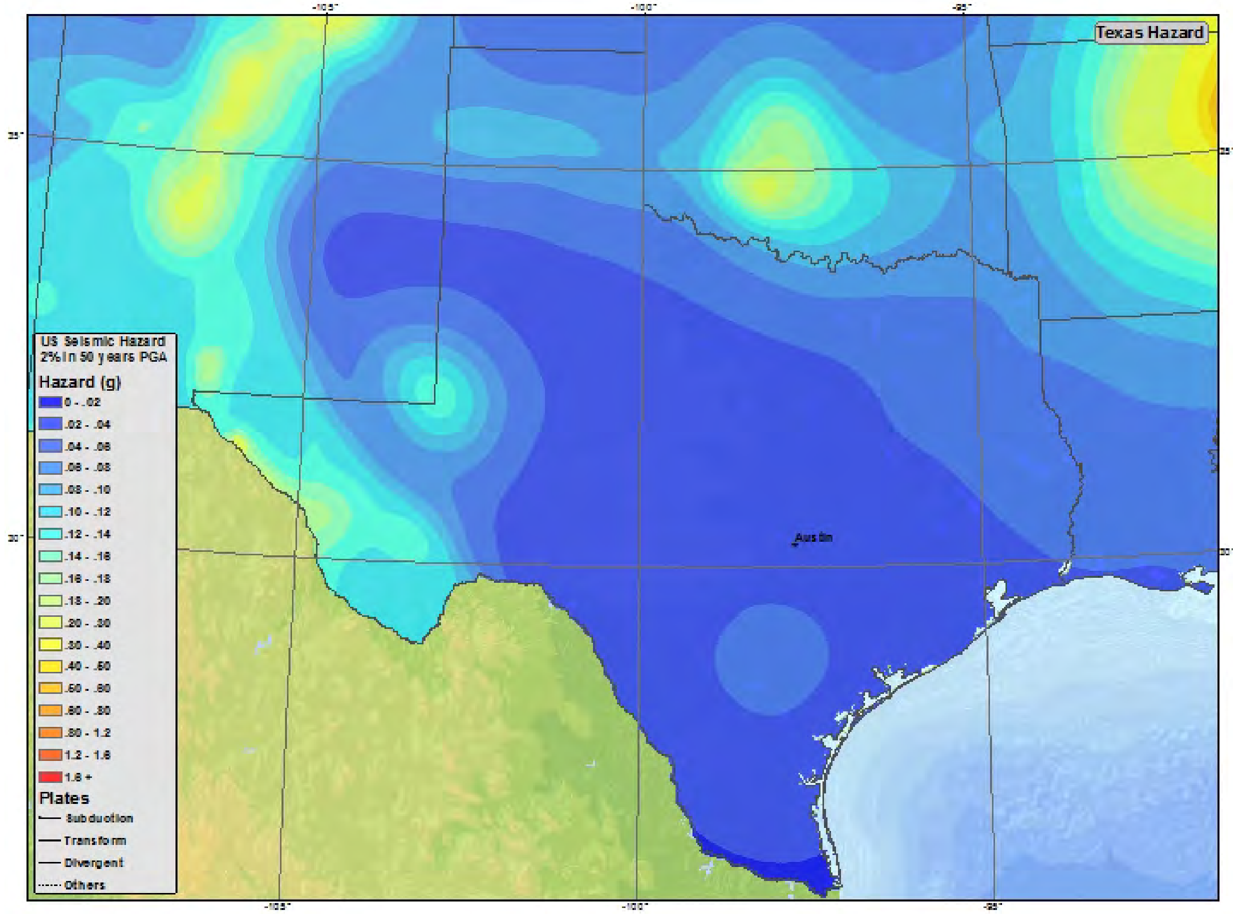


Figure 4-1 Texas Geo Hazardous Map

4.7.2 Fault.

A fault study was not performed as part of this study because a review of published information revealed that many faults exist along the Texas gulf coast region; however, the effects of the faults on the ship channel and the placement areas are minimal. This information is found in a report from USGS and Texas Bureau of Economic Geology titled "Complete Report for Gulf-margin Normal Faults, Texas (Class B) No. 924". The report states: "…the gulf-margin normal faults in Texas are assigned as Class B structures because their low seismicity and because they may be decoupled from underlying crust, making it unclear if they can generate significant seismic ruptures that could cause damaging ground motion."

4.8 PRELIMINARY SLOPE STABILITY ANALYSIS

4.8.1 Containment Dike and Training Dike Typical Sections.

The containment dike crown width is proposed to be 11 feet and the training dike crown width is proposed to range from 6 to 8 feet for each of the seven upland PAs. The proposed height of the containment dikes includes 2 feet for ponding and an additional 3 feet for freeboard. The three feet freeboard estimate is considered adequate based on the size and fetch lengths of the placement areas and the prevailing winds common to the project areas. Containment dike typical sections for each PA are shown on Drawing Nos. F-02 through F-08.

To accommodate the new work dredge operation, each of the PAs must be raised prior to new work dredging. The perimeter containment dike of PA 4B requires a major reconstruction due to erosion. It is recommended that construction of the raised perimeter dikes be completed a minimum of three months prior to start of channel improvement dredging. The construction schedule indirectly includes a settlement period for dikes. A preliminary plan includes constructing the containment dike raise by side-cast borrow construction.

4.8.2 Containment Dikes Stability Analysis

Examining subsurface soil information along the containment dikes indicated fair to good foundation conditions. Wind and rain generated containment dike slope surface erosion was observed for PA 2 and 4A during site visit and this type of surface erosion is anticipated to continue to occur. Historically, foundation settlement has not been observed on any of the upland confined PA containment dikes.

Preliminary containment dike slope stability analyses were performed using lab test results and field logs from the subsurface soil investigations performed in 2008 and 2009 for the PAs and channel. Soil sample classifications were developed in accordance with ASTM 2487 Unified Soil Classification System. Undrained shear strengths were obtain from Q (UU) tests. Undrained shear strengths were computed by averaging test results from similar high plasticity clay (CH) or low plasticity clay (CL) strata. These average strengths were subsequently used in the slope stability analyses. Effective (drained) frictional angles were obtained from ASTM D 3080, Consolidated Drained Direct Shear Test. Effective frictional angles were correlated with calculated plasticity indexes. The friction angle vs. plasticity index is presented in Figure 4-2.

Friction angles were estimated according to standard penetration test (SPT) blow counts for silty sand and clayey sand strata.

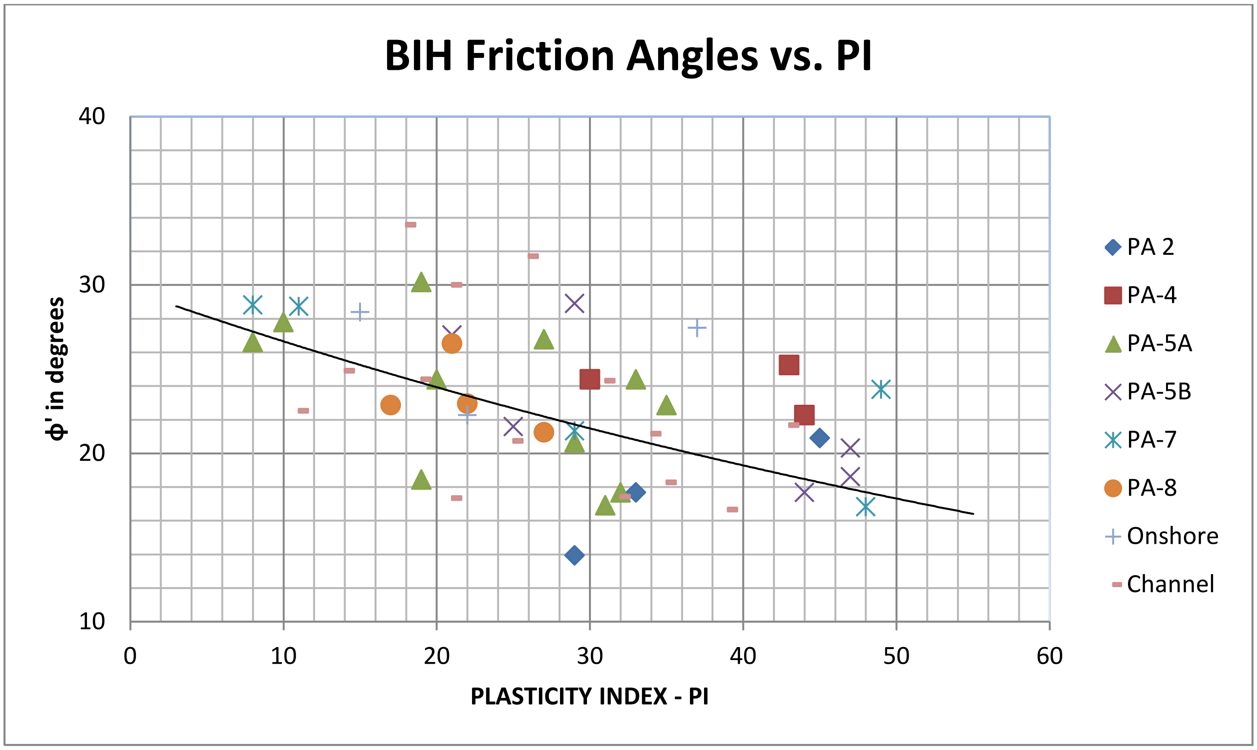


Figure 4-2 Friction Angles vs. Plasticity Index

The perimeter containment dikes were analyzed with 3 horizontal to 1 vertical (3H:1V) side slopes. Slope stability analyses were computed using the GeoStudio 2012 SLOPE/W software using the limit equilibrium Morgenstern-Price analysis method. The drained (long term) and undrained (short term) conditions were analyzed for the perimeter dikes. The analyses indicated the undrained conditions resulted in lower factors of safety, thus controlled the allowable containment dike elevations. Results of the undrained analyses are presented in Drawing Nos. F-25 through F-31 for the containment dikes.

Stability analyses were performed for the containment dikes in all existing upland confined PAs. Because of the close proximity of PA4A, 4B, 5A and 5B to the channel, slope stability analysis was also done for the channel slope in these areas.

The slope stability is determined by the factor of safety which is defined in USACE EM 1110-2-1902, equation C-1 as:

$$\textit{Factor of Safety (F)} = \frac{\textit{Total available shear strength (S)}}{\textit{Equilibrium shear stress (T)}}$$

For effective stresses, the factor of safety can be expressed as:

$$F = (c' + (\sigma\text{-}u)\tan(\phi')))/\tau \qquad \text{(equation C-2)}$$

For total stresses, the factor of safety can be expressed as:

$$F = (c + \sigma^*\tan(\phi)) / \tau \qquad \text{(equation C-4)}$$

Drained shear strength (effective stress) was measured in the soil laboratory by direct shear tests in accordance with ASTM D 3080. Undrained shear strength (total stress) was measured using unconsolidated undrained triaxial tests (UU) and unconfined compressive tests (UC). In addition to UU and UC shear strength tests, pocket penetrometer field tests were performed to estimate the undrained shear strength of samples during soil drilling operations. Shear strength parameters are defined in EM1110-2-1902 as:

Total Shear Strength (S) = $c + \sigma \tan(\phi)$ *(equation 2-1)*

Effective shear strength: $S = c' + \sigma' \tan(\phi')$ *(equation 2-2)*

where:
S *= maximum possible value of shear strength*
c *= cohesion intercept*
σ *= normal stress on the failure plane*
u *= pore water pressure*
ϕ *= total stress friction angle*
$\sigma' = (\sigma\text{-}u)$ *effective normal stress on the failure plane*
c' *= effective stress cohesion intercept*
ϕ' *= effective stress friction angle.*

Additional slope stability analyses are recommended during PED phase along with additional soil investigations. The recommended minimum end of construction factor of safety is **1.3** from table 6-6 in EM 1110-2-5027. The foundation and embankment materials will experience some consolidation and strengthening with overburden stress over time until a long-term equilibrium has been established. The following is a summary of foundation analyses for each PA.

Placement Area No. 2. Boring numbers 08-102 through 08-109 were taken from this PA to 70 feet depth. The bottom elevations were approximately -48 feet NAVD 88, dependent on the existing crown elevation. Soils encountered in semi-compacted containment dike (between elevations -2 to 25 feet) generally consisted of silty sands. Below the containment dike and down to about elevation -33 feet the soils encountered consisted of predominately a thick layer of high plasticity clay (CH) with thin layers of silt (ML) and lean clay (CL) interspersed in the CH stratum. Below about elevation -33 feet to the boring termination depth soils were predominately sandy silts (SM) and ML.

Soil information from boring 08-104 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of 42 feet.

Placement Area No. 4A. Boring number 08-110 through 08-125 were taken from this PA to 75 feet deep. The bottom elevations were approximately -55 feet NAVD 88, dependent on the existing crown elevation. Soils encountered in semi-compacted dike (between elevations 0 to +21 feet) generally consisted of clay with silts. Below the containment dike and down the soil encountered consisted of lean clay from medium to hard clay, fat clay from medium to very firm and ML from 30% to 95% passing the No. 200 sieve.

Soil information from boring 08-120 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of 38 feet.

Placement Area No. 4B. Borings were not taken in the 2008 soil investigation because PA 4B was not included in the initial assessment. Boring 08-159 and 08-160 were in the vicinity of this PA and were used to assess this PA's foundation materials. Boring 08-159 and 08-160 were taken from surface elevations to 75 feet deep. Soil encountered in this location generally consisted of high to medium plasticity clays and sand-silt mixtures.

Soil information from boring 08-160 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of 40 feet. Since no sample was taken for 4B, foundation shear strength investigation is recommended during PED.

Placement Area No. 5A. Boring number 08-126 through 08-130 were taken from this PA to 50 feet depth. The bottom elevations were approximately at elevation -42 feet NAVD 88, dependent on the existing crown elevation. Soils encountered in semi-compacted perimeter dike (between elevations +7 to +2 feet) generally consisted of clay materials. Below the containment dike the soils encountered consisted of clay with layers of silt at various elevations.

Soil information from boring 08-129 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation +42 feet NAVD 88.

Placement Area No. 5B. Boring number 08-131 through 08-138 were taken from this PA to 50 feet depth. The bottom elevations were approximately -40 feet NAVD 88, dependant on the existing crown elevation. Soil encountered in semi-compacted containment dike (between elevations -2 to +12 feet) generally consisted of clay materials. Below the containment dike the soils encountered consisted predominately of clay with thin layers of silts at various elevations.

Soils information from boring 08-133 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of 45 feet NAVD 88.

Placement Area No. 7. Boring number 08-139 through 08-147 were taken from this PA to 65 feet depth. The bottom elevations were approximately -45 feet NAVD 88, dependent on the existing crown elevation. Soil encountered in semi-compacted containment dike (between elevations -5 to +20 feet) generally consisted of clay. Below the containments dike the soils encountered consisted predominately of clay with layers of silt at various elevations.

Soils information from boring 08-140 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of +55 feet NAVD 88.

Placement Area No. 8. Boring numbers 08-148 through 08-158 were taken from this PA to 50 feet depth. The bottom elevations were approximately -30 feet NAVD 88, dependent on the existing crown elevation. Soils encountered in semi-compacted containment dike (between elevations -5 to 20 feet) generally consisted of silty sands and clay. Below the containment dike the soils encountered consisted predominately of clay with interspersed silt layers.

Soils information from boring 08-157 was used to analyze the end of construction slope stability. This containment dike meets factor of safety requirements for up to elevation of +52 feet NAVD 88.

The undrained (End of Construction) factors of safety and maximum allowable containment dike elevations resulting from the slope stability analyses for each upland confined PA are listed in Table 4-2. Additional geotechnical investigation and analyses should be conducted prior to exceeding the recommended maximum dike elevations shown.

Table 4-2 Slope Stability Analysis Results

Placement Area	Factor of Safety (FS) End of Construction Condition	Maximum Containment Dike Elevations
2	1.331	+42
4A	1.309	+38
4B	1.319	+40
5A	1.301	+42

5B	1.344	+45
7	1.329	+55
8	1.310	+52

4.8.3 Containment Dike Toe Erosion Protection

Erosion along the toes of the containment dikes in PA 4A and 4B have been noted historically. This erosion is a result of wind driven waves and ship wakes in the channel. Because of this situation, erosion protection is required at the toe of the PA 4A and PA 4B containment dikes to protect the long term stability. A preliminary proposal is to place articulated concrete mattresses (ACM) with underlying geotextile along the toes of the containment dikes and between the PAs from about Station 22+000 to Station 34+000. This proposed erosion protection plan is shown on Drawing C-06.

Surface erosion was also observed on the outside slopes of the containment dikes at all existing upland confined PAs; however, this surface erosion is not thought to compromise the overall stability of the dikes as long as the slopes are rehabilitated periodically. Providing hard erosion protection on these slopes is not cost effective and it is difficult to find vegetation that will grow because of the high salinity in the soils along the ship channel. To ease erosion impacts on the outside slopes, rehabilitation of the outside slopes is proposed during routine maintenance dredging operations.

4.8.4. Channel Slope Stabilities

The channel slopes were analyzed for both undrained (End of Construction) and drained (Long Term) conditions. EM 1110-2-5027, Table 6-6 recommends a minimum factor of safety of 1.3 for both the undrained and drained conditions for slopes less than 30 feet in height. For slopes with heights greater than 30 feet, EM 1110-2-1902, Table 3-1 recommends minimum factors of safety of 1.3 and 1.5 for undrained and drained conditions, respectively for earth and rock-fill dams. Considering the relatively low consequences of failure of a channel slope compared to failure of a dam, a minimum factor of safety of 1.3 for both undrained and drained conditions was selected for this analysis.

The existing side slopes of the main channel and turning basin template are 3H:1V. The proposed side slope is 3H:1V for the proposed deepened Main Channel and 2.5H:1V for the proposed deepened Turning Basin Extension and Turning Basin.

Because of the close proximity of PAs 4A, 4B and 5 to the channel, the channel slope stability was analyzed in these areas. The calculated minimum factor of safety for the drained condition is 1.612 in the areas closest to PA5 and 1.893 in the areas near PA 4A and 4B. The effects of the placement area loads on the channel slope were also investigated and found no negative impact to the channel slope stability. Slope stability analysis results for the proposed channel slope indicate the selected minimum factor of safety for would be met for both undrained and drained conditions. Results of the channel slope stability analyses are shown on Drawing Nos. F-32 through F-35.

The Entrance Channel and the Jetty Channel side slope heights vary according to the natural sea bottom elevation. As a result, dredging in these areas normally occur only near the bottom of the channel template. Recent hydro-surveys indicate that there is limited scour at the toe of the side slopes within the Jetty Channel between approximately Station -04+000 and Station -5+600. There is an existing repair contract ongoing to repair the jetties and this scour issue with a completion date of June 2014. After the jetty maintenance repair is completed, the jetties should be in a good and stable condition for several years. This assumption is based on the jetty's normal operations that are free from a major hurricane impact. Therefore, no construction costs associated with this issue are included in this project.

4.9 CHANNEL DEEPENING EXCAVATION

4.9.1. Excavation Summary.

Material expected to be encountered during project dredging will include new work as well as shoaled materials. The shoaled materials will consist primarily of a mixture of silts and clays in the Main Channel. From approximately east of the Port Isabel Ship Channel shoaled materials are likely to be predominantly silts sands with some shell fragments. New work materials along the channel consist of lean clays (CL) and fat clays (CH), sand-silt mixtures (SM), sand-clay mixtures (SC) and silty or clayey fine sand (ML). These materials are shown on the boring logs. Generally, the channel borings terminated between about elevation -62 and -70 feet. A discussion of material to be dredged for each section is included in the following paragraphs:

Entrance Channel and Proposed Entrance Channel Extension (Station 0+000 to Station -17+000). New soils information was not obtained for this section as part of this study due to difficulties in obtaining the deep water borings. The soil information presented here is from the previous two deepening and widening projects. According to these soil profiles, soils deposited in the entrance channel areas consist of predominantly medium to occasionally stiff fat clays (CH) clays with silts and sand pockets and shell fragments are likely to be encountered in the dredge cut which is generally confined to between -40 and -50 MLLW. Soil borings and lab testing will be required for this area during PED.

Main Channel (Station 0+000 to Station 20+000). There are five borings (08-236 through 08-241) located within this reach. Boring 08-236 is located 200 feet west of station 0+000, in this area there is approximately 40 feet of silty sand SM below the surface, below the SM stratum there is a medium to stiff clay stratum. As the channel extend to the west the thickness of silty sand stratum gradually decreased to disappear at boring 08-238. The dredge cut extends up the existing channel slope to elevations which range from about 0 to -20 feet MLLW. The materials along the channel slope consist primarily of CL, CH and SM.

Main Channel (Station 20+000 to Station 36+000). There are five borings (08-242 through 08-244, 08-159 and 08-160) located within this reach. The soils in this reach consist of CH with layers of CL and SM. Below about elevation -52 there is stratum of SM. In this reach the dredge cut may extend up the existing slopes to elevation -10 feet MLLW. Materials along the slopes consist primarily of from medium to hard clay with silty sand pockets, and calcareous nodules.

Main Channel (Station 36+000 to Station 39+000). One boring (08-245) is located within this reach. There is great disparity of the soil characteristic between this boring and those taken in adjacent reaches. The soils encountered throughout this boring consist of alternating layers of SM, CH, CL and inorganic silt (ML).

Main Channel (Station 39+000 to Station 45+000). Two borings (08-246 and 08-247) are located within this reach. There is approximately 40 feet of CH with a couple of thin strata of CL interbedded. Beneath the clay stratum, there are deposits of SC and SM. Materials along the slopes consist primarily of medium to hard clays with calcareous nodules, below the excavation elevation there is a thick layer of silty sand.

Main Channel (Station 45+000 to Station 69+000). Four borings (08-248 through 08-252) are located within this reach. Materials along the slopes consist primarily of medium to hard clay with sand seams, calcareous and ferrous nodules, silty clay and silty sand are interbedded in the thick clay stratum. Inorganic silt was seen from about elevation -52 to about elevation -60 feet.

Main Channel, Turning Basin Extension, and Turning Basin (Station 69+000 to 89+500). Seven boring (08-253 through 08-259) are located within this reach. Materials along the slope primarily consist of medium to hard clays with calcareous nodules, sand and shell fragments. There is a thick stratum of silty sand, and clayey sand deposits from the drilling surface down to approximately -28 feet in boring 08-253 and down to approximately -14 feet in boring 08-256.

4.9.2 Channel Excavation and Material Placement.

The channel new work materials from the Jetty Channel, Entrance Channel, and proposed Entrance Channel Extension (from Station 0+00 to Station -17+000) would be excavated by hopper dredge and placed in the existing New Work ODMDS shown on Drawing No. C-10. New work dredge materials from the Main Channel, Turning Basin Extension, and Turning Basin (from Station 0+000 to Station 89+500) would be excavated by pipeline dredge and placed into PAs 2, 4B, 5A, 5B, 7 and 8. This material would be placed along the interior of the containment dikes at locations determined during PED. Maintenance material dredged from the Main Channel, Turning Basin Extension, and Turning Basin would be placed in PAs 4A, 4B, 5A, 5B, 7 and 8. Upland placement area plans and typical containment dike sections are shown on Drawing Nos. F-02 through F-08.

4.9.3 New Work Dredge Quantities.

The Brazos Island Harbor deepening project will require the placement of about 14.1 MCY of new work materials from the channel into existing PAs. Table 3 presents the new work quantities and placement per reach.

Table 4-3 New Work Quantities and Placement

Reach Description	Reach Stationing	Dredging Quantity (cy)	Placement Area	Type of Dredge
Entrance Channel Extension, Entrance Channel and Jetty Channel	-17+000 to 0+000	2,066,000	New Work ODMDS	Hopper
Main Channel	0+000 to 07+000	937,000	2	Pipeline dredge
NA	NA	0	4A	NA
Main Channel	7+000 to 25+000	2,689,000	4B	Pipeline dredge
Main Channel	25+000 to 50+000	3,612,000	5A	Pipeline dredge
Main Channel	50+000 to 70+000	2,599,000	5B	Pipeline dredge
Main Channel, Turning Basin Extension	70+000 to 82+000	1,804,000	7	Pipeline dredge
Turning Basin Extension, Turning Basin	82+000 to 89+500	386,000	8	Pipeline dredge
Total New Work	-	14,093,000	-	-

4.10 CONSTRUCTION TECHNIQUES, LIMITATIONS AND PROBLEMS

4.10.1. Placement Area Information.

The existing PAs available for this project include three existing open water sites: New Work ODMDS; Maintenance ODMDS; and Feeder Berm Site 1A beneficial use site. Seven existing upland confined PAs are available for this project and include PAs 2, 4A, 4B, 5A, 5B, 7, and 8. Table 4-7 in Section 4.10.2 provides estimated containment dike lengths and PA areas. A brief description and designated use for each of the open water PAs follows.

> <u>New Work ODMDS.</u> This offshore placement area occupies 350 acres of open water area with no containment dikes, and is reserved only for deepening new work materials from the Jetty Channel, Entrance Channel, and proposed Extended Entrance Channel

(Station 0+000 to Station -17+000). Coordinates of the control points for the New Work ODMDS, as outlined in the "Brazos Island Harbor 42-Foot Project, Texas Ocean Dredged Material Disposal Site Designation" report, dated November 1991, are presented in Table 4-4.

Table 4-4 New Work ODMDS Control Points

Control Point No.	Latitude	Longitude	Northing (Y)	Easting (X)
1	26^0 05' 16"	97^0 05' 04"	16,559,975.766	1,448,788.403
2	26^0 05' 10"	97^0 04' 06"	16,559,429.626	1,454,083.306
3	26^0 04' 42"	97^0 04' 09"	16,556,599.632	1,453,841.842
4	26^0 04' 47"	97^0 05' 07"	16,557,044.843	1,448,547.713

Maintenance ODMDS. This offshore PA occupies 352 acres of open water with no containment dikes. It is reserved for maintenance materials dredged from the existing Jetty Channel and Entrance Channel (Station 0+000 to Station -13+000), and proposed Entrance Channel Extension (Station -13+000 to Station -17+000). The Maintenance ODMDS is not planned to be used for maintenance operations; however would be available should it be needed. Coordinates of the control points for the Maintenance ODMDS (also known as PA 1), as outlined in the "Brazos Island Harbor Ocean Dredged Materials Disposal Site Designation" report, dated July 1990, are presented in Table 4-5.

Table 4-5 Maintenance ODMDS Control Points

Control Point No.	Latitude	Longitude	Northing (Y)	Easting (X)
1	26^0 04' 32"	97^0 07' 26"	16,555,390.361	1,435,890.262
2	26^0 04' 32"	97^0 06' 30"	16,555,446.327	1,440,996.513
3	26^0 04' 02"	97^0 06' 30"	16,552,417.497	1,441,029.918
4	26^0 04' 02"	97^0 07' 26"	16,552,361.528	1,435,923.292

Feeder Berm BU Site 1A. Feeder Berm BU Site 1A occupies 313 acres in a near shore open water area with no containment dikes, and is reserved for maintenance dredge materials from the Main Channel, Entrance Channel, and Jetty Channel (Station 11+000 to Station -13+000), and proposed Extended Entrance Channel (Station -13+000 to Station -17+000). The purpose of this PA is to provide material for littoral transport for renourishment of South Padre beaches. Coordinates of the control points for Feeder

Berm Site 1A, according to the "Underwater Feeder Berm Construction" report, dated 1988, are presented in Table 4-6.

Table 4-6 Maintenance Feeder Berm BU Site 1A Control Points

Control Point No.	Latitude	Longitude	Northing (Y)	Easting (X)
1	26^0 06' 11"	97^0 09' 23"	16,565,270.617	1,425,115.409
2	26^0 06' 15"	97^0 08' 55"	16,565,701.700	1,427,663.599
3	26^0 05' 19"	97^0 09' 13"	16,560,461.499	1,428,631.538
4	26^0 05' 23"	97^0 08' 45"	16,560,030.355	1,426,083.032

4.10.2 Containment Dike Construction.

Construction to raise the existing PA containment dikes is recommended to be completed at least 3-months prior to placement of new work dredge material from the channel deepening project. Specifics for raising the dikes would be identified during PED. The general plan will be to utilize side-cast borrow construction when possible. If side-cast borrow construction of a containment dike is not possible, then borrow materials would have to be hauled from other locations within the PA. All fill materials will be placed in lifts that measure about 12 inches after being semi-compacted. All exterior disturbed slope surfaces should be seeded after construction for erosion protection with the exception of PA 4A. Additional soil investigations are required during PED to properly locate borrow material.

No expansion is proposed to the existing foot print of the seven existing upland confined placement areas. The containment dikes of the PAs will be raised to the inside to various heights to accommodate confinement of new work and shoaled dredge materials prior to dredging. The proposed containment dike elevations include additional height to accommodate 2 feet of ponding and 3 feet of freeboard. Table 4-7 summarizes containment dike lengths and proposed work within each affected PA. Interior training dikes will be constructed to control flows to the new drop-outlet structures within the interior of the PAs. Final locations of the training dikes would be determined during PED. Following dredging operations, construction of perimeter drainage ditches are recommend to facilitate drainage and drying of the PA interiors. Providing positive drainage of the PA interiors following dredge cycles has been found to promote additional consolidation of the interior sediments and dike fill materials. This can result in both additional PA capacity due both to lowered interior elevations and higher allowable containment dike elevations. Actual interior drainage ditch sections and lengths would be determined during PED following each dredge cycle.

Table 4-7 Placement Area Dike Construction

Placement Area	Existing Containment Dike Length (ft)	PA Type	PA Size, Ac	Construction
New Work ODMDS	NA	Open Water	350	NA
Maintenance ODMDS	NA	Open Water	352	NA
Feeder Berm Site 1A	NA	Open Water	313	NA
2	7,642	Confined	71	Dike Raising, training dike construction
4A	33,910	Confined	469	Dike Raising, training dike construction prior to maintenance dredging
4B	16,338	Confined	243	Perimeter Dike Construction, training dike construction
5A	21,628	Confined	704	Dike Raising, training dike construction
5B	29,343	Confined	1020	Dike Raising, training dike construction
7	20,471	Confined	257	Dike Raising, training dike construction
8	18,024	Confined	288	Dike Raising, training dike construction

All existing placement areas have been in service and used recently to store maintenance materials and previous new work materials with the exception of PA 4B. Since PA 4B has not been used for some time, the majority of the containment dike is severely eroded. The proposed plan includes rehabilitating and raising the containment dike in PA 4B and raising the containment dikes of all other existing upland PAs (except PA 4A) prior to dredging to deepening the channel to contain the new work dredge materials. PA 4A is not scheduled to be used for the new work materials, therefore the containment dike will not be raised for this project.

The majority of the new work dredge materials from the channel are clay materials, which are excellent materials for constructing containment dikes. The ideal discharge location of the new work material is along and near the perimeter containment dikes; placement in this manner will facilitate use of side-cast construction techniques for future perimeter dike raising. These discharge locations will be identified during PED.

4.10.3. Channel Excavation.

Excavation from the Main Channel, Turning Basin Extension, and Turning Basin (Sta. 0+00 to Sta. 89+500) will be accomplished using a hydraulic pipeline dredge with a cutter-head. Excavation of the Jetty Channel, Entrance Channel, and proposed Entrance Channel Extension (Station 0+000 to Station -17+000) will be accomplished by hopper dredge. New work removed by hopper dredge will be disposed at the offshore New Work ODMDS. New work materials excavated from the Main Channel, Turning Basin Extension, and Turning Basin will be placed in upland confined PAs as shown in Table 4-3. Drainage from upland placement areas will decant to the ship channel through the drop-outlet structures.

4.10.4. Relocations

At the time of this study, no structures were identified within the channel template. The NFS is responsible for modifying or upgrading existing berthing/dock facilities to accommodate the proposed 52’ channel depth.

4.10.5. Dredge Excavation Construction Sequence.

The project is planned to be completed in several contracts beginning with the Extended Entrance Channel, then the Entrance and Jetty Channel. The work would then proceed upstream in the Main Channel and Turning Basin Extension, ultimately culminating at the western end of the Turning Basin. A detailed design and construction schedule would be developed in PED.

4.11 POTENTIAL BORROW LOCATIONS WITHIN PLACEMENT AREAS

4.11.1. Borrow Materials and Dike Construction Procedures.

Sufficient borrow material to raise the PA containment dikes prior to deepening the channel is assumed for each of the PAs. Borrow locations and quantities will be verified with additional borings and survey in the PED phase. During new work dredging, firm to hard new work materials are recommended to be discharged along the interior of the PAs containment dikes or stockpiled in easily accessible locations for future dike raising construction. The new work materials deposited along the interior of containment dikes will become a part of the future dike foundation. Additional consolidation of the hydraulically-placed new work materials within the PAs can be achieved through proper drainage efforts. The dredge materials stockpiled may be excellent borrow materials for future dike raising construction. Table 4-8 presents dike crown elevation changes associated with the channel deepening. The following is a summary of borrow materials type and location at each placement area and recommended dike construction methods.

Placement Area No. 2. Boring numbers 08-163 through 08-171 were taken from this PA to the 20 foot depth. Sands and silty sands were identified in boring number location 08-163, and 08-166 through 0808-169 located directly adjacent to the interior side of the containment dike. Approximately 5 feet of clay materials suitable for containment dike raise and new training dike construction are located in boring number 08-164, 08-165 and 08-170.

Placement Area No. 4A. Boring numbers 08-171 through 08-185 and PA4-B1 through PA4-B9 were taken from this PA to the 20-foot depth. Clay materials obtained from adjacent to the perimeter dike can be used for containment dike raise construction.

Placement Area No. 4B. No borrow borings were taken within this PA for this study.

Placement Area No. 5A. Boring numbers 08-186 through 08-199 were taken from this PA to the 20-foot depth. Clay materials adjacent to the perimeter dike can be obtained by dragline.

Placement Area No. 5B. Boring numbers 08-201 through 08-214 were taken from this PA to the 20-foot depth. Clay materials adjacent to the perimeter dike can be obtained by dragline.

Placement Area No. 7. Boring numbers 08-216 through 08-225 were taken from this PA to the 20-foot depth. Clay, silty clay, and mixture of combination of clay and sand were encountered along the interior of the perimeter dike.

Placement Area No. 8. Boring numbers 08-226 through 08-235 were taken from this PA to the 20-foot depth. High plasticity clays, sand silts and few spots of lean clay were encountered in the borings along the interior of the containment dike. There are also high mound areas within the PA that can be excavated and hauled for dike construction.

Table 4-8 Existing and Proposed Elevations of Placement Area Containment Dikes

PA	Estimated Existing Containment Dike Elevations (ft)	Planned Raised Containment Dike Elevation (ft)	Estimated Containment Dike Raise (ft)
2	+27	+36	9
4A	+17 to +23	NA	0

4B	+7	+19	12
5A	+6	+12	6
5B	+12	+15	2
7	+20	+26	6
8	+22	+25	3

4.11.2. Placement Areas and Associated Drop-outlet Structures.

Preliminary plans are to have new work dredged material discharged in designated discharge corridors interior of and along the southeast containment dikes in each PA used. Training dikes are proposed to be constructed within the PAs in conjunction with new drop-outlet structure installation to maximize effluent water quality. PA 4A would not have new drop outlet boxes constructed prior to the proposed channel improvements; however, the three existing boxes would be replaced prior to placement of future maintenance materials. Actual drop-outlet structure and training dike locations will be determined in PED. Table 4-9 contains estimated training dike lengths and drop outlet structure information.

Table 4-9 Proposed PA Training Dike and Drop-outlet Structures

Placement Area	Proposed Training Dike Length (ft)	Number of New Drop-outlet Structures	Number Existing of Drop-outlet Structures	Current Drop-outlet Condition
2	1,800	1	1	Not Functioning, extensive rehabilitation required
4A	4,500	3	3	Silted, Not Functioning, expansive excavation
4B	2,200	1	0	Not functioning
5A	4,000	1	1	Silted
5B	6,000	1	2	Functional, Maintenance performed 2012 by the NFS
7	4,500	1	1	Functional, maintained by the NFS
8	4,000	1	1	Functional, maintained by the NFS

4.12 OPERATION AND MAINTENANCE

4.12.1. Summary.

Operation and maintenance of the channel will consist of periodic maintenance dredging of all reaches of the channel and turning basin. The operation and maintenance dredge quantities are estimated based on Hydraulic and Hydrology (H-H) engineering analyses using historical dredge data. Historically, the maintenance dredge cycle varies in the separate reaches because of shoaling differences within each. These dredge frequencies historically range from about 18 months to 5 years for the various reaches.

4.12.2. Shoaling Rate.

Shoaling rates were developed for the proposed 52-ft channel and used to develop the Dredge Material Management Plan (DMMP). Specific details of this study, including the final recommended shoaling rates for the proposed project, are included in the Hydrology and Hydraulics portion of the Engineering Appendix.

4.12.3. Operation Maintenance Quantities and Placement

The amount of dredged material during the period of analysis is estimated to be 61,674,000 CYS and the total amount of shoaled material occurring during this period is 62,919,500 CYS. The differences are generated due to dredging cycles. Annual shoaling volume estimates (Table 6-5) were used to estimate the 50-year total volume per reach. The 50-year total volume in Table 4-10 is based on each dredging cycle for each reach within the 50-year period. These cycles vary between reaches. The total dredged quantity during the 50-year period of analysis (POA) is not equal to 50 years times the annual shoaling rate (1,258,390 CYS) because the dredging cycles do not equate to even 50-year intervals.

Table 4-10 50-Year DMMP

Channel Reach	Station No.	PA	Volume per Cycle (cy)	Cycle Length (yr)	Number of Cycles	50-Year Total Volume (cy)
Extended Entrance/Entrance /Jetty	-17+000 to 0+000	Feeder Berm BU 1A	706,000	1.5	33	23,298,000
Main Channel	0+000 to 11+000	Feeder Berm BU 1A	727,000	4.5	11	7,997,000
Main Channel	11+000 to 28+000	PA 4A	736,000	4.0	12	8,832,000
Main Channel	28+000 to 34+000	PA 4B	172,000	4.0	12	2,064,000
Main Channel	34+000 to 50+000	PA 5A	494,000	4.0	12	5,928,000
Main Channel	50+000 to 65+000	5B	718,000	5.0	10	7,180,000
	Permit Dredging	5B	831,000	6.0	8	6,648,000

Main Channel	65+000 to 79+415	7	586,000	6.0	8	4,688,000
	Permit Dredging	7	415,000	6.0	8	3,320,000
Turning Basin Extension/Turning Basin	79+415 to 89+500	8	241,000	7.0	7	1,687,000
	Permit Dredging	8	415,000	6.0	8	3,320,000
50-Yr Total Federal Channel Operation and Maintenance Dredge Materials (cy):						61,674,000
50-Yr Total Permit Dredging Materials (cy):						13,288,000
Total Operation and Maintenance Volume (cy):						74,962,000

4.12.4. Placement Areas Capacities for Operation Maintenance.

Prior to use for placement of maintenance materials, each of the PAs 4A, 4B, 5A, 5B, 7, and 8 should be evaluated for dike stability and general condition. The estimated allowable containment dike elevations shown in Table 4-11 are adequate to contain the anticipated 50-year maintenance volumes. Preliminary engineering analysis indicates these maximum elevations are achievable; however, additional geotechnical investigation and analysis is recommended prior to dike raising.

Table 4-11 - Estimated PA Elevation and Remaining Capacity

PA	Estimated Current Elevation (ft)	Estimated After New Work Elevation (ft)	Estimated After 50 Years O&M Elevation (ft)	Estimated Allowable Elevation (ft)	Estimated Remaining Capacities after 50 Yrs O&M (cy)
2	+27	+36	Not Used	+42	897,000
4A	+17 to +23	NA	35	+38	5,336,000
4B	+7	19	24	+40	5,881,000
5A	+6	+12	17	+42	28,673,000
5B	+12	+15	19	+45	44,979,000
7	+20	+26	38	+55	6,198,000
8	+22	+25	28	+52	9,972,000

4.13 PROJECT BORINGS

Project boring plans for each PA are shown on Drawing Nos. F-02 through F-08. Logs of borings with soil descriptions are shown on Drawing Nos. F-09 through F-22. Locations of the channel borings are shown on Drawing Nos. C-02 through C-09. Historic Channel borings are shown on Drawings F-23 and F-24.

4.14 ADDITIONAL EXPLORATION, TESTING AND ANALYSIS FOR PED

Additional soil exploration and lab testing will be required during PED to refine the engineering analysis for PAs and channel. Additional soil investigations are especially required for PA4B, the Jetty Channel, and the Entrance Channel. A summary of anticipated lab tests is provided in

Table 4-12: Recommended Additional Laboratory Tests

Description	Standards	Number of Testing
Classification of Soils for Engineering Purpose	ASTM D 2487	Design Geotechnical Engineer's judgment
Atterberg Limit Test	ASTM D 4318	Design Geotechnical Engineer's judgment
Consolidated-Undrained Triaxial Test	ASTM D 4767	Design Geotechnical Engineer's judgment
Unconsolidated-Undrained Triaxial Test	ASTM D 2850	Design Geotechnical Engineer's judgment
Compaction Test	ASTM D 698	For borrow construction materials
Unconfined Compression Test	ASTM D 2166	Design Geotechnical Engineer's judgment
Moisture Content of Soil	ASTM D 2216	Design Geotechnical Engineer's judgment
Standard Test Method for Particle-size Analysis of Soils	ASTM D 422	Design Geotechnical Engineer's judgment

4.15 SUMMARY OF THE LABORATORY-TESTING PROGRAM COMPLETED

Placement area containment dike foundation and channel field investigations were completed in 2009. Laboratory testing of selected soils samples was completed in May 2010. All testing was completed in accordance with ASTM standards as stated in previous sections.

4.16 REFERENCES

USDA "Soil Survey of Cameron County, Texas" (1977) United States Department of Agriculture Soil Conservation Service in cooperation with Texas Agriculture Experiment Station;

USGS “Geologic Hazards Science Center Map” United States Geological Survey;

USACE ER 1110-2-1150 “Engineering and Design for Civil Works;” 1999

USACE EM 1110-2-5025 “Dredging and Dredged Material Disposal” 1983;

USACE EM 1110-2-1100 “Coastal Engineering Manual – Part VI” 2002;

USACE, “Environmental Impact Statement for Brazos Island Harbor 42-foot Project, Texas Ocean Dredged materials Disposal Site Designation” 1991;

USACE, “EIS, Brazos Island Harbor Ocean Dredged Materials Disposal Site Designation” 1990;

USACE” EIS, Underwater Feeder Bern Construction for BIH” 1988.

5.0 ENVIRONMENTAL ENGINEERING

5.1 ENVIRONMENTALLY RENEWABLE MATERIALS

Not Applicable

5.2 DESIGN OF POSITIVE ENVIRONMENTAL ATTRIBUTES INTO THE PROJECT

Potential environmental attributes for this project include increasing navigational efficiency of vessels using the channel, increasing ability of the channel to accommodate offshore rigs for maintenance and repair and fabrication of new rigs, and beneficially using sediments from channel modifications and maintenance for environmental restoration.

5.3 INCLUSION OF ENVIRONMENTALLY BENEFICIAL OPERATIONS AND MANAGEMENT FOR THE PROJECT

Creation of new placement areas were not needed for this project. The operation and maintenance plan consisted of utilizing existing placement areas. Site monitoring and management plans for disposal are necessary to ensure proper management of sites, to minimize the potential for adverse environmental impacts, and to ensure compliance with laws, regulations and permits.

5.4 BENEFICIAL USES OF SPOIL OR OTHER PROJECT REFUSE DURING CONSTRUCTION AND OPERATION

The beneficial use of dredged maintenance material was used to decrease shoreline erosion at the BUS, Feeder Berm, 1A. Maintenance material from certain reaches of the channel can be used for placement in the existing Feeder Berm located near the north jetty and shoreline. This sandy material deposited in the Feeder Berm is redeposited by cross-shore currents on the shoreline of South Padre Island, decreasing shoreline erosion.

5.5 ENERGY SAVINGS FEATURES OF THE DESIGN

Energy saving features of the design include shortening pumping distances between dredge vessels and the placement areas. This reduces the load on the pump and minimizes the amount of fuel needed.

5.6 MAINTENANCE OF THE ECOLOGICAL CONTINUITY IN THE PROJECT WITH THE SURROUNDING AREA AND WITHIN THE REGION

The ecological continuity in the project with the surrounding area and within the region should not be interrupted permanently with the current dredging and material placement plans.

5.7 CONSIDERATION OF INDIRECT ENVIRONMENTAL COSTS AND BENEFITS

Indirect environmental costs were considered in the Improvement Project. The water quality may be affected by turbidity and the exhaust from the dredge during construction and future maintenance may have an minor effect on the degradation of air quality. Indirect benefits considered are shoreline nourishment.

5.8 INTEGRATION OF ENVIRONMENTAL SENSITIVITY INTO ALL ASPECTS OF THE PROJECT

Consideration and coordination has been given to environmental, social and economic effects of proposed project modifications in accordance with the National Environmental Policy Act (NEPA) in all aspects of the project.

5.9 THE PERUSAL OF THE ENVIRONMENTAL REVIEW GUIDE FOR OPERATIONS (ERGO) WITH RESPECT TO ENVIRONMENTAL PROBLEMS THAT HAVE BECOME EVIDENT AT SIMILAR EXISTING PROJECTS AND, THROUGH FORESIGHT DURING THIS DESIGN STAGE, HAVE BEEN ADDRESSED IN THE PROJECT DESIGN

There are minimal environmental impacts which don't require mitigation for this project.

5.10 INCORPORATION OF ENVIRONMENTAL COMPLIANCE MEASURES INTO THE PROJECT DESIGN

Environmental Compliance Measures incorporated into the project design included USACE Environmental Operating Principles (EOP). The EOP principles ensure conservation, environmental preservation and restoration. Sediment material was tested and the Texas Water Quality Standards and U.S. Environmental Protection Agency Water Quality Criteria were not exceeded thereby making it safer to dispose of material in placement areas. Dredge material placement was confined to the existing footprints avoiding impacts to coastal natural resources. Coordination with the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) under the Endangered Species Act was done, thereby removing risks of impacts to endangered species or their habitats. Nevertheless, there may be a potential impact to sea turtles during hopper dredging. Regulations are stipulated heavily to avoid or minimize these impacts.

6.0 HYDROLOGY AND HYDRAULICS

6.1 INTRODUCTION

Brazos Island Harbor (BIH) is a natural tidal inlet. The inlet is a closed inlet and has no freshwater inflow component. It stretches approximately 18 miles beginning at the Gulf of Mexico and ending at a turning basin. The channel does exchange waters with Lower Laguna Madre, Gulf Intracoastal Waterway (GIWW), Bahia Grande (San Martin Lake), and South Bay. GIWW ties into the channel approximately 2 miles west of the jetties at the entrance, and this has minor impacts on the tide timing and elevations. Figure 6-1 shows the project area, and the water bodies associated with BIH.

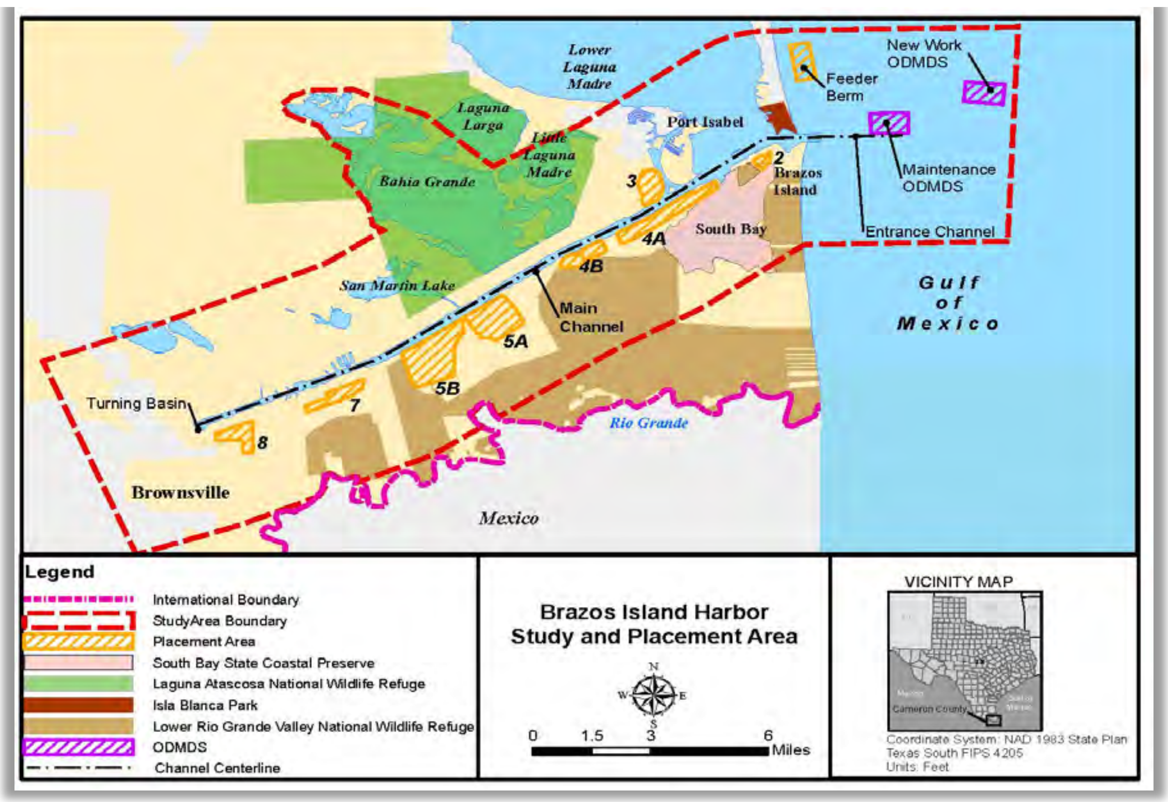


Figure 6-1 – Project Area

6.1.1 Datum and Tidal Information

The datum used for this project is Mean Lower-Low Water (MLLW). The MLLW datum adjustment in the project vicinity is on average .31 ft below MLT. This elevation difference varies along the length of the BIH channel. A summary of gage data as of 2013 in the project vicinity is provided in Table 6-1. All elevations are in the MLLW datum unless otherwise specified. For all future dredging contracts the MLLW datum will be used. For additional information on datum conversions reference EM 1110-2-6056.

Gage ID	*MLT - MLLW*	*NAVD88 - MLLW*
SPICGS 003 (Coast Guard Sta.)	0.251	-0.984
90024 B (South Bay)	0.339	-0.905
9770 B (Port Isabel)	0.342	-0.896

Table 6-1 Datum Information

Tides in the BIH study area range from a low tide of 0.81 foot below MSL to a high flood tide of 0.56 feet above MSL. Mean range is 1.15 feet and the diurnal range is 1.37 feet (National Oceanic and Atmospheric Administration, [NOAA], 2013a).

6.1.2 Historical Information

The entrance to the BIH channel has been modified several times in the past dating back to 1882. Past modifications to the channel include deepening's/widening's and the addition of jetties. In 1882 the original South Jetty was constructed using brush mattresses and clay bricks. This jetty was destroyed by storm in 1887. In 1927 the first channel improvements were completed, deepening the channel to 18 ft, and construction of northern and southern stone dikes extending into the Gulf. The current Jetties were constructed in 1935 with rock groins constructed to protect the landward end of the jetties. The channel was deepened to 21 ft in 1936, 31 ft in 1940, 35 ft in 1947 and to 38 ft in 1960. Major rehabilitation of the jetties was completed in 1966. The North jetty was extended in 1978. The channel was deepened from 38 ft to 44 ft in 1992. Altering the channel by adding jetties and changing the depth/width for navigation resulted in increased shoaling in the channel and changes in the longshore sediment transport in the vicinity of the project.

Located along the Gulf Coast the project study area is prone to exposure to tropical storms and hurricanes. Some notable storms to make landfall in the area include Hurricane Alice in 1954, Hurricane Gladys in 1955, Tropical Storm Alma in 1958, Hurricane Beulah in 1967, Tropical Storm Candy in 1968, Hurricane Caroline in 1975, Hurricane Allen in 1980, Hurricane Barry in 1983, Hurricane Gilbert in 1988, Tropical Storm Arlene in 1993, Tropical Storm Josephine in 1996, Hurricane Bret in 1999, Hurricane Erika in 2003, and Hurricane Dolly in 2008. This is only a partial list, and historical records dating back approximately 200 years show similar patterns in frequency and intensity of tropical storms and hurricanes hitting the area. Based on historical data the project vicinity experiences a major storm event every 5-10 years on average.

6.2 HYDRODYNAMICS

In order to assess the impacts from the proposed alternatives on both navigation and the ecosystem, a numerical analysis of the proposed changes to the system was performed. The Engineer Research and Development, Coastal and Hydraulics Laboratory (ERDC-CHL) performed a numerical model study for proposed changes to the channel (Tate 2011).

6.2.1 Data Collection, Technical Approach and Modeling Techniques

For this study, the 2D shallow-water module of CHLs Adaptive Hydraulics Modeling system (AdH) was used for all simulations. This tool solves for depth and depth-averaged velocity throughout the model domain. In this application, density effects due to salinity or other factors are neglected, so their effects on the flow were not included in these simulations and results. This area is well mixed, with few vertical salinity gradients and very small fresh water inflows in the channel.

Simulations were performed for several widening and deepening scenarios, and the results were used to evaluate the impacts. The model is driven by tidal elevations applied at the ocean boundaries out from the Gulf entrances at Brazos Santiago and Port Mansfield. The tide data applied was obtained from the NOAA station at Bob Hall Pier. In addition to the tide and inflow conditions that drive the model simulations, wind stresses are applied to the model based on the wind speed and direction at various locations. Three wind stations were used for these simulations: TCOON #51, TCOON #17, and TCOON #3.

6.2.2 Model Simulation Results

Discharge comparisons between with and without project conditions were made. Velocity magnitudes and direction, and water surface elevations were compared at several locations along the ship channel and in the Laguna Madre.

Although the depth variation with each plan does affect the results, the impact is not as great as produced by width increase. The deepen only plans follow the same general velocity response as the existing condition channel configuration, but there is a slight shift in the phasing of the flows and in the peak velocity magnitudes with the changes in depth. Average velocities in the current channel were determined to range from approximately .8 ft/s to -1.6 ft/s (the negative refers to velocities during ebb tide). The velocities for the deepening plans were estimated to be .7 ft/s to -1.4 ft/s by the hydrodynamic model.

Water surface elevation comparisons were performed for all analysis locations. There are small differences in the water surface elevation in the channel due to the widening and/or deepening. These differences increase slightly with each deepening, although each change is quite small.

For the 52' deepening the maximum change in water surface elevations during flood tide conditions is estimated to be approximately .05 ft, and during ebb tide the maximum change in water surface elevation was estimated to be .1 ft. Overall, the effect of the change in channel dimensions does not affect the water surface elevations in the study area in a way that would impact navigation.

6.2.3 Summary and Conclusions

ERDC-CHL performed two-dimensional numerical hydrodynamic modeling for the Brownsville Ship Channel including the lower Laguna Madre. The model was used to analyze changes to the discharge, velocity, and water surface elevation for several plan conditions that include widening and deepening the entire ship channel or sections thereof. These comparisons show that a change in width greatly affects the velocity variation across the ship channel while the change to overall discharge is small. The water surface elevations also remain unchanged, essentially, from the existing conditions at all locations including South Bay.

Low velocities and the fact that the plan changes do not greatly change the magnitudes of velocity and water surface elevation from the existing conditions indicate that none of these changes to the ship channel should adversely impact navigation along the channel. Results from these model studies are provided for ship simulations whereby further navigational analyses can be performed.

6.3 STORM SURGE IMPACTS ANALYSIS

A Storm Surge Impacts Analysis was performed by ERDC-CHL to determine potential changes in storm surge considering with project and future operation and maintenance (O&M) conditions. Storm surge simulations and analyses were used to quantify the impacts of the BIH widening and/or deepening conditions, as well as estimate 50-year future conditions based on O&M dredge placement area estimated elevations (Ratcliff & Massey 2013). The study limits of the Surge Impact Analysis are displayed in Figure 6-2.

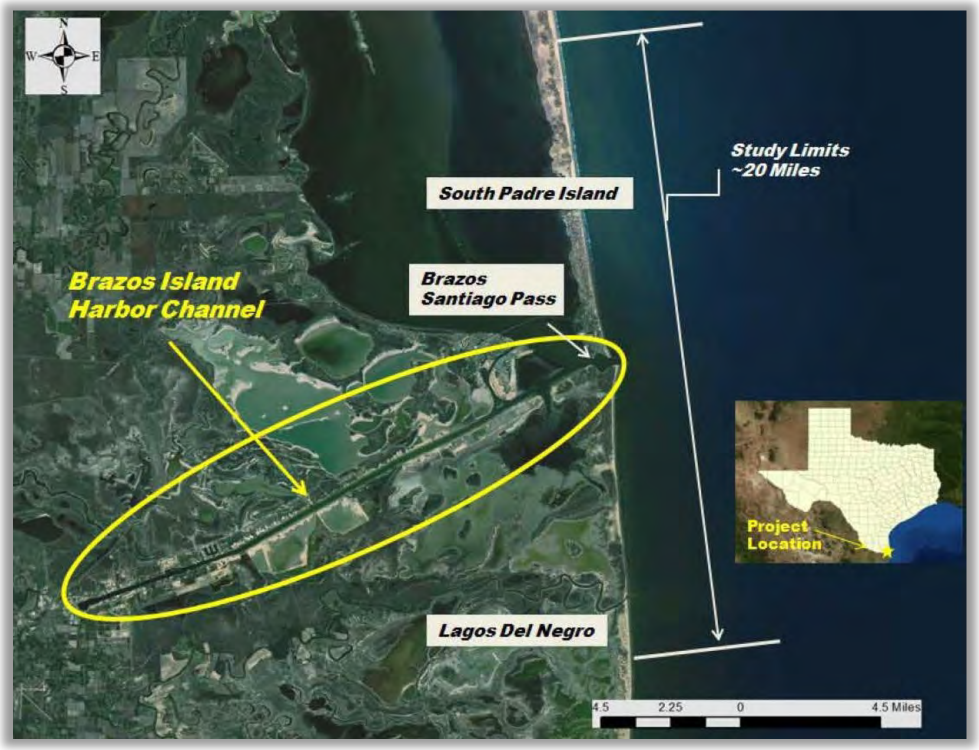


Figure 6-2 –Storm Surge Impacts Analysis Study Limits

6.3.1 Data Collection and Modeling Techniques Used

Baseline storm surges used for the analyses were obtained from the FEMA Texas Joint Storm Surge Study (JSS). The FEMA Texas JSS used the ADvanced CIRCulation (ADCIRC) model together with the ERDC STeady-state WAVE (STWAVE) model to perform storm surge and wave simulations. The ADCIRC mesh from the FEMA Texas JSS was modified to reflect the project geometry and channel design specifications of BIH.

6.3.2 Storm Surge Modeling

CHL created two ADICRC grids. One grid represents “existing conditions”. Existing conditions includes existing channel dimensions and existing PA elevations. The second grid represents future 50-year conditions of O&M dredging with project design channel dimensions and estimated PA elevations.

Based on analyses of peak storm surge in the BIH vicinity as well as storm characteristics including intensity, forward speed, and angle of approach, a total of 15 storms were selected (Figure 6-3. Storm intensity is defined by the minimum atmospheric pressure in units of millibars (mb) at the center (or eye) of the storms, over the entire storm event. The lower the central pressure (CpMin) indicates a stronger more intense storm. Storm size is defined by the distance from the center of the storm to the location of maximum winds (Rmax in nautical miles). Storm forward speed is the average speed of the center of the storm (Vf_avg in knots). The FEMA Texas JSS includes both “high intensity” storms of Category 3 or greater and “low intensity” storms of Category 1. Table 6-2 shows the FEMA Texas JSS storm numbers (JPMOS_Num), the synthetic start and end dates, and the storm group of either high or low intensity. These storms were estimated to have the most impacts to the BIH study region.

CpMin	Rmax (nm)	StartDate	EndDate	Vf_avg(kn)	JPMOS_Num	StormGroup
900	21.8	20230729	20230802	11.00	218	High Intensity 152
900	12.5	20770728	20770802	6.88	272	High Intensity 152
900	12.5	20810728	20810802	7.61	276	High Intensity 152
900	18.4	20820728	20820802	7.61	277	High Intensity 152
900	17.7	20900726	20900802	6.00	285	High Intensity 152
900	17.7	20550729	20550802	11.00	326	High Intensity 152
900	17.7	21430726	21430802	6.00	338	High Intensity 152
930	17.7	20060729	20060802	14.13	362	High Intensity 152
930	17.7	11580730	11580802	17.00	353	High Intensity 152
930	17.7	21130730	21130802	17.00	357	High Intensity 152
930	17.7	19630730	19630802	17.00	358	High Intensity 152
975	11	20150729	20150802	11.00	404	Low Intensity 71
975	17.7	20060728	20060802	6.00	470	Low Intensity 71

Table 6-2 – Characteristics of Selected Storms

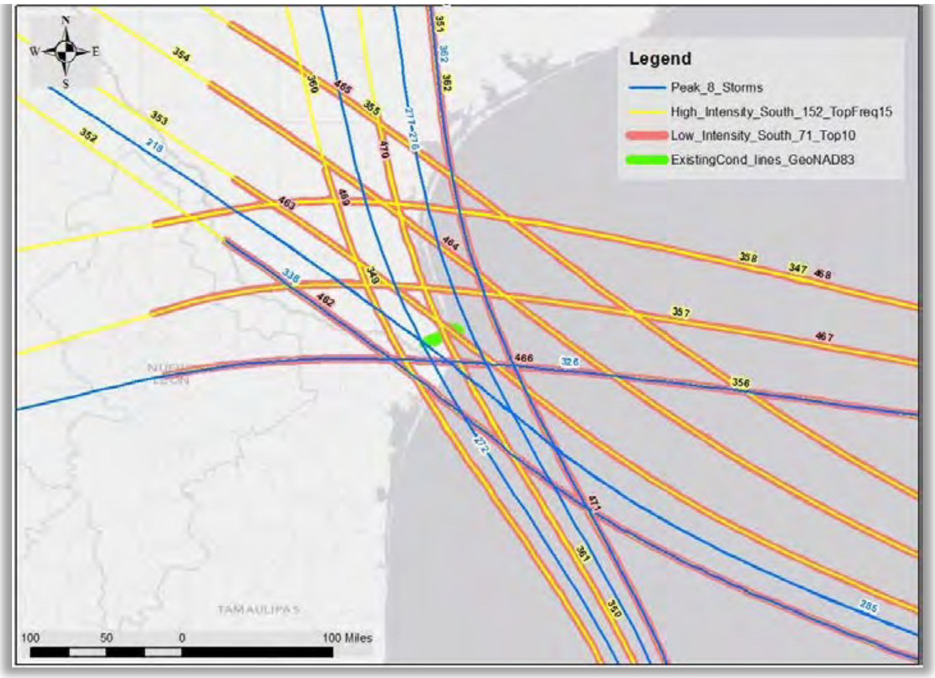


Figure 6-3 –Storms Selected for Surge Modeling

6.3.3 Summary and Conclusions

ERDC CHL refined the previous FEMA JSS mesh in the area of interest to create two new ADCIRC mesh configurations. The first mesh created represented the existing conditions, with current channel geometry and dredge PA elevation set to existing USACE elevations. The other mesh reflected the proposed BIH project channel design with PA regions set at estimated 50-year O&M uniform elevations. A total of 14 synthetic storms and 1 historic storm (Hurricane Allen) were simulated to compute the difference in the peak water level between the existing and the 50-year project design conditions.

Differences in storm surge were estimated in the BIH region for the future condition compared to the existing condition (Table 6-3). The increases in surges are generally on the southern side of the channel.

Storm	Peak Surge Increase with Project and 50 Yr O&M (ft)
218	1.8
272	1.5
276	0.9
277	1.2
285	1.9
326	2.6
338	1.9
353	0.5
357	0.2
358	0.3
362	0.3
404	0.4
466	0.2
470	0.1
721	0.9

Table 6-3 - Peak Surge Impact Summary

Changes in surge for the project conditions depended greatly on the intensity of the storm and the angle of approach.

6.4 SHOALING AND SEDIMENTATION ANALYSIS

Shoaling and sedimentation naturally occurs in channels, widening and/or deepening can increase the shoaling and sedimentation in the channel and can increase corresponding dredging needs for O&M. Shoaling estimates were performed for each plan configurations for consideration in selecting the final tentatively selected plan. Additionally, the jetties leading into the Brazos Ship Channel alter the natural longshore drift patterns along the Gulf of Mexico coast, and act as a sediment trap. An analysis was performed to estimate the change in shoaling and sedimentation due to the proposed project.

6.4.1 Historical Shoaling Estimates

Available dredging history data was collected from June 1952 through March 2011 from the USACE dredging histories database. This data provided a basis for estimating existing shoaling rates, and also to evaluate how previous channel modifications have altered shoaling in the channel. The data gathered was used in calculating average annual shoaling rates by reach. All material that was/is shoaled was assumed to be removed in these estimates.

6.4.2 Condition Surveys

Condition surveys were used to look at areas where increased shoaling has historically occurred. This survey data was used in shoaling estimates discussed in section 6.4.3.

6.4.3 Shoaling Estimates

To calculate shoaling for deepening alternatives "PIANCE Report n° 102-2008 Equation #3.32 – Volume of Cut Method" was used. The volume of cut equation and parameters are:

$$h_T = h_0 - (h_0 - h_e)\left(1 - exp\left\{-\frac{\upsilon T_*}{h_0}\right\}\right)$$

$$h_T = channel\ depth\ after\ time\ t = T_*$$

$$h_0 = channel\ depth\ at\ time\ t = 0$$

$$h_e = morphological\ equilibrium\ depth\ (generally\ water\ depth\ surrounding\ channel)$$

$$\upsilon = siltation\ rate\ parameter$$

The PIANC method only calculates the increase in shoaling due to deepening. In order to calculate additional shoaling due to widening alternatives proportionality methods were used. Condition surveys were used to derive the value per reach by examining the height of the channel adjacent to where it's typically dredged. Volume of Cut Method calibration data for the tentatively selected plan is shown in Table 6-4.

Exisitng Conditions Calibration Data							Adjusted Shoaling Rate for TSP					
Reach		h_T (ft)	h_0 (ft)	h_e (ft)	υ	Shoaling Rate (ft/yr)	h_T (ft)	h_0 (ft)	h_e (ft)	υ	Shoaling Rate (ft/yr)	% Increase
-17+000	-13+000	43	46	18	6	3.3	52	56	18	6	3.7	113%
-13+000	0+000	42	46	18	7	4.0	51	56	18	7	4.5	113%
0+000	6+000	41	44	18	5	3.0	51	54	18	5	3.4	114%
6+000	11+000	42	44	18	4	2.0	52	54	18	4	2.3	114%
11+000	28+000	42	44	18	4	2.0	52	54	18	4	2.3	114%
28+000	39+000	43	44	18	2	1.0	53	54	18	2	1.1	113%
39+000	50+000	42	44	18	4	2.0	52	54	18	4	2.3	114%
50+000	83+600	42	44	18	4	2.0	52	54	18	4	2.3	114%
83+600	86+000	35	36	18	3	1.4	42	44	18	3	1.7	108%
86+000	88+710	34	36	18	4	2.0	34	36	18	4	2.0	100%
88+710	89+500	34	36	18	4	2.0	34	36	18	4	2.0	100%

Table 6-4 –Volume of Cut Shoaling Calibration Data

6.4.4 Results

A summary of estimated shoaling rates for all alternatives considered is presented in Table 6-5. Shoaling increases are higher in areas where widening and deepening are both occurring. Results indicate that shoaling rates will increase more within the entrance channel which accurately reflects the fact that current shoaling rates are already higher in the entrance channel. Shoaling amounts are lower for the jetty section of the channel where velocities are high and erosion is an issue. Moving west/inland the shoaling increases in Dolphin Cove where the channel widens and the velocities decrease providing conditions for sediments to settle out. There are minor increases in shoaling for the remainder of the channel for the alternatives considered. To offset any increases in shoaling dredged material from the jetty and cove area will be placed in the existing feeder berm nourishing the South Padre Island beach. Additional impacts from the channel modifications are detailed in the following section.

Table 6-5– Alternative Shoaling Estimates(Shown at the end of the Appendix)

6.5 SHORELINE IMPACT ANALYSIS

The Corps contracted engineering consultants HDR (Heilman 2011) to perform an analysis to address the potential for wave-field alterations to cause impacts to the adjacent Gulf shorelines 10 miles to the north and south of Brazos Santiago Pass (Figure 6-4) for proposed modifications to the entrance channel.

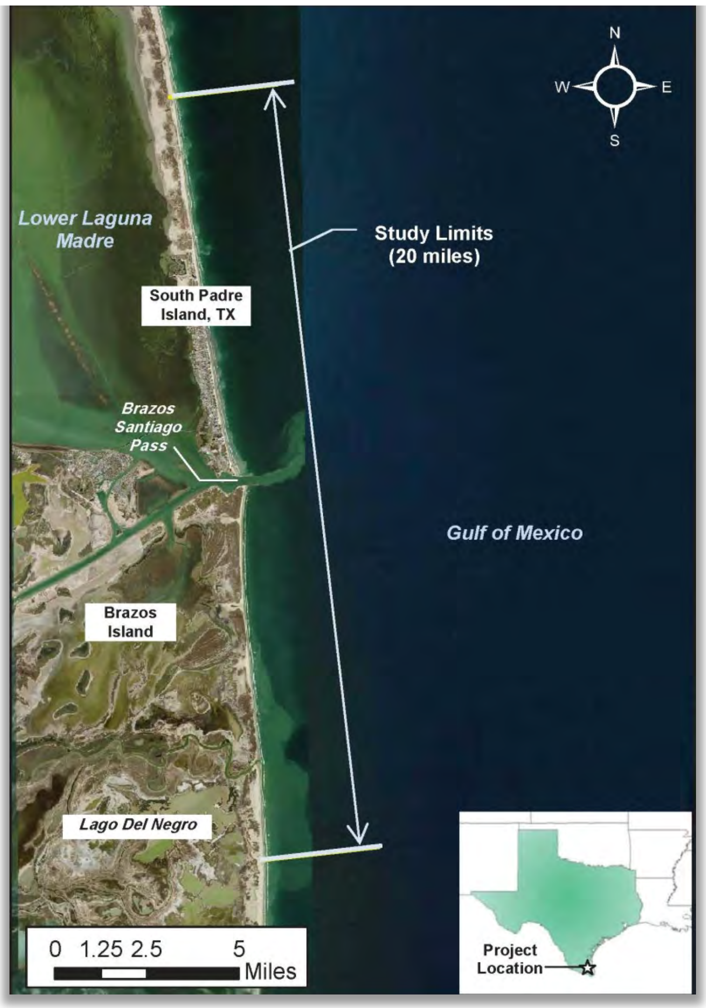


Figure 6-4 – Shoreline Impacts Study Limits

6.5.1 Historical Longshore Transport and Erosion Rates

To the south of the BIH entrance channel is Brazos Island, the southernmost barrier island in Texas. Brazos Island is uninhabited and bordered on its southern side by the Rio Grande River. Net longshore sediment transport is generally from south to north within this region. Like most modified inlets on the Texas coast, construction of the BSP jetties and continued maintenance of the entrance channel have disrupted the natural movement of sediments and altered long term shoreline change trends in the vicinity of the project.

6.5.2 Shoreline Impacts Due to Change in Wave Incident Angle

Wave field alterations caused by the deepened and extended channel could potentially cause shoreline impacts within the study area if they result in a significant reduction or increase in net LST gradients. Changes to LST were calculated based on percent changes in wave height and wave angle for each wave direction.

Along Brazos Island, net LST would continue to transport sand from the south towards BSP. This sand would continue to primarily be impounded by the jetty, with a modest percentage being transported around the jetty and deposited within the ship channel. Even if net LST is slightly reduced, the beach within 3 miles south of BSP would be expected to remain stable to accretional. Sediment that is bypassed around the jetty is accounted for as a separate process in the sediment budget. If the maximum calculated percent changes in longshore transport at the south and north jetties are applied to the bypassing rates shown in the sediment budgets, the net LST would decrease by approximately 7,350 CY/YR to the north and (2) increase by approximately 330 CY/YR to the south.

Longshore transport and shoreline change rates were developed by applying the maximum percent change in LST from the sediment budget. Existing erosion rates are not expected to increase by more than 0.1 ft/yr. Impacts to the shoreline along SPI and to the north would likely be indiscernible when considering the natural variability in ongoing coastal processes that control shoreline change.

6.5.3 Deepening Impacts on Longshore Sediment Transport

In addition to shoreline impacts from changes in wave incident angles, longshore transport impacts by the channel deepening must also be considered. The entrance channel acts as a sediment trap and decreases the longshore transport downdrift of the jetties. These downdrift beaches along South Padre Island are a popular tourist destination and maintaining beach width is important to the area residents and businesses. Deepening the channel will result in an increase in sediment removal from the littoral system. Deepening the entrance and main channel will decrease the amount of material bypassing the jetties that currently moves north along the South Padre Island Beach.

Impacts caused by the deepening of the entrance channel and deepening of channel extending west will be offset by dredging the sand from the channel and placing it into an existing feeder berm located north of the jetties, offshore the adjacent South Padre Island beach. This will reintroduce the sediments into the littoral system north of the jetties and result in negligible impacts to longshore transport north of the jetties due to the deepening. This feeder berm has been used by the Corps to offset impacts the longshore sediment transport processes due to modifications to BIH.

6.5.4 Summary and Conclusions

Overall, if the proposed channel modifications are constructed, existing shoreline change trends would continue. Beaches adjacent to BSP would not be expected to experience significant impacts from the proposed channel deepening and/or widening. Based on the assessments presented in the HDR report, the following conclusions and recommendations are provided:

- Construction of the proposed channel modifications would result in relatively minor alterations to the typical nearshore wave field. The changes are unlikely to be detectable considering the scale of variability in natural coastal processes at the site.

- Maximum increases in erosion of 0.5 ft/yr and 0.1 ft/yr south and north of BSP, respectively, are estimated for the proposed channel modifications due to changes in incident wave angles. Changes of this magnitude are not likely to be measureable in the field.

- If the proposed channel modifications are constructed, current shoreline change trends would be expected to generally continue. Beaches adjacent to BSP would not be expected to experience significant increased impacts from the channel resulting from the proposed deepening and/or widening.

- Changes in longshore sediment transport caused by the deepening of the channel will be offset by dredging the sand from the channel and placing it into an existing feeder berm located north of the jetties, offshore the adjacent South Padre Island beach. This will reintroduce the sediments into littoral system north of the jetties and result in negligible impacts to longshore sediment transport. Material from Station 11+000 to -17+000 has been deemed suitable for beach nourishment using the existing feeder berm.

6.6 NAVIGATION STUDY AND GEOMETRICAL ANALYSIS FOR RIG MOVEMENT

6.6.1 ERDC Navigation Study

A Navigation Study for Brazos Island Harbor was performed by the Corps ERDC Coastal Hydraulic Laboratory (Webb, Lambert, Davis 2012). Principal imports and exports of the port include chemicals, petroleum, grain, cotton, sulfur, citrus, glass, steel, ores, fertilizers, and crude rubber. Brownsville was the nation's second largest in-transit harbor by volume. In addition, one large oil rig construction and servicing firm and four ship-breaking facilities are located on the main channel.

The Brazos Santiago Pilots Association has set navigation guidelines for BIH. Deep draft vessels are not permitted to meet each other in any part of the channel, but tug and barge traffic is allowed to pass as arranged by the Harbormaster. Rig and scrap vessels transit the channel during daylight only. Specific navigation issues mentioned by the pilots include the narrowness of the channels and crosscurrents (particularly during ebb tide) due to tidal exchange with the Laguna Madre. These are most difficult for inbound runs since the ship must slow for the turn from the entrance channel into the main channel.

Currents and depths for the simulation study were input from a hydrodynamic study conducted at ERDC as described in the Hydrodynamics section of this Appendix. Databases were developed for the maximum strength of flood and ebb tidal currents at the western end of the entrance channel.

Databases were initially developed for the existing condition, the pilots performed validation testing of the existing conditions prior to any widened runs. The pilots felt that the existing condition simulation accurately reflected navigation in Brazos Island Harbor.
Several sets of simulations were run. A summary of the vessels simulated in the Navigation Study is presented in Tables 6-6.

Table 6-6 - Vessels Simulations in the ERDC Navigation Study

Run	Channel	Vessel	Heading	Tide	Wind
1	Existing	750- x 120- x 36 ft Tanker	Inbound	Ebb	20 knot SE
2	Existing	750- x 120- x 36 ft Tanker	Inbound	Flood	20 knot SE
3	Plan 1	846- x 157- x 47- ft Garnet	Inbound	Ebb	20 knot SE
4	Plan 1	846- x 157- x 47- ft Garnet	Inbound	Flood	20 knot SE
5	Plan 2	846- x 157- x 47- ft Garnet	Inbound	Ebb	20 knot SE
6	Plan 2	846- x 157- x 47- ft Garnet	Inbound	Flood	20 knot SE
7	Plan 1	1087- x 195- x 24- ft VLCC	Inbound	Ebb	20 knot SE
8	Plan 1	1087- x 195- x 24- ft VLCC	Inbound	Flood	20 knot SE
9	Plan 2	1087- x 195- x 24- ft VLCC	Inbound	Ebb	20 knot SE
10	Plan 2	1087- x 195- x 24- ft VLCC	Inbound	Flood	20 knot SE
11	50 ft	846- x 157- x 47- ft Garnet	Inbound	Ebb	20 knot SE
12	50 ft	846- x 157- x 47- ft Garnet	Inbound	Flood	20 knot SE
13	50 ft	1087- x 195- x 24- ft VLCC	Inbound	Ebb	20 knot SE

14	50 ft	1087- x 195- x 24- ft VLCC	Inbound	Flood	20 knot SE
15	100 ft	846- x 157- x 47- ft Garnet	Inbound	Ebb	20 knot SE
16	100 ft	846- x 157- x 47- ft Garnet	Inbound	Flood	20 knot SE
17	100 ft	1087- x 195- x 24- ft VLCC	Inbound	Ebb	20 knot SE
18	100 ft	1087- x 195- x 24- ft VLCC	Inbound	Flood	20 knot SE
19	150 ft	846- x 157- x 47- ft Garnet	Inbound	Ebb	20 knot SE
20	150 ft	846- x 157- x 47- ft Garnet	Inbound	Flood	20 knot SE
21	150 ft	1087- x 195- x 24- ft VLCC	Inbound	Ebb	20 knot SE
22	150 ft	1087- x 195- x 24- ft VLCC	Inbound	Flood	20 knot SE

The 2012 ship simulation found that without widening plans were not acceptable (Plan 1, Plan 2, and 50 foot widening). The 2012 simulation determined the 100 foot widening was acceptable, while the 150 foot widening was excessive. Therefore the 2012 ship simulation recommended a 350 foot wide channel.

During analysis of the final array of alternatives, the economics and fleet forecasts were reexamined and the forecasts for future traffic patterns utilizing the facilities were changed. This occurred after completion of the 2012 ship simulation, therefore the forecasted fleets for the 2012 simulations did not accurately represent future fleets. This change led to the discarding of the recommendations of the 2012 simulations.

The optimal design vessel width for the future channel is currently a Panamax tanker vessel with a 106 foot beam. With a 250 foot channel this relates to a width/beam ration of 2.4. EM 1110-2-1613 contains guidance on width criteria for deep draft navigation. The guidance states that 2.5 would be a conservative ratio and indicates ratios for straight canals with small currents such as BIH typically result in lower ratios. Consultation with ERDC and review of the deep draft navigation guidance determined beam/width ratio of 2.4 is acceptable.

Additionally, the BIH ship breaker industry recently conducted a separate ship simulation study with ERDC to model transits of aircraft carriers, which is now the largest vessel that facility expects to service. This analysis indicated no widening of the channel is currently needed.

6.6.2 Oil Rig Movement Modeling

In addition to the ERDC Navigation Study In May 2010, a geometric analysis was performed by DOF Subsea to show a real time oil rig movement simulation for two rigs. The design rig for the modeling was based on the widest beam and deepest draft expected in the Port of Brownsville navigation channel. The analysis was performed with the rig's thrusters in place. These thrusters require additional channel depth beneath the oil rig. Significant savings to the industry could occur if these thrusters did not have to be removed before entering the channel because the removal process requires additional time, significant costs and specialized diver expertise. This geometric analysis results supported the need for the 52-foot channel depth.

The recent report developed for the Section 6009 benefits forecasts more drillships working in the Gulf of Mexico rather than semi-submersibles in the future. These drillships have a geometric configuration that requires additional depth to traverse the channel and would not need additional widening. For additional information on this topic, reference the Economic Appendix and Section 6009 benefits report for this study.

6.6.3 Summary and Conclusions

Consolidating the engineering and economic studies and analyses for this project with comments from the pilots and sponsor, it was decided the existing channel width is sufficient and no widening will be part of the recommended project. Deepening is needed to provide adequate freeboard to vessels/rigs utilizing the channel. The need for deepening and no widening was determined by the economic analysis performed for this study. The 2012 ship simulation conducted of this study simulated vessel no longer expected to represent future conditions. Therefore recommendations from that analysis are not applied for the recommended alternative of this feasibility study. Analysis of the deepest and widest oil rigs was conducted to verify channel dimensions. For additional information reference the Economic Appendix of this study.

6.7 RELATIVE SEA LEVEL RISE

This document uses current USACE guidance to assess sea level rise for the Brazos Island Harbor, TX system. Corps of Engineers guidance (EC 1165-2-212, October 2011) specifies the procedures for incorporating relative sea level rise 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 sea-level rise for both existing and proposed projects. The Corp 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 rise are best determined by local tide records (preferably with at least a 40 year data record.)
- Moderate - Estimate the “intermediate” rate of local mean sea-level change using the modified NRC Curve I.

•High - Estimate the “high” rate of local mean sea-level change using the modified NRC Curve III.

The Modified NRC equation is given below:

(1) $\eta(t)=(0.0017+M)t+bt^2$

Where:

$\eta(t)$ = the relative sea level rise for year t (meters)

t = the elapsed time since the baseline year of 1992 (years)

M = the local rate of subsidence (+) or uplift (-) (meters/year)

b = the rate of acceleration of eustatic sea level rise (meters/year^2)

The values of b are chosen such that the sea level due to eustatic rise at year 2100 is equal to 0.5, 1.0, and 1.5 m respectively.

The following equation results from manipulating equation (1) to account for eustatic sea level rise starting in 1992.

(2) $E(t_2)-E(t_1) = 0.0017(t_2-t_1)+b(t_2^2-t_1^2)$

Where:

$E(t_2)-E(t_1)$ = Eustatic mean sea level trend meters/year

b = the rate of acceleration of eustatic sea level rise (meters/year^2)

t_1 = time between construction date and 1992 (years)

t_2 = time between end of design life and 1992 (years)

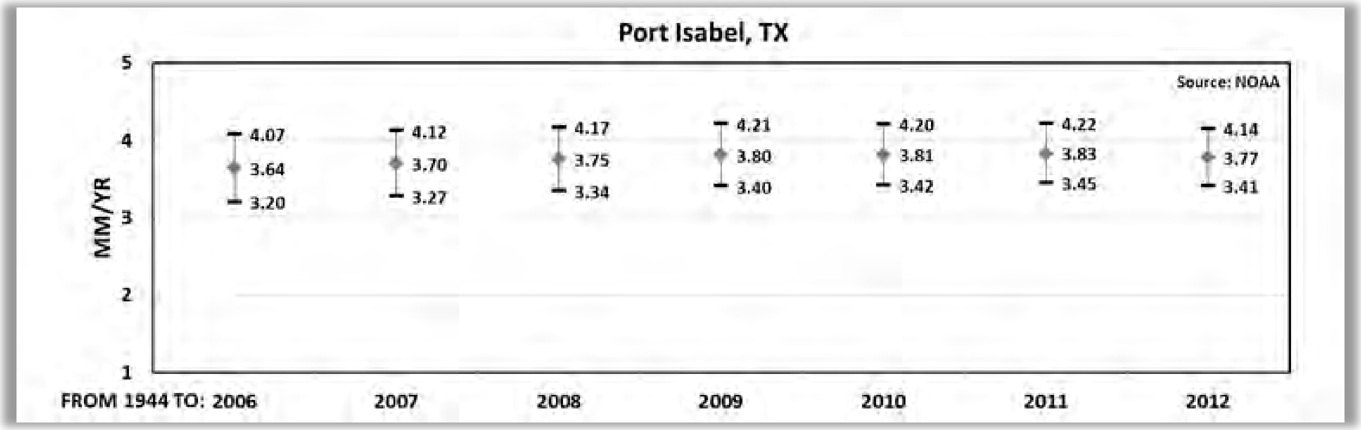
Table 6-7 - Rate of acceleration of eustatic sea level rise for each Modified NRC curve

NRC Curve	b (meters/year^2)
NRC I	2.71E-05
NRC II	7.00-05
NRC III	1.13 E-04

6.7.1 Historic RSLR

The recent historic rate of local relative sea level rise can be obtained from local tide records with reasonably high confidence. The nearest tide gage with over 40 years of record is located at Port Isabel, Texas, located approximately two miles north of the channel and 3 miles west of South Padre Island. The NOAA mean sea level trend at this site (from 1944 to 2011) is equal to 3.83 ± 0.39 mm /yr (0.01257 ± 0.0013 ft/yr) with a 95% confidence interval.

Figure 6-5 - Relative Sea Level Rise Trend from NOAA, Port Isabel, Texas



If the estimated historic eustatic rate equals the global average rate given for the Modified NRC curves (approximately 1.7 mm/yr as of 2012 (0.00558 ft/yr)), this results in an estimated observed subsidence rate of 3.83 – 1.7 = 2.13 mm/yr (0.00699 ft/yr).

6.7.2 Subsidence Discussion

To date, there is no scientific consensus on what the local subsidence rate should be for future projections. According to the Texas Department of Water Resources it is difficult to determine if subsidence has occurred within this region based on bench marks, because elevation changes are so small that they are within standards of accuracy. Therefore it is assumed that subsidence is negligible.

6.7.3 New RLSR analysis as per the Updated Corps Guidance

According to the most recent guidance, the subsidence rate should be chosen based on the tidal record analysis. Figure 6-6 displays the computed sea level rise based on the new guidance for the low (historic) rate, the intermediate (Modified NRC Curve I) rate, and the high (Modified NRC Curve III) rate. The sea level rise rates based on basal peat rates are also shown for the three NRC curves. The computed sea level rise given here assumes a 50 year period of analysis, and gives the predicted rise for the years 2016-2066.

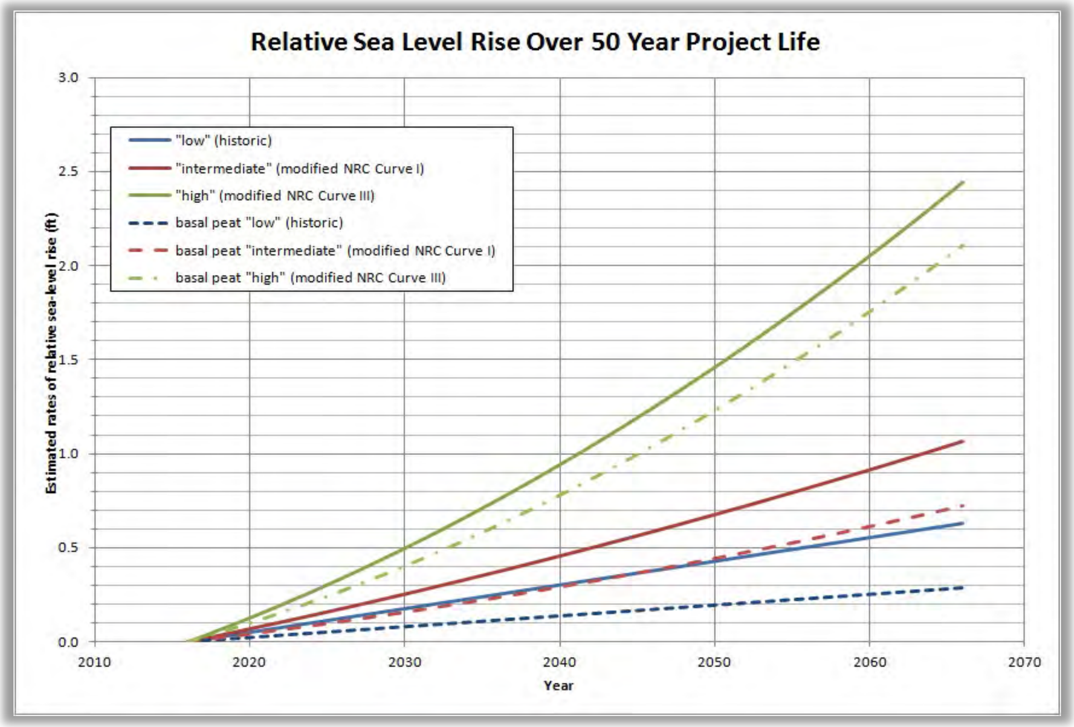


Figure 6-6: Relative Sea Level Rise Projections Over Period of Analysis

Relative sea level rise values for the 50 year period of analysis are summarized in Table 6-8.

Table 6-8: Estimates of Future Relative Sea Level Rise (2016-2066)

Method	Low (ft(cm))	Intermediate (ft(cm))	High (ft(cm))
Tide Gage	.628 (19.15)	1.064 (32.43)	2.445 (74.52)
Basal Peat	.287 (8.75)	.723 (22.03)	2.104 (64.12)

6.7.4 Project Related RSLR Impacts

Possible impacts of sea level rise on the BIH entrance channel jetties were evaluated. Jetty elevations were taken from the document "USACE Gulf Coast Jetties & Texas City Dike Repair, Survey Data, Brazos Island Harbor Jetties" prepared for USACE by Huitt-Zollars in September 2009. Based on the table on page 2 of the BIH Jetties Survey Submittal, the lowest elevation of the jetties is 2.52 ft (south jetty - HZ301). This elevation is higher than the "high" estimate of RSLR at 2066. Therefore it is not expected that sea level rise (low, moderate, or high estimated values) will change the functionality or performance of the existing jetties.

6.7.5 Conclusions

Brazos Island Harbor is a very long channel with no additional sources of inflow, making it lack hydrodynamic complexity. Widening and deepening projects on such channels historically do not have much impact on altering the relative sea level rise rate. This simplifies the sea level rise analysis and modeling was therefore not required. Modeling was done to examine surge impacts from the project. Any additional impacts from relative sea level rise on surge are expected to be insignificant. The sea level rise rates for the area are relatively low with the tide gage rates for “low”, “intermediate”, and “high” sea level rise rates of 0.628 ft, 1.064 ft, and 2.445 ft. respectively, over the 50 year period of analysis. The historic average rate for the project area is about 1.26 ft per 100 years according to NOAA Mean Sea Level trends using the Port Isabel, TX tide gage. Based on the results of the sea level rise analysis, it was determined that:

1. Sea level rise of 2 to 2.5 ft is considered in the shoaling analysis for future project considerations. The effect of sea level rise on shoaling is minimal.

2. Any placement areas that require protection should be armored an additional 2 to 2.5 ft. vertically upslope.

3. The engineering design needs to ensure that the estimated “high” sea level rise rate will not negatively impact the functionality of the project design.

4. Modeling was done to examine surge impacts from the project which were minimal and any additional impacts from relative sea level rise on surge are expected to be insignificant.

6.8 HYDROLOGY AND HYDRAULICS SUMMARY AND CONCLUSIONS

The U.S. Army Corps of Engineers Galveston District (SWG) is currently engaged in a feasibility study to determine the federal interest in widening and/or deepening the Brazos Island Harbor Channel in Cameron County, Texas. A comprehensive H&H analysis of alternative plans was conducted to evaluate possible H&H impacts of each plan. This Engineering Appendix summarizes the studies and analysis performed to determine impacts of the proposed plans.

The H&H analysis for BIH evaluated the array of alternative plans for impacts on hydrodynamics, storm surge, shoaling and sedimentation, shoreline impacts, navigation impacts, and impacts from relative sea level rise. Surge impacts were found to be negligible for the tentatively selected plan of a 52 ft deepening. Some minimal hydrodynamic impacts are estimated. Shoaling and sedimentation changes were estimated and are presented. Relative sea level rise was estimated, and is not expected to adversely impact the proposed project.

6.9 REFERENCES

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Rosati, Julie & Kraus, Nicholas. Sea Level Rise and Consequences for Navigable Coastal Inlets. Shore & Beach. Vol. 77. No 4. Fall 2009.

Tate, J., Ross, C., Brownsville Ship Channel Hydrodynamic Modeling, January 2012.

Thomas, R, Desktop Evaluation of Shoaling - Federal Feasibility Study to Deepen and Widen the Brownsville Ship Channel, March 2009

Ratcliff, J., Massey, C., Brazos Island Harbor, Texas: Storm Surge Impacts Phase II, DRAFT, May, 2013.

Webb, D., Davis, T, Lambert S, Navigation Study For Brazos Island Harbor, improvement Project Data Report, March, 2012

Heilman, Daniel (HDR), Shoreline Impact Analysis - Federal Feasibility Study to Deepen and Widen the Brownsville Ship Channel, HDR, June 2011

7.0 HAZARDOUS AND TOXIC MATERIALS

7.1 HTRW EVALUATION

A Hazardous, Toxic and Radioactive Waste Assessment was conducted for the Brownsville Ship Channel by SOL Engineering Services, LLC. Based on the analysis described in the report, there are no chemical contaminants that indicate a cause for concern with the placement of materials in the PA's or as BU material in the feeder berm.

8.0 ENVIRONMENTAL OBJECTIVE AND REQUIREMENTS

Significant ecological, aesthetic and cultural values must be preserved and protected. Natural resources should also be conserved. The human and natural environments should be maintained and restored as needed. Plans implemented to improve navigation should avoid damaging the environment and contain methods to minimize or mitigate damages to the environment. The Environmental Operating Principles (EOP) provide measures on how to preserve, manage and improve our air, water and land resources.

9.0 OPERATION AND MAINTENANCE

The required maintenance dredging of the 52-foot channel will increase to 1,258,390 CY/YR from the current 1,103,480 CY/YR for the 42-ft channel for a net increase of 154,910 CY/YR. The plan proposed for operation and maintenance is discussed in the Section 4.12.1 Operation and Maintenance.

10.0 ACCESS ROADS

Access roads are not required for the channel dredging. Channel deepening will be accomplished by a floating plant. Existing access roads for the project site are available for use during construction. If construction is done when the area is saturated, improvements may need to be done for access roads for upland Placement Areas except PA 7 and PA 8. Additional access to project site can be made by water.

11.0 PROJECT SECURITY

This project consists mainly of channel dredging and levee work. A security plan will not be needed.

12.0 COST ESTIMATES

<u>LOCATION AND DESCRIPTION:</u>
Port of Brownsville is located on the south Texas coast near the border of U.S. and Mexico. The study area encompasses the entire Brownsville Ship Channel and surrounding region. The entrance channel is located offshore of Cameron County, Texas, in the Gulf of Mexico, and ends at Port of Brownsville Main Harbor. Brownsville Ship Channel provides deep draft access from the Gulf of Mexico through a jetty entrance channel to Brownsville, and a side channel, authorized to 36-feet, and a shallow draft Fishing Boat Harbor near Port Isabel. The primary purpose of the study is navigation, which consists of enlarging the existing Brownsville Ship Channel by deepening the entrance channel, jetty channel, the lower section of the main channel, the upper section of the main channel, and turning basin.

The MII is developed using October 2013 price levels and the latest labor rates for Galveston District. The estimate is divided into seven (7) contracts. Each contract is organized in accordance with a work breakdown structure. Midpoint dates for the construction contracts are developed in conjunction with the project manager for developing the fully-funded costs. The estimate is prepared in accordance with ER 1110-2-1302 Civil Works Cost Engineering, dated 15 Sep 08. The costs are escalated in accordance with the above Engineering Regulation and EM 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS) dated 31 Mar 2013. All data is input into the Total Project Cost Sheet (TPCS).

Marine fuel price is averaged, locked in at $3.30/gallon (October 2013). Diesel fuel price is locked in at $4.00/gallon (October 2013). There are no impacts to utilities anticipated. There are no Hazardous, Toxic, and Radioactive Wastes anticipated. The Operation and Maintenance estimate is dated October 2013, with an effective pricing date of October 2013. A formal Cost Risk Analyses is performed with the cooperation of the PDT and Cost Engineering Directory of Expertise (DX) of the Walla Walla District (October 2013). The risks are quantified and a cost risk model developed to determine a contingency at 80% Confidence Level (CL). The new contingencies along with the updated estimates are used to revise the TPCS. An ATR Certification of Cost Estimate is provided by Walla Walla District.

CONTRACT 01:
This contract is for hopper dredging -17+000 to 00+000 and delivery to New Work Ocean Dredged Material Placement Area (Offshore). The stationing listed is located on the Gulf of Mexico side of the jetties (entrance channel) and is unsuitable for a pipeline dredge due to wave action. The approximate duration is seven (7) months.

CONTRACT 02:
This contract is for dike raising and rehabilitation of Placement Area 4B and Placement Area 5A. The approximate duration is 15 months. Associated Costs provided by Department of Engineering Services of the Brownsville Navigation District (21 Oct 2013).

CONTRACT 03:
This contract is for dike raising and rehabilitation of Placement Area 7 and Placement Area 8. The approximate duration is seven (7) months. In addition, this contract is for pipeline dredging 70+00 to 82+000 and 82+000 to 89+500 and delivery to Placement Area 7 and Placement Area 8, respectively. The stationing listed is located in the upper section of the main channel and turning basin. The approximate duration is 10 months. The approximate duration of the total contract is 13 months as dike raising and rehabilitation can occur, in some instances, concurrently with pipeline dredging.

CONTRACT 04:
This contract is for pipeline dredging 25+000 to 50+000 and delivery to Placement Area 5A. The stationing listed is located in the middle section of the main channel. The approximate duration is 16 months.

CONTRACT 05:
This contract is for dike raising and rehabilitation of Placement Area 2. The approximate duration is three (3) months. In addition, this contract is for pipeline dredging 00+000 to 07+000

and delivery to Placement Area 2. The stationing listed is located in the lower section of the main channel near the jetties (entrance channel). The approximate duration is three (3) months.

CONTRACT 06:
This contract is for pipeline dredging 07+000 to 25+000 and delivery to Placement Area 4B. The stationing listed is located in the middle section of the main channel. The approximate duration is 11 months.

CONTRACT 07:
This contract is for dike raising and rehabilitation of Placement Area 5B. The approximate duration is three (3) months. In addition, this contract is for pipeline dredging 50+000 to 70+000 and delivery to Placement Area 5B. The stationing listed is located in the upper section of the main channel near the turning basin. The approximate duration is nine (9) months.

ACCOUNT CODE 12 – NAVIGATION PORTS AND HARBORS:
Dredge quantities are developed by SWG, Engineering Division, Engineering (EC-EG). One (1) large hopper dredge is to be used for Contract 01 with offshore placement (with an option for the Contractor to bid Contract 05 as pump-out to PA 2 based on durations and schedules). The remainder of the channel is to be dredged with 30" pipeline dredges, with the material discharged into various, existing placement areas located along the waterway (PA 2, 4B, 5A, 5B, 7 and 8). Dredging costs are developed using Cost Engineering Dredge Estimating Program (CEDEP). Dredge production rates and losses are reduced to account for Resident Management System (RMS) historical effective working times and stiffer "new work" materials. Costs for mobilization and demobilization are developed using CEDEP assuming the dredges are based in New Orleans, Louisiana. Dredge estimates are based on standard operation practices for the Galveston District, which assume conventional contracting practices of large business IFBs. For estimation purposes and contractor capabilities (derived from current Sabines Neches Waterway dredging project, which includes four pipeline dredges working simultaneously), no more than three (3) dredges will be underway at any given time. In addition, dredges will be located no less than one (1) mile apart due to Coast Guard regulations; for estimate purposes, the dredges have been strategically spaced at stations so as not to impede dredging workflow.

The cost for Sea Turtle Protection is associated with hopper dredging and includes: 1) cost for two (2) trawlers per hopper; 2) a sea turtle protection device fitted to the hopper; and 3) 24-hour monitoring survey.

The cost for raising placement areas is included under this code of account. Part of the cost for raising a placement area includes clearing, grubbing, and stripping the area; seeding the outside of the dikes is not considered. Labor rates and overhead costs are adjusted to reflect Galveston District, Region 6. The placement area dikes are built using 3-CY dragline buckets, with an optimal production rate of 125-CY/HR, respectively. A total of three (3) draglines are working at the same time. For estimate purposes, dike works are lumped by perimeter and training dikes, locations, and bucket sizes. Articulated concrete block is to be placed approximately 22+000 to 34+000. Production assumed at 50-CY/HR in addition to transport of material from Central Texas via railcars, then trucks, then barges, and finally to the site. Material characteristics are provided by SWG, Engineering Division, Geotechnical and Structural Section (EC-ES).

ACCOUNT CODE 30 – ENGINEERING AND DESIGN:
The cost for this account are developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager.

ACCOUNT CODE 31 – CONSTRUCTION MANAGEMENT:
The cost for this account are developed using the guidelines provided in the TPCS, with the agreement of the cost engineer and the project manager.

12.1 REFERENCES

ER 1110-2-1302 Civil Works Cost Engineering
EM 1110-2-1304 Civil Works Construction Cost Index System (CWCCIS)

13.0 SCHEDULE FOR CONSTRUCTION

Construction schedule is provided at the end of this Appendix.

14.0 SPECIAL STUDIES

Not Applicable

15.0 DATA MANAGEMENT

The Engineering Appendix is located electronically and maintained on the shared drive at S:\shared files\BIH Feasibility Study\BIH Engineering Appendix\Draft Engineering Appendix Report. Plans, Specifications and Project information will also be available on the S drive.

16.0 USE OF METRIC SYSTEM MEASUREMENTS

English units is the familiar system used in this area. Throughout the feasibility study, surveys, design, drawings and analyses were completed with the English unit system. Converting from the English to the Metric system would have caused impacts to the project schedule.

17.0 FIGURES AND TABLES

Civil Design Figure and Tables

Figure	**Descriptions**
Figure 1-1	Study Area

Geotechnical Figures and Tables

Hydrology and Hydraulics Figures and Tables

Cost Engineering Table

Attachments

CONSTRUCTION SCHEDULE

CONTRACT	DESCRIPTION	DURATION (month)	DESIGN MIDPOINT	START DATE	MIDPOINT	END DATE
1	Dredge: ODMDS	7	Oct-16 (2017Q1)	Oct-17 (2018Q1)	Jan-18 (2018Q2)	Apr-18 (2018Q3)
2	Dike: PA 5A, PA 4B	15	Oct-16 (2017Q1)	Oct-17 (2018Q1)	May-18 (2018Q3)	Dec-18 (2019Q1)
3	Dike: PA 8, PA 7 Dredge: 8, 7	13	Oct-16 (2017Q1)	Oct-17 (2018Q1)	Apr-18 (2018Q3)	Oct-18 (2019Q1)
4	Dredge: 5A	16	Feb-17 (2017Q2)	Feb-18 (2018Q2)	Sep-18 (2018Q4)	May-19 (2019Q3)
5	Dike: PA 2 Dredge: 2	6	Feb-17 (2017Q2)	Feb-18 (2018Q2)	May-18 (2018Q3)	Jul-18 (2018Q4)
6	Dredge: 4B	11	Jan-18 (2018Q2)	Jan-19 (2019Q2)	Jun-19 (2019Q3)	Nov-19 (2020Q1)
7	Dike: 5B Dredge: 5B	12	Mar-18 (2018Q2)	Mar-19 (2019Q2)	Aug-19 (2019Q4)	Feb-20 (2020Q2)

#201105-C

US Army Corps of Engineers
Galveston District

BRAZOS ISLAND HARBOR, TEXAS
BROWNSVILLE SHIP CHANNEL
IMPROVEMENTS PROJECT

Brownsville Ship Channel Feasibility Study, Cameron County, Texas

Value Engineering Study Report

October 2011

Design Consultant

HDR

Value Engineering Consultant

ARCADIS

Infrastructure · Water · Environment · Buildings

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PMCM Division

Jon Plymale CESWG-EC-PS, VEO
Value Engineering Officer
US Army Corps of Engineers
Galveston District
PO Box 1229
Galveston, TX 77553-1229

Subject:
Brazos Island Harbor, Texas
Brownsville Ship Channel Improvements
Value Engineering Study Report #201105-C

Date:
October 18, 2011

Contact:
Howard Greenfield

Phone:
410.381.1990 x 20

Email:
Howard.greenfield@
Arcadis-us.com

Our ref:
NL99DZ02.0000

Dear Mr. Plymale:

Bioengineering ARCADIS LLC is pleased to submit two hard copies and one digital copy of the subject value engineering (VE) report documenting the events and results of the workshop conducted October 3-6, 2011, in Galveston, Texas. The VE team produced three alternatives with the potential to save significant project costs and increase the benefit-to-cost ratio for the preferred dredging plan that should be investigated by the USACE Project Development Team (PDT). Implementation of these alternatives will assist the Galveston District in its efforts to obtain funding for the project.

We wish to take this opportunity to thank you, the District's PDT, and the representative from HDR Engineering, Inc. for providing timely and valuable data for the VE team to use in developing its alternatives.

Please do not hesitate to call me if you or any report reviewer has questions relating to the information presented.

Sincerely,

ARCADIS U.S., Inc.

Howard B. Greenfield, PE, CVS
Associate Vice President

Copies:
Dana Lawton, ARCADIS

Imagine the result

TABLE OF CONTENTS

SECTION ONE – EXECUTIVE SUMMARY

INTRODUCTION

This value engineering (VE) study report, #201105-C, documents the events and results of the VE study conducted by the Bioengineering ARCADIS LLC for the Galveston District, U.S. Army Corps of Engineers (USACE) (The District). The subject of the study was the Brazos Island Harbor, Texas, Brownsville Ship Channel Improvements Project, Plan Formulation Phase of the Brownsville Ship Channel Feasibility Study, Cameron County, Texas being developed by HDR Engineering, Inc. for The District's Project Development Team (PDT). The study was conducted October 3-6, 2011, in Galveston, Texas.

Comprising the VE team were specialists in marine dredging and sediment management, marine cost estimating, a representative from The District, and a Certified Value Specialist (CVS) Team Leader. The team used the following six-phase VE Job Plan to guide its deliberations.

- Information Gathering Phase
- Function Analysis Phase
- Creative Idea Generation Phase
- Evaluation/Judgment Phase
- Alternative Development Phase
- Presentation Phase

PROJECT DESCRIPTION

This project is being developed to foster economic development in the Brownsville and Cameron County, Texas area by attracting new users to the 17-mile Brownsville Ship Channel to increase port industry. To accomplish this, channel modifications will be required to improve navigational capabilities. The currently proposed modifications will increase the current width and depth of the main channel and channel entrance. The channel modifications will allow vessels with larger beams and deeper drafts to enter the port through the channel from the Gulf of Mexico entranceway. The feasibility study investigated 19 alternatives for achieving some or all of these goals, each attaining a different benefit-to-cost ratio (BCR). A screening of the alternatives yielded 14 viable alternatives including a No-Action scenario to be utilized as a comparative baseline.

These 14 alternatives were reviewed by the USACE PDT and found insufficient to meet project goals. Subsequently, a ship simulation utilizing loaded tankers was performed. This simulation was conducted from the channel entrance in the Gulf of Mexico and traversed approximately 6.4 miles into the main channel. Additionally, an oil rig Geometric Analysis was performed using two variable sized oil rigs with thrusters in place traversing the same simulation area as the tankers. The results of the simulations determined that a 350-ft.-wide channel would be necessary to accommodate these vessels while a -50 ft. mean low tide (MTL) depth would be required to accommodate the larger oil rigs. As a result, the PDT determined that these dimensions would provide the basis for the channel modifications. These dimensions would be applied to the entire length of the channel including the turning basin at the Brazos Harbor, Port of Brownsville. The accompanying economic benefits resulting from accommodating the proposed tankers and oil rigs used in the study were in the process of being calculated by the PDT.

The channel modifications would incorporate maintenance and new work utilizing a combination of hopper and cutterheads dredges. Sands removed at the entrance (maintenance) of the channel would be used to enhance the beaches along San Padre Island, if beneficial use funds are available, or placed in an offshore placement area in the Gulf of Mexico. New work dredged material, primarily silt and clay, from the remaining portions of the channel would be placed in existing placement areas located adjacent to the ship channel. The existing levees around the placement areas would require slight modifications to accommodate the placement of this dredged material.

At the time of the VE study, The District had not completed a revised cost estimate incorporating the selected channel modifications. The VE team was able to develop a cost estimate using a combination of the dredge material quantities (provided by The District) and pricing from a previous cost estimate prepared in 2008 as the basis, which resulted in a cost of approximately $238 million. This cost was used as the basis for the VE team's comparisons during the alternative development phase of the study.

CONCERNS AND OBJECTIVES

As previously detailed, the project has evaluated multiple scenarios which ultimately resulted in channel modifications to 350 ft. wide and -50 ft. MLT deep. The width and depth modifications are expected to yield the most favorable BCR. As with all Federal Civil works projects, this channel improvements project is vying for federal funding with other projects across the country to obtain the limited federal funds available for this type of project. The VE team was tasked with identifying specific changes to the current governing channel modifications that would result in a potential cost savings to the project and an increase in the BCR.

RESULTS OF THE STUDY

In reviewing the existing project, the VE team concluded that a sound approach was being pursued by the USACE PDT in formulating an optimum concept. One critical item affecting the project was the placement of dredged material. Fortunately, proper port planning resulted in ideal conditions, as placement areas were constructed directly adjacent to the ship channel. The placement areas contain ample capacity to accommodate the anticipated dredge volume in addition to already containing levees. Such a condition provides for uncomplicated placement and yields cost efficiency. As a result, the VE team concluded that the placement component of the current channel improvements plan required no modifications.

The primary project element affecting cost was the volume of material scheduled for removal. The VE team identified several options which would help reduce the dredged material volume and selected three scenarios to further evaluate. Each option is identified by an Alternative No. (Alt. No.) for tracking purposes. The letter component of the alternative number indicates the function of the project being addressed, and the number indicates the order in which it evolved during the brainstorming phase of the Job Plan. These are summarized on the following *Summary of Value Engineering Alternatives* table and discussed below.

Alt. No. WC-5 suggests that the channel only be widened to 300 ft. inland of the Port Isabel connection to the main channel. The ship simulations and oil rig study were only conducted to just past this point in the channel and revealed some potential navigational problems, which the VE team believes are due to some specific aspects of this portion of the channel. Beyond this point, starting at about Station 28+000, the channel is very straight and contiguous on both sides. It is believed that this configuration will not adversely affect ship navigation and a significant cost reduction can be achieved by limiting the channel expansion to only 50 ft. resulting in a 300 ft.-wide channel. In addition, if the navigational problems are due to the sizes of the ships used in the simulations, then an analysis of the number of ships projected to use the channel should be undertaken. If the number of larger ships is relatively small, then the benefits side of the BCR could be revised slightly, still resulting in a large increase in the BCR due to the reduced cost. Alternatively, means could be taken to reduce the navigational problems, such as selectively widening the channel where navigational problems are expected to occur.

In Alt. No. DC-1, the VE team investigated making the channel a little shallower, -48 ft. MLT, from Station 84+200 to the end of the harbor. At this point, the oil rigs that require the deeper draft are not using the channel, and the larger, deeper draft ships, have unloaded some or most of their cargo, thus negating the need for the -50 ft. MLT depth.

The turning basin at the innermost part of the channel also provides a potential cost reduction. It is believed that the current basin depth is sufficient to accommodate the ships projected to use the ship channel because the heavy loads will have been off-loaded by the time the deep-draft ships reach this area and the oil rigs do not have to use the turning basin. Alt. No. DC-2 discusses this option.

If all three alternatives are implemented, a total of $35,868,000 could be saved, assuming that only 80% of the cost savings associated with Alt. No. DC-2 is used, because of the overlap with Alt. No. DC-1.

SUMMARY OF VALUE ENGINEERING ALTERNATIVES

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALT. NO.	DESCRIPTION	ORIGINAL COST	ALTERNATIVE COST	PRESENT WORTH OF COST SAVINGS: INITIAL COST SAVINGS	RECURRING COST SAVINGS	TOTAL PW LCC SAVINGS
WC-5	Only widen the channel to 300 ft. from Station 28+000 to Station 79+415 in lieu of 350 ft.	$238,301,000	$209,721,000	$28,580,000		$28,580,000
DC-1	Only deepen the channel to 48 ft. from Station 84+200 to the end of the turning basin in lieu of 50 ft.	$238,301,000	$236,392,000	$1,909,000		$1,909,000
DC-2	Do not deepen the turning basin	$238,301,000	$231,577,000	$6,724,000		$6,724,000
					Total Cost Savings	**$35,868,000**

Note: Total Cost Savings assumes 80% of Alt. No. DC-2 because of overlap with Alt. No. DC-1

SECTION TWO – STUDY RESULTS

GENERAL

The ultimate results of the VE study conducted on the Brownsville Ship Channel Improvement project are projected to be the benefits that can be realized by the Galveston District, U.S. Army Corps of Engineers (USACE) (The District), the owner, users and HDR Engineers, Inc., the designer. The results will directly affect the project's design and will require coordination between the USACE Project Development Team (PDR) to determine the disposition of each alternative.

During the study, many ideas for potential value enhancement were conceived and evaluated by the team for technical merit, applicability to the project, implementability considering the project's status, and the ability to meet the owner's project value objectives. Research performed on those ideas considered to have potential to enhance the value of the project resulted in the development of individual alternatives identifying specific changes to the project as a whole, or individual elements that comprise the project. For each alternative developed, the following information is provided:

- A summary of the original design;
- A description of the proposed change to the project;
- A capital cost comparison and life cycle discounted present worth cost comparison of the alternative and original design (where appropriate);
- A descriptive evaluation of the advantages and disadvantages of selecting the alternative; and
- A brief narrative to compare the original design and the proposed change and provide a rationale for implementing the change into the project.

The capital cost comparisons used unit quantities contained in the project cost estimate prepared by the designers, whenever possible. If unit quantities were not available, team member or owner databases were consulted. A composite markup of 20%, as described in Section Four – Value Analysis and Conclusions of the report, was used to generate an all-inclusive project cost for the construction items.

Each alternative developed is identified with an alternative number (Alt. No.) to track through the value analysis process and thus facilitate referencing among the Creative Idea Listing and Evaluation worksheets, the alternatives, and the Summary of Value Engineering Alternatives table. The Alt. No. includes a prefix that refers to a major project function listed below:

FUNCTION	PREFIX
Widen Channel	WC
Deepen Channel	DC

KEY ISSUES

As with all Federal Civil works projects, this project is in competition with other similar projects for funding from the federal government. The key to obtaining federal project funding is to provide an alternative which results in a meaningful Benefits-to-Cost Ratio (BCR). The PDT is currently identifying additional economic benefits that could be obtained by increasing the channel width and depth to service larger vessels and oil rigs. However, it is also necessary to ensure that any and all costs are optimized.

STUDY OBJECTIVES

The objective of the study was to identify specific changes to the current design concept that would reduce costs thereby increasing its BCR.

RESULTS OF THE STUDY

Research of the ideas identified as having potential for achieving the study's objective resulted in the development of three alternatives detailed in this section of the report for consideration by the USACE PDT and the designer.

EVALUATION OF ALTERNATIVES AND DESIGN SUGGESTIONS

During review of the study results, the reader should consider each part of an alternative on its own merit. Each area within an alternative that is determined to be acceptable should be considered for use in the final design, even if the entire alternative is not implemented. Variations of these alternatives by the USACE PDT or designer are encouraged.

All alternatives were developed independently to provide a broad range of options to consider for implementation. Therefore, some of them are mutually exclusive, so acceptance of one may preclude the acceptance of another. In addition, some of the alternatives may be interrelated, so acceptance of one or more may not yield the total cost savings shown for each alternative.

The reader should evaluate all alternatives carefully in order to select the combination of ideas with the greatest beneficial impact on the project. Once this has been accomplished, the total cost savings resulting from the VE study can be calculated based on implementing a revised, all-inclusive design solution.

VALUE ENGINEERING ALTERNATIVE

ARCADIS

PROJECT:	**BROWNSVILLE SHIP CHANNEL IMPROVEMENTS** *Brazos Island Harbor, Texas* **Plan Formulation Stage**	ALTERNATIVE NO.: **WC-5**
DESCRIPTION:	**ONLY WIDEN THE CHANNEL TO 300 FT. FROM STATION 28+000 TO STATION 79+415 IN LIEU OF 350 FT.**	SHEET NO.: **1 of 3**

ORIGINAL DESIGN: (sketch attached):

The existing project channel is authorized to depth a depth of -42 feet mean low tide (MLT) and a width of 250 feet. Currently, the depth of the channel ranges between -44 feet MLT offshore and -42 feet MLT for the inland portion of the channel and the width of the majority of the inland channel is 250 feet wide.

The current design for the new project is to deepen the channel -50 feet MLT and to widen the channel to 350 feet over the full length of the authorized channel plus the turning basin.

ALTERNATIVE: (sketch attached)

Reduce the channel width from 350 ft. to 300 ft. from Sta. 28+000 to 79+415.

ADVANTAGES:

- Reduces the volume of new construction dredged material due to 300 foot width
- Same channel depth
- Reduce future maintenance dredging in the 300 foot channel
- Supports short term port needs
- Reduces volume of disposal material thus leaving additional room for future material generated during maintenance operations

DISADVANTAGES:

- Limits large vessel operations in the 300 foot channel.
- May limit long range port development

DISCUSSION:

In the provided documentation, mainly the Ship Simulation data provided by ERDC, the majority consensus recommends the widening of the channel to 350 feet to provide more efficient vessel operating conditions in the channel. This appears to be primarily driven at approximately stations 1+423.55 and 22+000 where the simulated inbound vessels experienced insufficient channel side clearance through the channel transit. At station 1+423.55, there is an approximate 25 degree inbound port turn and at station 22+000 there is an approximate 5 degree inbound starboard turn. At both of these locations, ships are correcting for this condition by operating outside of the channel due to the current width of the channel. Above station 24+000 to the turning basin, there appears to be no operating concerns. With this being the case, this alternative proposes a channel width of 350

COST SUMMARY	INITIAL COST	PRESENT WORTH RECURRING COSTS	PRESENT WORTH LIFE-CYCLE COST
ORIGINAL DESIGN	$ 238,301,000	—	$ 238,301,000
ALTERNATIVE	$ 209,721,000	—	$ 209,721,000
SAVINGS (Original minus Alternative)	$ 28,580,000	—	$ 28,580,000

VALUE ENGINEERING ALTERNATIVE

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **WC-5**

DESCRIPTION: **ONLY WIDEN THE CHANNEL TO 300 FT. FROM STATION 28+000 TO STATION 79+415 IN LIEU OF 350 FT.**

SHEET NO.: **2 of 3**

DISCUSSION:

feet from stations -6+000 to station 28+000. The remainder of the channel from station 28+000 to station 79+415 would only be widened to 300 feet. The depth of the channel throughout the length would remain at 50 feet.

To verify the applicability of this change, a simulation should be undertaken from station 28+000 to station 79+415. This section of the channel was not included in the original simulation.

Additionally, an evaluation should be conducted to determine the number of potential ships of the two types used in the simulation that would call on Brazos Island Harbor. If the results of the evaluation indicate that only a small number of vessels are unable to successfully navigate the channel at the reduced width (300 ft.), then the costs to widen the channel to 350 ft. would not be justified and project cost saving could be realized.

Implementing this alternative could also boost the Benefit-to-Cost ratio of the project to make it more competitive with other projects vying for funding.

COST WORKSHEET

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **WC-5**
SHEET NO.: **3 of 3**

PROJECT ITEM	ORIGINAL ESTIMATE						ALTERNATIVE ESTIMATE				
ITEM	UNITS	NO. OF UNITS	COST/ UNIT	SUB-TOTAL	CONT	TOTAL	NO. OF UNITS	COST/ UNIT	SUBTOTAL	CONT	TOTAL
Mob & Demob Hopper Dredge	EA	1	$694,600.00	$694,600.00	25%	$868,250	1	$694,600.00	694,600.00	25%	$868,250
Dredge - Jetty Channel	CY	4,615,795	$4.81	$22,201,973.95	40%	$31,082,764	4,615,795	$4.81	22,201,973.95	40%	$31,082,764
Silent Inspector Jetty Channel	LS	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Turtle Monitoring - Jetty Channel	LS	1	$182,000.00	$182,000.00	25%	$227,500	1	$182,000.00	182,000.00	25%	$227,500
Mob & Demob Trawler	EA	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Trawler - Jetty Channel	LS	1	$535,500.00	$535,500.00	25%	$669,375	1	$535,500.00	535,500.00	25%	$669,375
Mob & Demob Pipeline Dredge	EA	1	$1,675,000.00	$1,675,000.00	25%	$2,093,750	1	$1,675,000.00	1,675,000.00	25%	$2,093,750
Dredge - Main Channel	CY	9,874,126	$7.77	$76,721,959.02	40%	$107,410,743	7,684,729	$7.77	59,710,344.33	40%	$83,594,482
Dredge - Turning Basin	CY	504,123	$7.55	$3,806,128.65	40%	$5,328,580	504,123	$7.55	3,806,128.65	40%	$5,328,580
Mob Demob Levees	EA	7	$225,000.00	$1,575,000.00	25%	$1,968,750	7	$225,000.00	1,575,000.00	25%	$1,968,750
Hydraulic Con. Exterior Levee PA4E	LF	8,000	$86.00	$688,000.00	25%	$860,000	8,000	$86.00	688,000.00	25%	$860,000
Hydraulic Con. Exterior Levee PA4	LF	27,090	$130.00	$3,521,700.00	25%	$4,402,125	27,090	$130.00	3,521,700.00	25%	$4,402,125
Hydraulic Con. Exterior Levee PA5A	LF	21,600	$135.00	$2,916,000.00	25%	$3,645,000	21,600	$135.00	2,916,000.00	25%	$3,645,000
Hydraulic Con. Exterior Levee PA5B	LF	29,560	$115.00	$3,399,400.00	25%	$4,249,250	29,560	$115.00	3,399,400.00	25%	$4,249,250
Hydraulic Con. Exterior Levee PA7	LF	20,200	$110.00	$2,222,000.00	25%	$2,777,500	20,200	$110.00	2,222,000.00	25%	$2,777,500
Hydraulic Con. Exterior Levee PA8	LF	17,510	$115.00	$2,013,650.00	25%	$2,517,063	17,510	$115.00	2,013,650.00	25%	$2,517,063
Mech. Con. Exterior Levee PA 2	CY	556,067	$3.50	$1,946,234.50	25%	$2,432,793	556,067	$3.50	1,946,234.50	25%	$2,432,793
Mech. Con. Exterior Levee PA 4E	CY	164,747	$3.50	$576,614.50	25%	$720,768	164,747	$3.50	576,614.50	25%	$720,768
Mech. Con. Exterior Levee PA 4	CY	556,950	$3.50	$1,949,325.00	25%	$2,436,656	556,950	$3.50	1,949,325.00	25%	$2,436,656
Mech. Con. Exterior Levee PA 5A	CY	411,840	$3.50	$1,441,440.00	25%	$1,801,800	411,840	$3.50	1,441,440.00	25%	$1,801,800
Mech. Con. Exterior Levee PA 5B	CY	563,611	$3.50	$1,972,638.50	25%	$2,465,798	563,611	$3.50	1,972,638.50	25%	$2,465,798
Mech. Con. Exterior Levee PA 7	CY	415,432	$3.50	$1,454,012.00	25%	$1,817,515	415,432	$3.50	1,454,012.00	25%	$1,817,515
Mech. Con. Exterior Levee PA 8	CY	333,857	$3.50	$1,168,499.50	25%	$1,460,624	333,857	$3.50	1,168,499.50	25%	$1,460,624
Outlet Structure	EA	10	$225,000.00	$2,250,000.00	25%	$2,812,500	10	$225,000.00	2,250,000.00	25%	$2,812,500
Stripping	AC	1,491	$2,400.00	$3,578,400.00	25%	$4,473,000	1,491	$2,400.00	3,578,400.00	25%	$4,473,000
Ditching	AC	2,728	$334.00	$911,152.00	25%	$1,138,940	2,728	$334.00	911,152.00	25%	$1,138,940
Levee Turfing	AC	138	$2,200.00	$303,600.00	25%	$379,500	138	$2,200.00	303,600.00	25%	$379,500
Levee Watering	AC	138	$2,400.00	$331,200.00	25%	$414,000	138	$2,400.00	331,200.00	25%	$414,000
Cellular Concrete Mats - Solid Core	SF	1,000	$7.46	$7,460.00	25%	$9,325	1,000	$7.46	7,460.00	25%	$9,325
Navigation Aids	LS	1	$1,476,000.00	$1,476,000.00	25%	$1,845,000	1	$1,476,000.00	1,476,000.00	25%	$1,845,000
Bond Costs	LS	1	$4,980,000.00	$4,980,000.00	10%	$6,225,000	1	$4,980,000.00	4,980,000.00	10%	$6,225,000
Subtotal						$198,583,869					$174,767,608
Markup (%) at 20%						$39,716,774					$34,953,522
TOTAL						$238,300,643					$209,721,130
TOTAL (ROUNDED)						**$238,301,000**					**$209,721,000**

VALUE ENGINEERING ALTERNATIVE ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **DC-1**

DESCRIPTION: **ONLY DEEPEN THE CHANNEL TO 48 FT. FROM STATION 84+200 TO THE END OF THE END OF THE TURNING BASIN IN LIEU OF 50 FT.**

ORIGINAL DESIGN: (sketch attached):

The existing project channel is authorized to depth a depth of -42 feet mean low tide (MLT) and a width of 200 feet. Currently, the depth of the channel ranges between -44 feet MLT offshore and -42 feet MLT for the inland portion of the channel and a width of the majority of the inland channel is 300 feet wide.

The current design for the new project is to deepen the channel to -50 feet MLT and to widen the channel to 350 feet over the full length of the authorized channel plus the turning basin.

ALTERNATIVE: (sketch attached)

Use a channel depth of -50 feet MLT from approximate station -6+000 to approximate station 84+200 and a depth of -48 feet MLT between from Station 84+200 to the end of the turning basin.

ADVANTAGES:

- Reduces the volume of new construction dredged material due to -48 foot MLT depth
- Reduces future maintenance dredging in the -48 foot MLT deep channel.
- Supports short term port needs

DISADVANTAGES:

- Limits large vessel operations in the -48 foot MLT deep channel
- May limit long range port development
- Need to lighten load vessels to transit through turning basin

DISCUSSION:

In the documentation provided by USACE-Galveston, the proposed new channel depth of -50 MLT is mainly to support the existing and emerging dynamic oil exploration platform industry and some ships (bulk carriers) with deeper drafts. Dynamic platforms are floating marine structures that float over an exploration site and utilize propulsion positioning systems to remain on station to support drilling operations as opposed to a fixed structure affixed to the ocean bottom. The propulsion systems on these platforms are located 40-48 feet below the water surface. The facilities that service these platforms are located below station 76+000. Because of the current depth limiting conditions of -45 feet MLT through this reach, these propulsion systems must be removed prior to entering the channel so the platforms can be serviced. The cost associated with removing the propulsion systems is $3M to $5M per platform.

COST SUMMARY	INITIAL COST	PRESENT WORTH RECURRING COSTS	PRESENT WORTH LIFE-CYCLE COST
ORIGINAL DESIGN	$ 238,301,000	—	$ 238,301,000
ALTERNATIVE	$ 236,392,000	—	$ 236,392,000
SAVINGS (Original minus Alternative)	$ 1,909,000	—	$ 1,909,000

VALUE ENGINEERING ALTERNATIVE

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **DC-1**

DESCRIPTION: **ONLY DEEPEN THE CHANNEL TO 48 FT. FROM STATION 84+200 TO THE END OF THE END OF THE TURNING BASIN IN LIEU OF 50 FT.**

SHEET NO.: **2 of 3**

DISCUSSION: (continued)

Additionally, the -50 foot MLT depth supports the future vessel traffic to docks located below Station 84+200 and other future bulk cargo facilities that will require the deeper draft and utilize the wider channel. The depth of -48 feet MLT may be sufficient to support industry above station 84+200. However, deeper draft vessels (greater than 48 feet) may not be able to utilize the turning basin unless the vessel is partially unloaded prior to entering the turning basin with its full load.

COST WORKSHEET

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **DC-1**
SHEET NO.: **3 of 3**

PROJECT ITEM	ORIGINAL ESTIMATE						ALTERNATIVE ESTIMATE				
ITEM	UNITS	NO. OF UNITS	COST/ UNIT	SUB-TOTAL	CONT	TOTAL	NO. OF UNITS	COST/ UNIT	SUBTOTAL	CONT	TOTAL
Mob & Demob Hopper Dredge	EA	1	$694,600.00	$694,600.00	25%	$868,250	1	$694,600.00	694,600.00	25%	$868,250
Dredge - Jetty Channel	CY	4,615,795	$4.81	$22,201,973.95	40%	$31,082,764	4,615,795	$4.81	22,201,973.95	40%	$31,082,764
Silent Inspector Jetty Channel	LS	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Turtle Monitoring - Jetty Channel	LS	1	$182,000.00	$182,000.00	25%	$227,500	1	$182,000.00	182,000.00	25%	$227,500
Mob & Demob Trawler	EA	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Trawler - Jetty Channel	LS	1	$535,500.00	$535,500.00	25%	$669,375	1	$535,500.00	535,500.00	25%	$669,375
Mob & Demob Pipeline Dredge	EA	1	$1,675,000.00	$1,675,000.00	25%	$2,093,750	1	$1,675,000.00	1,675,000.00	25%	$2,093,750
Dredge - Main Channel	CY	9,874,126	$7.77	$76,721,959.02	40%	$107,410,743	9,809,523	$7.77	76,219,993.71	40%	$106,707,991
Dredge - Turning Basin	CY	504,123	$7.55	$3,806,128.65	40%	$5,328,580	420,103	$7.55	3,171,777.65	40%	$4,440,489
Mob Demob Levees	EA	7	$225,000.00	$1,575,000.00	25%	$1,968,750	7	$225,000.00	1,575,000.00	25%	$1,968,750
Hydraulic Con. Exterior Levee PA4E	LF	8,000	$86.00	$688,000.00	25%	$860,000	8,000	$86.00	688,000.00	25%	$860,000
Hydraulic Con. Exterior Levee PA4	LF	27,090	$130.00	$3,521,700.00	25%	$4,402,125	27,090	$130.00	3,521,700.00	25%	$4,402,125
Hydraulic Con. Exterior Levee PA5A	LF	21,600	$135.00	$2,916,000.00	25%	$3,645,000	21,600	$135.00	2,916,000.00	25%	$3,645,000
Hydraulic Con. Exterior Levee PA5B	LF	29,560	$115.00	$3,399,400.00	25%	$4,249,250	29,560	$115.00	3,399,400.00	25%	$4,249,250
Hydraulic Con. Exterior Levee PA7	LF	20,200	$110.00	$2,222,000.00	25%	$2,777,500	20,200	$110.00	2,222,000.00	25%	$2,777,500
Hydraulic Con. Exterior Levee PA8	LF	17,510	$115.00	$2,013,650.00	25%	$2,517,063	17,510	$115.00	2,013,650.00	25%	$2,517,063
Mech. Con. Exterior Levee PA 2	CY	556,067	$3.50	$1,946,234.50	25%	$2,432,793	556,067	$3.50	1,946,234.50	25%	$2,432,793
Mech. Con. Exterior Levee PA 4E	CY	164,747	$3.50	$576,614.50	25%	$720,768	164,747	$3.50	576,614.50	25%	$720,768
Mech. Con. Exterior Levee PA 4	CY	556,950	$3.50	$1,949,325.00	25%	$2,436,656	556,950	$3.50	1,949,325.00	25%	$2,436,656
Mech. Con. Exterior Levee PA 5A	CY	411,840	$3.50	$1,441,440.00	25%	$1,801,800	411,840	$3.50	1,441,440.00	25%	$1,801,800
Mech. Con. Exterior Levee PA 5B	CY	563,611	$3.50	$1,972,638.50	25%	$2,465,798	563,611	$3.50	1,972,638.50	25%	$2,465,798
Mech. Con. Exterior Levee PA 7	CY	415,432	$3.50	$1,454,012.00	25%	$1,817,515	415,432	$3.50	1,454,012.00	25%	$1,817,515
Mech. Con. Exterior Levee PA 8	CY	333,857	$3.50	$1,168,499.50	25%	$1,460,624	333,857	$3.50	1,168,499.50	25%	$1,460,624
Outlet Structure	EA	10	$225,000.00	$2,250,000.00	25%	$2,812,500	10	$225,000.00	2,250,000.00	25%	$2,812,500
Stripping	AC	1,491	$2,400.00	$3,578,400.00	25%	$4,473,000	1,491	$2,400.00	3,578,400.00	25%	$4,473,000
Ditching	AC	2,728	$334.00	$911,152.00	25%	$1,138,940	2,728	$334.00	911,152.00	25%	$1,138,940
Levee Turfing	AC	138	$2,200.00	$303,600.00	25%	$379,500	138	$2,200.00	303,600.00	25%	$379,500
Levee Watering	AC	138	$2,400.00	$331,200.00	25%	$414,000	138	$2,400.00	331,200.00	25%	$414,000
Cellular Concrete Mats - Solid Core	SF	1,000	$7.46	$7,460.00	25%	$9,325	1,000	$7.46	7,460.00	25%	$9,325
Navigation Aids	LS	1	$1,476,000.00	$1,476,000.00	25%	$1,845,000	1	$1,476,000.00	1,476,000.00	25%	$1,845,000
Bond Costs	LS	1	$4,980,000.00	$4,980,000.00	10%	$6,225,000	1	$4,980,000.00	4,980,000.00	10%	$6,225,000
Subtotal						$198,583,869					$196,993,026
Markup (%) at 20%						$39,716,774					$39,398,605
TOTAL						$238,300,643					$236,391,631
TOTAL (ROUNDED)						**$238,301,000**					**$236,392,000**

VALUE ENGINEERING ALTERNATIVE ARCADIS

PROJECT:	**BROWNSVILLE SHIP CHANNEL IMPROVEMENTS** *Brazos Island Harbor, Texas* **Plan Formulation Stage**	ALTERNATIVE NO.: **DC-2**
DESCRIPTION:	**DO NOT DEEPEN THE TURNING BASIN**	SHEET NO.: **1 of 3**

ORIGINAL DESIGN: (sketch attached)

The turning basin is to be deepened from its current depth of -36 feet to -50 ft Mean Low Tide (MLT) to match the channel depth leading in from the Gulf of Mexico. This is premised on the possibility that deeper draft ships may need to use the turning basin in the future or that the deepened basin could potentially attract larger ships.

ALTERNATIVE: (sketch attached)

Do not deepen the turning basin.

ADVANTAGES:

- Eliminates capital dredging.
- Does not compromise on project performance
- Optimizes the depth of the Turning Basin by taking into account its intended and likely use in the future
- Does not consume placement area storage capacity, although the volume of material deposited into the placement area on a relative basis would only be a modest amount and conserving storage capacity is not a concern

DISADVANTAGES:

- The Turning Basin at a 36-foot MLT depth would not be capable of handling the larger, deeper draft.

DISCUSSION:

According to the Martin Report, the driver for establishing the cargo vessel design draft at -47 feet MLT is based solely on an assumed Panamax-size vessel utilizing the channel to carry imported steel slab. Accommodation of this size ship would significantly lower the freight rate per ton of slab and further reduce the number of vessels that would be required to move the steel slabs. For the VE alternative, it is being assumed that the steel slab will

COST SUMMARY	INITIAL COST	PRESENT WORTH RECURRING COSTS	PRESENT WORTH LIFE-CYCLE COST
ORIGINAL DESIGN	$ 238,301,000	—	$ 238,301,000
ALTERNATIVE	$ 231,577,000	—	$ 231,577,000
SAVINGS (Original minus Alternative)	$ 6,724,000	—	$ 6,724,000

DISCUSSION:

always be offloaded prior to ships entering the Turning Basin, which would reduce draft requirements to less than -36 feet MLT. The Martin Report states that interviews with the importers of other products, most notably other steel products, petroleum products, grain, scrap, and limestone did not indicate that a deeper channel would result in the use of larger ships. Therefore, it appears that the design depth of the Turning Basin could be established based on the minimum vessel draft that would be required when returned light-loaded or empty.

COST WORKSHEET

ARCADIS

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
Plan Formulation Stage

ALTERNATIVE NO.: **DC-2**

SHEET NO.: **3 of 3**

PROJECT ITEM	ORIGINAL ESTIMATE						ALTERNATIVE ESTIMATE				
ITEM	UNITS	NO. OF UNITS	COST/ UNIT	SUB-TOTAL	CONT	TOTAL	NO. OF UNITS	COST/ UNIT	SUBTOTAL	CONT	TOTAL
Mob & Demob Hopper Dredge	EA	1	$694,600.00	$694,600.00	25%	$868,250	1	$694,600.00	694,600.00	25%	$868,250
Dredge - Jetty Channel	CY	4,615,795	$4.81	$22,201,973.95	40%	$31,082,764	4,615,795	$4.81	22,201,973.95	40%	$31,082,764
Silent Inspector Jetty Channel	LS	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Turtle Monitoring - Jetty Channel	LS	1	$182,000.00	$182,000.00	25%	$227,500	1	$182,000.00	182,000.00	25%	$227,500
Mob & Demob Trawler	EA	1	$20,000.00	$20,000.00	25%	$25,000	1	$20,000.00	20,000.00	25%	$25,000
Trawler - Jetty Channel	LS	1	$535,500.00	$535,500.00	25%	$669,375	1	$535,500.00	535,500.00	25%	$669,375
Mob & Demob Pipeline Dredge	EA	1	$1,675,000.00	$1,675,000.00	25%	$2,093,750	1	$1,675,000.00	1,675,000.00	25%	$2,093,750
Dredge - Main Channel	CY	9,874,126	$7.77	$76,721,959.02	40%	$107,410,743	9,771,188	$7.77	75,922,130.76	40%	$106,290,983
Dredge - Turning Basin	CY	504,123	$7.55	$3,806,128.65	40%	$5,328,580	80,000	$7.55	604,000.00	40%	$845,600
Mob Demob Levees	EA	7	$225,000.00	$1,575,000.00	25%	$1,968,750	7	$225,000.00	1,575,000.00	25%	$1,968,750
Hydraulic Con. Exterior Levee PA4E	LF	8,000	$86.00	$688,000.00	25%	$860,000	8,000	$86.00	688,000.00	25%	$860,000
Hydraulic Con. Exterior Levee PA4	LF	27,090	$130.00	$3,521,700.00	25%	$4,402,125	27,090	$130.00	3,521,700.00	25%	$4,402,125
Hydraulic Con. Exterior Levee PA5A	LF	21,600	$135.00	$2,916,000.00	25%	$3,645,000	21,600	$135.00	2,916,000.00	25%	$3,645,000
Hydraulic Con. Exterior Levee PA5B	LF	29,560	$115.00	$3,399,400.00	25%	$4,249,250	29,560	$115.00	3,399,400.00	25%	$4,249,250
Hydraulic Con. Exterior Levee PA7	LF	20,200	$110.00	$2,222,000.00	25%	$2,777,500	20,200	$110.00	2,222,000.00	25%	$2,777,500
Hydraulic Con. Exterior Levee PA8	LF	17,510	$115.00	$2,013,650.00	25%	$2,517,063	17,510	$115.00	2,013,650.00	25%	$2,517,063
Mech. Con. Exterior Levee PA 2	CY	556,067	$3.50	$1,946,234.50	25%	$2,432,793	556,067	$3.50	1,946,234.50	25%	$2,432,793
Mech. Con. Exterior Levee PA 4E	CY	164,747	$3.50	$576,614.50	25%	$720,768	164,747	$3.50	576,614.50	25%	$720,768
Mech. Con. Exterior Levee PA 4	CY	556,950	$3.50	$1,949,325.00	25%	$2,436,656	556,950	$3.50	1,949,325.00	25%	$2,436,656
Mech. Con. Exterior Levee PA 5A	CY	411,840	$3.50	$1,441,440.00	25%	$1,801,800	411,840	$3.50	1,441,440.00	25%	$1,801,800
Mech. Con. Exterior Levee PA 5B	CY	563,611	$3.50	$1,972,638.50	25%	$2,465,798	563,611	$3.50	1,972,638.50	25%	$2,465,798
Mech. Con. Exterior Levee PA 7	CY	415,432	$3.50	$1,454,012.00	25%	$1,817,515	415,432	$3.50	1,454,012.00	25%	$1,817,515
Mech. Con. Exterior Levee PA 8	CY	333,857	$3.50	$1,168,499.50	25%	$1,460,624	333,857	$3.50	1,168,499.50	25%	$1,460,624
Outlet Structure	EA	10	$225,000.00	$2,250,000.00	25%	$2,812,500	10	$225,000.00	2,250,000.00	25%	$2,812,500
Stripping	AC	1,491	$2,400.00	$3,578,400.00	25%	$4,473,000	1,491	$2,400.00	3,578,400.00	25%	$4,473,000
Ditching	AC	2,728	$334.00	$911,152.00	25%	$1,138,940	2,728	$334.00	911,152.00	25%	$1,138,940
Levee Turfing	AC	138	$2,200.00	$303,600.00	25%	$379,500	138	$2,200.00	303,600.00	25%	$379,500
Levee Watering	AC	138	$2,400.00	$331,200.00	25%	$414,000	138	$2,400.00	331,200.00	25%	$414,000
Cellular Concrete Mats - Solid Core	SF	1,000	$7.46	$7,460.00	25%	$9,325	1,000	$7.46	7,460.00	25%	$9,325
Navigation Aids	LS	1	$1,476,000.00	$1,476,000.00	25%	$1,845,000	1	$1,476,000.00	1,476,000.00	25%	$1,845,000
Bond Costs	LS	1	$4,980,000.00	$4,980,000.00	10%	$6,225,000	1	$4,980,000.00	4,980,000.00	10%	$6,225,000
Subtotal						$198,583,869					$192,981,129
Markup (%) at 20%						$39,716,774					$38,596,226
TOTAL						$238,300,643					$231,577,355
TOTAL (ROUNDED)						**$238,301,000**					**$231,577,000**

SECTION THREE – PROJECT DESCRIPTION

The Brazos Island Harbor (BIH) Project, also known as the Brownsville Ship Channel (BSCH) Improvements Project, is an existing deep-draft navigation project located on the lower Texas coast. The Port of Brownsville, a man-made basin 4,200 feet long and varying in width from 400 feet to 1,200 feet, lies three miles north of the Rio Grande River and the Mexican border, and five miles east of the City of Brownsville. The BIH is the southernmost navigation channel in the state of Texas (Figure 1) and the western terminus of the Gulf Intracoastal Waterway system (GIWW).

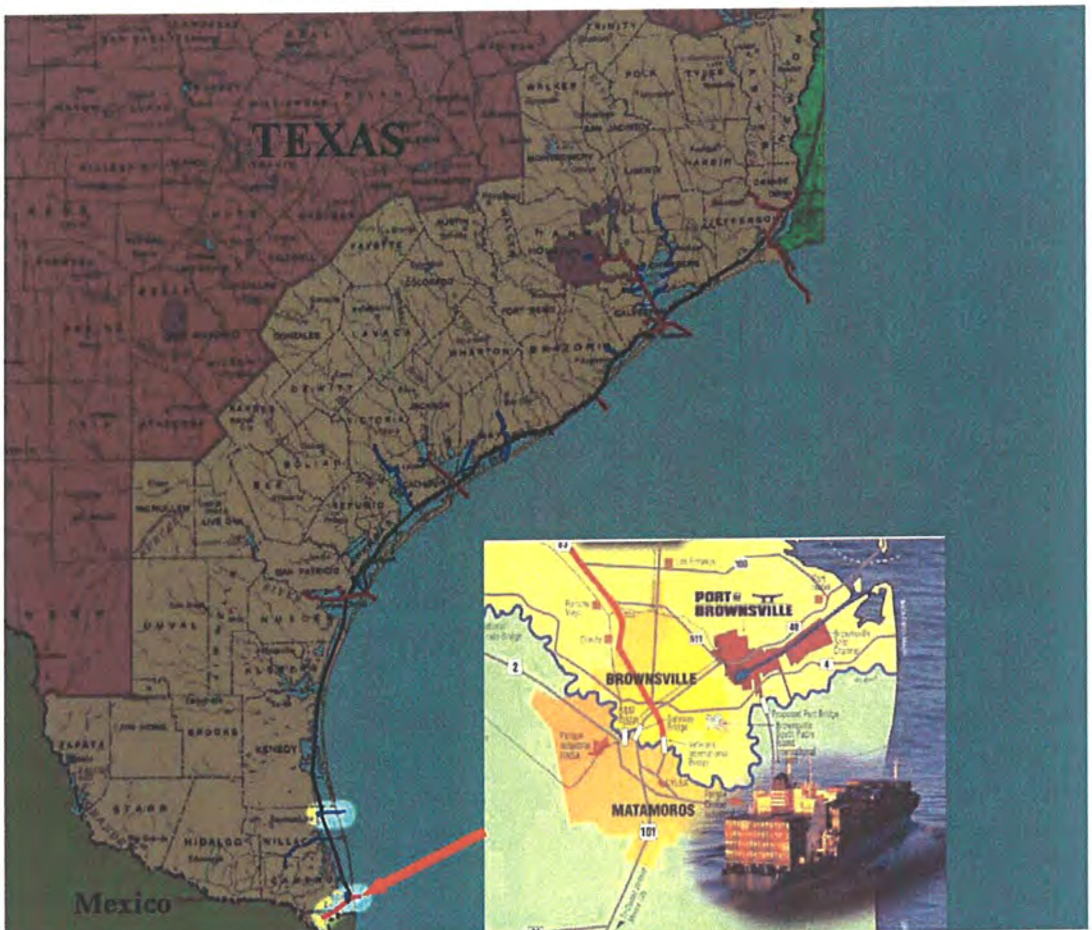


Figure 1. Project Location Map

The BIH provides for 42-foot deep navigation on the inland portion of the channel and a 44-foot depth in the offshore entrance channel. The BIH is essentially a straight waterway with no bridges or other obstructions for the entire length of the waterway. The existing waterway consists of the following features (also see Table 1, Dimensions of Existing Brownsville Ship Channel):

- Entrance / Jetty Channel - A dual-jettied 44-foot deep by 300-foot wide entrance channel for a distance of 2.5 miles converging to a natural water depth of 44 feet in the Gulf of

Mexico; The two rock jetties that protect the Entrance Channel are over 5,000 feet in length and 1,200 feet apart.

- Main Channel - A 42-foot deep by 200-foot wide by 14.8 mile long channel within the inland segment of the waterway;
- Turning Basin Extension - A 36-foot deep channel with widths varying from 325 to 400 feet for a length of 5,200 feet; and
- Turning Basin – A turning basin with a depth of 36 feet and a width of 1,200 feet.

Channel Reach	**Constructed Depth (feet)**	**Constructed Bottom Width (feet)**	**Channel Length (miles)**
Entrance Channel / Jettied Channel (Gulf of Mexico to Laguna Madre)	44	300	2.5
Main Channel (Laguna Madre to Turning Basin Extension)	42	250	14.8
Turning Basin Extension	36	325 - 400	5,200 feet
Turning Basin	36	1,200	4,200 feet

Table 1. Dimensions of Existing Brownsville Ship Channel

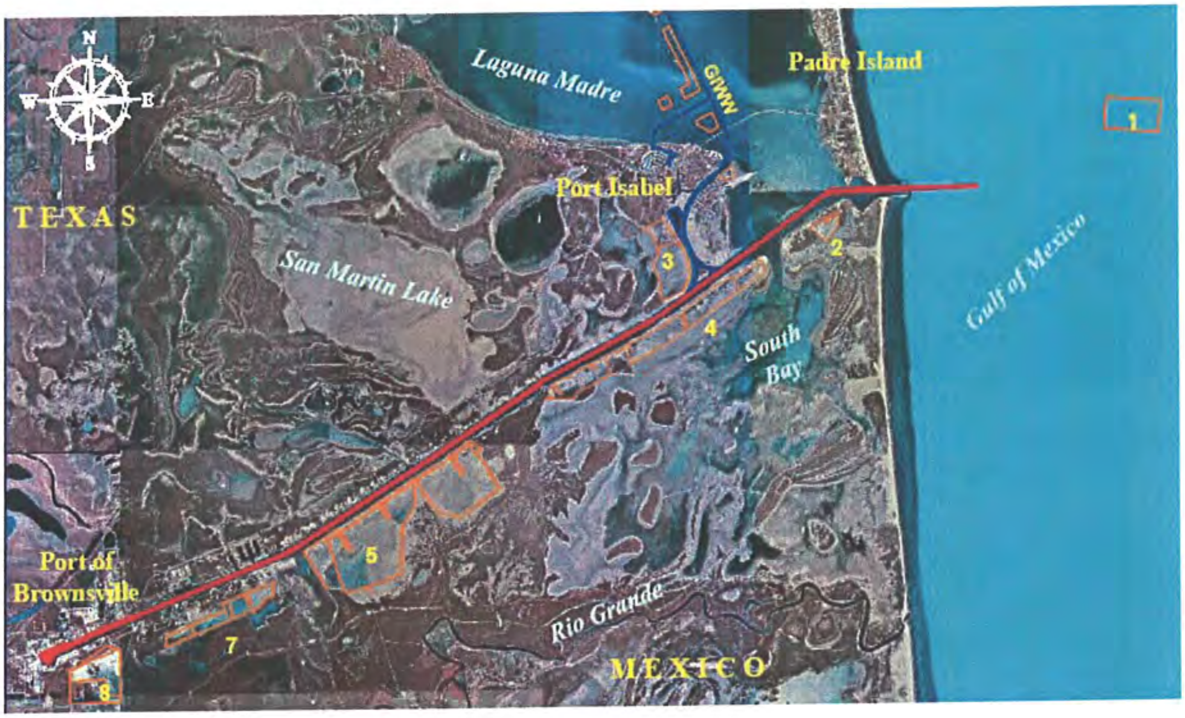
A reconnaissance study was undertaken to determine whether commercial navigation benefits would be produced by deepening and widening the BIH sufficient to offset the costs and environmental consequences of any proposed improvements. The reconnaissance study concluded that channel deepening and widening appeared to be feasible and that it would be in the Federal interest to conduct more detailed, feasibility-level studies at a 50/50 cost shared basis with the non-Federal Sponsor, the Brownsville Navigation District (BND).

Physical Description of the Study Area

The BIH is deep-draft navigation channel located in Cameron County, Texas, approximately three miles from the Texas and Mexico border. Due to its close proximity to Mexico, the BIH not only serves coastal towns in the Lower Rio Grande Valley (LRGV) of Texas, like Brownsville and Port Isabel, but the waterway also serves ports in northeastern Mexico. The project area is located entirely within Cameron County, Texas, and encompasses the entire BIH and the surrounding region.

The project area is located in the LRGV and encompasses approximately 103,250 acres (160 square miles), extending 3 miles north, south, and west of the BIH and continuing 5 miles offshore into the Gulf of Mexico (Figure 2). The LRGV is one of the most biologically diverse areas in North America because biological communities from the desert, coastal, temperate, sub-tropical, and tropical zones converge. The diversity of ecosystems located within the project area provide habitat for an array of terrestrial and coastal flora and fauna, including a variety of threatened and endangered species, as well as providing an important stopping point for a substantial number of migratory birds.

Figure 2. Brownsville Ship Channel and Surrounding Areas



Consistent with much of the Texas Gulf coast, the area includes barrier islands, shallow inland lagoons, and a relatively flat inland area. Unique to the area are extensive mud tidal flats and clay dune formations, or lomas, several of which lie adjacent to the ship channel.

The major inland bay is the Laguna Madre. The Laguna Madre is a long, narrow, shallow, hypersaline lagoon extending from Corpus Christi Bay to the southern end of Port Isabel. Laguna Madre lies between the Texas mainland and Padre Island, is approximately 120 miles long, and ranges from 4 to 6 miles wide. Lower Laguna Madre is within the project study area. One of two main inlets connecting Laguna Madre to the Gulf of Mexico, the Brazos-Santiago Pass Inlet, is also located within the study area. The GIWW is a shallow draft navigation channel 125 foot wide and 12 foot deep that traverses the entire length of the Laguna Madre.

The existing BIH is approximately 17 miles long with depths ranging from 44 feet in the offshore portion and 42 feet for the inland channel. The majority of the inland portion of the channel is 300 feet wide (Figure 3 and Table 1). The main channel crosses the southern portion of the Laguna Madre and then divides into the Port Isabel Channel and the BIH.

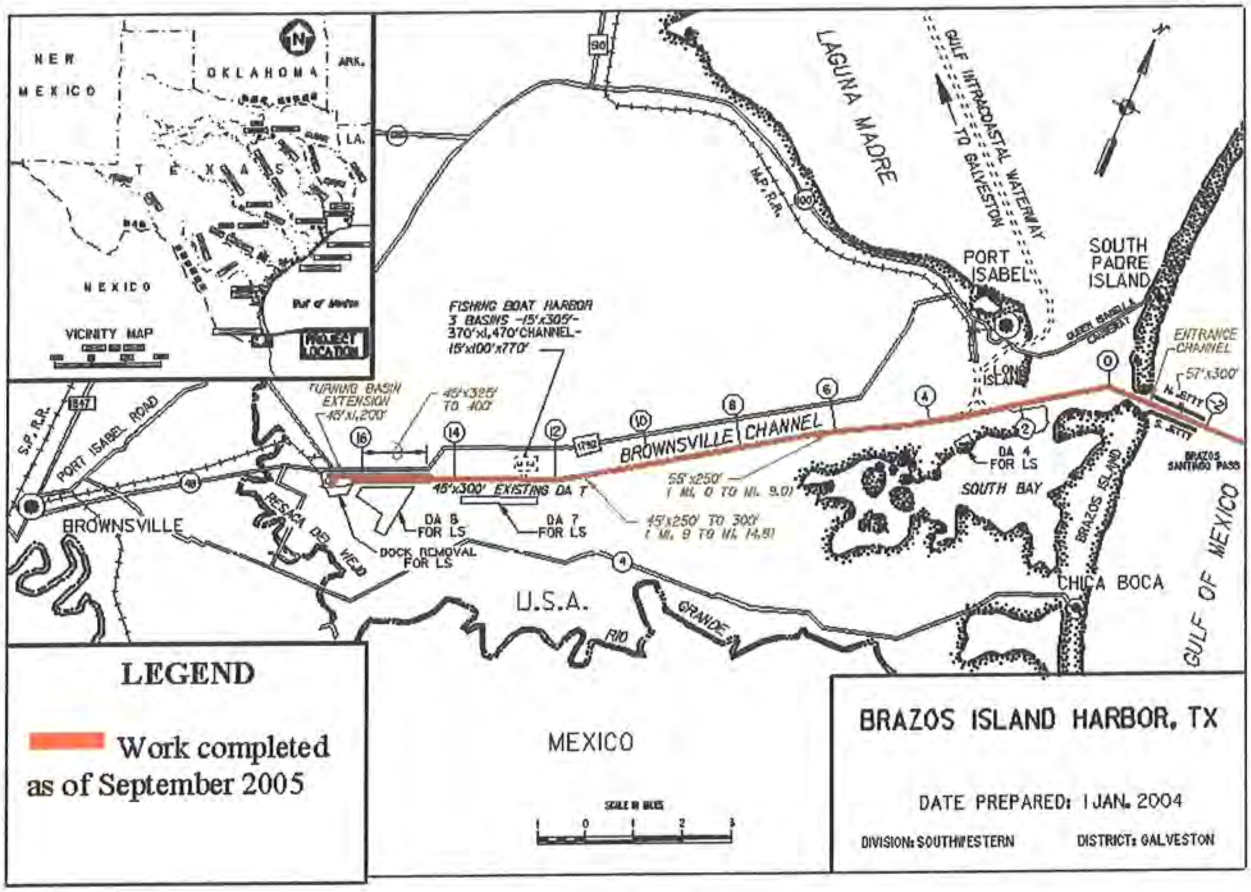


Figure 3. Existing BIH Dimensions

CURRENT STATUS OF THE DRAFT FEASIBILITY STUDY

The Galveston District PDT and its planning consultant, HDR Engineering, Inc., initially developed 19 alternatives for widening and deepening the channel to accommodate larger vessels with greater beams and deeper drafts and oil rigs in need of repair. An initial screening of these alternatives resulted in the 13 alternatives considered viable and the No Action Plan. They were:

- 1.a. Deepen (only) the entire existing channel to a depth of 45-feet
- 1.b. Deepen (only) the entire existing channel to a depth of 48-feet
- 1.c. Deepen (only) the entire existing channel to a depth of 50-feet
- 2.a. Deepen existing channel to 45-foot depth and widen channel by 200-feet
- 2.b. Deepen existing channel to 48-foot depth and widen channel by 200-feet
- 2.c. Deepen existing channel to 50-foot depth and widen channel by 200-feet
- 3.a. Deepen entire channel to 45-foot depth and construct 75-foot wide and 42-foot deep shelves on either side of the channel
- 3.b. Deepen entire channel to 48-foot depth and construct 75-foot wide and 42-foot deep shelves on either side of the channel
- 3.c. Deepen entire channel to 50-foot depth and construct 75-foot wide and 42-foot deep shelves on either side of the channel

- 4.0 Widen existing channel by 200 feet
- 5.a. Construct new turning basin, deepen channel to 45-foot depth from channel entrance to new turning basin, widen remaining portion of the channel by 200 feet from the new turning basin to the existing turning basin
- 5.b. Construct new turning basin, deepen channel to 48-foot depth from channel entrance to new turning basin, widen remaining portion of the channel by 200 feet from the new turning basin to the existing turning basin
- 5.c. Construct new turning basin, deepen channel to 50-foot depth from channel entrance to new turning basin, widen remaining portion of the channel by 200 feet from the new turning basin to the existing turning basin
- 6.0 No-Action alternative

The economic benefits and costs were determined for each alternative, and Benefit/Cost ratios (BCRs) were developed. In 2008, the costs ranged from $69 million for the No-Action Alternative to $375 million for alternative 5.c and BCRs ranged from 0.49 to 1.18.

To evaluate the potential to increase the BCR by accommodating larger ships and oil rigs, the District conducted two studies. The first was hydrodynamic simulations performed using two ships: an 846 ft. x 154 ft. x 47 ft. tanker and a 1087 ft. x 195 ft. x 24 ft. Very Large Crude Carrier (VLCC) traveling inbound into the channel to beyond where the confluence to Port Isabel intersects the channel. The simulations performed with the channel widened from 250 ft. to 350 ft. showed "runs (that) were more successful than those in the 300 ft. channel and the pilots were comfortable with the 350 ft. width. The pilots had no difficulty with the channel widened 150 ft. (400 ft. wide) but felt that the width was wider than necessary." This would allow larger vessels and more heavily loaded vessels with deeper drafts to use the channel and thus provide additional economic benefits to the area.

A second *Brownsville Ship Channel Deepening & Widening Study Oil Rig Movement Geometric Analysis Through the Brownsville Ship Channel* illustrated how two different sized oil rigs with their thrusters in place could move through the a 350 ft. wide by 50 ft. deep channel. The success of this modeling confirmed that larger oil rigs could use the improved channel, which again would increase the overall economic benefits of the project.

Because of the results of these two studies, the PDT adopted a 100 ft. channel widening from 250 ft. to 350 ft. and a deepening to -50 ft. MLT for the entire length of the channel as the preferred alternative, and baseline for the VE study.

The channel modifications would incorporate maintenance and new work utilizing a combination of hopper and cutterheads dredges. Sands removed at the entrance (maintenance) of the channel would be used to enhance the beaches along San Padre Island if beneficial use funds are available or placed in an offshore placement area in the Gulf of Mexico. New work dredged material, primarily silt and clay, from the remaining portions of the channel would be placed in existing placement areas located adjacent to the ship channel. The existing levees around the placement areas would require slight modifications to accommodate the placement of this dredged material.

PROJECT COSTS

At the time of the VE study, the PDT was in the process of estimating the cost for the channel modifications. Quantities of dredged material were calculated for the various stretches of the channel. Utilizing these quantities and the unit prices and contingencies included in a previous cost estimate (October 2008 for deepening the channel to -50 ft.MLT and widening it to 200 ft. with hydraulic levee construction) the VE team estimated costs of approximately $238 million. This cost was used as the comparative basis for evaluating the original design with the VE alternative designs.

SECTION FOUR – VALUE ANALYSIS AND CONCLUSIONS

GENERAL

This section describes the Value Analysis (VA) procedure used during the VE study conducted for the USACE Galveston District, by the Bioengineering ARCADIS, LLC on the Brownsville Ship Channel Improvements project. The workshop was conducted from October 3rd through the 6th, 2011, at the USACE Galveston District offices in Galveston Texas. The workshop was conducted as part of the Brownsville Ship Channel Feasibility Study Plan Formulation stage. HDR Engineering, Inc. has been selected by The District to assist with the development of the project and has provided information for use by the VE team.

A systematic approach was used in the VE study which was divided into three parts: (1) Preparation Effort, (2) Workshop Effort, and (3) Post-Workshop Effort. A task flow diagram outlining each of the procedures included in the VE study is attached for reference.

Following this description of the VA procedure, separate narratives and supporting documentation is provided which details the following:

- VE workshop participants
- Economic data
- Cost model
- Function analysis
- Creative ideas and evaluations

PREPARATION EFFORT

Preparation for the workshop consisted of scheduling workshop participants and tasks and gathering necessary project documents for team members to review prior to attending the workshop. Documents such as those listed below were used as the basis for generating VE alternatives and costs:

- Draft Brownsville Ship Channel Feasibility Study, Brazos Island Harbor, Texas, dated February 2008, prepared by HDR Engineering, Inc.
- Brazos Island Harbor Channel Improvement Project, Draft Feasibility Report, dated February 2008, prepared by HDR Engineering, Inc.
- Brazos Island Harbor Channel Improvement Project, NEPA Documentation, Affected Environment Analysis and Future Without Project Condition
- Brazos Island Harbor Engineering Appendix, Cost Estimates, dated January 2008
- Brazos Island Harbor, Texas, Brownsville Ship Channel in Cameron County, Specifications for Dredging, dated February 2002, prepared by the Department of the Army, Galveston District, Corps of Engineers

ARCADIS Value Engineering Study Task Flow Diagram

Preparation Effort

Coordinate Project →
- Verify Schedule
- Suggest Format for Designer Presentation
- Outline Project Responsibilities
- Outline Needed Background Data
- Define *Project Value Objectives*
- Identify Project Constraints

Prepare for Workshop →
- Collect Project Data
- Distribute Data to Team Members
- Verify Cost Data
- Team Members Become Familiar with Project

Construct Cost Models →
- Construct Cost Models
- Construct Graphic Function Analysis
- Outline High Cost Areas

LCC Model
- Process Areas
- Staffing
- Chemicals
- Energy
- User Impact

Workshop Effort

Information Phase →
- Introduction by VETL
- Project Description and Presentation by Designer
- Outline Owner Requirements
- Review Project Data
- Visit Project Site (Alt.)

Function Identification and Analysis Phase →
- Analyze Project Costs and Energy Usage
- Perform Function Analysis and FAST Diagram
- Identify High Cost and Energy Areas
- Calculate Cost/Worth Ratios
- Identify Paradigms

List Ideas Generated During Function Analysis

Creative Phase →
- Introduction by VETL
- Creative Idea Listing:
  - Quantity of Ideas
  - Association of Ideas

- Brainstorming
- Creative Thinking:
  - Group & Individual

Use Checklist for Ideas

Evaluation Phase →
- Eliminate Impractical Ideas
- Rank Ideas with Advantages/Disadvantages
- Evaluate Alternatives (Include Non-Economic considerations: Safety, Reliability, Environment, Aesthetics, O & M, etc.)
- Select Best Ideas for Implementation

Development Phase →
- Develop Proposed Alternatives
- Prepare Alternative Design Sketches
- Estimate Costs
- Perform Life Cycle Comparison
  - Initial Cost
  - Redesign Cost
  - O & M Cost
  - LCC Cost

Presentation Phase
- Summarize Findings
- Present VE Ideas to Owner/User/Designer
- Oral Presentation

Post-Workshop Effort

VE Study Report →
- Prepare Preliminary VE Report
- Designer Prepares Responses to VE Report
- Owner Evaluates Recommendations

Implementation Phase →
- Participate in Implementation Meeting with Owner/User/Designer/VE Team, as needed
- Prepare Final VE Report

Final Acceptance
- Redesign by Designer

- Brazos Island Harbor, Texas in Cameron County, Texas, Project Manual for Placement Area No. 4 Rehabilitation, dated June 2003, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Brazos Island Harbor, Texas, Main Channel to Turning Basin in Cameron County, Texas, Specifications for Pipeline Dredging, dated July 2005, Department of the Army, Galveston District, Corps of Engineers
- Brazos Island Harbor, Texas, Brownsville Inside Jetty Channel in Cameron County, Texas, Project Manual for Emergency Hopper Dredging, dated January 2007, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Brazos Island Harbor, Texas, Brownsville Inside Jetty Channel in Cameron County, Texas, Project Manual for Dredging, dated March 2008, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Unrestricted Procurement Brazos Island Harbor, Texas, Brownsville Ship Channel and Port Isabel Channel in Cameron County, Texas, Project Manual for Emergency Pipeline Dredging, dated November 2009, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Brazos Island Harbor, Texas, Port Isabel Channel and Turning Basin in Cameron County, Texas, Project Manual for Placement Area No. 3, Levee Repair and Erosion Protection, dated July 2009, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Unrestricted Procurement Brazos Island Harbor, Texas, Brownsville Ship Channel – Main Channel, Jetty Channel and Port Isabel Channel in Cameron County, Texas, Project Manual for Pipeline Dredging, dated November 2009, prepared by the Department of the Army, Galveston District, Corps of Engineers
- Brownsville, Texas, Brazos Island Harbor Reconnaissance Report Section 905(b) Analysis, dated September 2004, prepared by the U.S. Army Engineer District, Galveston Southwestern Division
- Desktop Evaluation of Shoaling, Task Order No. 5, Federal Feasibility Study to Deepen and Widen the Brownsville Ship Channel, dated December 11, 2008, prepared by HDR Engineering, Inc.
- Brazos Island Harbor Channel Improvement Project, Feasibility Scoping Meeting, dated May 2008
- Memorandum for Record: Review Plan Approval for Brazos Island Harbor Feasibility Study, dated July 10, 2007
- Project Management Plan for Brazos Island Harbor Project, Brownsville, Texas, dated May 20, 2009, prepared by URS Group, Inc.
- Economic Benefits of Maintaining the Current Dimensions of The Brownsville Navigation District and Deepening the Channel to 48 Feet, dated October 24, 2006, prepared by Martin Associates/John C. Martin Associates, LLC
- Brownsville Ship Channel Deepening & Widening Study, Oil Rig Movement Modeling Through the Brownsville Ship Channel, prepared by the DOF Subsea
- Real Estate Appendix (Efforts conducted thru the Initial Plan Formulation)
- Brazos Island Harbor Draft Steel Scrap Transportation Analysis Report, dated July 2009, prepared by the U.S. Army Corps of Engineers
- Draft Brownsville Ship Channel Hydrodynamic Modeling, prepared by U.S. Army Corps of Engineers, Engineer Research and Development Center

- Brazos Island Harbor, Texas, Emergency Pipeline Dredging, Brownsville Ship Channel and Port Isabel Chanel Plans, dated November 2008, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Dredging, Brownsville Inside Jetty Channel Plans, dated March 2008, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Port Isabel Channel and Turning Basin Placement Area No. 3, Levee Repair and Erosion Protection Plans, dated July 2009, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Pipeline Dredging, Brownsville Ship Channel – Main Channel, Jetty Channel and Port Isabel Channel Plans, dated July 2009, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Pipeline Dredging, Main Channel to Turning Basin Plans, dated July 2005, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Pipeline Dredging, Brownsville Ship Channel Plans, dated August 2010, prepared by U.S. Army Engineer District, Galveston Corps of Engineers
- Brazos Island Harbor, Texas, Rig Forecast for VE study
- Brazos Island Harbor, Texas, RIO 901-252
- Draft FSM – EnvAPP 2-1-2008 Rev.
- Rig Dry Dock Data, dated March 2010
- Rig Fleet as of 22 January 2009
- Brazos Island Harbor, Texas, Draft Feasibility Study, Second Screening Matrix, dated February 2008

Information relating to the project's purpose and need, owner concerns, project stakeholder concerns, design criteria, project constraints, funding sources and availability, regulatory agency approval requirements, and the project's schedule and costs is valuable as it provides the VE team with the project's progression and current status.

Project cost information provided by The Galveston District was used by the VE team as the basis for a comparative analysis. To prepare for this exercise, the VE team leader used the cost estimates for the 14 options prepared by The District to develop cost models for the project. The models were used to distribute the total project cost among the various elements or functions of the project. The VE team used these models to identify the high-cost elements or functions that drive the project and the elements or functions providing little or no value so that the team could focus on reducing or eliminating their impact.

VALUE ENGINEERING WORKSHOP EFFORT

The VE workshop was a four-day effort beginning with an orientation/kickoff meeting on Monday, October 3, 2011, and concluding with the final VE Presentation on Thursday, October 6, 2011. During the workshop, the VE Job Plan was followed in compliance with SAVE International guidelines for conducting a VE study. The Job Plan guided the search for alternatives to mitigate or eliminate high-cost drivers, secondary functions providing little or no value, and potential project risks. Alternatives to specifically address the owner's project concerns and enhance value by improving operations, reducing maintenance requirements, enhancing constructability, and providing missing functions were also considered. The Job Plan includes six phases:

- Information Phase (with a site visit)
- Function Identification and Analysis Phase
- Creative/Speculation Phase
- Evaluation/Judgment Phase
- Alternative Development Phase
- Presentation of Study Results Phase

Information Phase

At the beginning of the study, the decisions that have influenced the project's design and proposed construction methods have to be reviewed and understood by the VE Team. For this reason, the workshop began with a presentation of the project by the USACE PDT and the HDR design team to the VE team. The presentation highlighted the information provided in the documentation reviewed by the VE team prior to commencement of the workshop and expanded on it to include a history of the project's development and underlying influences that caused the design to progress to its current state. During this presentation, VE team members were given the opportunity to ask questions and obtain clarification about the provided information.

Function Identification and Analysis Phase

Having gained additional insight to the project, the VE team proceeded to define the functions provided by the project, identifying the costs to provide these functions, and determining whether the value provided by the functions has been optimized. Function analysis is a means of evaluating a project to verify if expenditures actually perform the requirements of the project or if there are disproportionate amounts of money spent on support functions. Elements performing support functions add cost to the project but have a relatively low worth to the basic function.

Function is defined as the intended use of a physical or process element. The team attempted to identify functions in the simplest manner using measurable noun/verb word combinations. To accomplish this, the team first looked at the project in its entirety and randomly listed its functions, which were recorded on Random Function Analysis Worksheets (provided in the Function Identification and Analysis section). Then the individual function(s) of the major components of the project depicted on the cost model were identified.

After identifying the functions, the team classified the functions according to the following:

Abbreviation	Type of Function	Definition
HO	Higher Order	The primary reason the project is being considered or project goal.
B	Basic	A function that must occur for the project to meet its higher order functions.
S	Secondary	A function that occurs because of the concept or process selected and may or may not be necessary.
R/S	Required Secondary	A secondary function that may not be necessary to perform the basic function but must be included to satisfy other requirements or the project cannot proceed.
G	Goal	Secondary goal of the project.
O	Objective	Criteria to be met

LO	Lower Order	A function that serves as a project input.

Higher order and basic functions provide value, while secondary functions tend to reduce value. The goal of the next job phase is to reduce the impact of secondary functions and thereby enhance project value.

To further clarify the impact of the various functions, the team assigned costs to provide the functions or group of functions indicated by a specific project element using the cost estimate and cost model(s). Where possible, they seek to find the lowest cost, or worth, to perform the function. This is accomplished using published data from other sources or team knowledge obtained from working on other similar projects to establish cost goals and then comparing them to the current costs. By identifying the cost and worth of a function or group of functions, cost/worth ratios were calculated. Cost/worth ratios greater than one indicated that less than optimum value was being provided. Those project functions or elements with high cost/worth ratios became prime targets for value improvement.

FAST Diagramming

In order to further enhance its understanding of the project, the team used these random functions to construct a Function Analysis Systems Technique (FAST) Diagram. The FAST Diagram portrays the relationships of the functions by answering the questions how, why, and when the functions occur. Reading the diagram from left to right, the reader views the higher order function(s), and when he/she asks "How does it occur," the function(s) to the right supplies the answer. If the reader starts at the right side of the page, he/she views the lower order function(s). When the question, "Why does this function exist" is asked, the answer is provided to the function(s) directly to the left. Functions above or below one another take place simultaneously, responding to the "when" question.

On the FAST diagram, heavy-lined boxes and lines connect higher order, basic, and lower order functions. Light-lined boxes and lines connect secondary functions. The scope of the functions that the VE team worked on is defined by the project scope lines. Understanding the relationships among the functions within the scope lines aids the team in seeking out alternative solutions to accomplish the project's higher order goals.

As well as looking at areas with high cost/worth ratios, the team used the cost model(s) previously prepared to seek out the areas where most of the project funds are being applied. Because of the absolute magnitude of these high-cost elements or functions, they also became initial targets for value enhancement.

Overall, these exercises stimulated the VE team members to focus on apparently low value areas and initially channel their creative idea development in these places.

Creative/Speculation Phase

This VE study phase involved the creation and listing of ideas. Starting with the functions or project elements with high cost/worth ratios, a high absolute cost compared to other elements in the project, and secondary functions providing little or no value and using the classic brainstorming technique, the VE team began to generate as many ideas as possible to provide the necessary functions at a lower total life cycle cost, or to improve the quality of the project. Ideas for improving operation and maintenance, reducing project risk, and simplifying constructability were also encouraged. At this stage of the process, the VE team was looking for a large quantity of ideas and free association of ideas. A Creative Idea Listing worksheet was generated and organized by the function or project element being addressed.

USACE and the HDR design team may wish to review these creative lists since they may contain ideas that were not pursued by the VE team but can be further evaluated for potential use in the design.

Evaluation Phase

Since the goal of the Creative/Speculation Phase was to conceive as many ideas as possible without regard for technical merit or applicability to the project goals, the Evaluation Phase focused on identifying those ideas that do respond to the project value objectives and are worthy of additional research and development before being presented to the owner. The selection process consisted of the VE team evaluating the ideas originated during the Creative/Speculation Phase based on USACE's value objectives identified through conversations with the owner. Based on the team's understanding of the owner's value objectives, each idea was compared with the present design concept, and the advantages and disadvantages of each idea were discussed.

How well an idea met the design criteria was also reviewed. Based on the results of these reviews, the VE team rated the idea by consensus using a scale of 1 to 5, with 5 or 4 indicating an idea with the greatest potential to be technically sound and provide cost savings or improvements in other areas of the project; 3 indicating an idea that provides marginal value but could be used if the project was having budget problems; 2 indicating an idea with a major technical flaw, and 1 indicating an idea that does not respond to project requirements. Generally, ideas rated 4 and 5 are pursued in the next phase and presented to the owner during the Presentation Phase.

The team also used the designation "DS" to indicate a design suggestion, which is an idea that may not have specific quantifiable cost savings but may reduce project risk, improve constructability, help to minimize claims, enhance operability, ease maintenance, reduce schedule time, or enhance project value in other ways. Design suggestions could also increase a project's cost but provide value in areas not currently addressed. These are also developed in the next phase of the VE process.

Development Phase

In this phase, each highly rated idea was expanded into a workable solution designated as a VE alternative. The development phase consisted of describing the current design and the alternative solution, preparing a life cycle cost comparison where applicable, describing the advantages and disadvantages of the proposed alternative solution, and writing a brief narrative to compare the original design to the proposed change and provide a rationale for implementing the idea into the design. Sketches and design calculations, where appropriate, were also prepared in this part of the study. The VE alternatives are included in the Study Results, Section Two, of this report.

Presentation Phase

The goals of the last phase of the workshop were to summarize the results of the study, to prepare draft Summary of Value Engineering Alternatives worksheets to hand out at the presentation, and to present the key VE alternatives and design suggestions to USACE and the HDR design team and other interested parties. The presentation was held on October 6, 2011, at the Galveston District, USACE, Galveston, Texas. The purpose of the meeting was to provide the attendees with an overview of the suggestions for value enhancement resulting from the VE study and afford them the opportunity to ask questions to clarify specific aspects of the presented alternatives. Procedures for implementing the results of the study were discussed, and arrangements were made for the reviewers of the VE report to contact the VE team in order to obtain further clarifications, if necessary. Draft copies of the Summary of Value Engineering Alternatives worksheets and the developed VE alternatives were given to The District and design team to facilitate a timely review and speedy implementation of the selected ideas.

POST-WORKSHOP EFFORT

The post-workshop portion of the VE study consisted of the preparation of this VE Study Report. Personnel from USACE and the HDR design team will analyze each alternative and prepare a short response, recommending incorporation of the alternative into the project, offering modifications before implementation, or presenting reasons for rejection. ARCADIS is available at your convenience as you review the alternatives. Please do not hesitate to call on us for clarification or further information as you consider an implementation approach.

Upon completing their reviews, the owner and designer will meet and, by consensus, select VE alternatives and design suggestions to incorporate into the project.

VALUE ENGINEERING WORKSHOP AGENDA

Bioengineering ARCADIS LLC will conduct a four-day value engineering (VE) study on the Brazos Island Harbor, Texas, Brownsville Ship Channel Feasibility Study, Cameron County, TX during the week of October 3-6, 2011. The feasibility study is being performed by the U.S. Army Corps of Engineers, Galveston District and is at the Plan Formulation Phase of development.

The VE study opening and closing presentations on Monday and Thursday afternoons will be conducted in:

Conference Room 275
Galveston District Headquarters Building – Jadwin Building
2000 Fort Point Road
Galveston, TX 77553
Contact: Jon Plymale (409) 766-6375

For the remaining days of the workshop, the VE team will meet at the:

Holiday Inn Resort
Galveston-On The Beach
5002 Seawall Boulevard
Galveston, TX 77551
Hotel Front Desk: 1-409-7405300

The Galveston District Project Development Team will be available to answer questions during the study effort. A suggested outline for the Project Development Team's presentation follows the agenda. Representatives from the Galveston District are encouraged to attend.

AGENDA

Monday, October 3, 2011

1:00 pm - 1:30 pm **VE Team Gathers To Organize and Review Project** (at the Jadwin Building)

1:30 pm - 1:45 pm **Introduction to the Workshop**

Welcome and opening remarks by the Galveston COE
Team Member Introductions
VE Process, Workshop Organization and Agenda
Objectives of the Workshop

1:45 pm - 3:30 pm **Owner's / Designer's Presentation / Information Gathering Phase**

Representatives from the Galveston District will present information concerning the project including: project goals; the rationale for the concepts; criteria for specific areas of study, project constraints and the reasons for the design decisions. Included should be a project budget review and confirmation.

3:30 pm - 5:00 pm **Function Analysis Phase**

The VE team members will familiarize themselves with the cost model(s) and the project data for each area of study. The cost model(s) will be refined, as necessary. The VE team will perform a function analysis by defining the function of each project element or system in the cost model, selecting the primary or basic functions, and determining the worth, or least cost, to provide the function. Cost/worth or value index ratios will be calculated, and high cost/low worth areas for study identified

Tuesday, October 4, 2011

8:00 am - 12:00 pm **Creative Phase**

The team will conduct a brainstorming session and list as many ideas as possible for consideration. The aim is to obtain a large quantity of ideas through free association, by eliminating roadblocks to creativity and deferring judgment. The VE Team Leader will be responsible for developing an idea listing for the team.

Noon - 1:00 pm **Lunch**

1:00 pm - 5:00 pm **Evaluation Phase**

The VE team will analyze the ideas listed in the creative phase and select the best ideas based on criteria obtained from a discussion of the ideas' advantages and disadvantages. This will be accomplished by assigning each idea a *Gut Feel Index* rating between 1 and 5, with 5 being the best, based on the team's consensus of how well the idea meets the noted criteria.

If it is necessary to chose one of several ideas for providing the same function, then the team may engage in an analysis that weighs the various criteria and then uses these weighted criteria to compare each of the alternative ideas prior to making the selection.

The team selects the highly rated ideas for research and development.

Wednesday, October 5, 2011

8:00 am - 12:00 pm **Development of VE Alternatives Phase**

The VE team will develop creative ideas into alternate designs. Initial and life cycle cost estimates comparing original and proposed alternatives will be prepared. Selected alternatives will be developed and supported with sketches, calculations and written substantiation for change. Suppliers of materials and equipment will be contacted and specialists consulted, as necessary. The VE team leader will describe how the forms used to present the VE alternatives are prepared.

9:00 am - 10:00 am **Interim Meeting with the Galveston District** (optional)

The VE team leader will meet with the Galveston District Project Manager to review the creative ideas selected for research and development by the VE team. The goal of this meeting is to identify any ideas with fatal flaws or issues that must be addressed during the development of an idea to enhance its implementability

Noon - 1:00 pm **Lunch**

1:00 pm - 6:00 pm **Development Phase** (continued)

Thursday, October 6, 2011

8:00 am - 8:15 am **Review Status and Progress of the Team**

The VE team will assess their status and plan for completion of the alternatives development.

8:15 am - 12:00 pm **Development Phase** (continued)

Noon - 1:00 pm **Lunch**

1:00 pm - 3:00 pm **Recommendation Phase**

The VE team will prepare a summary of the value engineering alternatives with descriptions and initial and life cycle costs for a verbal presentation to the Galveston District Project Development Team. *Summary of Value Engineering Alternative* sheets are copied for distribution to VE presentation attendees. Several copies of the Draft Value Engineering Alternatives are provided to the Project Development Team to facilitate a timely review.

3:00 pm - 4:15 pm **Presentation Phase** (at the Jadwin Building)

The VE team presents its alternatives to the Galveston District Project Development Team and is available to clarify any points.

4:15 pm - 4:30 pm **Implementation Procedures**

The process for accepting / accepting with modification / rejecting the VE alternatives is described and a schedule for meeting to finalize implementation decisions is established.

4:30 pm **Adjourn**

OUTLINE FOR VE TEAM PRESENTATION

The Project Development Team is actively involved in the planning and design of the project to be value engineered. They have spent a great deal of time and effort in developing their concepts.

However, the concepts are influenced by outside input from many sources. In order to perform its work most efficiently, the VE team needs to understand the factors that have influenced the concept development. The object is to avoid duplication of efforts and to aid the team in becoming familiar with the project.

To achieve this objective, the Galveston District's Project Development Team is asked to give a presentation at the beginning of the VE workshop session. To assist them, we have outlined the information that, as a minimum, should be addressed:

- Scope of the Project Development Team's effort
- Participating firms
- Existing site conditions
- Regulatory requirements
- Basis of design
- Rationale and steps in development of design
- Design concepts for civil, dredging, structural, mechanical, electrical, instrumentation & controls, security, etc.
- Hours of operation - Staffing Plan
- Pertinent information from user participation
- Constraints imposed by the Owner
- Appropriate codes
- Explanation of information provided by the Designer to the VE team
- Summary of cost estimate
- Construction phasing

This information is provided as an outline to aid the owner and designers. The presentation is the owner's and designers' responsibility and they may conduct the initial presentation in the manner they feel most comfortable.

VALUE ENGINEERING WORKSHOP PARTICIPANTS

The VE team was organized to provide specific expertise in the unique project elements involved with the project. The multidisciplinary team comprised specialists in marine dredging and sediment management, marine cost estimating, construction experience, sustainability experience and a working knowledge of VE procedures. The following lists the VE team members:

Participant	Specialization	Affiliation
Howard B. Greenfield, PE, CVS	VE Team Leader	ARCADIS U.S., Inc.
Joseph E. Sensebe, PE	Dredging Specialist	ARCADIS U.S., Inc.
Richard DeWan	Environmental Scientist	ARCADIS U.S., Inc.
Mark Hendry	Environmental Engineer	ARCADIS U.S., Inc.
John R. Ewing	Cost Estimator/Construction Specialist	Civil Design & Construction, Inc.
Jon Plymale	Value Engineering Officer	Galveston District, USACE

DESIGNER'S PRESENTATION

An overview of the project was presented on October 3, 2011, by representatives from USACE and the HDR design team. The purpose of this meeting, in addition to being an integral part of the Information Phase of the VE study, was to bring the VE team up-to-speed regarding the overall project specifics. Additionally, the meeting afforded the owner and design team the opportunity to highlight in greater detail those areas of the project requiring additional or special attention. An attendance list for the meeting is attached.

VALUE ENGINEERING TEAM'S PRESENTATION

A VE presentation was conducted by the VE team on October 6, 2011 at the Galveston District, USACE, Galveston, TX to review VE alternatives with The District PDT and representatives from the design team. Copies of the Draft Summary of Value Engineering Alternatives worksheets were provided to the attendees. Four copies of the draft, unedited, VE alternatives were provided to USACE to facilitate a timely review. An attendance list for the meeting is attached.

ARCADIS

VE STUDY SIGN-IN SHEET

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas
In-Brief: October 3, 2011 *Out-Brief: October 6, 2011*

IN-BRIEF	OUT-BRIEF	NAME	ORGANIZATION/TITLE	PHONE NUMBER	EMAIL ADDRESS
✓	✓	Howard Greenfield	ARCADIS/Team Leader	410-381-1990	Howard.greenfield@arcadis-us.com
✓	✓	John Ewing	Civil Design & Construction/Estimator	225-765-1802	jawing@cdcbr.com
✓	✓	Jon Plymale	COE/VE Officer	409-766-6375	Jon.e.plymale@usace.army.mil
✓	✓	Cris Michalsky	COE/Cost Engineer	409-766-6351	Cris.j.michalsky@usace.army.mil
✓	✓	Byron Williams	COE/Project Manager	409-766-3140	Byron.d.williams@us.army.mil
✓	✓	Katie Williams	COE/Economist	409-766-3146	Kathleen.a.williams@usace.army.mil
✓	✓	Janelle Stokes	COE/Environmental Lead	409-766-3039	Janelle.s.stokes@usace.army.mil
✓	✓	Samantha Lambert	COE/H&H Engineer	409-766-6350	Samantha.lambert@usace.army.mil
✓	✓	Joe Sensebe	ARCADIS/Project Mgr.	504-832-4174	Joseph.sensebe@arcadis-us.com
✓	✓	Richard DeWan	ARCADIS/Principal Env. Scientist	609-860-0590	Richard.dewan@arcadis-us.com
✓	✓	Mark Hendry	ARCADIS/Staff Env. Engineer	410-923-7809	Mark.hendry@arcadis-us.com
✓	✓	Neil McLellan	HDR	713-256-6362	Neil.mclellan@hdrinc.com
✓	✓	Brenda Hayden	COE/Civil Engineer	409-766-3902	Brenda.r.hayden@usace.army.mil
✓	✓	Sheri Willey	USACE/Planning Lead	409-766-3917	Sheridan.s.willey@usace.army.mil
	✓	Herbie Maurer	Maurer Advisory Port Rep.	713-703-5219	Herbie.maurer@sbcglobal.net
	✓	Willie Joe Honzu	USACE	409-766-3161	
	✓	Ariel Chavez	Brownsville Port Engineer/BIH	956-838-7002	

ECONOMIC DATA

The comparisons of life cycle costs between the VE alternatives and the current design solutions were performed on the basis of discounted present worth. To accomplish this, the VE team developed economic criteria to use in its calculations based on information gathered from USACE and the design team. The following parameters were used when calculating discounted present worth:

Year of Analysis:	2008
Construction Start Date:	Unknown
Construction Completion Date:	Unknown
Planning Period (n):	50
Discount Rate: (FY08)	4.875%

A composite markup of 20% was used when comparing the construction costs of the current design with the alternative design to account for the following:

- Engineering & Design
- Construction Management

COST MODEL

The VE team prepared a Pareto Chart, or Cost Histogram, for the project that follows this page. This Cost Histogram displays the major construction elements identified in the cost estimate prepared by the designer in descending order of magnitude and thus identifies the high cost areas in the project. The high cost elements provide the VE team with one focus for its work during the study.

As shown on the Cost Histogram, 80% of the project's costs are in the following project elements:

- Dredge – Main Channel
- Dredge – Jetty Channel
- Bond
- Dredge – Turning Basin
- Stripping
- Hydraulic Const. Exterior Levee PA 4

COST HISTOGRAM

ARCADIS

PROJECT: BRAZOS ISLAND HARBOR, TX

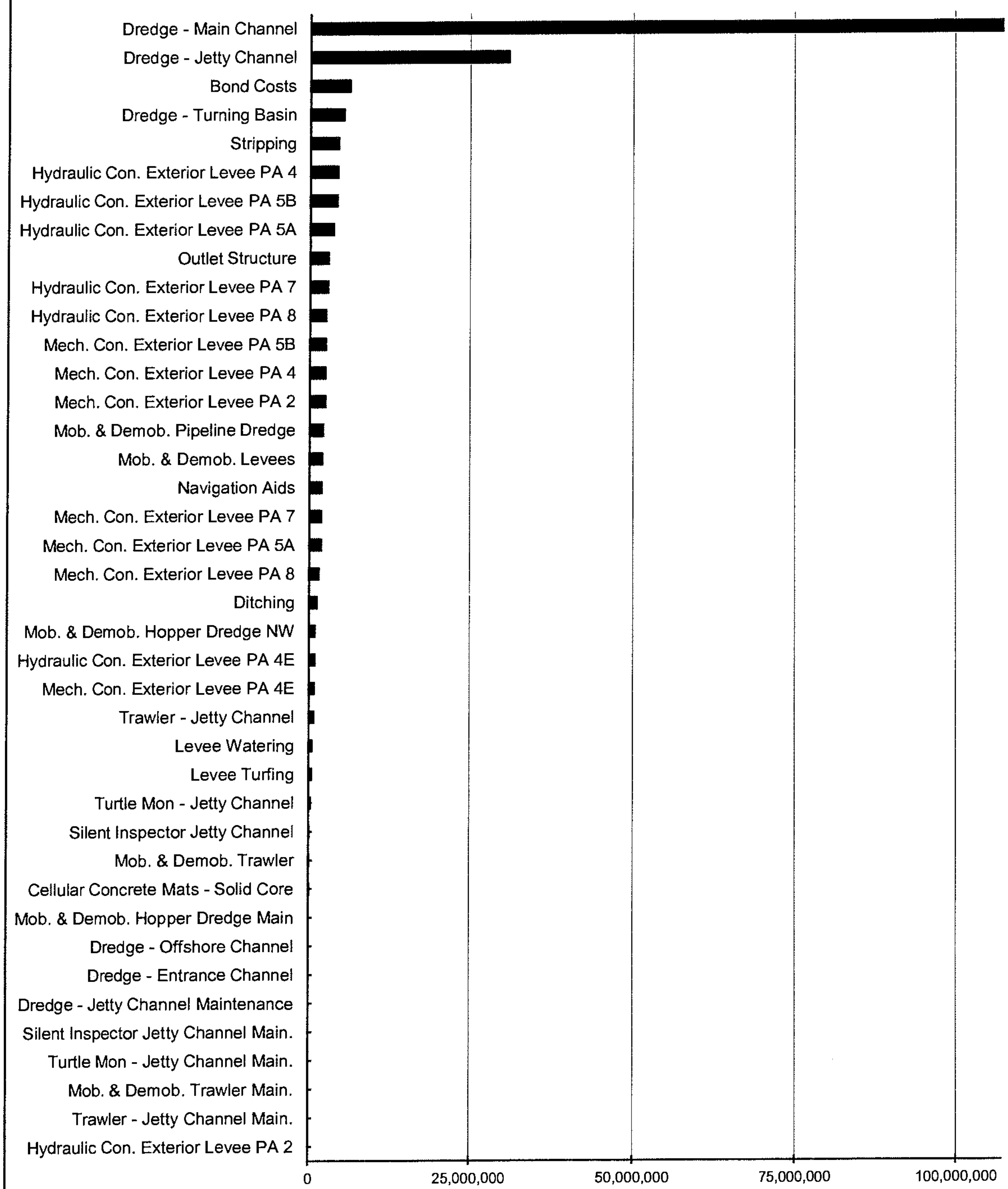
ALTERNATIVE: DEEPEN CHANNEL TO 50 FT. & WIDEN BY 100 FT. (based on deepen to 50 ft. and widen by 200 ft.)

PROJECT ELEMENT	COST	PERCENT	CUM. PERCENT
Dredge - Main Channel	107,410,743	54.09%	54.09%
Dredge - Jetty Channel	31,082,764	15.65%	69.74%
Bond Costs	6,225,000	3.13%	72.88%
Dredge - Turning Basin	5,328,580	2.68%	75.56%
Stripping	4,473,000	2.25%	77.81%
Hydraulic Con. Exterior Levee PA 4	4,402,125	2.22%	80.03%
Hydraulic Con. Exterior Levee PA 5B	4,249,250	2.14%	82.17%
Hydraulic Con. Exterior Levee PA 5A	3,645,000	1.84%	84.00%
Outlet Structure	2,812,500	1.42%	85.42%
Hydraulic Con. Exterior Levee PA 7	2,777,500	1.40%	86.82%
Hydraulic Con. Exterior Levee PA 8	2,517,063	1.27%	88.09%
Mech. Con. Exterior Levee PA 5B	2,465,798	1.24%	89.33%
Mech. Con. Exterior Levee PA 4	2,436,656	1.23%	90.55%
Mech. Con. Exterior Levee PA 2	2,432,793	1.23%	91.78%
Mob. & Demob. Pipeline Dredge	2,093,750	1.05%	92.83%
Mob. & Demob. Levees	1,968,750	0.99%	93.82%
Navigation Aids	1,845,000	0.93%	94.75%
Mech. Con. Exterior Levee PA 7	1,817,515	0.92%	95.67%
Mech. Con. Exterior Levee PA 5A	1,801,800	0.91%	96.58%
Mech. Con. Exterior Levee PA 8	1,460,624	0.74%	97.31%
Ditching	1,138,940	0.57%	97.89%
Mob. & Demob. Hopper Dredge NW	868,250	0.44%	98.32%
Hydraulic Con. Exterior Levee PA 4E	860,000	0.43%	98.76%
Mech. Con. Exterior Levee PA 4E	720,768	0.36%	99.12%
Trawler - Jetty Channel	669,375	0.34%	99.46%
Levee Watering	414,000	0.21%	99.66%
Levee Turfing	379,500	0.19%	99.86%
Turtle Mon - Jetty Channel	227,500	0.11%	99.97%
Silent Inspector Jetty Channel	25,000	0.01%	99.98%
Mob. & Demob. Trawler	25,000	0.01%	100.00%
Cellular Concrete Mats - Solid Core	9,325	0.00%	100.00%
Mob. & Demob. Hopper Dredge Main	0	0.00%	100.00%
Dredge - Offshore Channel	0	0.00%	100.00%
Dredge - Entrance Channel	0	0.00%	100.00%
Dredge - Jetty Channel Maintenance	0	0.00%	100.00%
Silent Inspector Jetty Channel Main.	0	0.00%	100.00%
Turtle Mon - Jetty Channel Main.	0	0.00%	100.00%
Mob. & Demob. Trawler Main.	0	0.00%	100.00%
Trawler - Jetty Channel Main.	0	0.00%	100.00%
Hydraulic Con. Exterior Levee PA 2	0	0.00%	100.00%
Subtotal	**$ 198,583,869**	**100.00%**	
Engineering & Design @ 10.00%	**$ 19,858,387**		
Construction Management @ 10.00%	**$ 19,858,387**		
TOTAL	**$ 238,300,643**	**Comp Mark-up:**	20%

COST HISTOGRAM

ARCADIS

PROJECT: BRAZOS ISLAND HARBOR, TX



Costs in graph are not marked-up.

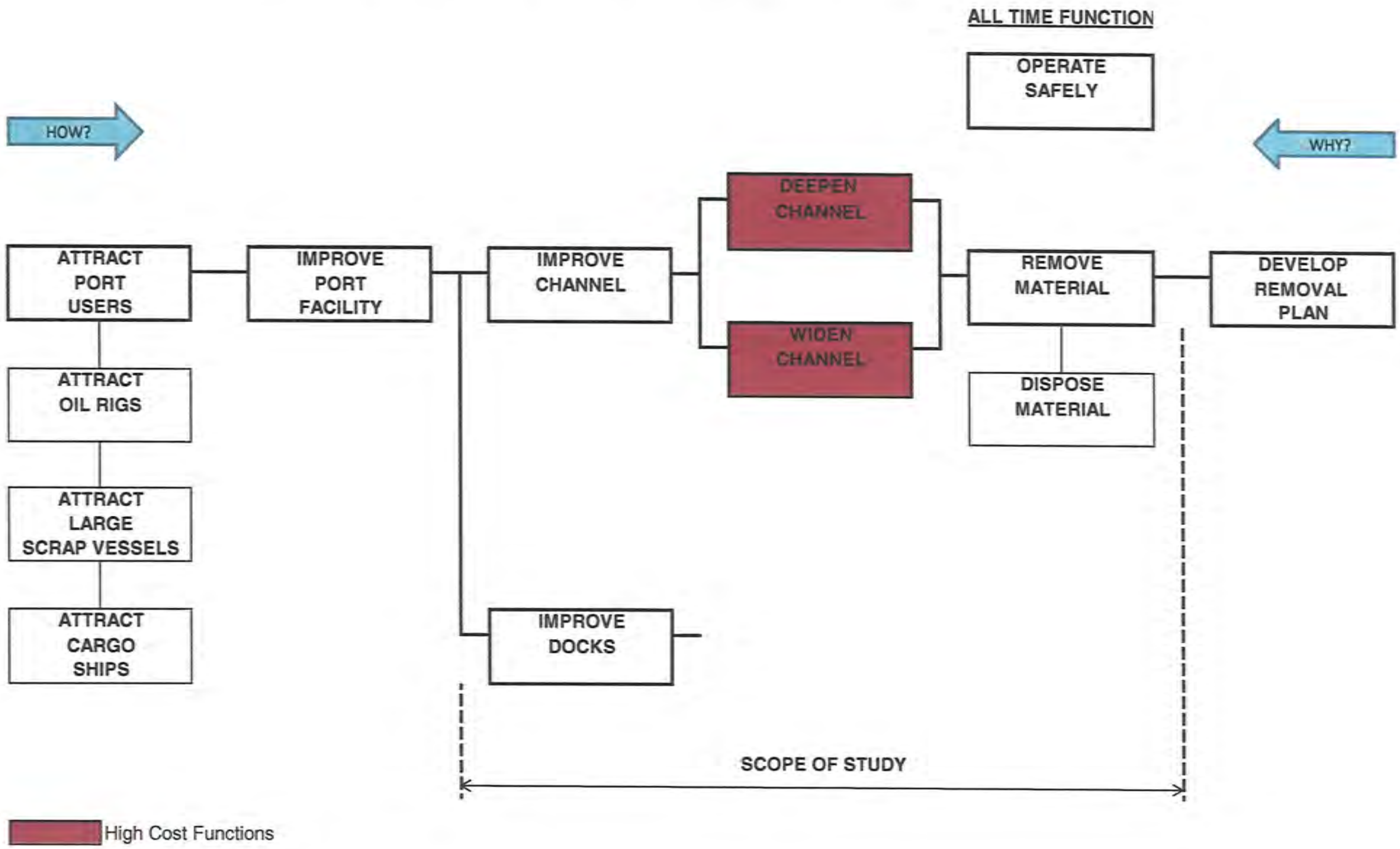
FUNCTION ANALYSIS

A function analysis was performed to (1) understand the project purpose and need, (2) define the requirements for each project element, (3) ensure a complete and thorough understanding by the VE team of the basic function(s) needed to attain the given project purpose and need, (4) identify other public goals, and (5) identify secondary functions that should be addressed by the VE team. The FAST Diagram completed by the team for the project in its entirety and the various elements follow.

BROWNSVILLE SHIP CHANNEL IMPROVEMENTS

Brazos Island Harbor, Texas

FUNCTION ANALYSIS SYSTEMS TECHNIQUE DIAGRAM



CREATIVE IDEA LISTING AND EVALUATION OF IDEAS

During the Creative/Speculation Phase, numerous ideas were generated for the Brownsville Ship Channel Improvements using conventional brainstorming techniques. These ideas were recorded and are shown with their corresponding ranking on the attached Creative Idea Listing Worksheets. For the convenience of tracking an idea through the VA process, the ideas were grouped into the following project functions and numbered according to the order in which they were conceived. The following letter prefixes were used to identify the project function.

PROJECT FUNCTION	PREFIX
Widen Channel	WC
Deepen Channel	DC

The ideas were ranked on a qualitative scale of 1 to 5 on how well the VE team believed the idea met the project purpose and need criteria. To assist the team in evaluating the creative ideas, the advantages and disadvantages of each new idea compared to the existing design solution were discussed based on the owner's value objectives for the project. The following are the value objectives for this project:

Criteria

- Does it support attracting users
- Save costs
- Accelerates availability
- Improve efficiency of operations

After discussing each idea, the team evaluated the ideas by consensus. This effort produced 3 ideas rated 4 or 5 to research and further develop into formal VE alternatives and over 6 ideas to develop as design suggestions to be included in the Study Results section of the report. Highly rated ideas that were not developed further may have been combined with another related idea(s) or discarded as a result of additional research indicating the concept as not being cost effective or technically feasible. The reader is encouraged to review the Creative Idea Listing and Evaluation worksheet since it may suggest additional ideas that can be applied to the design.

ARCADIS

CREATIVE IDEA LISTING

PROJECT: **BROWNSVILLE SHIP CHANNEL IMPROVEMENTS**
Brazos Island Harbor, Texas

NO.	IDEA DESCRIPTION	RATING
WIDEN CHANNEL (WC)		
WC-1	Do not widen channel	2
WC-2	Partially widen channel for full length	See WC-5
WC-3	Partially widen channel in strategic locations	See WC-6
WC-4	Reduce extent of lead into turning basin	2
WC-5	Reduce channel width to 300 ft.	4
WC-6	Reduce channel width to the current 200 ft. with passing areas	2
WC-7	Maintain 250 ft. channel width and change operating procedures	3
DEEPEN CHANNEL (DC)		
DC-1	Only deepen channel to 48 ft. beyond amfels; 50 ft. up to amfels; 48 ft. beyond this point	4
DC-2	Do not deepen turning basin	4

Rating: 1→2 = Not to be developed 3→4 = Varying degrees of development potential 5 = Most likely to be developed
DS = Design suggestion ABD = Already being done

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

CESWG-DE 27 Feb 11

MEMORANDUM FOR Commander, US Army Engineer Division, Southwestern (ATTN: CESWD-RBT (Mr. Loc Nguyen), 1100 Commerce Street, Dallas, TX 75242-1317

SUBJECT: MSC Acceptance of VE Implementation, Brazos Island Harbor General Re-evaluation Study, Brownsville, Texas

1. Background

Brazos Island Harbor (BIH), located at the southern tip of the Texas coast, provides deep draft access from the Gulf of Mexico through a jettied entrance channel to Brownsville. The channel comprises the Port of Brownsville which lies three miles north of the Rio Grande River and Mexican border and five miles east of the City of Brownsville. The Port of Brownsville is primarily a bulk commodity port handling both liquid and dry cargo. Principal imports and exports include chemicals, liquid petroleum, gas, clays, petroleum, grain, agricultural products, sulfur, steel, bulk minerals, ores, fertilizers, and aluminum. The port serves as an important in-transit port for trade to and from Mexico and at one time was the nation's second largest in-transit harbor by volume. BIH is approximately 22 miles long and maintained at depths of 44 feet in the offshore reach, 42 feet in the Main Channel, and 36 feet in the Turning Basin Extension, which is authorized to a depth of -42 feet Mean Low Tide (MLT). The only turning basin at the channel's terminus is 36 feet. Current channel widths vary by channel reach as follows: 300 feet for the Entrance Channel, 300 to 400 feet for the Jetty Channel, 250 feet for the Main Channel, and 400 to 325 feet for the Turning Basin Extension. The Turning Basin is 1,200 feet wide. Construction of the project to its current dimensions was completed in 1996. BIH is the southernmost navigation channel in the state of Texas and the western terminus of the Gulf Intracoastal Waterway system.

A reconnaissance study concluded that commercial navigation benefits could possibly be derived by deepening and widening the BIH sufficient to offset the construction cost and any environmental consequences and that accordingly it would be in the Federal interest to conduct a more detailed, feasibility-level study. As a result, a feasibility study was initiated and has since progressed through the Plan Formulation Phase of the study. The feasibility study report is scheduled to be completed by August 2014. A Value Engineering (VE) study of the project alternatives that were under consideration was introduced towards the end of the Plan Formulation Phase. This study was completed on 06 October 2011.

The proposed plan for the BIH improvements calls for deepening and widening the Entrance Channel to 52 feet by 350 feet, the Main Channel and Turning Basin Extension to 50 feet by 350 feet, and only deepening the Turning Basin to 50 feet.

2. Acceptance of VE Proposals

The VE study recommended the implementation of 3 alternatives to the conceptual designs for the channel improvements. Collectively, these alternatives indicated a potential first cost savings of $35,868,000. Individually, each alternative indicated a cost savings of more than $1.0M. The Project Delivery Team decided to accept two of the VE proposals, which totaled to $8.6M in cost savings. The third proposal was rejected. Since this proposal indicated a cost savings potential of more than $1.0M, MSC concurrence on its non-acceptance is required and therefore being requested.

3. Recommendation regarding Implementation of VE Alternatives

VE Alternatives DC-1 and DC-2 were accepted and should considerably reduce the project cost. Following is a discussion of these alternatives and their associated cost savings. VE Alternative WC-5 was rejected for the reasons given in Paragraph 4.

a) Alternative DC-1 – Only deepen the channel to 48 feet from Station 84+200 to the end of the Turning Basin in lieu of 50 feet. The proposed new channel depth of -50 feet MLT is principally to accommodate the existing and emerging dynamic oil exploration platform industry and some ships (bulk carriers) with deeper drafts. Dynamic platforms are floating marine structures that float over an exploration site and utilize propulsion positioning systems to remain on station to support drilling operations as opposed to a fixed structure affixed to the ocean bottom. The propulsion systems on these platforms are located 40 - 48 feet below the water surface. The facilities that service these platforms are located below station 76+000. Because of the current depth-limiting conditions of -45 feet MLT through this reach, these propulsion systems must be removed prior to entering the channel so the platforms can be serviced. The cost associated with removing the propulsion systems is $3M to $5M per platform. Additionally, the -50-foot MLT depth supports the future vessel traffic to docks located below Station 84+200 and other future bulk cargo facilities that will require the deeper draft and utilize the wider channel. The depth of -48 feet MLT may be sufficient to support industry above Station 84+200. However, deeper draft vessels (greater than -48 feet) may not be able to utilize the turning basin unless the vessel is partially unloaded prior to entering the turning basin with its full load. The cost avoidance potential associated with this alternative is $1.9M.

b) Discussion DC-2 – Do not deepen the Turning Basin from its existing -36-foot depth. According to a report on the economic benefits of maintaining the existing channel dimensions and deepening the channel to -48 feet (referred to as the Martin Report), the driver for establishing the cargo vessel design draft at -47 feet MLT is based solely on an assumed Panamax-size vessel utilizing the channel to carry imported steel slab.

Accommodation of this size ship would significantly lower the freight rate per ton of slab and further reduce the number of vessels that would be needed to move the steel slabs. For the VE alternative, it is assumed that the steel slab will always be offloaded prior to ships entering the Turning Basin which would reduce draft requirements to less than -36 feet MLT. The economic benefits report stated that interviews with the importers of other products, most notably other steel products, petroleum products, grain, scrap, and limestone did not indicate that a deeper channel would result in the use of larger ships. Therefore, it was decided that the Turning Basin did not have to be deepened. The cost avoidance potential associated with this alternative is $6.7M.

4. Justification for Rejection of VE Alternative WC-5 - Only widen the channel to 300 feet from Station 28+000 to Station 79+415 in lieu of 350 feet.

The subject channel reach is relatively straight, consisting of three (3) long, straight segments abutting at two (2) slight bends. When the channel was modeled by the Engineering Research Development Center Coastal Hydraulics Laboratory (ERDC-CHL) and real-time simulation runs with the design vessels were conducted, the modeling and simulations intentionally excluded the "straight" reach to which VE Alternative WC-5 pertains. The reason for this is because ERDC-CHL, the district, and the pilots felt that running simulations on in-bound ships along the reach from Station 26+000 to the Turning Basin would only be redundant given that the current and bank effects would be consistent throughout. Consequently, ERDC-CHL made its recommendation regarding the widening based on what it had learned the last time the ship channel was studied when ship simulation runs were made along the entire length of channel. That study was completed in 1990 for improvements that were subsequently constructed in 1995. The information obtained from the simulation runs in fact was used to support the thinking that channel widths could be made considerably less wide than those specified in Corps of Engineers' design guidance when the channel is uniform and straight and very small currents are involved (reference EM 1110-2-1613 - Engineering and Design - Hydraulic Design of Deep Draft Navigation Projects concerning channel width criteria where the Brazos Island Harbor project is cited).

The VE alternative suggests that a 300-foot wide channel might be sufficient along the straight reach of channel beyond Station 28+000 noting that the 350-foot width recommendation appears to have been driven primarily by the turns in the channel at Stations 1+424 and 22+000 where the simulated inbound vessels experienced insufficient channel side clearance when turns were being made. At both locations, inbound ships often transit outside the channel when making the turns as pilots correct/adjust their alignments. From Station 24+000 to the turning basin however, there appears to be no operating concerns. The VE alternative goes on to suggest that if a 300-foot wide channel does present navigation challenges for the two design vessels evaluated, consideration should be given in comparison to the project cost to the number of design vessels that will be calling on the port to see if accommodating them is going to be economically worthwhile.

VE Alternative WC-5 was rejected based on ERDC-CHL's expert opinion that a 300-foot wide channel beyond Station 28+000 is not going to be wide enough for the design ships. This opinion is supported through extrapolation by the results of the ship simulation study that was completed in 1990 and premised on channel width design guidance found in EM 1110-2-1613 which validates channel widths for studied uniform, straight canals with very small currents between 2.20 and 2.50 times the design ship beam. When ship simulation runs were last made along the entire length of the BIH, the results yielded a channel width-to-design ship beam ratio for the straight reach of 2.36 as being adequate. EM 1110-2-1613 conservatively recommends a value of 2.50 times the design ship beam for canals where the currents are negligible. The existing 250-foot wide channel was based on a Panamax tanker having a beam of 106 feet, which yields a channel width-to-beam width of 2.36. Based on the design tanker for the channel widening being considered, which has a 157-foot beam, the 300-foot and 350-foot wide channels would result in channel width-to-beam ratios of 1.91 and 2.23 respectively. While the 2.23 ratio for the 350-foot wide channel has a slightly lower width-to-beam ratio than the existing channel (at 2.36), ERDC-CHL believes this ratio is reasonable. For the 300-foot wide channel however, the 1.91 ratio is significantly below what current Corps of Engineers' design guidance suggests and therefore would probably only be marginally adequate at best. Simulation runs on a 300-foot wide channel would have to done to know with any certainty whether this width would be adequate, but in ERDC-CHL's judgment it probably would not be given its experience. ERDC-CHL believes in a conservative approach to the channel widening to approximate the width-to-beam ratio of the existing channel. The PDT accepted this recommendation.

5. Request for MSC Concurrence. Two (2) of the three (3) VE alternatives were accepted for implementation. The one alternative that was not accepted is based on ERDC-CHL's recommendation that a 350-foot wide channel is the optimum width for a safe navigable channel. A channel of less width is not supported by current Corps of Engineers design guidance and would likely start to pose challenges to efficient navigation of the channel. I concur with the PDT's decisions on the VE alternatives and respectfully request MSC concurrence.

6. Questions. Direct all inquiries to Mr. Byron Williams, Project Manager, at 409-766-3140.

CF: CESWG-PM-J
CESWG-EC-E
CESWG-EC-PS

CHRISTOPHER W. SALLESE
COLONEL, EN
Commanding

Table 6-5 Alternative Shoaling Estimates

DS Stationing	US Stationing	Current 42' Channel Annual Shoaling Rate (Cy/yr)	45' Deepening Only Annual Shoaling Rate (Cy/yr)	48' Deepening Only Annual Shoaling Rate (Cy/yr)	50' Deepening Only Annual Shoaling Rate (Cy/yr)	52' Deepening Only Annual Shoaling Rate (Cy/yr)	45' Deepening and 25' Widening Each Side Annual Shoaling Rate(Cy/yr)	48' Deepening and 25' Widening Each Side Annual Shoaling Rate(Cy/yr)	50' Deepening and 25' Widening Each Side Annual Shoaling Rate(Cy/yr)	52' Deepening and 25' Widening Each Side Annual Shoaling Rate(Cy/yr)	45' Deepening and Widening to 350' Width Annual Shoaling Rate (Cy/yr)	48' Deepening and Widening to 350' Width Annual Shoaling Rate (Cy/yr)	50' Deepening and Widening to 350' Width Annual Shoaling Rate (Cy/yr)	52' Deepening and Widening to 350' Width Annual Shoaling Rate (Cy/yr)
-17000	-13000	50,000	89,280	122,610	144,830	167,040	89,280	122,610	144,830	167,040	111,900	156,340	185,970	215,600
-13000	-6000	169,570	169,570	168,600	168,000	167,370	169,570	171,830	173,340	174,850	226,230	229,250	231,270	233,280
-6000	-1000	106,470	108,200	109,100	109,700	110,300	108,200	109,620	110,580	111,530	134,820	136,210	137,130	138,060
-1000	0	25,020	25,420	25,630	25,770	25,920	25,420	25,570	25,730	25,900	25,370	25,660	25,860	26,050
0	1500	18,670	18,970	19,220	19,380	19,540	18,970	19,220	19,380	19,540	18,940	19,160	19,300	19,450
1500	2329	11,480	11,710	11,850	11,950	12,040	13,310	13,470	13,570	13,670	13,090	13,220	13,310	13,400
2329	6000	58,020	59,000	59,460	59,170	60,880	68,630	69,420	69,950	70,470	75,560	76,340	76,860	77,380
6000	11000	65,940	67,030	67,930	68,530	69,130	78,040	78,920	79,510	80,120	85,900	92,270	96,520	100,770
11000	16000	75,300	76,570	77,610	78,300	78,990	89,140	90,170	90,850	91,530	98,010	99,020	99,690	100,360
16000	21000	49,830	50,640	51,310	51,750	52,230	58,970	59,630	60,070	60,510	64,880	65,540	65,980	66,410
21000	28000	50,450	51,260	51,920	52,360	52,810	59,680	60,340	60,780	61,220	65,770	66,430	66,870	67,310
28000	34000	41,140	41,790	42,330	42,690	43,050	48,680	49,220	49,580	49,930	53,560	54,100	54,450	54,810
34000	39000	30,750	31,230	31,630	31,890	32,160	36,400	36,860	37,170	37,480	39,930	40,320	40,580	40,840
39000	44000	32,380	32,890	33,310	33,600	33,880	38,340	38,830	39,150	39,480	38,340	38,830	39,160	39,480
44000	50000	54,930	55,780	56,510	57,000	57,480	66,950	66,780	66,850	66,870	71,550	72,270	72,750	73,230
50000	56000	54,560	55,440	56,160	56,640	57,120	64,540	65,260	65,740	66,220	70,980	71,680	72,160	72,640
56000	62000	56,670	57,590	58,340	58,850	59,350	67,030	67,770	68,270	68,770	73,800	74,540	75,040	75,530
62000	63000	8,300	8,440	8,550	8,620	8,690	9,850	9,970	10,060	10,140	10,210	10,320	10,390	10,460
63000	63770	6,770	6,880	6,970	7,030	7,080	8,000	8,090	8,150	8,210	8,820	8,900	8,960	9,020
63770	65000	10,830	10,100	10,630	10,980	11,330	11,000	11,140	11,230	11,330	12,570	12,730	12,840	12,950
65000	70000	41,160	41,800	42,340	42,700	43,080	41,810	42,350	42,710	43,070	47,740	48,280	48,640	49,000
70000	75000	30,120	30,590	30,980	31,240	31,500	30,590	30,590	30,590	30,590	34,950	35,340	35,600	35,860
75000	79415	22,020	22,370	22,650	22,840	23,050	22,370	22,650	22,840	23,030	25,550	25,840	26,030	26,220
79415	79610	1,000	1,020	1,030	1,040	1,050	1,020	1,030	1,040	1,050	1,080	1,080	1,080	1,080
79610	80000	2,000	2,030	2,060	2,070	2,090	2,030	2,060	2,070	2,090	2,030	2,060	2,070	2,100
80000	83400	14,580	14,810	14,990	15,120	15,250	14,810	15,300	15,630	15,960	14,810	15,000	15,120	15,200
83400	83600	820	840	850	850	860	840	850	850	860	860	870	880	890
83600	86000	10,830	11,000	11,100	11,180	11,250	11,000	11,530	11,880	12,230	11,780	11,910	12,010	12,100
86000	86215	930	930	930	930	930	930	930	930	930	1,000	1,000	1,000	1,000
86215	87000	820	820	820	820	820	820	820	820	820	900	900	900	900
87000	88500	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,630	1,630	1,630	1,630
88500	89500	570	570	570	570	570	570	570	570	570	650	650	650	650
Cumulative Volume		1,103,480	1,156,120	1,199,540	1,227,950	1,258,390	1,258,340	1,304,950	1,336,270	1,367,560	1,443,210	1,507,690	1,550,700	1,593,660
Increase From Original Channel			52,641	96,060	124,470	154,910	154,860	201,470	232,790	264,080	339,730	404,210	447,220	490,180
Percent Increase From Original Channel			104.77%	108.71%	111.28%	114.04%	114.03%	118.26%	121.10%	123.93%	130.79%	136.63%	140.53%	144.42%