US Army Corps
of Engineers
Galveston District

**DEFICIENCY CORRECTION EVALUATION REPORT
AND FINDING OF NO SIGNIFICANT IMPACT
WITH ENVIRONMENTAL ASSESSMENT**

Houston Ship Channel Project Deficiency Report (Flare at the Intersection of the Houston Ship Channel and Bayport Ship Channel) Houston-Galveston Navigation Channels, Texas

March 2016

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Executive Summary

PURPOSE OF REPORT

The purpose of the proposed project is to correct a design deficiency on the Houston Ship Channel (HSC) and conduct a corrective action through a channel modification required to make the project function on an interim basis as initially intended in a safe, viable, and reliable manner. The ultimate fix will require a study of the HSC within Galveston Bay to address potential channel widening, passing lanes, and anchorage areas under the authority of Section 216 of the Flood Control Act of 1970, Review of Completed Projects. Figure ES 1-1 shows the approximate area of the safety concern resulting from the design deficiency.

AUTHORIZED PROJECT

The *Houston-Galveston Navigation Channels, Texas, Limited Reevaluation Report and Final Supplemental Environmental Impact Statement* (1995 LRR/SEIS) was completed in November 1995. The Houston-Galveston Navigation Channels, Texas, Project (HGNC) was subsequently authorized in the Water Resources Development Act of 1996 (WRDA 1996), Section 101(a)(30), P.L. 104-303. The HGNC is a multipurpose project with two separable elements, the HSC and the Galveston Channel. The two project purposes are to provide navigation improvements to the ports of Houston and Galveston, and to provide environmental restoration for the Houston portion of the Project through the beneficial use (BU) of dredged material. The project is located in the Galveston Bay system in Galveston, Harris, and Chambers Counties, Texas. The total Project provided for a 45-foot HSC and Galveston Channel.

MODIFICATIONS TO AUTHORIZED PROJECT

1. The centerline alignment of the HSC in the Bay Reach was shifted to the east to avoid impacts to Morgans Point. This resulted in widening the channel only on the west side of the existing HSC at its intersection with the Bayport Ship Channel (BSC).
2. The existing HSC Bend located immediately south of Five Mile Cut and the HSC intersection with the BSC was increased an additional two degrees resulting in a 15-degree bend (HSC Bend).
3. Barge lanes were constructed on either side of the HSC in the Bay Reach via separate legislation (Energy and Water Development Appropriations Act, 2001) during the project construction due to heightened concerns of the interaction between faster moving large vessels with slower moving barge tows.

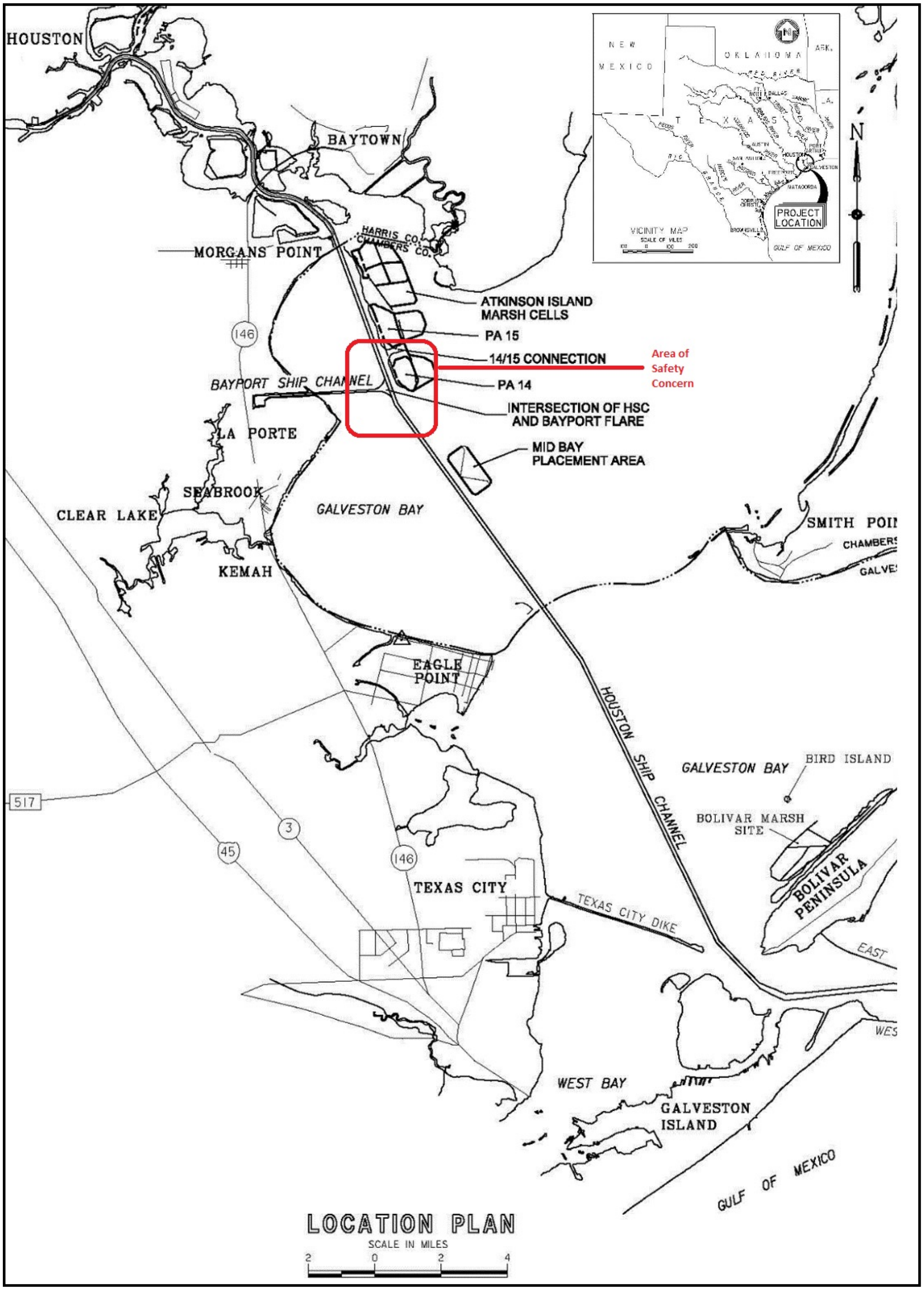

Figure ES 1-1: Plate No. 1, HGNC Project Map with Approximate location of Area of Concern

MODIFICATION IMPACTS

The HSC contains a deficiency inherent in the design of the WRDA 1996 project. The deficiency encompasses: 1) the transiting of and meeting in the 15-degree bend of the HSC near the intersection of the HSC and BSC, and 2) the turn from the HSC into the BSC. Figure ES 1-2 shows the area of safety concern resulting from the design deficiency. These actions to improve overall navigation on the HSC resulted in unintended negative impacts on the HSC and on the adjacent BSC in the specific area of concern. Vessels turning off the HSC into BSC are required to make two significant course changes in about a ship length; both course changes were increased with the realignment of this HSC reach.

BAYPORT SHIP CHANNEL

The BSC is a major tributary channel that existed prior to the HGNC authorization. It was not designed or constructed by the U.S. Army Corps of Engineers (USACE). The BSC became a Federally-maintained channel when Federal maintenance of the BSC was authorized by an amendment to Section 819 of the WRDA 1986, P.L. 99-662: *"The project for navigation at the Houston Ship Channel (Greens Bayou), Texas, authorized pursuant to section 301 of the River and Harbor Act of 1965 (79 Stat. 1091), the project for navigation at the Houston Ship Channel (Barbour Terminal Channel), Texas, authorized pursuant to section 107 of The River and Harbor Act of 1960 (74 Stat. 486), and the project for navigation At the Houston Ship Channel (Bayport Ship Channel), Texas, authorized by Section 101 of the River and Harbor Act of 1958 (72 Stat. 298), are modified to authorize and direct the Secretary to assume responsibility for maintenance to forty-foot project depths, as constructed by non-Federal interests prior to enactment of this Act."* The USACE assumed maintenance of the channel in April 1993 with a Local Cooperation Agreement (LCA) authorized by the WRDA 1986 amendment.

AUTHORITY TO CORRECT

Various authorities, including those identified in Engineer Regulation (ER) 1130-2-520, *Navigation and Dredging Operations and Maintenance Policies* (Chapter 8) and ER 1165-2-119, *Modifications to Completed Projects*, were assessed to determine whether the proposed work could be accomplished within existing authorities or if additional authority is required. Because the BSC is not a Federal navigation channel, it is a non-Federally improved channel, general operations and maintenance (O&M) authorities may not be used.

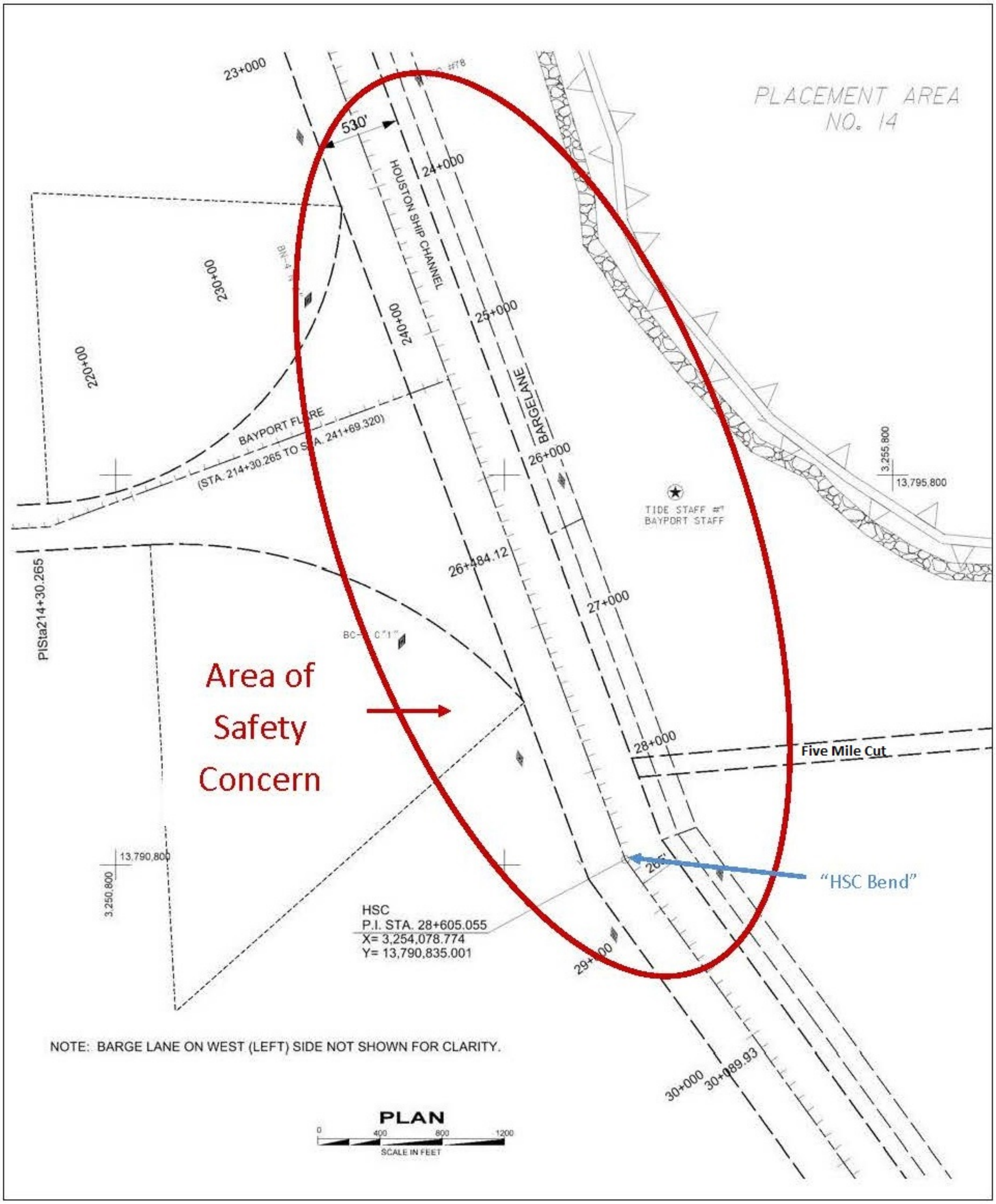

Figure ES 1-2: Area of Safety Concern at HSC Bend and Flare in Vicinity of BSC

Extensive coordination was conducted with the Headquarters, USACE (HQ USACE). The USACE, Galveston District submitted the May 4, 2015 White Paper (see Appendix - E Pertinent Documents) outlining the navigation safety issues on the HSC since its construction was completed in 2005. By memorandum dated April 1, 2015, the Director of Civil Works (DCW) concurred with the District's request to proceed with a Project Deficiency Report (PDR) to address a design deficiency on the HSC and recommend a corrective action. This PDR documents the scope of the plan to alleviate the navigation safety concerns in the vicinity of the intersection of the HSC and BSC.

The HGNC Project is classified as a completed Federal project. Based on the criteria in ER 1165-2-119 (*Modifications to Completed Projects)*, the construction required for the corrective action recommended in this report is authorized under the existing project authority for the WRDA 1996 Project. The referenced ER states that a design or construction deficiency is a flaw in the Federal design or construction of a project that significantly interferes with the project's authorized purposes or full usefulness as intended by Congress at the time of original project development. Corrective action, therefore, falls within the purview of the original project authority. The construction and O&M of the recommended plan can be implemented under the WRDA 1996 project authority.

DESIGN DEFICIENCY CRITERIA:

At the time of the USACE Engineer Research and Development Center (ERDC) simulations conducted for the 1995 LRR, USACE guidance for the design of two-way deep-draft navigational channels specified a minimum bank-to-ship clearance of 60 feet and a minimum ship-to-ship clearance of 80 feet. ERDC's recommendation of a maximum combined vessel beam width of less than 280 feet for two-way traffic was based on this guidance.

Two reports were developed to provide analyses of the issues in the area of concern. ERDC completed the report titled *Mental Models Expert Elicitation in Support of Identifying Project Deficiencies in the Houston Ship Channel,* dated December 2015 (2015 EE Report). This report captured an expert elicitation conducted in March and April 2015, to understand the relationships between influences that increase the risk of an incident on the HSC in the vicinity of the HSC/BSC intersection. The analysis included subject matter experts (SME) representing the Port of Houston or Houston Pilots Association membership, science and technology experts who had recently worked on or had knowledge about the HSC and similar projects, and USACE staff from the Galveston District and Southwestern Division (SWD).

USACE, Galveston completed the report titled *Empirical Data Supporting the Assessment of Design Deficiency in the Houston Ship Channel* on January 15, 2016 which used vessel-tracking data from the Automatic Identification System (AIS) to assess navigation deficiencies (2016 AIS Report). The 2016 AIS Report presents an analysis of dynamic and static vessel traffic data in the Bay Reach of the HSC to assess whether the 530-foot channel adequately supports two-way traffic for the class of vessels it was designed for, using the design guidance in place for deep-draft navigation channels at the time of the study. The objective of the analysis is to utilize historical ship traffic data to evaluate whether the 530-foot channel is performing as intended.

These two reports provided the information used to analyze the five criteria for design deficiency specified in ER 1165-2-119. Table ES 1-1 provides the analysis of the five design deficiency criteria.

The actions to improve navigation on the HSC resulted in unintended negative impacts on both the HSC and adjacent BSC. Vessels turning off the HSC into BSC are required to make two significant course changes in about a ship length; both course changes were increased with the realignment of this HSC reach.

The WRDA 1996 design makes the distance between the HSC Bend, where the 15-degree turn to starboard (right) is required to the beginning of the Flare where a 75-degree port (left) turn is required to enter the BSC, to be approximately 1.3 times the Length Overall of the containerships using the HSC. This situation violates a requirement in Engineer Manual (EM) 1110-2-1613, dated April 8, 1983, which recommends a distance of at least five times the ship length of a straight segment between successive turns. If this is not possible, then ship simulation testing is required to develop appropriate channel alignments and dimensions, which was not done in the design of the WRDA 1996 project.

The BSC/HSC intersection is designated by the U.S. Coast Guard as a “precautionary zone” under 33 CFR 161.35 *Navigation and Navigable Waters, Vessel Traffic Management, Vessel Traffic Service Houston/Galveston*, under Table 161.35(B), because of the high concentration of traffic and safety risks associated with the congestion at this intersection. There is significant risk of future collisions and the associated potential environmental impacts, which could include vessel spills.

Table ES 1-1 Proposed Corrective Action Meets Five Criteria of ER 1165-2-119

Criteria from ER 1165-2-119	Design Deficiency (Safety)	Criteria Met (Y/N)
Criteria 1 - It is required to make the project function as initially intended by the designer in a safe, viable and reliable manner.	*Channel width: Historical ship traffic data shows that when the design vessels are engaged in two-way passage in the HSC, there is at least an 80 percent incidence of either bank-to-ship clearance or ship-to-ship clearance violation. *Channel bend: Empirical data also shows the incidence of bank excursions increases by 67% to 70% in the area of concern, compared with bank excursions in the straight reaches of the channel leading to the bend. The data strongly suggests that the channel design at the bend is deficient and that the bend in the channel south of the BSC entrance exacerbates the navigation safety concerns.	Y
Criteria 2 - It is not required because of changed conditions.	Criteria 1 shows channel has not functioned as intended; this is not required because of changed condition.	Y
Criteria 3 - It is generally limited to the existing project features.	- Infringement upon the BSC by the authorized project has caused the HSC project to fail at the intersection with BSC. Coordination through Division Counsel verified that though not typical, activities can incorporate areas outside of the original footprint. The key test is that remedial measures must not change the scope of function of the authorized project. - The HSC Bend is an existing project feature.	Y
Criteria 4 - It is justified by safety or economic considerations	- Clearance violations (ship-to-ship/ bank-to-ship) occur in HSC channel and HSC Bend about 80 % of the time. - **Before the project ships traveling north on the HSC and turning into the BSC had two ship lengths between turns to stabilize themselves and plan the next turn between the starboard turn near the Five Mile Cut and the Port turn into the BSC. Recommended between-turn distance is five ship lengths. - **Once construction completed turn starts earlier (1.5 ship lengths). - U.S. Coast Guard Precautionary Zone - Frequent near misses and some collisions - It is justified by Safety Issues.	Y
Criteria 5 - It is not required because of inadequate local maintenance.	The Galveston District performs routine maintenance of the HSC as required. As such, this criterion is not applicable.	Y

**2016 AIS Report:*
***2015 EE Report*

ERDC SHIP SIMULATIONS

Prior to receiving the approval to proceed with a PDR, the area of concern was being studied under discretionary authority in an attempt to improve efficiencies in what has been designated as the area of concern. During the previous study, ERDC performed a ship simulation, documented in the report titled *Navigation Study for Bayport Flare Improvement Final Data Report*, dated February 2012 (2012 ERDC Report). The ship simulation documented in the report was not conducted to demonstrate design deficiency. A final decision to use the ship simulation for the PDR was based on the evaluation of current ship simulation capabilities balanced against the cost of analysis and expert evaluation of the anticipated model results. The ship simulations used more recent vessel types based on earlier project direction at substantial cost and time savings to the project.

Table ES-1-2 includes the vessels tested for the 1995 LRR and the design vessel used in the 2012 ERDC Report. The primary ship tested for the 2012 ERDC Report is the *Susan Maersk*, an 1130- by 140-foot container ship drafting 40 feet.

Table ES 1-2 Ship Simulation Test Ship Characteristics

ERDC Ship Simulation	**Ship Type**	**LOA (*feet*)**	**Beam (*feet*)**	**Draft (*feet*)**
ERDC 1994 Report	Bulk Carrier	775	106	39
	Tanker	920	144	39
	Bulk Carrier[1]	971	140	44
	Tanker[2]	990	156	44
	Tanker	990	156	Ballast
	Bulk Carrier	971	140	49
	Tanker	1013	173	49
ERDC 2012 Report	Container	1140	140	40

[1] *Outbound Design Vessel*
[2] *Inbound Design Vessel*

As the project evolved into a design deficiency action, the PDT and SMEs discussed conducting additional ship simulation using the design vessels from the 1995 LRR. The expert and PDT member discussion ultimately indicated that the recommended correction based on the ship simulation presented, using the larger vessel, would not be substantially different from the corrective action that would have been recommended had the smaller design vessel been used in the simulation. This conclusion was based on evaluation of previous model efforts, current vessel trajectories, and hydrodynamics in the area of the Flare. The recommended solution based on the larger vessel, if in error at all, would err on the large side, resulting in a safer channel.

PROPOSED CORRECTIVE ACTION

The 2012 ERDC Report tested six alternatives, which modified the existing Flare at the HSC confluence with the BSC. Vessels entering the BSC typically do so with tug assistance due to reduction in speed and sharp turn necessary for safe entrance into the channel. The modification to the Flare was proposed to allow larger vessels to call at Bayport and reduce the number of tugs required to make the turn. As demonstrated in the 2016 AIS Report the WRDA 1996 project, specifically the bend (HSC Bend) in the channel south of the BSC entrance, is exacerbating navigation safety concerns with the HSC.

The ERDC report recommended Alternative 3, which increased the existing 3,000 feet southern radius of the Flare to 4,000 feet, and widened the HSC by a maximum of 235 feet to the east between about HSC Station 26+484 and HSC Station 30+090 (Figure ES 1-3). This design virtually eliminates the zigzag turns required by the existing condition; i.e., making a 15-degree turn to starboard (right) and then within a ship length or two (depending on the size of the ship) making almost a 90-degree turn to port (left). The recommended design change allows a ship entering the BSC to make a smooth turn to the starboard beginning near the HSC Bend.

Ultimately, Alternative 3 provides the most improved navigation safety, is lowest cost, has the least environmental impact, and least amount of dredged material resulting from the corrective action. The recommended corrective action does not require the acquisition of real property. The approximately 1.94 million cubic yards (MCY) of new work dredged material resulting from the recommended corrective action would be placed into the existing upland confined Placement Area (PA) 14 located less than a mile from the project area. The new work material (consisting predominantly of clays) would be beneficially used for future dike raising, thus increasing the capacity of PA 14.

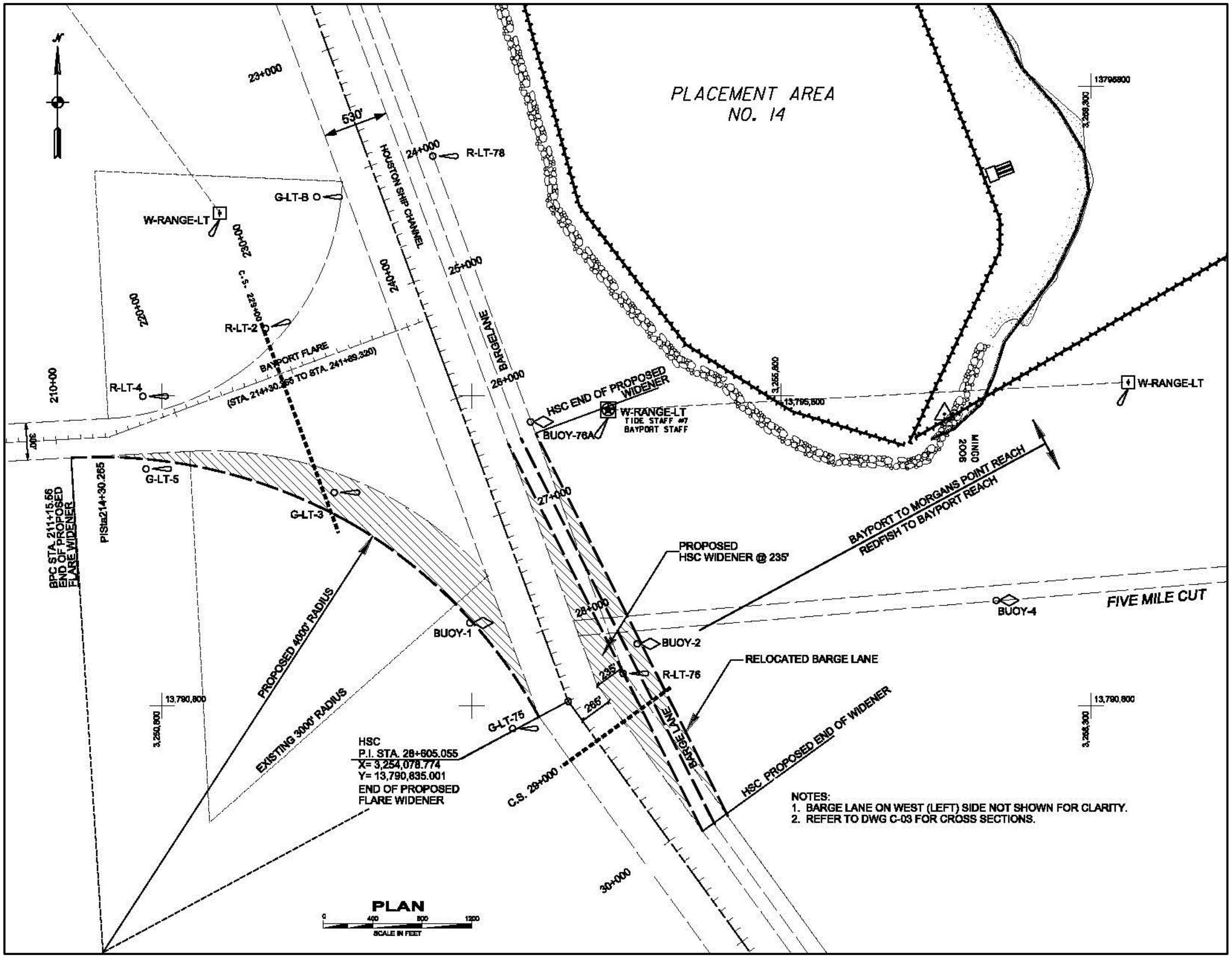

Figure ES 1-3: Plate C-02, Flare and HSC New Work Dredging Plan

The project would result in approximately 205,000 cubic yards (cy) of increased average annual O&M volumes from the Flare and approximately 23,000 cy annually from the HSC Widener. The total increase over the 20-year maintenance increment, taking into account dredging cycle lengths and number of cycles anticipated, would be approximately 4.58 MCY. The maintenance materials would be placed in nearby HSC PAs and BU sites, including existing PA 15, PA 14, Mid Bay PA, Atkinson Island BU Marsh Cells M7/8/9, and M10, as well as any other existing Atkinson Island BU Marsh Cells requiring renourishment. The future PA 15/PA 14 connection would also be utilized for maintenance. The project area would be dredged for routine maintenance at the same times and frequencies as the associated channels. The corrective action to the HSC would result in unavoidable, permanent impacts to approximately 29.9 acres of oyster reef. Functional assessment modeling determined that restoration of 30.1 acres of oyster reef on the San Leon Reef in the Clear Lake embayment of Galveston Bay, Chambers County, Texas would mitigate for the functional impacts to oyster habitat.

The estimated Project First Cost of the corrective action at October 2015 price levels is (a) $35,106,000, including a 100 percent Federal share of (b) $70,000, and non-Federal share of (c) $25,000, an estimated 75 percent Federal share of (d) $26,259,000, and an estimated 25 percent non-Federal share of (e) $8,753,000. The Fully Funded Cost of the project, which includes Project Costs and expected escalation totals, is $35,873,000. The 20-year O&M for the Flare and Widener incremental dredging is estimated at a Project First cost of $32,106,000 and a Fully Funded cost of $42,011,000.

The findings and recommendations of Houston Ship Channel Project Deficiency Report (HSCPDR) will be incorporated into the final Post Authorization Change Report addressing the 902 cost limit issues on the HGNC (*Houston-Galveston Navigation Channels, Texas, Post Authorization Change Report and Section 902 Cost Limit Determination* submitted March 2016. The approval authority resides with the Assistant Secretary of the Army (Civil Works) or ASA(CW).

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APPENDICES

FIGURES

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List of Acronyms

1994 ERDC Report	J. Christopher Hewlett, *Ship Navigation Simulation Study, Houston-Galveston Navigation Channels, Texas, Report 1 Houston Ship Channel, Bay Segment*, U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report HL-94-3, April 1994.
1995 LRR/SEIS	*Houston-Galveston Navigation Channels, Texas, Limited Reevaluation Report and Final Supplemental Environmental Impact Statement* (1995 LRR) completed in November 1995.
2012 ERDC Report	*Navigation Study for Bayport Flare Improvement Final Data Report*, February 2012.
AAHU	Annual Average Habitat Unit
2015 EE Report	Matthew D. Wood & Zachary A. Collier, *Mental Models Expert Elicitation in Support of Identifying Project Deficiencies in the Houston Ship Channel*, U.S. Army Corps of Engineers, Engineer Research and Development Center, December 2015.
2016 AIS Report	Senanu Agbley, Ph.D., P.E., *Empirical Data Supporting the Assessment of Design Deficiency in the Houston Ship Channel*, U.S. Army Corps of Engineers, Galveston District, January 15, 2016.
ACHP	Advisory Council on Historic Preservation
AIS	Automated Information System
AM	Advance Maintenance
AO	Allowable Overdepth
APE	Area of Potential Effect
ASA(CW)	Assistant Secretary of the Army for Civil Works
BA	Biological Assessment
BSC	Bayport Ship Channel
BU	Beneficial Use
BUG	Beneficial Use Group
CAA	Clean Air Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CHL	Corps of Engineers Coastal Hydraulic Laboratory
Corps	U.S. Army Corps of Engineers
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DDNPCX	The Deep Draft Navigation Planning Center of Expertise

DMMP	Dredged Material Management Plan
EA	Environmental Assessment
EFH	Essential fish habitat
EL	Elevation
EM	Engineer Manual
EPA	U.S. Environmental Protection Agency
ER	Engineer Regulation
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
FHWA	Federal Highway Administration
FWOP	Future Without-Project
FY	fiscal year
HGNC	Houston-Galveston Navigation Channels
HPA	Houston Pilots Association
HSC	Houston Ship Channel
HSCPDR	Houston Ship Channel Project Deficiency Report
HTRW	Hazardous, Toxic and Radioactive Waste
LCA	Local Cooperation Agreement
LOA	Length Overall
LOE	Lines of Evidence
MCACES	Micro Computer Aided Cost Engineering System
MCY	million cubic yards
MLLW	mean lower low water
MLT	mean low tide
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and maintenance
P&G	Principles and Guidelines
PA	placement area
PAL	Planning Aid Letter
PCA	Project Cooperation Agreement
PCBs	Polychlorinated Biphenyls
PDR	Project Deficiency Report
PHA	Port of Houston Authority

P.I.	Point of Intersection
PPX	Post-Panamax Vessels
PX1	First Generation Panamax
PX2	Second Generation Panamax
PPX1	First Generation Post-Panamax
PPX2	Second Generation Post-Panamax
PX	Panamax
RPEC	Regional Planning and Environmental Center
RSLC	Relative Sea Level Change
SHPO	State Historic Preservation Officer
SPX	Sub-Panamax
SIP	State Implementation Plans
TCEQ	Texas Commission on Environmental Quality
TCOON	Texas Coastal Ocean Observation Network
T&E	Threatened and Endangered
TEU	Twenty-Foot Equivalent Units
TMDL	Total Maximum Daily Load
TPWD	Texas Parks and Wildlife Department
TSCA	Toxic Substances Control Act
TxGLO	Texas General Land Office
TXNDD	Texas Natural Diversity Database
USACE	United States Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WCSC	Waterborne Commerce Statistics Center
WES	U.S. Army Engineer Waterways Experiment Station
WOE	Weight of Evidence
WRDA 1996	Water Resources Development Act of 1996

1 INTRODUCTION

1.1 Purpose and Need

The Houston Ship Channel (HSC) contains a deficiency inherent in the design in the *Houston-Galveston Navigation Channels, Texas, Limited Reevaluation Report and Final Supplemental Environmental Impact Statement* completed in November 1995 (1995 LRR/SEIS). The Houston-Galveston Navigation Channels, Texas, Project (HGNC) was authorized in the Water Resources Development Act of 1996 (WRDA 1996), Section 101(a)(30), P.L. 104-303. The channel design for the HGNC did not fully account for impacts of the channel improvements within the HSC in the vicinity of the Bayport Ship Channel (BSC). Recent analyses have shown the HGNC Project is not performing as intended in the vicinity of the HSC intersection with the Bayport Ship Channel (BSC). Increased traffic and vessel size afforded by the channel improvements authorized by WRDA 1996 has increased the potential for collisions and accidents within this section of the HSC. The intersection of the HSC and BSC has been a major safety concern since construction of the Houston portion of the 45-foot project was completed in 2005.

The purpose of the proposed project is to correct a design deficiency and conduct a corrective action through a channel modification required to make the project function on an interim basis as initially intended in a safe, viable, and reliable manner.

Additional improvements will be evaluated under the upcoming feasibility study of the HSC, including Galveston Bay to address potential channel widening, passing lanes, and anchorage areas. The study will be conducted under the authority of Section 216 of the Flood Control Act of 1970, Review of Completed Projects. This Project Deficiency Report (PDR) will document the scope of the plan to alleviate the immediate and ongoing navigation safety concerns in the vicinity of the intersection of the HSC and BSC.

1.2 HGNC Project Authority

The HGNC Project was constructed as a multipurpose project with two separable elements, the HSC and the Galveston Channel. The two project purposes are to provide navigation improvements to the ports of Houston and Galveston, and to provide environmental restoration for the Houston portion of the Project through the beneficial use (BU) of dredged material. Construction of the HSC portion of the project was completed by 2005 (fiscally completed in 2007), while the Galveston Channel was completed in 2011.

The project is located in the Galveston Bay system in Galveston, Harris and Chambers Counties, Texas. The total Project (Figure 1-1) provides for a 45-foot mean low tide (MLT) Houston and Galveston Channels by:

- Extending the Entrance Channel an additional 3.9 miles to the 47-foot bottom contour in the Gulf of Mexico along the existing alignment,
- Deepening the Entrance Channel to 47 feet over its 800-foot width and 10.5 mile length,
- Enlarging the HSC to a depth of 45 feet and a width of 530 feet from Bolivar Roads to Boggy Bayou, plus wideners on curves, and
- Enlarging the Galveston Channel (excluding the last 2,571 feet at the most westward end) to a depth of 45 feet and a width, which varies between 650 and 1,112 feet.

The project also allowed for up to 4,250 acres of marsh located in mid and upper Galveston Bay, and a 12-acre bird island located in East Galveston Bay (Evia Island). Of the 4,250 acres of marsh restoration, 690 acres were constructed as part of the initial navigation channel improvements and the remaining acres were deferred for future channel maintenance dredging cycles. Mitigation features include construction of 172 acres of oyster reef and planting of 0.86 acres of trees for a bird rookery adjacent to Alexander Island Placement Area (PA).

The HGNC Project was authorized in WRDA 1996, Section 101(a)(30), P.L. 104-303 at a total cost of $298,334,000 ($197,237,000 Federal and $101,097,000 non-Federal).

> *(30) Houston-Galveston Navigation Channels, Texas. – "The project for navigation and environmental restoration, Houston-Galveston Navigation Channels, Texas: Report of the Chief of Engineers, dated May 9, 1996, at a total cost of $298,334,000, with an estimated Federal cost of $197,237,000 and an estimated non-Federal cost of $101,097,000, and an average annual cost of $786,000 for future environmental restoration over the 50-year life of the project, with an estimated annual Federal cost of $590,000 and an estimated annual non-Federal cost of $196,000. The removal of pipelines and other obstructions that are necessary for the project shall be accomplished at non-Federal expense. Non-Federal interests shall receive credit toward cash contributions required during construction and subsequent to construction for design and construction management work that is performed by non-Federal interests and that the Secretary determines is necessary to implement the project."*

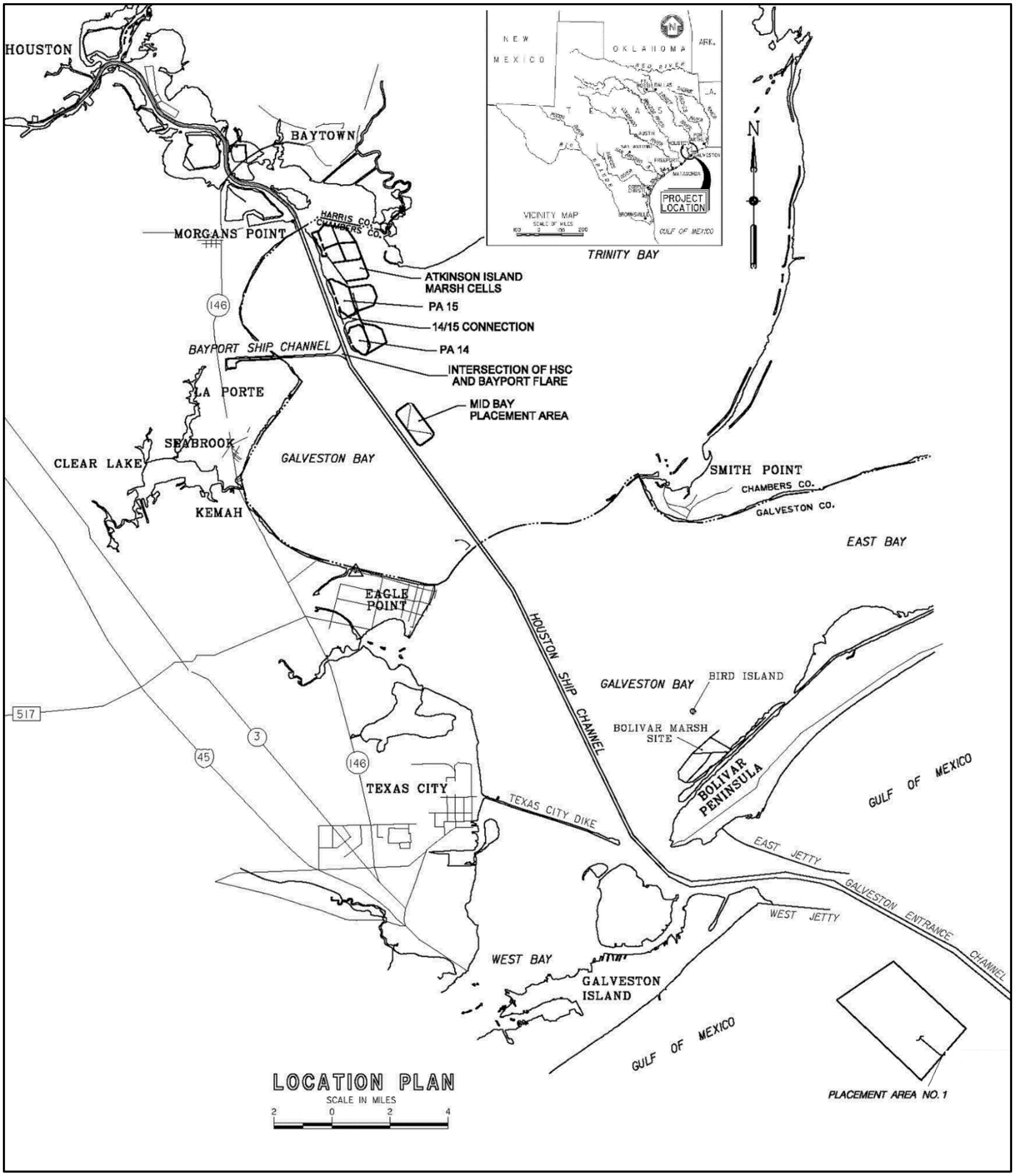

Figure 1-1: Plate No. 2, Houston-Galveston Navigation Channels, Texas Project

Based on the criteria in Engineer Regulation (ER) 1165-2-119 (*Modifications to Completed Projects)*, the construction required for the corrective action recommended in this report is authorized under the existing project authority for the WRDA 1996 Project. The referenced ER states that a design or construction deficiency is a flaw in the Federal design or construction of a project that significantly interferes with the projects authorized purposes or full usefulness as intended by Congress at the time of original project development. Corrective action, therefore, falls within the purview of the original project authority.

The ER also states that construction to correct a design deficiency should be limited to the necessary corrective work and should be consistent with original project purposes at the time of original construction. The corrective action recommended in this report specifically stays within the design intent of the original project. This corrective action will be shown to meet all the conditions of eligibility to be constructed under the original project authority. These five eligibility requirements are listed in ER 1165-2-119 and are specifically addressed in Section 2.0 Conditions for Recommending Corrective Action.

1.3 Authority to Address Navigation Safety Issue on HSC

There was a significant amount of coordination with the Headquarters, U.S. Army Corps of Engineers (HQ USACE) on the authority to address the navigation issues on the HSC in the vicinity of the BSC. An assessment of the various authorities was made to determine whether the proposed work could be accomplished within the existing WRDA 1996 Project authority or whether additional authority is required. Authorities investigated include those identified in Chapter 8, Engineer Regulation (ER) 1130-2-520, *Navigation and Dredging Operations and Maintenance Policies*, dated November 29, 1996, which states that "increases in navigation channel dimensions at entrances, bends, sidings, and turning places within a project to allow for free movement of boats shall be in accordance with the provisions of:

- Section 5 of the Rivers and Harbor Act of March 14, 1915 (33 USC 562),
- Section 117 of the Rivers and Harbor Act of August 13, 1968, PL 90-483 (33 USC 562a),
- Section 3 of the Rivers and Harbor Act of 1945 (33 USC 603a), or
- Section 224 of PL 102-580, (WRDA 1992), amended 33 USC 562, and shall be approved by HQ USACE.

It was determined that the aforementioned authorities are general Operation and Maintenance (O&M) authorities applicable only to the federally improved project. Although the design negatively affected the BSC, these authorities cannot be used to correct navigation safety issues on a non-federally improved project.

Generally, new authorization is required for the modification of completed projects; however, ER 1165-2-119, *Modifications to Completed Projects*, dated September 20, 1982, provides an exception for work to correct a design or construction deficiency.

A White Paper dated May 4, 2015 (see Appendix E – Pertinent Documents), was coordinated through HQ USACE. The paper presented the details of the navigation safety issues on the HSC since its construction was completed in 2005 (fiscally complete in 2007), and the District's recommendation to proceed with a project deficiency report under the authority of Section 216 of the Flood Control Act of 1970, Review of Completed Projects.

1.4 Implementation Guidance

The Galveston District received concurrence by memorandum dated April 1, 2015, from the Director of Civil Works, to proceed with a Project Deficiency Report (PDR) to address a design deficiency on the HSC and recommend a corrective action (see Appendix E – Pertinent Documents).

The HGNC Project is classified as a completed Federal project. Therefore, ER 1165-2-119 applies to the HGNC project modification. The construction, and O&M of the recommended plan can be implemented under the WRDA 1996 project authority.

The findings and recommendations of Houston Ship Channel Project Deficiency Report (HSCPDR) will be incorporated into the final Post Authorization Change Report addressing the 902 cost limit issues on the HGNC (*Houston-Galveston Navigation Channels, Texas, Post Authorization Change Report and Section 902 Cost Limit Determination* dated in-process). The approval authority resides with the Assistant Secretary of the Army (Civil Works) or ASA(CW).

1.5 Project Location (Site of Deficiency)

The location of the identified deficiency is situated along the HSC segment that crosses Galveston Bay between Redfish Reef to the south and Morgans Point to the North. Specifically, it is located northwest of the Mid Bay PA in the vicinity of the intersection between the HSC (between HSC Station 30+000 and HSC Station 23+000) and the BSC as shown in Figure 1-2.

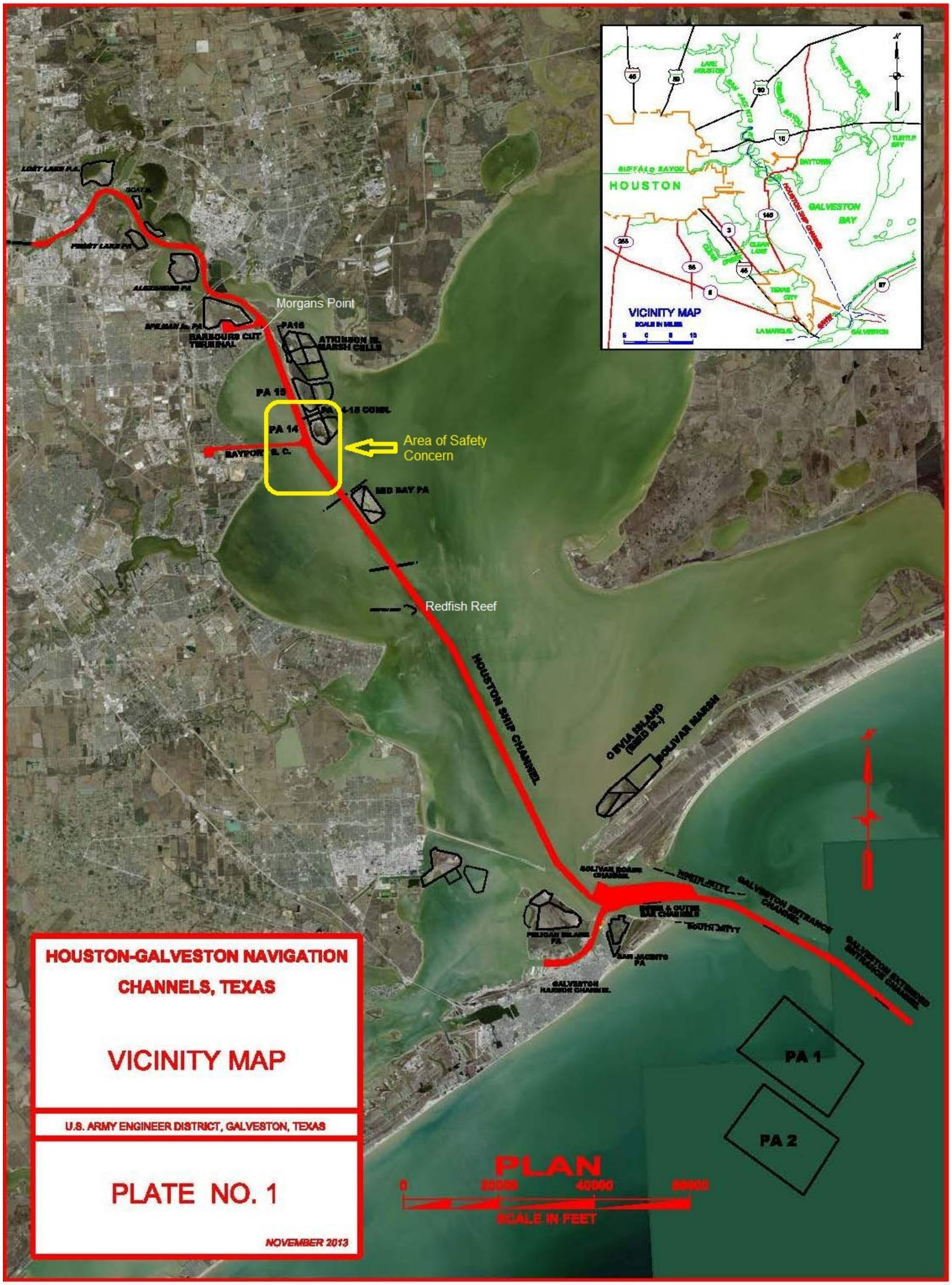

Figure 1-2: Plate No. 1, HGNC Project Map with Approximate location of Area of Concern

The study area is located in the Texas Congressional Districts within Galveston, Harris and Chamber Counties, Texas. The Congressional delegation is composed of:

Senator John Cornyn
Senator Ted Cruz
Representative Brian Babin (TX-36)
Representative Ted Poe (TX-02),
Representative John Culberson (TX-07)
Representative Al Green (TX-09)
Representative Randy Weber (TX-14)
Representative Sheila Jackson-Lee (TX-18)
Representative Pete Olson (TX-22)
Representative Gene Green (TX-29)

1.6 Related Reports and Studies

An investigation was performed by the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) for the 1995 LRR/SEIS study. The Technical Report HL-94-3, titled *Ship Navigation Simulation Study, Houston-Galveston Navigation Channels, Texas, Report 1, Houston Ship Channel, Bay Segment*, dated April 1994, addresses the simulations conducted for the project area (1994 ERDC Report) during the 1995 LRR Study.

The study for the 45-foot Houston and Galveston Channels is documented in the 1995 LRR/SEIS for the HGNC project; the project authorized in WRDA 1996. Subsequent to the WRDA 1996 authorization, the Energy and Water Development Appropriations Act, 2001, as enacted by Section 1(a)(2) of Public Law 106-377, authorized Barge Lanes to be constructed on either side of the HSC. Coordination for the barge lanes in the project area is documented in the *Final Environmental Assessment, Houston-Galveston Navigation Channels, Texas, Project, Upper Bay Barge Lanes,* dated January 2003.

The BSC, constructed in the late 1960's to the mid 1970's, is currently being improved under the Port of Houston Authority (PHA) BSC Improvements Project, which was documented in the BSC Improvements Project 33 United States Code (USC) Section 408 and Section 204(f) of WRDA 1986 Environmental Assessment (EA).

The *Final Environmental Assessment, Expansion of Placement Areas 14 and 15, Houston Ship Channel, Chambers County, Texas*, dated January 2010, documents more localized information around the PAs being proposed for use in this project.

The Corps Coastal Hydraulic Laboratory (CHL), a part of the Engineer Research and Development Center (ERDC), located at WES, performed simulations to address the HSC navigational safety issues near the intersection of the BSC. The February 2012 report, *Navigation Study for Bayport Flare Improvement Final Data Report* (2012 ERDC Report) results showed the composite track plots for each of the alternatives considered for alleviating the safety issue. The ERDC report recommended increasing the existing southern radius of the Flare from 3,000 feet to 4,000 feet, and widening the HSC by a maximum of 235 feet to the east between about HSC Station 26+484 and HSC Station 30+090.

An Expert Elicitation was conducted in March and April 2015, with Subject Matter Experts (SMEs) affiliated with Houston Pilots Association, Port of Houston, USACE Galveston, Southwestern Division, and researchers from ERDC, as well as private consultants who had done work in support of the HSC and its tributary channels. As documented in ERDC's final December 2015 report, *Mental Models Expert Elicitation in Support of Identifying Project Deficiencies in the Houston Ship Channel (2015 EE Report)*, one key finding is the identification of a design deficiency on the HSC from the turn at Five Mile Cut to the Bayport Flare.

Galveston District completed a report in January 15, 2016 titled *Empirical Data Supporting the Assessment of Design Deficiency in the Houston Ship Channel* (2016 AIS Report). The report presents an analysis of dynamic and static vessel traffic data in the Bay Reach of the HSC to assess whether the 530-foot channel adequately supports two-way traffic for the class of vessels it was designed for, using the design guidance in place for deep-draft navigation channels at the time of the study. The report conclusions drawn from the analysis suggest there is a design deficiency for the class vessels for which the channel was designed and the channel design at the bend is deficient; the bend in the channel south of the BSC entrance exacerbates the navigational safety concerns, and has resulted in unintended negative impacts on the adjacent BSC.

1.7 Report Scope and Content

This PDR and EA are prepared in accordance with ER 1165-2-119 *Modifications to Completed Projects*, ER 1105-2-100 *Planning Guidance Notebook, Principles and Guidelines* adopted by the Water Resources Council, Council on Environmental Quality (CEQ) regulations and guidance for implementation of the National Environmental Policy Act (NEPA), and ER 200-2-2 *Procedures for Implementing NEPA*

This PDR presents available information related to:

- Existing conditions in the vicinity of the intersection between the HSC and the BSC.
- Problem identification
- Recommended corrective action
- Environmental effects of recommended corrective action and impacts
- Public involvement and agency coordination

1.8 Study Participants

The PHA is the non-Federal sponsor for the environmental restoration features and the navigation improvements to the HSC. The ERDC Risk Integration Team Environmental Risk Assessment Branch developed the Lines of Evidence (LOE)/Weight of Evidence (WOE) Report used for this PDR and included as an appendix to the EA. The PDR was prepared by Galveston District. The EA was prepared by the PHA. The National Deep Draft Navigation Planning Center of Expertise (DDNPCX) performed the Agency Technical Review on the PDR, EA, and Appendices.

1.9 Nomenclature

Advance Maintenance (AM). This consists of dredging deeper than the authorized channel dimensions to provide for the accumulation and storage of sediment. In critical and fast-shoaling areas, it is required to avoid frequent re-dredging and to ensure the reliability and least overall cost for operating and maintaining the project authorized dimensions.

Allowable Overdepth (AO). An additional depth outside the channel template is permitted to allow for inaccuracies in the dredging process.

Flare. The term "Flare" will be used in this report to indicate the Flare at the intersection of the HSC and BSC.

Non-Pay Dredging. This is dredging outside the channel template that may occur due to such factors as unanticipated variations in substrate, incidental removal of submerged obstructions, or wind or wave conditions.

Station. The term "Station" refers to a horizontal distance in feet measured along the centerline of the channel. It is used to indicate the relative location of a particular portion of the channel. HSC station numbers are preceded with "HSC". BSC station numbers will be preceded by "BSC" to differentiate between stationing for the HSC.

Reaches. In the 1995 LRR/SEIS the project was broken up into four reaches (Figure 1-3). To alleviate confusion those reaches are defined below:

1. Offshore Reach – the common entrance channel;
2. Galveston Channel Reach – the separable channel to the Port of Galveston;
3. Bay Reach – the portion of the HSC which crosses Galveston Bay to Morgans Point; and
4. Bayou Reach – the portion of the HSC extending from Morgans Point, up the San Jacinto River and Buffalo Bayou to Boggy Bayou.

The HSCPDR /EA is specific to the Bay Reach portion of the HSC.

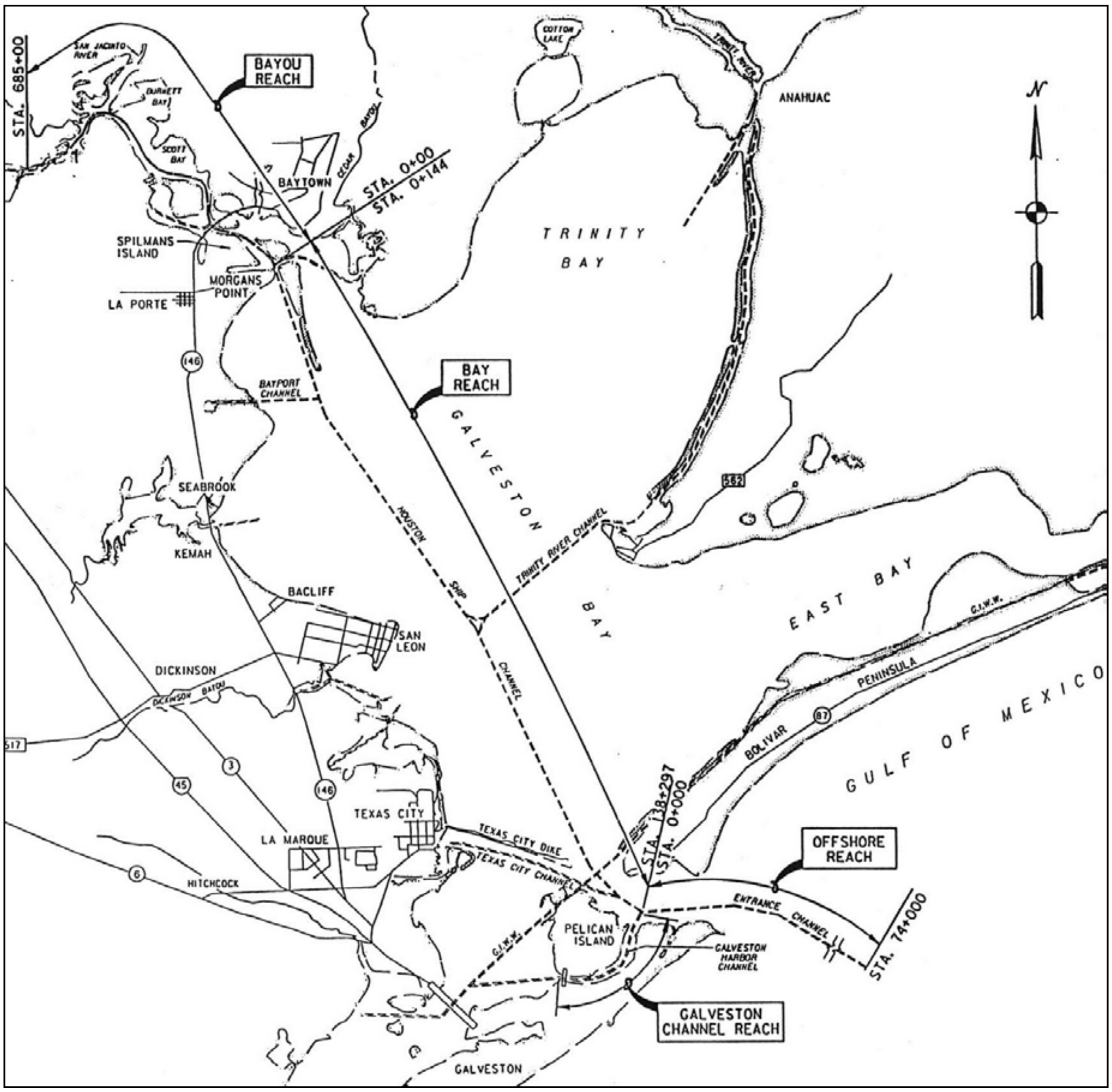

Figure 1-3: Four Reaches of the HGNC, Texas Project (WRDA 1996 Project)

HSC Bend. The term "HSC Bend" in this report refers to the existing 15-degree turn (bend) in the HSC that resulted from the construction of the WRDA 1996 project. The bend existed prior to the WRDA 1996 project; however, the WRDA 1996 project increased the bend by 2.5 degrees away from Morgans Point, exacerbating its effect on the HSC. The HSC Bend is located at HSC Point of Intersection (P.I.) Station 28+605.06.

Hazardous Condition. As per 33 CFR 160.215, the term "hazardous condition" is defined broadly, to include "any condition that may adversely affect the safety of any vessel…": Hazardous condition means any condition that may adversely affect the safety of any vessel, bridge, structure, or shore area or the environmental quality of any port, harbor, or navigable waterway of the United States. It may, but need not, involve collision, allision, fire, explosion, grounding, leaking, damage, injury, or illness of a person aboard, or manning-shortage.

1.10 Datum and Tidal Information

The SWG Engineering Documentation Report dated June 2015, titled *MLT to MLLW Vertical Datum Conversion: Galveston Harbor, Texas City Ship Channel, Houston Ship Channel*, is included in the Engineering Appendix. Following the dual convention of the Engineering Appendix the datums will be listed with the Mean Lower-Low Water (MLLW) datum first, with the Mean Low Tide (MLT) datum in parenthesis. Elevations, which are not indicated as dual, are MLT.

The Galveston District recently converted the HSC to the MLLW datum, and for all future dredging contracts, the MLLW datum will be used. The MLLW datum adjustment in the project vicinity is 1.47 feet plus MLT at the Texas Coastal Ocean Observation Network (TCOON) gage at Morgans Point, Texas, located roughly five miles north of the BSC. This elevation difference varies along the length of the HSC. For additional information on datum conversions, reference Engineer Manual (EM) 1110-2-6056.

Tides in the study area range from an ebb tide of -1.2 feet MLLW to a high flood tide of 1.7 feet MLLW (at National Oceanic and Atmospheric Administration (NOAA) Station 8770613, Morgans Point, Texas)). The mean tide range at Morgan's Point is 1.13 feet, and the diurnal range is 1.31 feet.

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2 CONDITIONS FOR RECOMMENDING CORRECTIVE ACTION

This Chapter presents the analysis of project deficiency criteria outlined in ER 1165-2-119 Paragraph 7a. Analysis included the 1995 LRR, supporting appendices, ERDC ship simulations, 2015 EE report, and 2016 AIS Report. The analysis showed that all five of the project deficiency criteria are met at this reach of the HSC.

2.1 Criteria 1 – It is required to make the project function as initially intended by the designer in a safe, viable, and reliable manner.

2.1.1 Intended Condition

In 1987, the Galveston District proposed a phased improvement plan for the HSC. The Phase I channel was proposed to be 530 feet wide and 45 feet deep. The intent of the improvement plan was to allow for safe two-way traffic in order to ease congestion in the channel. Towards this end, ship simulations were conducted at WES to test various combinations of vessel sizes to determine the types of vessels that could safely meet and pass in the HSC. At the time of the ship simulation study, USACE guidance for the design of deep-draft navigation channels for two-way traffic specified that vessels meeting and passing should have a minimum ship-to-ship clearance of 80 feet and a minimum ship-to-bank clearance of 60 feet for both vessels. The WES study concluded that the Phase I channel could safely handle two-way traffic for vessels having a combined beam width of 280 feet or less. Based on the WES study's recommendations, the Phase I project was designed, authorized, and constructed with the intention to accommodate the meeting and passing of vessels whose combined beam width is 280 feet or less.

2.1.2 Actual Project Performance

Construction of the Phase I channel was completed in 2005. Since then, several accidents and near miss events have been recorded or reported (see Section 2.4.2). These incidents involve vessels meeting and passing in the HSC, especially the channel reach just north of the turn at Five Mile Cut, in the vicinity of the BSC confluence. These incidents led to concerns surrounding the adequacy of the channel to safely handle two-way traffic, as intended.

To better understand these navigational safety concerns, an expert elicitation survey was conducted by ERDC ("2015 EE Report"). The study involved 13 subject matter experts (ship pilots, navigation engineers/scientists, and USACE staff) who had recently worked on or had knowledge about the HSC and similar projects. Among the concerns raised by the expert elicitation, a key safety concern raised was that the vast majority of incidents of two-way traffic, i.e., vessels meeting and passing each other in the vicinity of the Bayport Flare, could be classified by industry standards as near-miss events.

To ascertain that the high incidence of near-miss events identified in the expert elicitation was a result of a design deficiency, a quantitative analysis of project performance was conducted by SWG ("2016 AIS Report). Using AIS data, the statistics of ship and bank clearances were analyzed for instances where two vessels with a combined beam width of 280-feet or less (the vessel classes for which the project was designed) met and passed each other in the project area (the intended project function). The results from the AIS data analysis show that at least 80 percent of the time, the passing vessels violated the minimum clearances stipulated for safe navigation. In other words, the project does not function as intended 80 percent of the time.

2.2 Criteria 2 – It is not required because of changed conditions.

The Phase I Project was designed to allow for safe two-way passage for vessels having a combined beam width of 280 feet. The design guidance at the time of the study specified that vessels meeting and passing should have a minimum ship-to-ship clearance of 80 feet and a minimum ship-to-bank clearance of 60 feet for both vessels. The AIS data analysis focused solely on the class of vessels the channel was designed for and the design guidance in place at the time of the study. The project deficiencies identified by the AIS report are therefore not the result of changed conditions.

2.3 Criteria 3 – It is generally limited to the existing project features.

The recommended corrective action in the area of concern includes a bend easing (widening) on the east side of the HSC and increasing the radius of the Flare at the intersection of the HSC and BSC. While the Flare was not specifically a feature of the WRDA 1996 authorized project and was not designed by USACE, infringement upon the BSC by the authorized project has caused the HSC project to fail at the intersection. Coordination through Division Counsel verified that though not typical, activities can incorporate areas outside of the original footprint. The key test is that remedial measures must not change the scope of function of the authorized project. All features addressed by the corrective action are existing features.

2.4 Criteria 4 – It is justified by safety or economic considerations.

The corrective action addresses navigation safety concerns within the HSC, both for vessels turning into the BSC and vessels continuing along the HSC. Vessels turning must reduce their vessel speed, which reduces control of the vessel. Other vessels within the HSC must in turn reduce their speed to respond to the turning vessels. Corrective action will improve vessel maneuverability through the area, reduce the required zigzag turn into the BSC, lessen the tendency of vessels to veer from intended and safe course, and reduce the congestion on the HSC. Therefore, this reduces the risk of collisions and groundings from the vessels reducing speed and losing maneuverability during meeting/passing maneuver, which was considered the most critical navigation concern in the bay section.

2.4.1 Codified as a Precautionary Zone by the U.S. Coast Guard (USCG)

The USCG has identified the vicinity of the HSC/BSC intersection as a "precautionary zone". This zone is codified in the Federal Code of Regulations 33 CFR Section 161.35 Navigation and Navigable Waterways, Vessel Traffic Management, Vessel Traffic Service Houston/Galveston. This zone is an area within a 4,000-foot-radius of a center point of latitude 29 degrees, 36.7 feet N and longitude 94 degrees, 57.2 feet W (the intersection of the HSC and BSC). A precautionary zone is defined as "a routing measure comprising an area within defined limits where vessels must navigate with particular caution and within which the direction of traffic may be recommended.

2.4.2 Collisions and Close Calls

The May 2015 White Paper, 2015 EE Report, and 2016 AIS Report consistently identify the safety impacts of vessels transiting the HSC in the vicinity of the HSC Bend and intersection with the BSC. These unsafe conditions have existed since the widening and deepening of the HSC was completed. Non-structural implementations have not resolved the safety issues.

There have been two significant reportable accidents in the project vicinity (*Elka Apollon*/*MSC Nederland*, and the *MV Conti Peridot* and the *MT Carla Maersk*) since 2005. As noted in interviews with the Houston Pilots and with USCG, not all incidents on the waterway are formally reported, such as near misses etc. The 2011 *MSC Nederland* has a full report conducted by the National Transportation Safety Board (NTSB). However, the report for the March 2015 accident between the *MV Conti Peridot* and *Carla Maersk* will take another year to complete.

A collision occurred between the *MSC Nederland* (container ship with a 777-foot length and 106-foot beam) and the *Elka Apollon* (a chemical tanker with a 799-foot length and a 138-foot beam) on October 29, 2011. The *MSC Nederland* was a loaded container vessel traveling inbound on the HSC to the BSC. The chemical tanker ship *Elka Apollon* was carrying over 14 million gallons of naphtha, a highly volatile flammable liquid and was traveling outbound on the HSC. The two ships planned to meet and pass south of the BSC intersection before the *MSC Nederland* made the turn into the BSC. The pilot of the inbound *MSC Nederland* planned to let the *Elka Apollon* pass before turning to port into the BSC. The pilot conning the *Elka Apollon* ordered a series of rudder commands as the vessel transited the intersection of the two channels and approached the *MSC*

Nederland. A towboat, the *Mr. Earl*, underway in the vicinity and pushing an empty barge, was exiting the BSC as the *Elka Apollon* was passing. As the distance between the *Elka Apllon* and the *MSC Nederland closed*, the *Elka Apollon* crossed the centerline of the HSC and subsequently struck the port side of the *MSC Nederland*. The NTSB determined that the probable cause of the collision between the *Elka Apollon* and the *MSC Nederland* was the failure of the pilot conning the *Elka Apollon* to appropriately respond to changes in bank effects as the vessel transited the Flare on the outbound voyage on the HSC, causing the vessel to sheer across the channel and collide with the *MSC Nederland*. Contributing to the accident was the combination of the narrow waterway, bank effects at the Flare and traffic density at the time, which increased the challenges in a waterway with limited margin of error.

2.4.3 Hazardous Cargo

Approximately 78 percent of the cargo that calls on the Port of Houston is considered hazardous. This includes petroleum and chemical ships and barges as well as some containerized cargo. All calls at PHA pass through the area of the design deficiency. Given the volume of cargo classified as hazardous that utilizes the HSC, the stakes are extremely high. Collisions and other incidents carry the potential for the spillage of hazardous chemical cargo, which could result in environmental degradation, possible health risks, and economic losses. A collision that results in a breach of any of the hulls carrying these goods could have a catastrophic effect on the environment not seen since the Exxon Valdez.

2.4.4 Loss of refinery capacity due to channel closure.

Approximately 216,000 gallons of methyl tertiary butyl ether (MTBE) was released during the March 2015 collision between the *MV Conti Peridot* and the *MT Carla Maersk*. This resulted in the closure of the HSC for three days, as well as the imposition of restrictions on facilities operating upstream on the HSC. The ensuing gridlock, consisting of 48 inbound vessels and 35 outbound vessels that were unable to enter or leave the HSC, limited delivery of crude oil to five refineries with a combined capacity of 1.34 million barrels per day, and export from docks that turned over 600,000 barrels/day of propane and other refined products. The gridlock forced refineries to reduce production; Exxon Mobil was forced to cut oil-refining activity at its Baytown, Texas refinery because of the disruption in its oil supply. It should be noted that the Exxon Mobil Baytown refinery is the second largest petrochemical complex in the U.S. Any disruption in shipping activity resulting from closure of the HSC will have major economic impacts with serious consequences for the U.S. economy.

2.5 Criteria 5 – It is not required because of inadequate local maintenance.

The Galveston District performs routine maintenance of the HSC as required. As such, this criterion is not applicable.

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3 EXISTING CONDITIONS

3.1 Project Description in the Area of Safety Concern

The location of the identified deficiency is situated along the HSC segment that crosses Galveston Bay between Redfish Reef to the south and Morgans Point to the north. It is in the vicinity of the intersection between the HSC (between HSC Station 30+000 to HSC Station 23+000) and the BSC (Figure 3-1).

Figure 3-1: Aerial with Existing Condition in Area of Safety Concern

The HSC is constructed to a 45-foot authorized depth with a bottom width of 530 feet. The channel runs in a relatively straight course from around Eagle Point (see Figure 1-1) up to the HSC Bend. There is an approximate 15-degree bend or turn at HSC Point of Intersection (P.I.) Station 28+605.055; after which, the channel continues on a straight course to Morgans Point. Just north of the HSC Bend the Five Mile Cut shallow draft channel connects to the HSC just south of the BSC (40-foot authorized depth) and runs eastward. The Five Mile Cut channel dimensions are 8 feet deep by 125 feet wide. Barge lanes authorized to 125 feet wide by 12 feet deep are located immediately adjacent to and on either side of the HSC.

At the intersection of the HSC and BSC, the Flare has a non-tangential south radius of 3,000 feet and a non-tangential north radius of 2,000 feet due to implementation of the WRDA 1996 project; specifically, the 45-foot HSC completed in 2005. The Flare bottom width varies with the widest width approximately 3,394 feet at its union with the HSC and tapering to 300 feet at the union with the BSC. The Flare is currently maintained at a depth of 40.1 feet MLLW (40 feet MLT) with a 7-foot AM making the maintained depth at minus 48.5 feet MLLW (-47 feet MLT). The HSC at the intersection is currently maintained at a depth of 46.5 feet MLLW (45 feet MLT) with a 2-foot AM, making the maintained depth at minus 48.5 feet MLLW (-47 feet MLT). On each side of the HSC is the shallow-draft barge lane, which is currently maintained at a depth of 13.5 feet MLLW (12 feet MLT) with a bottom shelf width of 130 feet.

Maintenance material in this area has been historically placed in PA 14, PA 15, and Mid Bay PA and is expected to be available for marsh fill in Atkinson Island Marsh Cells M7/8/9, and M10, as well as any other existing Atkinson Island Marsh Cells requiring renourishment.

Table 3-1 provides a comparison of the HSC PA/BU sites located in the vicinity (within about 6.5 miles) of the proposed project area and provides the respective average pumping distance to the area of the safety concern, and whether the PA/BU site is available based on available capacity and any environmental constraints. Based on these properties it was determined the least cost available placement would be PA 14.

Table 3-1: Comparison of PA/BU Properties

Placement Area	Type	Average Pumping Distance (mi.)	Available Capacity	Environmental Constraints	Availability
Spilman Island	UC*	7.5	No	None	No**
PA 15	UC*	2.7	No	None	No**
PA 14	UC*	1.5	Yes	None	Yes
Mid Bay	UC*	4	Yes	None	Yes
Atkinson Island Marsh Cells M7/8/9	BU	3	No	Sediment Testing Required	Yes
Atkinson Island Marsh Cell M10	BU	1.75	No	Sediment Testing Required	Yes

**Upland Confined*

***Not Available during new Work Project Construction Period*

3.2 Environment and Cultural Resources in the Area of Safety Concern

A detailed description of the environment in the project area for the proposed corrective action is provided in the EA in Appendix A. The following summarizes the environmental conditions in the project area.

The project area is in the open water of upper Galveston Bay, which is a shallow estuary with a depth that varies approximately 6 to 9 feet. The bay bottom in the project area is comprised primarily of soft, un-vegetated bottom overlying native geological deposits of mostly stiff clays, with some sands and silts. Extensive oyster reef is also present, primarily along the margins of the HSC and BSC. The proposed project footprint is mostly within this oyster reef extent (approximately 29.9 acres), with a minority of the area, soft un-vegetated bay bottom.

Of the federally listed species listed for Chambers County, only Kemp's Ridley sea turtle, loggerhead sea turtle, and green sea turtle are likely to be present in Galveston Bay and in the project area in particular, only as transient species, given the habitat types present. Other marine species listed for the County, such as West Indian manatee would only occur as very rare transients.

Many species of fish and shellfish reside in the project area including Atlantic croaker, Gulf menhaden, Hardhead catfish, Blue crab, and brown shrimp. Galveston Bay, including the project area, is designated Essential Fish Habitat (EFH) for a variety of species, including Red drum, Gray snapper, Spanish mackerel, and brown, pink and white shrimp. The bay supports an important commercial and recreational fishery for many species, including the aforementioned species and others, such as Black drum, flounder, Spotted sea trout, and oysters. Dolphins are the only marine mammals expected to regularly occur in Galveston Bay.

The project area is in the State Water Quality Segment 2421 designated as fully supporting aquatic life use, recreational use, and general use. Other nutrients screened such as nitrate, chlorophyll-a, and total phosphorus have a concern for water quality based on screening levels. Fish consumption is not supported due to Polychlorinated biphenyl (PCB) and dioxin in edible fish tissues, and two Total Maximum Daily Load (TMDL) studies are in progress for these issues. However, it should be noted that extensive sediment testing in the project area (discussed in EA Section 3.1.5.2), does not indicate local impairment of sediments for these or other compounds.

Galveston Bay's pre-contact history is influenced primarily by Paleoindian settlement and use, evident in cultural remnants such as shell middens, and projectile points, and then more modern Native American groups such as the Atakapa and the Karankawa. Post-contact history is influenced in the early period by Spanish and French explorers, merchants, and missionaries, including the pirate Jean Lafitte, and in later periods by settlement of Texas by colonists from the U.S. and other countries, and activity during the Civil War. Such activity in the Bay would be expected to be evident by vessels and their cargo. The proposed project's Area of Potential Effect (APE) was surveyed for cultural resources, including remote sensing surveys, with no resources found.

3.3 Existing Economic Conditions

TONNAGE

The Port of Houston is consistently ranked first among U.S. ports in foreign waterborne tonnage, first in U.S. imports; first in U.S. export tonnage, and second in U.S. total tonnage. The Waterborne Commerce Statistics Center (WCSC) reported that 220 million short tons moved across HSC docks in 2013, up from 148.1 million short tons in 1996. Exports grew steadily over the period of record and imports grew until 2006 meeting a record high of 107 million short tons (Table 3-1). Major export commodities include petroleum products (46.8 million short tons), chemicals (17.4 million short tons), and food/farm products (5.4 million short tons). Petroleum products exports almost match activity of crude petroleum (49.5 million short tons) imports. Imports also included petroleum products (10.1 million short tons), chemical products (17.4 million short tons), and primary manufacturing goods (10.4 million short tons) of which all showed healthy growth. The *Galveston Bay Area Navigation Study Feasibility Report* in 1987 forecasted HSC commerce to total 176,972,000 short tons by 2005. As shown in Table 3-2, the actual 2005 short tons reported were 211,665,685, a 20 percent increase over that forecasted in the 1987 report.

On page D-5 of the 1995 LRR, it states "…nearly 25 percent of petrochemical tonnage was transported in vessels with design drafts of 40 feet or more. …Although transportation benefits associated with container cargo were not included in this report, the container fleet projections…reflects increased utilization of larger container vessels." Table 3-3 displays the historical and projected tonnage from the 1995 LRR.

Table 3-2: HSC Import/Export Tonnage Trend (short tons)

		FOREIGN			
	DOMESTIC	**IMPORTS**	**EXPORTS**	**FOREIGN TOTAL**	**GRAND TOTAL**
1996	61,124,588	58,041,465	29,016,823	87,058,288	148,182,876
1997	62,609,724	72,640,589	30,205,965	102,846,554	165,456,278
1998	60,520,562	75,118,513	33,431,259	108,549,772	169,070,334
1999	56,735,755	69,919,172	32,173,276	102,092,448	158,828,203
2000	62,616,967	87,031,704	36,918,575	123,950,279	186,567,246
2001	64,457,446	85,484,988	35,107,734	120,592,722	185,050,168
2002	62,372,636	80,026,918	35,161,131	115,188,049	177,560,685
2003	64,029,740	90,335,647	36,557,758	126,893,405	190,923,145
2004	64,510,816	97,713,314	39,823,197	137,536,511	202,047,327
2005	66,615,112	103,189,879	41,860,694	145,050,573	211,665,685
2006	69,269,334	106,905,495	45,971,921	152,877,416	222,146,750
2007	70,721,886	94,691,663	50,650,776	145,342,439	216,064,325
2008	65,808,295	92,018,956	54,380,670	146,399,626	212,207,921
2009	63,371,521	84,629,722	63,339,729	147,969,451	211,340,972
2010	67,572,638	88,507,605	71,052,988	159,560,593	227,133,231
2011	70,721,272	88,889,008	78,188,359	167,077,367	237,798,639
2012	75,742,260	83,816,269	78,627,053	162,443,322	238,185,582
2013	69,696,000	78,609,669	71,987,851	150,597,520	220,293,520

Summarized from WCSC data sets

Table 3-3: Table D1 in the 1995 LRR Report- Historical Tonnage and Projected Constrained Tonnage
(1,000s Short Tons).

Year	**Crude Oil**	**Petro & Chem Prod**	**Bulk/Grain**	**Container Cargo**
1990	23,472	36,421	5,663	4,166
1991	25,197	39,531	7,659	4,327
1992	27,171	42,672	7,135	3,881
2005	40,849	52,233	6,446	6,960
2015	40,717	59,631	7,179	9,077
2025	41,459	67,917	6,585	10,277
2035	42,210	72,782	5,512	10,277
2045	43,026	77,525	4,631	10,277
2055	43,443	78,773	4,223	10,277

Based on WCSC data for actual HSC tonnage in 2013, tonnage did not exceed what was projected for crude oil and petroleum, and chemical products, but did exceed tonnage projections for bulk/grains (Table 3-4). Bayport petroleum and chemical products totaled 4,229,000 tons in 2013. A total of 372,000 tons at Bayport were carried on vessels with sailing drafts greater than 41 feet. Subtracting Bayport tonnage from the rest of Houston gives 79,406,000 tons, but the draft-constrained tonnage was 71,465,000, which falls below the previous petroleum and chemical product forecast of 78,773,000 from the 1995 LRR.

Table 3-4: Actual HSC Historical Tonnage (1,000s of Short Tons)

Year	**Crude Oil**	**Petro & Chem Prod**	**Bulk/Grain**	**Container Cargo**
1990	21,980	26,564	6,286	
1991	22,578	29,215	8,160	
1992	24,836	31,477	7,697	
2013	40,053	83,635	9,844	17,508
2013 (Excluding Bayport)	40,053	79,406	9,844	
"Constrained Tonnage" (90% of Total)	36,048	71,465	8,860	

Summarized from WCSC data sets

Vessels carrying crude petroleum are currently the largest vessels using the HSC (excluding containers and cruise ships). Table D3 in the 1995 LRR shows distribution of crude petroleum tonnage by vessel class (1,000s Short Tons), displayed in Table 3-5. The last column in the table below shows actual 2013 distribution of crude petroleum tonnage by vessel class. A total of 386,000 short tons (less than 1 percent) of crude oil were carried on vessels larger than previously forecasted.

Table 3-5: Table D3 in the 1995 LRR Report- Distribution of Crude Petroleum Tonnage by Vessel Class (1,000s of Short Tons)

DWT	**1990**	**2005**	**2015**	**2055**	**2013 Actual**
<25,000	262	422	445	477	**33**
25-45,000	111	252	248	227	**0**
45-80,000	5,035	6,864	6,923	8,067	**1,626**
80-100,000	13,803	21,376	21,360	22,817	**4,160**
100-160,000	2,768	11,627	11,544	11,851	**33,859**
160-250,000	0	0	0	0	**386**
Houston Total	21,979	40,541	40,520	43,438	**40,053**

On page D-18 of the 1995 LRR it states "Increasing numbers of large container vessels are utilizing the Houston and Galveston channels; however deepening benefits for containerized cargo were not calculated for this report. …the Houston container cargo facility is located outside of the proposed deepening region. However, due to the interests of the local sponsors and to the relatively significant share that container cargo contributes to both study area tonnage and to the U.S. Gulf Coast container total, a separate container cargo forecast was included in this document." Table 3-6 below displays the distribution of containerized cargo tonnage by vessel class, detailed in the 1995 LRR in Table D8, and the 2013 actual containerized cargo tonnage. As mentioned above, the total containerized cargo tonnage exceeds the amount projected for the period of analysis. In

2013, containerized cargo tonnage was 19,125,000 short tons according to the PHA website. WCSC data shows the following distribution in the last column.

Table 3-6: Table D8 in the 1995 LRR Report- Distribution of Containerized Cargo Tonnage by Vessel Class (1,000s of Short Tons)

DWT	1990	2005	2015	2055	2013 Actual
12-15,900	667	586	735	869	**580**
16-41,900	2,291	2,397	2,555	2,701	**3,309**
42-57,900	1,208	2,178	2,832	3,273	**5,697**
>58,000	0	1,799	2,955	3,434	**7,922**
Total	4,166	6,960	9,077	10,277	**17,508**

TRIPS

It is noted that trips may be a more relevant measure for this project than tonnage carried, because the number of vessels and congestion are concerns for safety. The data is very limited in this regard because the previous analysis did not separate HSC trips by vessel class in its display of forecasts. Therefore, for relevant comparison, HSC total trips were compared to the previous forecast, and then percent distribution for the system was compared to recent HSC data. Table 3-7 shows the total foreign round trips by vessel class (Galveston, Houston, Texas City, & Ancillary Channels), as noted in Tables D-15 and D-12 of the 1995 LRR.

Table 3-7: Tables D-15 and D-12 of the 1995 LRR Report- Total Foreign Round Trips by Vessel Class (Galveston, Houston, Texas City, & Ancillary Channels)

DWT	1990	2005	2015	2055	2055 Distribution	2013 Actual Distribution
<40,000	10,968	11,204	11,611	13,247	70%	**56%**
41-80,000	1,883	2,584	3,030	3,376	18%	**30%**
80-100,000	951	1,249	1,359	1,449	8%	**6%**
100-175,000	254	632	710	802	4%	**8%**
175-199,999	0	0	0	0	0%	**0%**
200-279,999	0	0	0	0	0%	**0%**
Total Round Trips	14,056	15,668	16,710	18,874	100%	**100%**
Houston Only*	8,418	9,812	10,508	11,884		

**Without Project Condition in Table D-12. With Project Condition was not displayed in the 1995 LRR.*

WCSC data shows that the total number of foreign deep-draft round trips for Houston were 5,994 in 2013 (excluding containers), which is less than the projected total number of trips for the without-project condition. The without-project condition has a higher number of trips than the With-Project condition, but the With-Project condition number of trips was not displayed in the 1995 LRR.

DESIGN VESSEL(S)

The design vessels modeled in the Ship Simulation for the 1995 LRR were a tanker 990 X 156 X 44 (LOA X Beam X Draft) for inbound trips, and a bulk carrier 971 X 140 X 44 for outbound trips. The purpose of using two separate vessels was to capture when they were loaded. Other vessels tested are displayed in Table 3-8.

Table 3-8: Vessels modeled in Ship Simulations for the 1995 LRR Report

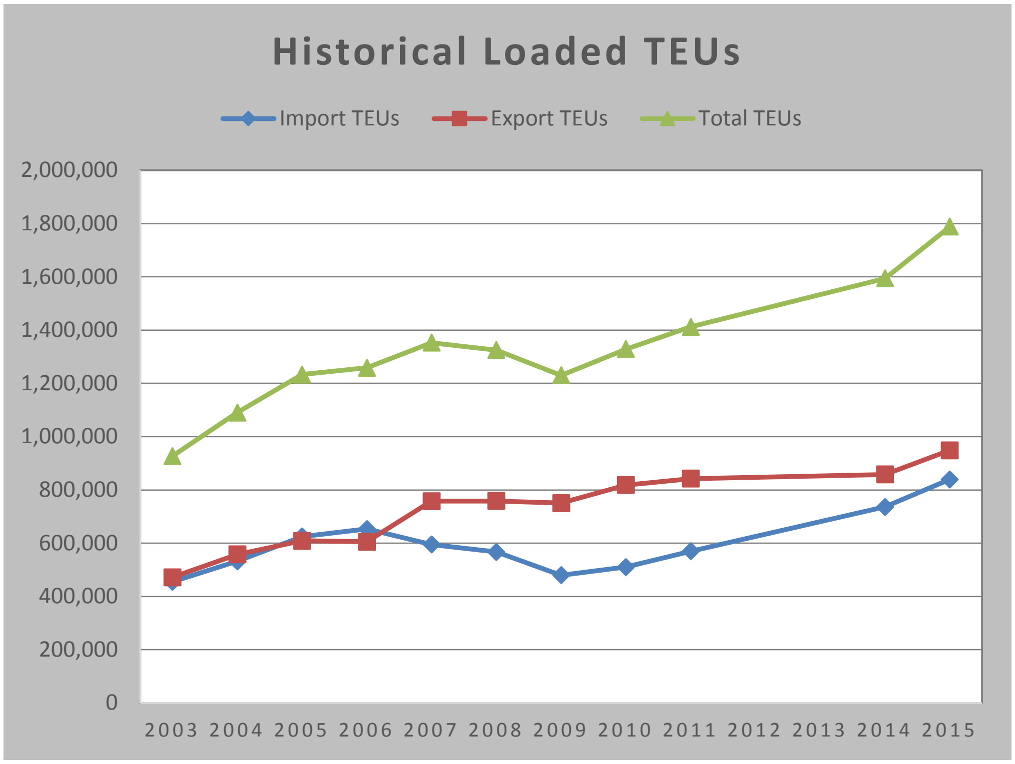
Ship Type	LOA (feet)	Beam (feet)	Draft (feet)
Bulk Carrier	775	106	39
Tanker	920	144	39
Bulk Carrier**	971	140	44
Tanker*	990	156	44
Tanker	990	156	Ballast
Bulk Carrier	970	140	49
Tanker	1013	173	49

*Inbound Design Vessel
**Outbound Design Vessel

In 2013, according to WCSC data, the largest crude oil tanker to traverse the HSC was a 900 X 164 X 57 with a DWT of 165,000. Therefore, the LOA was smaller than what the channel was designed for, but beam and design draft were greater. Container vessels with dimensions up to 1066 X 140 X 48 and 105,000 DWT also used the channel in 2013.

3.3.1 Containers

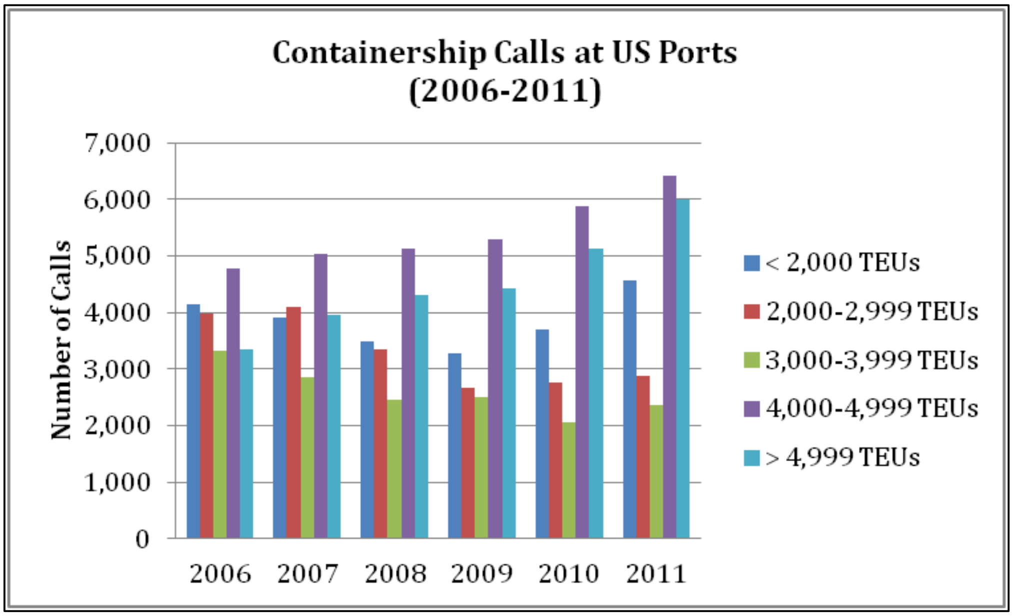
Based on container cargo processed through its facilities, the Port of Houston is the seventh largest container port in the U.S. and the leading container port on the Gulf of Mexico coast. According to U.S. Maritime Administration data, Houston typically handles over 65 percent of the container traffic in the Gulf of Mexico coast region and over 94 percent of the container traffic in Texas. WCSC shows an increase in loaded twenty-foot equivalent units (TEU) at HSC Figure 3-2. In anticipation of continued growth in containerized trade, the Port of Houston has been heavily investing in its terminals to accommodate the associated cargo and future fleet composition. The Port of Houston is currently dredging Bayport and Barbours Cut Channels. These two channels provide containerized cargo with access to the Bayport Terminal and Barbours Cut Terminal. The Port of Houston is currently dredging both channels to 45 feet deep to match the 45-foot deep HSC. In addition, the Port of Houston has identified $325 million in capital improvements to handle post-Panamax (PPX) vessels; approximately $283 million of this total is to be spent on continuing development at BSC and modernization at Barbours Cut Channel. Following historical trends at Houston, the containership fleet will include an increasing number of calls by PPX container ships, which make up a growing share of the world fleet.



Port of Houston

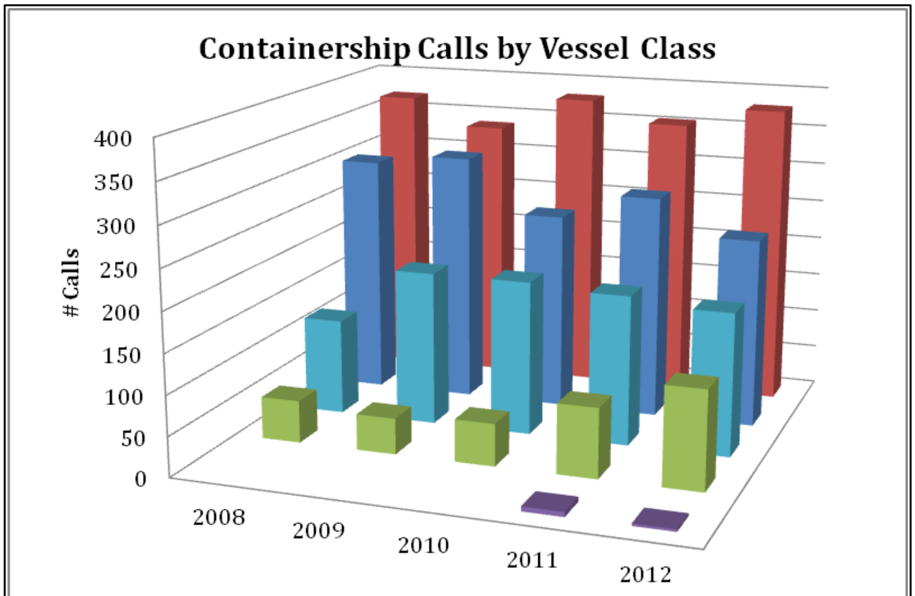
Figure 3-2: HSC 2003-2011 Loaded TEU Trend

The Panama Canal and most major ports in the U.S., Europe, and Asia will be able to accommodate vessels with operating drafts in excess of 45 feet. Vessels requiring operating drafts greater than 42 feet (Panamax (PX) and PPX) will continue to utilize the channel. The volume of cargo has continued to grow and larger vessels will comprise of a greater share of the vessel fleet calling at the Port of Houston. Figure 3-3 shows the trend of larger TEU capacity vessels calling at U.S. container ports from 2006-2011. Figure 3-4 provides the number of historical containership calls by vessel class for the HSC. As shown, the number of sub-Panamax (SPX) vessel calls is decreasing while the number of calls by larger vessel classes is increasing over time. Additionally, Figure 3-4 shows that in 2011, second generation post-Panamax (PPX2) vessels started to call and first generation post-Panamax (PPX1) vessel calls were on the rise. First generation Panamax (PX1) and second generation Panamax (PX2) vessels remained relatively constant while SPX vessel calls declined.



Source: U.S. Department of Transportation, Maritime Administration – Vessel Calls Snapshot, 2011

Figure 3-3: Container Vessel TEU Capacity Trends



	2008	2009	2010	2011	2012
PPX2				6	3
PPX1	53	45	53	87	123
PX2	121	194	194	188	179
SPX	303	316	249	282	238
PX1	370	336	380	354	379

Source: PHA

Figure 3-4: HSC Container Vessel Class Trends

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4 PROBLEM IDENTIFICATION

4.1 Problem Statement

- Improvements to the HSC portion of the project, authorized in WRDA 1996 and constructed by 2005, adversely modified the hydrodynamic effects of ships transiting the channel through Galveston Bay and making the 15-degree turn at the HSC Bend as well as its intersection with the BSC, creating an unsafe navigation condition, and ultimately a design deficiency.

The channel design for the HGNC is not functioning as intended and has negatively affected a secondary channel, the BSC. A hazardous and unacceptable navigation condition has resulted. Increased traffic and vessel size, as projected in the study authorized by WRDA 1996, has increased the potential for collisions and accidents within this section of the HSC. The intersection of the HSC and BSC has been a major safety concern for since completion of the 45-foot HSC in 2005. As outlined in Section 2, Conditions for Recommending Corrective Action, the five criteria from ER 1165-2-119, for a design deficiency have been met and the project does not function as intended 80 percent of the time. This is exacerbating navigational safety on both the HSC and the BSC.

As the construction of the 45-foot HSC was being completed, a significant navigation safety condition was identified between HSC 30+000 and HSC Station 23+000 of the HSC and the Flare intersection with the BSC. As shown in Figure 4-1, the HSC Bend is a 15-degree bend existing in the main channel within very close proximity to the mouth of the BSC.

The BSC is a major tributary channel that existed prior to the HGNC Project authorization. It was not designed or constructed by the USACE (or Corps). The BSC became a Federally-maintained channel when Federal maintenance of the BSC was authorized by an amendment to Section 819 of the WRDA 1986, P.L. 99-662: *"The project for navigation at the Houston Ship Channel (Greens Bayou), Texas, authorized pursuant to section 301 of the River and Harbor Act of 1965 (79 Stat. 1091), the project for navigation at the Houston Ship Channel (Barbour Terminal Channel), Texas, authorized pursuant to section 107 of The River and Harbor Act of 1960 (74 Stat. 486), and the project for navigation At the Houston Ship Channel (Bayport Ship Channel), Texas, authorized by Section 101 of the River and Harbor Act of 1958 (72 Stat. 298), are modified to authorize and direct the Secretary to assume responsibility for maintenance to forty-foot project depths, as constructed by non-Federal interests prior to enactment of this Act."* The USACE assumed maintenance of the channel in April 1993 with a Local Cooperation Agreement (LCA) authorized by the WRDA

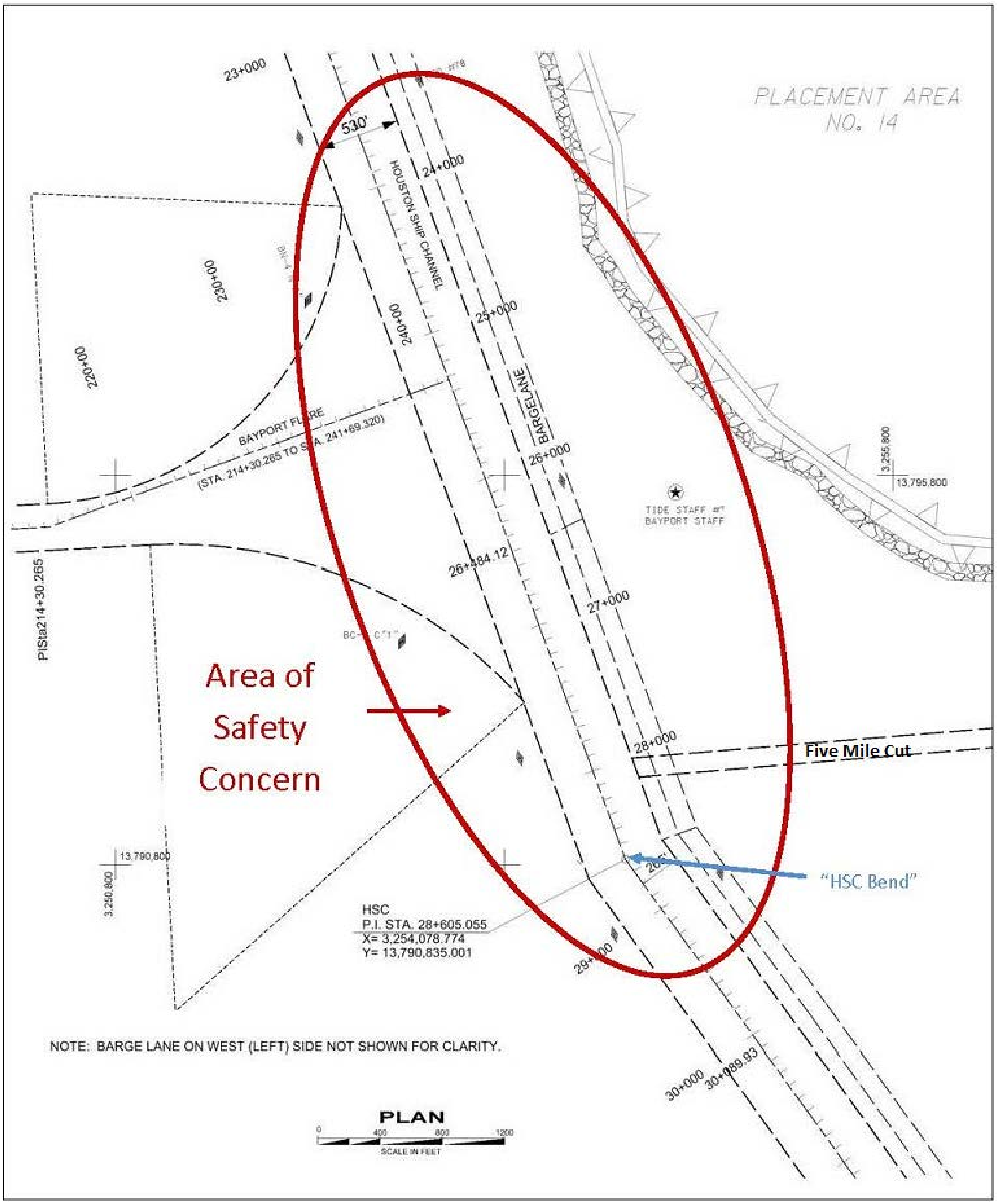

Figure 4-1: Area of Safety Concern at HSC Bend and Flare in Vicinity of BSC

This area of the HSC is a designated "precautionary zone" because of the high concentration of traffic and safety risks associated with the congestion at this intersection. This precautionary zone is designated by 33 CFR 161.35 – "*Navigation and Navigable Waters, Vessel Traffic Management, Vessel Traffic Service Houston/Galveston*" and is defined as "routing measure comprising an area within defined limits where vessels must navigate with particular caution and within which the direction of traffic may be recommended." As such, additional communication and coordination with the USCG is required by law to ensure channel safety among all vessels. This designation indicates the need for additional safety measures to prevent incidents and supports the continued need for separation of barge traffic from the larger vessels in the area. This reach of the HSC was named a significant safety deficiency by the Lonestar Harbor Safety Committee. It has been the site of serious ship collisions and near misses since the physical completion of the 45-foot HSC in 2005. See Pertinent Documents in Appendix E for the letter dated February 6, 2015, from the Lonestar Harbor Safety Committee.

Normal atmospheric conditions often include winds from the south or the north, which further contribute to the maneuverability problems. Channel traffic includes deep-draft vessels on the BSC and HSC, as well as barge traffic throughout the area. Traffic management systems and pilot-to-pilot coordination facilitate movement of the vessels through the intersections. Aside from basic traffic "rules of the road", there is no legal control over the barge traffic. The current conditions in the area of study have caused several allisions and collisions as described in Section 2.4.2 of this report.

A review of AIS data coupled with expert elicitation in coordination with ERDC, documents high vessel congestion in the HSC near its intersection with the BSC. Figure 4-2 highlights the congestion on the HSC. The drawing in the lower left identifies the highest congestion on the Bay Reach of the HSC is located south of the intersection with the BSC. The enlarged drawing highlights known groundings and collisions that have been experienced in this reach, and shows the USCG's precautionary zone.

Congestion in this critical reach of the waterway is exacerbated by a reluctance of pilots to meet in this bend with the meeting situation made worse by the presence of the opening to the BSC. The Houston Pilots have working rules (non-structural measures) that restrict the maximum vessel size from Bolivar Roads to Barbours Cut to 1,000 feet in length and 138 feet in beam. These are outlined in "*Houston Pilots Working Rules*, updated August 19, 2015, and included in Appendix E - Pertinent Documents. Many of the vessels using the HSC have beams in the range of 120 feet to 138 feet and frequently meet along the straight reaches. There are several reasons why pilots try to avoid meeting in this bend in the narrow 530-feet wide waterway. If two wide-bodied vessels meet in this narrow channel while making or approaching a turn, then they may only have 254 feet of clearance to divide between the vessels and the bank and between the two vessels. Divided equally, this would only leave 85 feet for each of the three spaces. However, the vessels cannot remain straight and parallel to the banks while making a turn and the length of the vessel becomes a critical factor; just 3 degrees of angle will add 61 feet of effective width to each vessel. The bank effects generated when the vessel approaches the edge of the channel will cause the vessel to turn away from the bank and put the bow towards the center of the channel. For the inbound vessel at this bend trying to make the turn to the right or starboard, this bank effect counters the turning of the ship and can cause the ship to veer into the outbound ship. If the outbound ship moves to the green side of the channel to use the bank effect as an assistance in making the turn, that advantage is lost due to the Flare at the intersection of the HSC and BSC. The ship will slide into the opening and then have to turn more sharply to make the bend and stay off the western or green bank. These factors combined with the presence of ships turning into the BSC and tug/barge units moving up, down and entering/exiting the channels near this bend make the entire reach a serious navigation challenge for pilots. Thus, many times the pilots will slow traffic to avoid meeting in this critical reach.

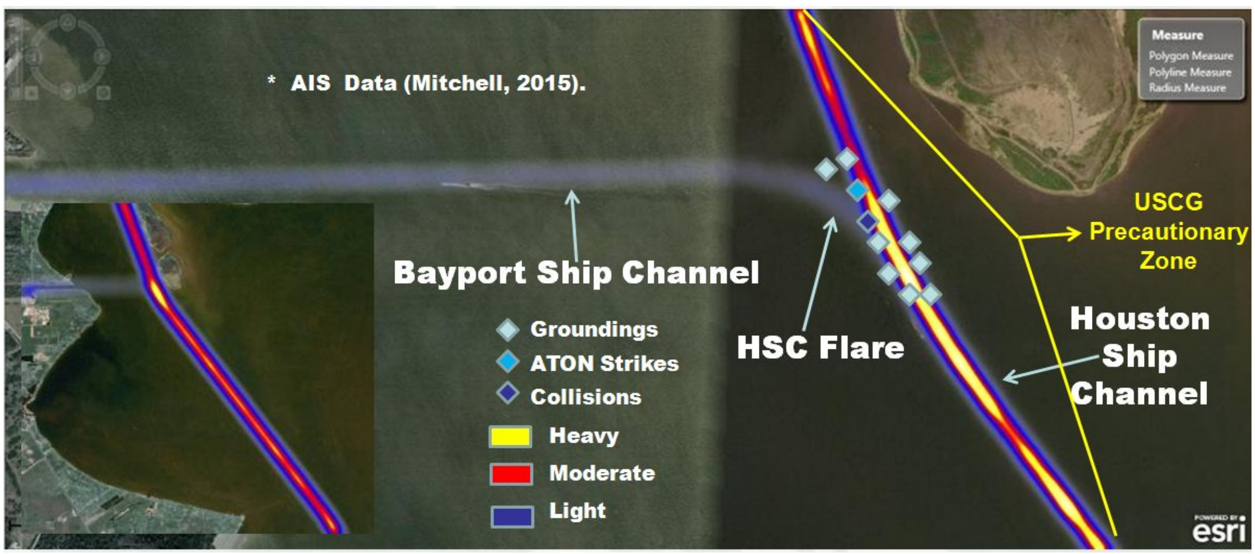

Figure 4-2: Figure of AIS Data Highlighting Known Groundings and Collisions

To reiterate the concern about the effects of vessels getting near the channel's banks, the ship simulations conducted for the WRDA 1996 project indicated concerns regarding the meeting of the design vessels being used for the project design. Because of the limitation of the channel width to 530 feet, a limitation of meeting ships' combined beams was set to 280 feet or less for meetings occurring in the straight channel segments. It was noted that "this criterion may result in operational restrictions being employed, e.g., holding other large ship traffic so that the channel is temporarily one-way or with restricted ship sizes traveling in the opposite direction of the large ship. These restrictions will most likely cause delays. If such operational procedures cannot be used then it is recommended that the intermediate channel (530 feet) be widened by at least 35 feet". This recommended additional 35 feet was not constructed.

The Galveston District had originally proposed design vessels having a combined beam width of 296 feet. In the course of the ship simulation, it was realized that in order to meet USACE guidance for bank and ship clearance, the design vessels had to be limited to a combined beam width of 280 feet. The 35-foot addition (to the 530 feet width) was intended to bring the combined beam width greater than 296-feet vessels into compliance with the USACE guidance at the time of the study. As revealed by the 2016 AIS Report, the 530-foot channel does not support two-way passage for combined beam widths less than 280 feet. Clearly, a 35-foot expansion would not have been adequate to support 296-foot vessels.

The ship simulation conducted for the WRDA 1996 project (ERDC 1994 Report) detailed concerns regarding the meeting/passing of the design vessels. The design vessels used in the 1995 LRR ranged in length from 921 feet to 990 feet, having beam widths of between 140 feet and 156 feet, with a loaded drafting 44 feet.

In summary, the navigation safety problems identified at the intersection are:

- The widening of the HSC and construction of barge lanes both modified the geometry of the intersection of the HSC and BSC for turns in and out of that channel.

- The navigation safety concerns are due to high vessel congestion in the HSC at the HSC Bend and the intersection between HSC and BSC at the Flare. A primary cause of this congestion is the slowdown of vessels on HSC as they transition the HSC Bend and the need for multiple tight turns in a short distance to get into the BSC.

- The navigability of turning from HSC onto the BSC with design vessels is hampered by an undersized turning radius compared to recommendations in EM 1110-2-1613, dated April 8, 1983.

- The navigability of turning from the HSC onto the BSC with design vessels is further exacerbated by a reduced distance between alternating turns compared to recommendations in EM 1110-2-1613.

- The navigability of vessels in the HSC is lessened by the absence of a widener at the HSC Bend as recommended in EM 1110-2-1613.

- The navigability of vessels turning from HSC onto the BSC was not modeled by ship simulation during the 1995 LRR study, as it was considered at the time to be outside of the scope of that study. Being outside the scope of the 1995 LRR does not negate the effects of the HSC on ships turning into the BSC.

- Although design vessels for the 45-foot HSC Federal channel were not simulated, 40-foot design vessels for the authorized BSC were simulated (ERDC 2012 Report). The results of these simulations were utilized to assist in determining the final recommendation.

- The ability to bypass the resulting congestion is restricted due to the hydrodynamics resulting from narrow channels, which increases probabilities of bank suction and ship-to-ship collisions during passing.

- The channel is not functioning as intended.

4.2 Without Project Conditions

The without project conditions (project without corrective action) are generally the same as described for the existing conditions discussed in Section 3. The channel is not functioning as intended. The problem is experienced by users transiting northbound in the HSC near the intersection with the BSC. Northbound deep-draft vessels must slow down considerably when making a turn from the HSC into the BSC due to the sharp tack angle that must be made. This situation is caused by the intersections existing configuration and that of the HSC approach to the intersection. North and southbound ships in the HSC must slow to avoid overtaking barges turning into BSC, or transiting past the Flare. North and southbound ships must moderate (slow) speed as an alternative to passing in the vicinity of the HSC Bend and Bayport, resulting in reduced control.

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5 SHIP SIMULATION STUDY

5.1 Decision to use ERDC Simulation after change to Design Deficiency

This study did not begin as a design deficiency. The ship simulation documented in the ERDC 2012 Report, was conducted prior to approval to proceed with the PDR. It was not performed to demonstrate design deficiency. The final decision to use this simulation was based on evaluation of current ship simulation capabilities balanced against the cost of analysis and expert evaluation of the anticipated model results. Ship simulations were conducted with more recent vessel types based on earlier project direction at substantial costs and time to the project.

An expert elicitation was conducted in March and April 2015, to understand the relationships between influences that increase the risk of an incident on the HSC in the area of the BSC, including any design deficiencies currently posing a safety risk to HSC traffic. These findings were documented and finalized in the 2015 EE Report. As the project evolved into a design deficiency action, the PDT and Subject Matter Experts (SME) discussed conducting additional ship simulations using the design vessels. The expert & team member discussion ultimately indicated that the recommended repair based on the ship simulation presented, using the larger vessel, would not be substantially different from the repair that would have been recommended had the smaller design vessel been used in the simulation. This conclusion was based on evaluation of previous model efforts, current vessel transit trajectories, and hydrodynamics in the area of the Flare. The recommended solution based on the larger vessel, if in error at all, would err on the large side resulting in a safer channel.

Additionally, the ship simulation in the ERDC 2012 Report was performed using channel dimensions that existed prior to the improvements recently constructed. ERDC confirmed that the PDR recommended plan from the 2012 ERDC Report would not change had the simulations been performed using existing (current) channel dimensions.

5.2 ERDC Simulation

As addressed in Engineering Appendix, Section 2.3 Navigation Study, the purpose of this ERDC Analysis was to determine through ship maneuvering simulations whether the proposed channel dimensions would be safe and efficient for each of the ships specified and if there would be operational limitations and special tug requirements for movements of these ships through six configurations.

Currents for both the existing and proposed channels were calculated by the Estuarine Engineering Branch at CHL. From the current modeling study (ERDC 2012 Report), peak spring ebb, and flood were used to build the ERDC Ship/Tow Simulator (STS) databases. Design depths (ERDC 2012 Report) were the authorized 40 foot depth plus 7 feet of advanced maintenance) in the Flare for all alternatives and the authorized 40 foot authorized depth plus 3 feet of advanced maintenance in the BSC. Winds were included in the database as well. As suggested by the harbor pilots, a constant wind of 25 knots from the north and southeast were included with the ebb and flood tide, respectively. These constant winds were used throughout the simulation and produce worst case operating scenarios for testing.

The ship model tested was the *Susan Maersk*, an 1140 x 140 foot containership drafting 40 feet. For comparison, Table 5-1 includes the vessels tested in the 1995 LRR.

Table 5-1: 1995 LRR Test Ship Characteristics

Ship Type	LOA (*feet*)	Beam (*feet*)	Draft (*feet*)
Bulk Carrier	775	106	39
Tanker	920	144	39
Bulk Carrier	971	140	44
Tanker	990	156	44
Tanker	990	156	Ballast
Bulk Carrier	971	140	49
Tanker	1013	173	49

The alternatives for which testing occurred are addressed in Section 6.7 Description of Structural Alternative Corrective Actions & Ship Simulation Results. The simulation results documented in the ERDC 2012 Report were used to determine the recommended corrective action.

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6 ALTERNATIVE CORRECTIVE ACTIONS

6.1 Planning Opportunities

Opportunities include the following:

- Perform corrective action to correct a design deficiency and eliminate navigation restrictions at the BSC and HSC intersection to enable the existing project to function as intended in a safe, viable, and reliable manner.

- Provide new work clays for PA 14 major dike raising to further support the O&M dredging plan for the HSC.

6.2 Planning Objectives

The following planning objective was used in the formulation and evaluation of alternative plans:

- Identify a safe, cost effective, environmentally acceptable corrective action to address a design deficiency on the HSC in the vicinity of the Bayport and HSC intersection in Chambers County, Texas.

The purpose of this report and recommended plan is to correct a design deficiency and conduct repairs required to make the project function in a safe, viable, and reliable manner.

6.3 Planning Constraints

Constraints are restrictions that limit the planning process. Plan formulation involves meeting the study objectives while not violating constraints. Specific study constraints include:

1. The process and plans must comply with Federal and State laws and policies.

2. Adverse effects on environmental resources, including oysters, will be avoided, minimized, or mitigated to offset those unavoidable impacts.

3. Placement of material in unconfined open water placement is not acceptable for this corrective action, unless appropriate sediment testing is done, and material complies with the requirements of the Offshore Dredge Material Disposal Area.

4. Placement of new work material is limited to the existing nearby confined upland PA 14 or alternate location, Mid Bay PA.

Criteria number 1 is a standard constraint for all studies. All of our actions must comply with our laws and policies. Criteria number 2 requires mitigation for any adverse impact the project has to fish and wildlife. Criteria numbers 3 and 4 were evaluated in coordination with the ERDC. The level of investigations for the LOE/WOE evaluation was conducted with the new work dredge material placement designated for confined upland PA 14. PA 14 is the least cost, environmentally acceptable placement and the upland confined PA in closest proximity for the new work material. Coordination with ERDC conducted subsequent to completion of the LOE/WOE resulted in ERDC's approval of the Mid Bay PA as an alternative placement option for new work material if PA 14 is not available at the time of construction.

6.4 Plan Formulation Process

The planning objectives and constraints form the basis for subsequent plan formulation, alternative screening and the identification of the recommended corrective action. The expected Future Without-Project (FWOP) Condition (synonymous to the "No-Action Plan") was developed for comparison with other alternatives. Additionally, structural and non-structural alternatives were developed. For the structural plans, two flare radii and three bend wideners were simulated. The maximum flood and ebb velocity fields for each alternative and the base condition were provided for use in the ERDC Ship/Tow Simulator as discussed in the Engineering Appendix Section 2.2.2. Because this is a corrective action for an engineering design deficiency, the placement of the new work material was designated for the existing PA 14, which is located in closest proximity to the area of safety concern and the least cost, environmentally acceptable option for placement. The corrective actions were evaluated and screened using the simulation process.

6.5 No-Action Alternative

USACE is required to consider the option of "No-Action" as one of the study alternatives in order to comply with the requirements of NEPA. With the No-action Plan (i.e. the FWOP), it is assumed that no project would be implemented by the Federal Government or by local interests to achieve these particular planning objectives. However, normal operation and maintenance activities, along with other probable channel improvements, are assumed to be implemented as currently performed. The No-action alternative would be to continue to maintain the HSC and BSC and Flare in their present configuration. The recommended corrective action would not be constructed. Safety challenges for vessel operators passing the BSC and the HSC Bend, and negotiating the turnout between the HSC and BSC would not change. The significant risk of collisions between vessels while navigating the turn would remain the same. The Corps would continue to perform annual maintenance dredging of the Flare; otherwise, navigation could be impeded due to the high shoaling in this area, resulting in reduced shipping volumes at the Port of Bayport. The Flare at the intersection of the HSC and BSC requires dredging annually. The BSC is dredged every two years, and the HSC is dredged every three years.

Under the No-action alternative, there would not be any new work dredging. Therefore, under the No-action alternative there would not be any impacts to additional open water or oyster habitat. However, the significant risks of collision, and the associated potential environmental impacts, which could include vessel spills, would remain and the project would continue not to function as originally intended.

6.6 Non-Structural Alternatives Corrective Actions

The non-structural alternative is the same as the existing condition except it includes the following operational measures (non-structural measures) to reduce or avoid hazards. These non-structural measures are already used to try and minimize the effects of the deficiency; however, they have not succeeded in alleviating the safety issues created by the design deficiency.

1. The area of safety concern has been designation by the U.S. Coast Guard as a precautionary zone under 33 CFR 161.35 - "*Navigation and Navigable Waterways, Vessel Traffic Management, Vessel Traffic Service Houston/Galveston*".

2. Currently the situation is managed by traffic management systems and pilot-to–pilot coordination to facilitate movement of the vessels through the intersections. Aside from basic traffic "rules of the road", there is no legal control over the barge traffic.

3. Vessels leaving the HSC to enter the BSC typically do so with tug assistance due to the reduction in speed and sharp turn necessary to safely enter the channel. The tugs assist the vessel in turning into the BSC and escort the vessel to the docks.

The non-structural measures currently used in this area are the most advanced system in existence. The HSC and the BSC use USCG operated Vessel Traffic Services (VTS) to coordinate movements in this area. Because of the areas precautionary designation, the most technologically advanced system to move and control traffic have been implemented at the behest of the USCG (i.e., current pilot rules and channel signals). In addition, VTS are currently used within the area and improvements to these systems are highly improbable. Hence, non-structural measures were not considered in the array of alternative plans since such have been implemented consequent to earlier incidents.

Note the construction of the corrective action would not preclude the use of tug assist. It will allow design vessels to turn with fewer or no tugs; however, the HSC pilots decide when to use tugs on the turn from the HSC to the BSC. Many factors are considered in the decision to use tugs, such as weather conditions, size of vessel, and experience of the pilot. As such, even with the corrective action there would most likely continue to be tug use in instances where larger than median design vessels traverses, inclement weather events prevails and older ship technology in use.

6.7 Description of Structural Alternative Corrective Actions Tested in ERDC Ship Simulation and Results of Testing

The following is a discussion of the structural alternatives modeled by ERDC. Figure 6-1 provides a depiction of the different radii and wideners considered for the six structural alternatives. Figures from the ERDC simulation are provided for those structural alternatives where testing results indicated failure.

The purpose of this modeling, performed by ERDC, was to determine through ship maneuvering simulations whether the proposed channel dimensions would be safe and efficient for each of the design ships and if there would be operational limitations and special tug requirements for movements of these ships through these alternative plans. Modeling depths were 47 feet (40 feet plus 7 feet of advanced maintenance) in the Flare and 43 feet (40 feet plus 3 feet of advanced maintenance) in the BSC. The primary ship design vessel was the *Susan Maersk*, an 1140- by 140-foot containership, drafting 40 feet. The primary design vessel has a draft of 40 feet and the BSC was modeled with a depth of 43 feet (40 feet plus 3 feet of AM.

Currents for both the existing and proposed channels were calculated by the Estuarine Engineering Branch at CHL. From the current modeling study, peak spring ebb and flood were used to build the ERDC Ship/Tow Simulator databases.

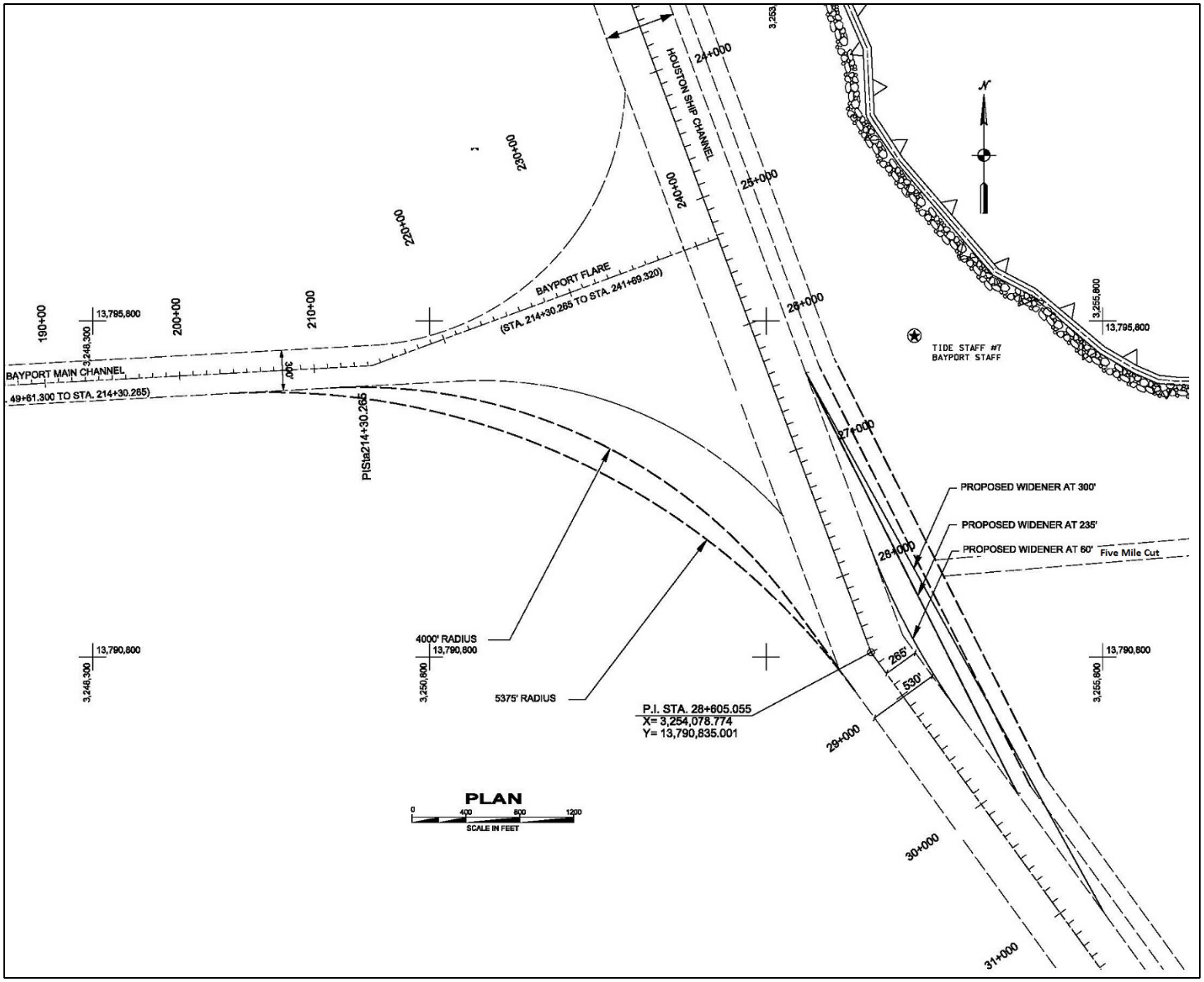

Figure 6-1: Structural Alternatives Modeled by ERDC in 2012 ERDC Report

6.7.1 Alternative 1 – Increase existing 3,000-foot Flare radius to 4,000-foot radius combined with a 60-foot bend easing on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 4,000 feet combined with a 60-foot wide bend easing (channel widener) on the eastern side of the HSC. This alternative would not require any deepening of the authorized BSC. The channel widener would be constructed to a depth of 45 feet to match the authorized depth of the HSC. This alternative represents the least amount of channel modification (dredging) in terms of dredged material.

Testing Result - This simulation (Figure 6-2) failed on the transit during the inbound transit on an ebb tide where the simulated ship encroached the HSC on the eastern side by 75 feet.

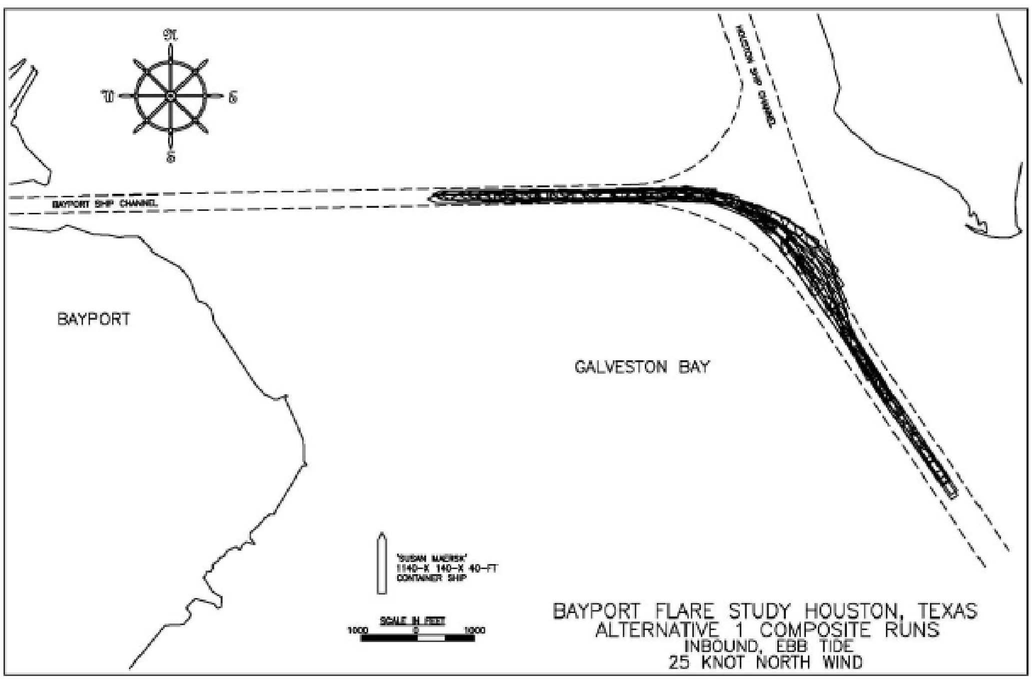

Figure 6-2: Plate 1, ERDC Simulation of Alternative 1 (Inbound, Ebb Tide)

6.7.2 Alternative 2 – Increase existing 3,000-foot Flare radius to 4,000-foot radius combined with a 300-foot bend easing on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 4,000 feet (same as Alternative 1) combined with a 300-foot wide bend easing (channel widener) on the eastern side of the HSC. This alternative would not require any deepening of the authorized BSC. The channel widener would be constructed to a depth of 45 feet to match the authorized depth of the HSC. Alternative 2 was considered to allow pilots more flexibility in setting up for the turn into the BSC or entering the HSC.

Testing Result - All inbound and outbound runs under ebb and flood tide were successful.

6.7.3 Alternative 3 – Increase existing 3,000-foot Flare radius to 4,000-foot radius combined with a 235-foot bend easing on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 4,000 feet (same as Alternative 1) combined with a 235-foot wide bend easing (channel widener) on the eastern side of the HSC. This alternative would not require any deepening of the authorized BSC. The channel widener would be constructed to a depth of 45 feet to match the authorized depth of the HSC. The easing in Alternative 3 is smaller than the easing in Alternative 2 and helps give an idea of how much of an easing may be necessary for safe navigation between the two ship channels.

Testing Result - All inbound and outbound runs under ebb and flood tide were successful. The tracks show no vessels encroaching on the proposed channel lines.

6.7.4 Alternative 4 – Increase the existing 3,000-foot Flare radius to a 5,375-foot radius with no channel widener on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 5,375 feet with no channel widener.

Testing Result **–** Two of the runs failed. Both the inbound and outbound flood tide runs were unsuccessful. The inbound vessel encroached (Figure 6-3) on the northern side of the BSC by about 10 feet. The outbound vessel (Figure 6-4) encroached on the eastern side of the HSC by about 190 feet.

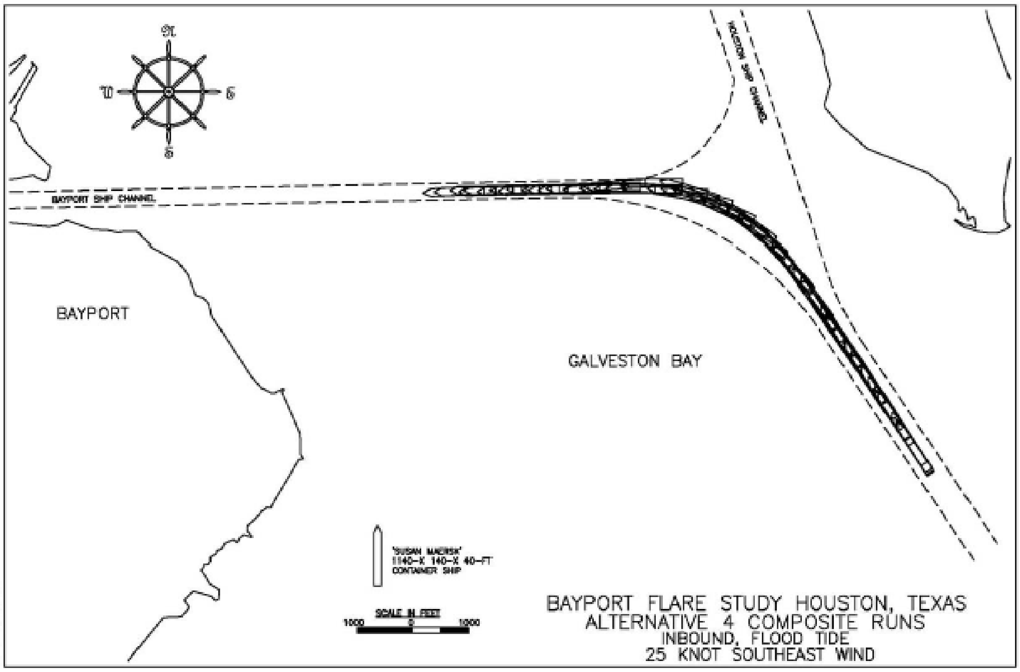

Figure 6-3: Plate 14, ERDC Simulation of Alternative 4 (Inbound, Flood Tide)

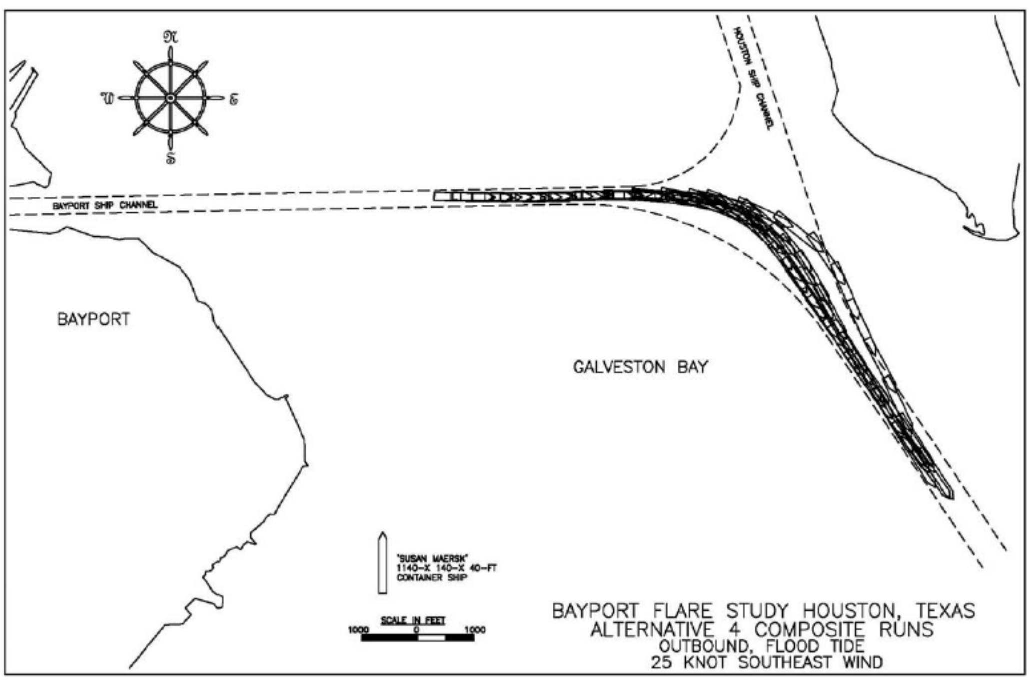

Figure 6-4: Plate 16, ERDC Simulation of Alternative 4 (Outbound, Flood Tide)

6.7.5 Alternative 5 – Increase existing 3,000-foot Flare radius to 5,375-foot radius combined with a 300-foot bend easing on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 5,275 feet (same as Alternative 4) combined with a 300-foot wide bend easing (channel widener) on the eastern side of the HSC. This alternative represents the greatest amount of channel modification in terms of dredged material. The channel widener would be constructed to a depth of 45 feet to match the authorized depth of the HSC.

Testing Result - All inbound and outbound runs under ebb and flood tide were successful. The tracks show no vessels encroaching on the proposed channel lines.

6.7.6 Alternative 6 – Increase existing 3,000-foot Flare radius to 5,375-foot radius combined with a 235-foot bend easing on the eastern side of the HSC.

Alternative Tested - This alternative would increase the existing Flare radius from 3,000 feet to 5,375 feet (same as Alternative 4) combined with a 235-foot wide bend easing (channel widener) on the eastern side of the HSC. This channel widener is smaller than the one proposed in Alternative 5. The channel widener would be constructed to a depth of 45 feet to match the authorized depth of the HSC.

Testing Result - All inbound and outbound runs under ebb and flood tide were successful. The tracks show no vessels encroaching on the proposed channel lines.

6.8 Ship Simulation Conclusions

In conclusion, the Pilots determined that the 4000-foot Flare radius allowed pilots to maintain sufficient speed for safely turning into and out of the BSC. Additional room allowed by the 5,375-foot radius compared to the 4,000-foot radius showed no added benefit. This was reiterated through pilot comments suggesting the 5375-foot Flare radius is too large and could even cause problems trying to enter the respective channel. They further commented that the 235-foot HSC bend easing was all that was necessary at this time. Therefore, Alternative 3 is the preferred simulated alternative.

Evaluation and Comparison of Alternative Corrective Actions

Ship simulation, with concurrence from the Harbor Pilots determined that the 4000-foot Flare radius the pilots were able to maintain sufficient speed for safely turning into and out of the BSC.

Additional room allowed by the 5,375-foot radius compared to the 4,000-foot radius showed no added benefit. This was reiterated through pilot comments suggesting the 5375-foot Flare radius is too large and could even cause problems trying to enter the respective channel. They further commented in the ship simulation report that the 235-foot HSC bend easing was all that was necessary at this time; pilot's comments were documented in Appendix A of the 2012 ERDC Report. Therefore, Alternative 3 is the preferred simulated alternative. The structural alternatives were then evaluated with screening criteria, as discussed below. The 2012 ERDC Report is included in the Engineering Appendix.

6.8.1 Screening of Alternative Corrective Actions

Project specific criteria related to the purpose of the project were used to screen the alternative corrective actions. The following screening criteria were used in the evaluation of the recommended corrective action.

1. Improve navigation safety
2. Determine the most cost effective alternative for construction
3. Avoid or minimize environmental impact
4. Evaluate for least amount of dredged material required to make the corrective action minimize dredged material quantity for placement in PA 14.

1. **Improve navigation safety –** In the initial stage of screening, key factors that affected navigability of vessels constrained by the current channel configurations were considered. This included navigability transiting the HSC Bend and the Flare, Corps channel design criteria, minimum widening identified by the Houston Pilots Association (HPA) to provide navigation efficiency through ship simulations, and effects of widening on the channel alignment.

2. **Cost effectiveness –** Total project costs and cost effectiveness considerations were used for initial screening. Preliminary project construction costs were developed considering cost factors such as dredging, dike construction, engineering design, potential mitigation, and construction management.

3. **Avoid or minimize adverse environmental impacts –** The project footprint is located in the open waters of upper Galveston Bay. Therefore, environmental impacts would be limited to open water marine habitat and would not involve terrestrial, wetland, or near-shore (tidal flats, beach, dunes etc.) impacts. Environmental marine field surveys provided geospatial data useful to gauging the marine habitat impacts and confirmed that oyster reef and unvegetated, featureless bay bottom would be impacted by channel widening. As a

result, oyster reef acreage-impacts were the primary measure of environmental impact used in the screening. For detail on the nature of the oyster reef habitat and quantities, see Chapter 3, Affected Environment in the EA.

4. **Determine Dredged material quantity –** The quantity of new work dredge material required for placement will have a cost impact; more dredging and more material will be higher cost. The larger the project footprint, the higher the quantity of new work requiring placement. The new work material will be placed in PA 14 and used for dike raising. This location is the closest existing upland confined PA to the project site, and was determined to be the least cost, environmentally acceptable placement.

The six structural alternatives and the No-action and Non-Structural alternatives were then evaluated using the screening criteria. The No-action and the Non-Structural alternatives did not improve navigation safety. The channel must operate efficiently and effectively for enhanced safety. Increasing the distance between transiting and passing vessels further would perhaps be safer in that localized area, but it would increase delays and limit the capacity of the channel, and perhaps create less safe conditions further away in the channel. In turn, the economics associated with transportation cost savings assumed for the project would be reduced because of these increased delays. Limiting channel capacity was not the intent of the original design. As such, operational restrictions such as increasing distances between transiting and passing vessels or one-way traffic are not considered viable options because it would significantly increase the costs of shipping on this busy waterway and significantly increase transportation costs. The available non-structural corrective actions do not alleviate the safety concerns. Even with the aforementioned non-structural safety measures that are already in place, the risk of a catastrophic collision occurring remains significantly high. It should be noted that none of the structural alternatives would result in eliminating the need for tug assistance. However, with a more suitable turning radius vessels would require fewer tugs during transit in the high-traffic zone at the HSC/BSC intersection. Additionally, precautionary status/measures will still be required because this is a high-traffic zone.

As shown in Table 6-1, Alternative 3 provides the most improvement for the navigation safety issue with the least amount of adverse environmental impact and dredging (and therefore the least cost).

Table 6-1: Alternative Corrective Action Screening

Alternative	Proposed Flare Radius (Existing 3,000 feet)	Proposed Bend easing on east side of HSC (feet)	Improve Navigation Safety?	Preliminary Cost (Dredging)	Dredged New Work Material Quantity (cy)	Environmental Impacts	
						Bay Bottom (Acres)[1]	Oyster Habitat (Acres)[2]
No-action (FWOP)	No change	0	Failed	0	-	0	0
Non-Structural	No change	0	Failed	0	-	0	0
Alternative 1	4,000 feet	60	Failed	$13.2M	1,534,834	36.17	22..8
Alternative 2	4,000 feet	300	Improved	$19.5M	2,319,022	63.18	40.6
Alternative 3	4,000 feet	235	Most Improved	$16.4M	1,942,838	56.67	29.9
Alternative 4	5,375 feet	0	Failed	$19.8M	2,410,987	49.45	34.4
Alternative 5	5,375 feet	300	Too large[3]	$26.3M	3,206,658	80.38	53.7
Alternative 6	5,375 feet	235	Too large[3]	$23.3M	2,830,474	73.87	43.0

[1]*Bay bottom is the sum of non-overlapping area of the features comprising the alternative; additionally, bay bottom acreage encompasses the oyster acreage. They are not two separate areas.*
[2]*Oyster impact acreage excludes acreage in existing barge lane, which has been mitigated for under the HGNC Barge Lanes project.*
[3]*Pilot comments suggested 5,375-foot radius too large and could even cause problems trying to enter channel.*

6.8.2 Selection of Recommended Corrective Action

The ERDC ship simulation study identified the corrective action, which will make the project function as initially intended in a safe, viable, and reliable manner as Alternative 3. This design virtually eliminates the zigzag turns required by the existing condition; i.e., making a 15-degree turn to starboard (right) and then within a ship length (1,000 feet) or two (depending on the size of the ship) making almost a 90-degree turn to port (left). The recommended design change allows a ship entering the BSC to make a smooth turn to the starboard beginning near the HSC Bend. Table 5-1, shown previously, provides the vessels tested in the 1995 LRR. The primary ship model tested in the ERDC 2012 Report was the *Susan Maersk*, an 1140- by 140-foot containership drafting 40 feet. As discussed earlier in Section 5.1, the recommended repair based on the 2012 ERDC Report using the larger vessel, would not be substantially different from the repair that would have been recommended had the smaller design vessel been used in the simulation. This conclusion was based on evaluation of previous model efforts, current vessel transit trajectories, and hydrodynamics in the area of the Flare.

The recommended corrective action assumes the new work dredged material resulting from the corrective action would be placed into the existing upland confined PA 14 located less than a mile from the project area. The new work material (consisting predominantly of clays) would be beneficially used for future dike raising, thus increasing the capacity of PA 14.

Any adverse environmental impacts that could not be avoided will be minimized to the greatest extent possible and the plan would include compensation for any impacts that could not be avoided. The mitigation plan is addressed under Section 7.7.3 in the PDR and Section 4.4 in the EA.

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7 RECOMMENDED CORRECTIVE ACTION

As a result of the screening and evaluation process described in the preceding sections, Alternative 3 was selected and is recommended for implementation. The No-action Alternative is also carried through for evaluation.

The No-action alternative, as described in Section 6.5, consists of taking no corrective action to address the design deficiencies in the existing channel design and make the channel function as intended. The navigation issues detailed in Section 4 would continue to occur, such as loss of maneuverability resulting from vessel slow-down due to congestion, and the continuation of the need to make two significant course changes in about a ship length (approximately 1,000 feet) to navigate the HSC Bend and turn into the BSC. The resultant congestion and increased risks for vessel collisions would continue. Although the adverse environmental impacts associated with the structural alternatives would not occur, the increased risk of collision from taking no-action would have its own environmental impact risks, such as from vessel content releases which could include refined and petrochemical products.

The recommended design deficiency corrective action based on the screening criteria in Section 6 and ERDC simulations is Alternative 3. A description of the recommended corrective action and proposed dredged material placement for new work and maintenance dredged materials is described below.

7.1 Detailed Description of the Recommended Deficiency Corrective Action

Alternative 3, the recommended design deficiency corrective action, consists of increasing the existing southern radius of the Flare to 4,000 feet, widening the HSC by a maximum 235 feet to the east between about HSC Station 26+484 and HSC Station 30+090, and relocating the existing barge lane to accommodate the widened HSC (Figure 7-1). The barge lane will be relocated to the east of the HSC widening, consistent with the original design.

The work would be accomplished using a hydraulic dredge with cutterhead and pumping the dredged new work materials to PA 14, located about one-half mile northeast of the project. Approximately 1.94 million cubic yards (MCY) of dredged new work materials would be stacked along the interior slope of the existing perimeter dike to form a berm and used for future dike raising construction.

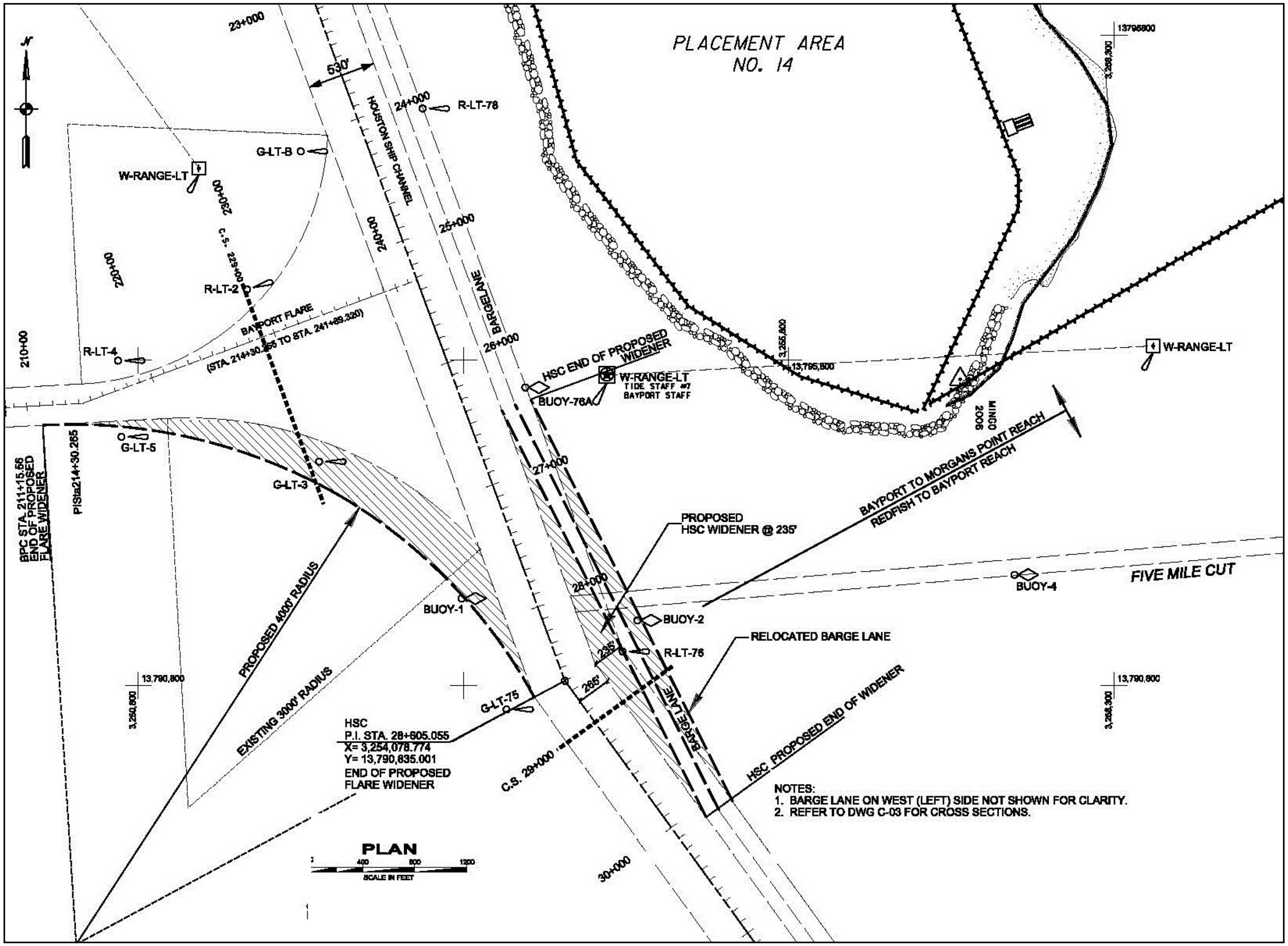

Figure 7-1: Plate C-02, Flare and HSC New Work Dredging Plan

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The upland confined Mid Bay PA would be considered an alternate location for new work placement for this project should unforeseen circumstances occur prior to construction precluding the use of or limiting the capacity of PA 14. However, the material must be similarly placed within the upland confined Mid Bay PA on the interior slope of the existing perimeter dike to form a berm, whereupon it may also be used for future dike raising construction.

7.1.1 Placement Areas

HSC PAs available for this project include existing PA 15, PA 14, and Mid Bay PA (all upland confined PAs). Also available for placement of the maintenance material are the Atkinson Island BU Marsh Cells M7/8/9, and M10, as well as any of the other existing Atkinson Island BU Marsh Cells requiring renourishment. The future PA 15/PA 14 Connection (upland confined PA) was also assumed available for future maintenance material storage.

PA 14 is in closest proximity to the project and it has been assumed it will be used for the placement of all new work material. PA capacities are provided in the Engineering Appendix Section 4.4 Placement Areas. See Section 7.2 for discussion on quantities. The new work and maintenance incremental placement plan is shown later in the report in Section 7.3.2.1 Dredged Material Maintenance Plan (20-Year).

A 20-year period of analysis is being used for the dredged material placement plan instead of a 50-year period of analysis. This is because the *"Houston Ship Channel, Texas, Dredged Material Management Plan"* (HSC DMMP), currently in process, is scheduled to be completed in July 2016, with no new PA/BU sites required. Additionally, a new feasibility study on the HSC has begun and it will require new PA/BU sites. The District decided to develop the placement for the material from the corrective action (construction and O&M) for a 20-year period. The aforementioned feasibility study will require a 50-year dredge material management plan (DMMP). As such, the specific study reaches involved in the feasibility study will overcome the DMMP and require new PA/BU sites.

7.1.2 New Work Placement

The new work from the project would be hydraulically placed in PA 14 in a berm along the interior of the perimeter dike. The upland confined Mid Bay PA would be considered an alternate location for new work placement for this project should unforeseen circumstances occur prior to construction precluding the use of or limiting the capacity of PA 14. As planned for PA 14, should Mid Bay be utilized for new work, the material would be placed in a berm along the interior of the existing containment dike at Mid Bay PA and use for future dike raising and/or improved dike foundation.

7.1.2.1 Initial PA 14 Dike Raise (Mechanical) Prior to Receiving New Work

Prior to the dredging the PA 14 containment dike would be mechanically raised three feet. The dike raised section interior toe would lie at the existing dike interior crest; therefore, the entire raised section would lie on the crown of the existing dike. New work material from the project would not be used for the initial dike raise. Borrow for the initial dike raise would be obtained by side cast method from the existing interior berm area located just interior of the existing dike. The interior berm was constructed during a fiscal year (FY) 2008 contract using borrow sources located within PA 14. Soil borings performed for that project indicate the material is consistent with the soil types utilized to construct the existing containment dike (See Engineering Appendix Drawings B-02 and B-07 through B-10).

Prior to receiving fill, the surface on the crest of the existing containment dike to receive fill would be stripped of light vegetation cover to about a four-inch depth, then scarified to promote adhesion of the new fill. The fill would then be placed in one-foot thick loose lifts and semi-compacted by a minimum specified number of passes using acceptable compaction equipment to be specified prior to construction. The raised section would have a 20-foot wide crown and have an outside slope of 4 horizontal units to 1 vertical unit (4H:1V) while the interior slope would be 3H:1V.

7.1.2.2 Hydraulically Placed Dike Foundation and New Work Placement

Using the proposed Flare bend easing and HSC widener configuration, the most current estimate of new work material resulting from the project (not including maintenance material) would be about 1.94 MCY. Including estimated non-pay volumes, the total new work volume would be about 2.05 MCY. Non-pay dredging is dredging outside the channel template that may occur due to such factors as unanticipated variations in substrate, incidental removal of submerged obstructions, or wind or wave conditions.

The plan would have the new work materials placed hydraulically into a 225-foot wide berm at elevation +26 feet NAVD88 along the interior slope of the raised containment dike. The top of the berm would be sloped to drain toward the interior of the PA and would have a 5H:1V slope at the interior end. It is anticipated that about 50 percent of the new work volume would be retained in the berm template. For capacity analysis, it was assumed the remaining 50 percent of the new work would flow into the interior of the PA.

The new work material would be stacked in the berm template using mechanical equipment as it is discharged from the pipeline. The pipeline discharge would be moved along the berm alignment during dredging to minimize the requirement to move the material once discharged. The cost for moving the dredge discharge and for mechanical manipulation of the discharged new work is included in the cost estimate. Training dikes would be constructed along the interior toe of the proposed berm and parallel to the existing containment dike. The training dikes would have periodic breaches to allow drainage and loss of less desirable materials into the interior of the PA while maximizing retention of the desirable new work clays in the berm.

By replacing some of the softer soils with stronger new work materials through displacement, the goal will be to create a stronger counteractive shear surface within the containment dike embankment to help prevent or reduce the chance of deep embankment failures as the dike is raised in the future. In addition, the hydraulically placed new work berm would serve as the base for future dike lifts which would be offset inward from the current dike configuration. This inward offset would increase the overall length of the counteractive shear surface in the dike embankment, allowing for an increased counteracting force against the driving weight of the dike embankment. Finally, a portion of the new work retained in the berm would be borrowed for future dike raises. A preliminary design plan view for the new work berm is shown in Figure 7-2 and Plate B-02 in the Engineering Appendix. A typical conceptual future dike cross section for the hydraulic berm placement is shown in Figure 7-3 and Plate B-03 in the Engineering Appendix. See Engineering Appendix Section 4.5.2 Hydraulically Placed Dike Foundation for more detailed information. See Engineering Appendix Section 4.6 for PA 14 Containment Dike Slope Stability Analysis.

7.2 Quantities

7.2.1 New Work Quantities

After-dredged survey cross sections were used from the latest O&M dredging contract to calculate new work volumes. There is no maintenance material within the new work volumes calculated for the Flare and the widener (Table 7-1). The maintained depth was the authorized depth of -41.5 MLLW (-40 feet MLT) plus the required AM depth of 7 feet in the Flare for a total maintained depth of -48.5 feet MLLW (-47 feet MLT). The OD was also included within the new work volume. The Non-Pay volume was not included. See Figure 7-4 for a cross section representing the new work area for the 235-widener on the east side of the HSC. See Figure 7-5 for a cross section representing the new work area for the Flare.

Table 7-1: New Work Volume for Corrective Action (Alternative 3)

Channel	**Volume (CY)**
Flare, 4,000-foot radius	1,523,352
HSC, 235 foot widener (*includes barge lane shelf*)	419,486
Total New Work	**1,942,838**

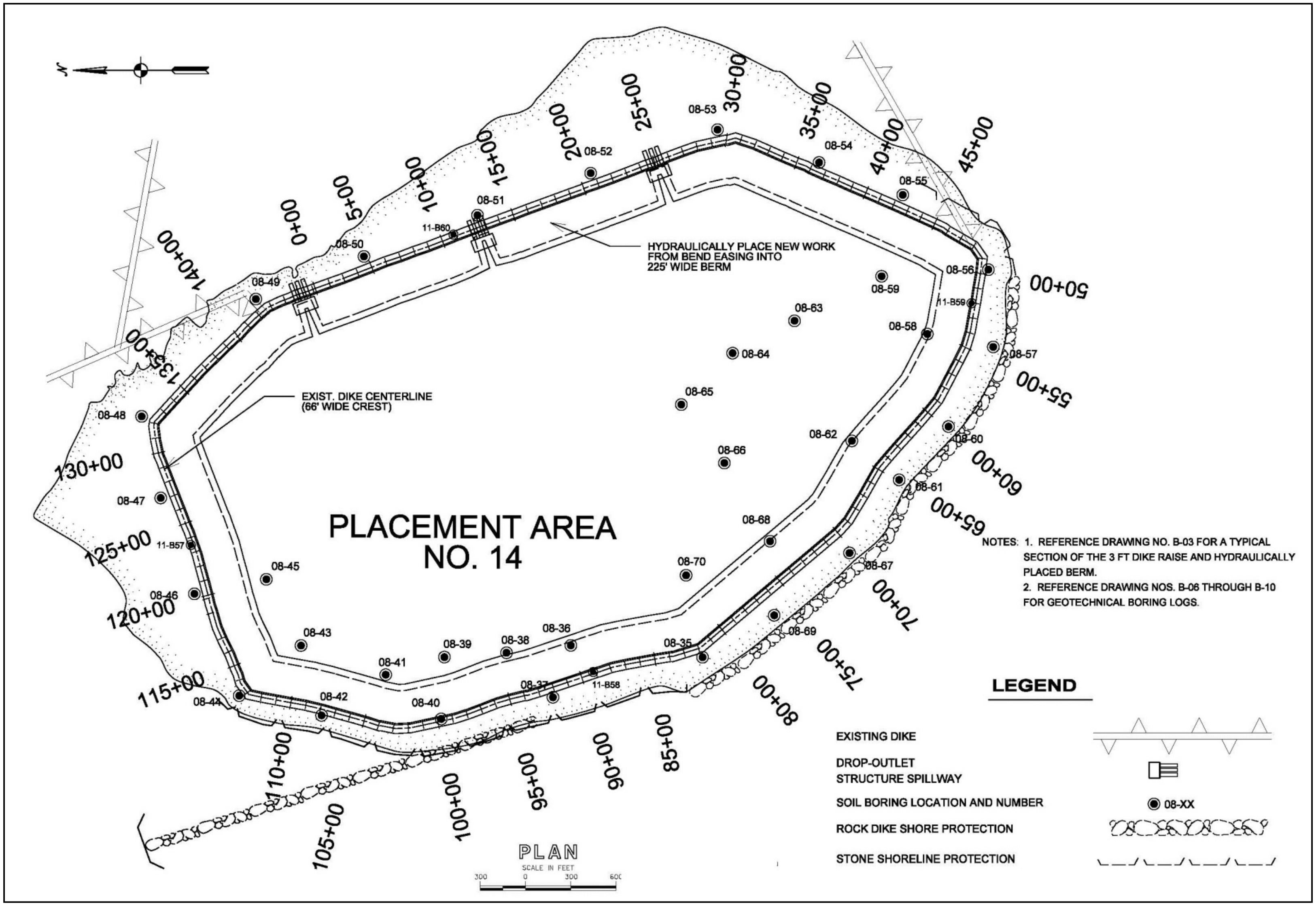

Figure 7-2: PA 14 Hydraulic Berm (and Borings)

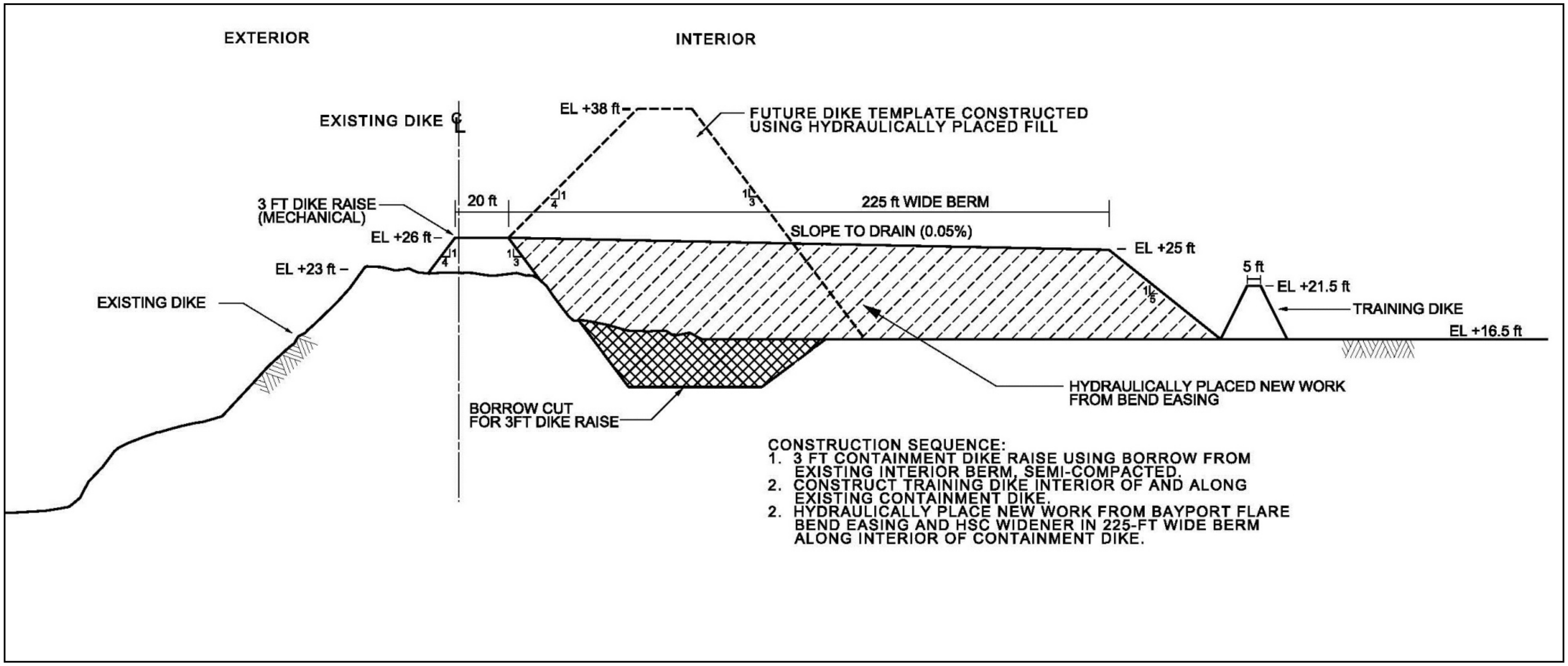

Figure 7-3: Typical Section Hydraulic Berm and Dike (not to scale)

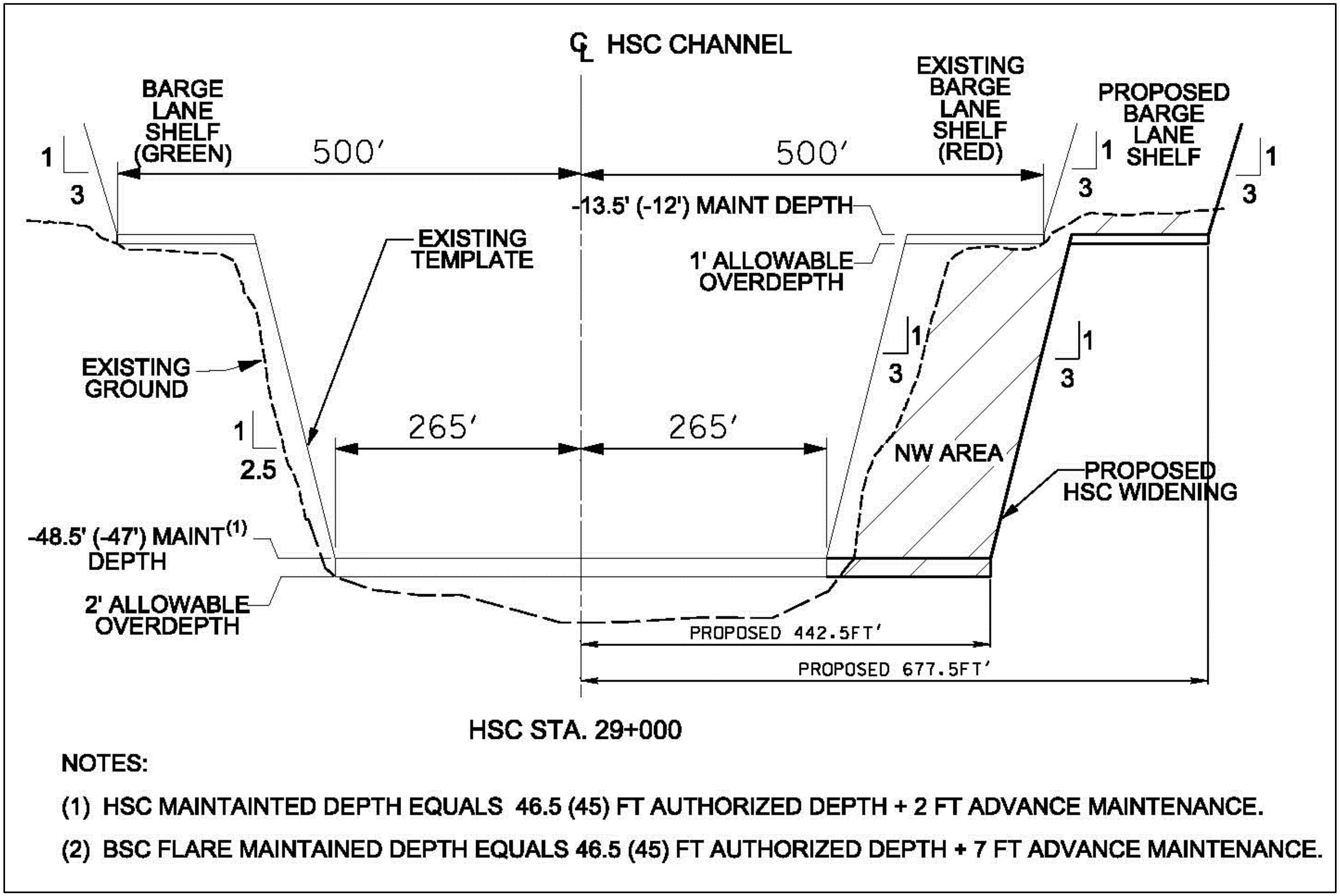

Figure 7-4: Cross Section of 235-foot Bend Easing on east side of HSC (Alternative 3; Corrective action)

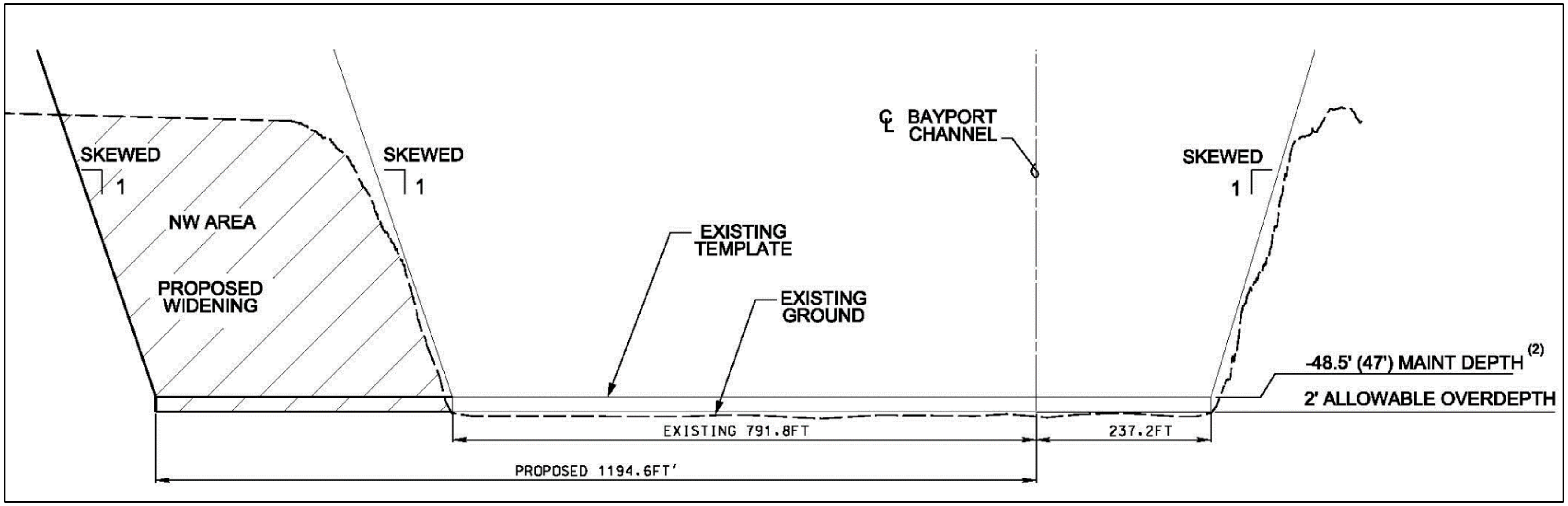

Figure 7-5: Flare Widening to 4,000 feet (Alternative 3; Corrective action)

7.2.2 Maintenance Quantities

Based on existing shoaling rates and patterns in this area of the waterway, the project would result in increased maintenance volumes on the order of about 204,914 CY annually from the Flare and 23,027 CY annually from the HSC Widener (Table 7-2). The resulting 20-year maintenance increment for the corrective action, taking into account dredging cycle lengths and number of cycles anticipated, would be about 4.58 MCY. This volume is the incremental difference above the existing condition O&M quantities. The maintenance materials would be placed in nearby HSC PAs and BU site, including existing PA 15, PA 14, Mid Bay PA, Atkinson Island BU Marsh Cells M7/8/9 and M10, as well as any other Atkinson Island BU Marsh Cells requiring renourishment. The future PA 15/PA 14 connection would also be utilized for maintenance. The project area would be dredged for routine maintenance at the same times and frequencies as the associated channels.

Table 7-2: Estimated Maintenance Volumes for Corrective Action (Alternative 3)

Channel	Annual Volume (CY)
BSC, 4,000-foot radius	204,914
HSC, 235 foot widener (*includes barge lane*)	23,027
Total Annual Maintenance Volume	**227,941**

Maintenance volumes for 20-year would be about 4.58 MCY

7.3 Geotechnical Investigations, Existing Soils Data, and PA Capacities

7.3.1 Geotechnical Investigations

Soil borings drilled between 1977 and 2009 within and near the proposed bend easing at the intersection of the HSC and BSC were reviewed to identify the existing bay and channel bottom soil conditions. Additional soil borings were not performed for this study. Additional borings were not needed for this effort. See Engineering Appendix Section 4.3 for more detail.

7.3.2 Existing Soils Data

As discussed in the Engineering Appendix, Section 4.3 Channel Project Area Historic Soils Data, analysis of the referenced historic boring logs indicates the new work materials within the Flare widening dredging template will consist of soft medium–plasticity silty clays, classified as CL-ML soils, on the bay bottom (about elevation -10 feet) down to about elevation -20 feet. The soft silty clays are underlain by firm to very stiff medium and high-plasticity clays and sandy clays classified as CH and CL soils which extend below elevation -20 feet to about elevation -50 feet.

Soils within the HSC widener and barge lanes dredging template are anticipated to consist predominantly of very soft to firm, medium to high plasticity silty clays and clays classified as CL-ML and CH soils. Cohesionless to semi-cohesionless silty sands, clayey sands, and silts were identified between about elevations -18 feet and -48 feet in the HSC widener area.

Measured grain size distributions of historic channel sediment samples representing dredged maintenance material in the project area indicate that the make-up of dredged maintenance material from the channel has consisted in the past, on average, of approximately 85 percent fine-grained materials and approximately 15 percent coarse grained or sandy materials.

7.3.2.1 Dredged Material Management Plan (20-Year)

Table 7-3 presents the new work and maintenance increment placement plan as well as the impact on estimated PA life for with- and without-project conditions. PA life is calculated using 2016 as the base year and 2017 as year one. This 20-year period of analysis is the same as that used in the ongoing HSC Dredged Material Management Plan study (HSC DMMP). Full details on the existing PAs and BU site to be used for maintenance are available in the Engineering Appendix, Section 4.4 Placement Areas.

Table 7-3: New Work and Maintenance Increment Placement Plan

Placement Area	Ultimate Capacity CY	New Work Volume CY	Maintenance Increment Volume CY	PA Life without Project YR	PA Life with Project YR
Mid Bay PA	29,310,000		285,108	20	20
PA 14	16,948,000	1,942,838	1,891,744	24	20
PA 15	22,682,000		560,776	25	23
PA 15/PA 14 Connection	11,523,000		1,229,484	29	27
Atkinson Is Marsh Cell M7/8/9	3,150,000		409,828	6	6
Atkinson Is Marsh Cell M10	2,490,000		204,914	8	8
Totals		**1,942,838**	**4,581,854**		

7.4 Real Estate Requirements

The proposed corrective action will result in approximately 1.94 MCY of new work material. Because of the proximity to the project area, the new work material will be placed in PA 14. The material will be hydraulically placed into PA 14 with the dredge pipeline placed across the channel. Portions of the pipeline will be submerged under water and other portions will be floating. PA 14 is a 323-acre upland confined PA located about one-half miles northeast of the project area. The PA is on the southern portion of Atkinson Island in upper Galveston Bay, east of the HSC and on the opposite side of the channel from the Bayport Channel. PA 14 is owned by the State of Texas and was constructed under navigation servitude. No staging areas are required for this project and access to the project area will be by barge. Therefore, all construction, including mitigation, will occur below the mean high water and navigation servitude shall be exercised; therefore, no real estate acquisition is required. Additionally, the proposed mitigation feature shall be a construction cost and not creditable as lands, easements, rights-of-way, relocations and disposal areas (LERRD).

7.5 Aids to Navigation (ATONs)

Several ATONs will have to be relocated due to the project work. Per email dated September 8, 2015, the USCG provided the quote for relocating the ATONs. The following ATONs required relocation. In the BSC, Green 3 and Green 5 must be relocated. In the HSC, Red 76 must be moved to the south end of the HSC Bend and one new marker must be added to the north end of the HSC Bend. All four of these markers are single-pile beacon markers. In addition, one buoy marker, Red 2, in the Five Mile Cut must be relocated. The average cost of relocating the single pile markers is approximately $12,000 each. The cost of relocating the buoy is estimated to be $8,000. The cost of adding one new beacon pile marker is also $12,000. These costs are presented in Table 7-4, are 100 percent Federal, and are not included in the Project First Costs. They are associated costs that are included in the total project costs. See Sections 3.9 and 5.1 of the Engineering Appendix for additional details. A copy of the USCG quote is included in Appendix E- Pertinent Documents.

Table 7-4: ATONs Relocation Costs quoted by USCG (September 2015)

Location	ATON	Cost (100% Federal)
BSC	Green 3 single-pile beacon marker	$12,000
BSC	Green 5 single-pile beacon marker	$12,000
HSC Bend	Red 76 single-pile beacon marker	$12,000
HSC Bend	Additional 3 single-pile beacon marker	$12,000
HSC Five-Mile Cut	Red 2 Buoy Marker	$8,000
	Total Relocation Costs for ATONs	**$56,000**

7.6 Risk and Uncertainty

7.6.1 Hydrodynamics

The hydrodynamics of the channel were studied using the Adaptive Hydraulics (AdH) model. AdH is a state-of-the-art hydraulics modeling system developed by the Coastal and Hydraulics

Laboratory, ERDC, capable of handling 2-dimensional and 3-dimensional hydraulic simulations using an adaptive computational grid. Simulations were performed for six alternative geometry conditions. The results were used to inform currents and velocities in the ship simulation study and also to inform With-Project shoaling rates (Engineering Appendix 2.6.2).

7.6.2 Shoaling

Widening and/or deepening a channel can increase the shoaling and sedimentation and can increase corresponding dredging needs for O&M. Shoaling rates estimated for the proposed modifications are based on values provided by the HSC DMMP 2015 analysis. The analysis assumes all shoaled material is dredged. If this is not the case, the actual shoaling rate may be higher than estimated. Causes of shoaling and pathways of shoaled material can be complex. Actual shoaling rates could be greater than estimated; this could cause a linear increase in O&M costs. The shoaling analysis method does not include possible impacts from sea level rise. It is noted that large storms, such as hurricanes, could alter the amount of shoaling in any given year (Engineering Appendix 2.6.2)

7.6.3 Storm Surge

A sensitivity analysis to determine potential impacts to storm surge under the With-Project and future O&M conditions was not performed. Baseline storm surges were composed of the suite of storm surges produced from the Federal Emergency Management Agency (FEMA). Changes are expected to be minor. However, additional surge modeling may be needed during the preconstruction engineering and design (PED) phase (Engineering Appendix Section 2.6.3).

7.6.4 Relative Sea Level Change

The project must consider possible trends that affect the area. One trend that would impact the area is regional sea level change (RSLC). RSLC estimates are based on historical data and contain uncertainty. Estimates of potential sea level change were performed as required by EC 1165-2-212, *Sea-Level Change Considerations for Civil Works Programs*. The aforementioned EC has since expired; however, the District has confirmed the calculations in EC 1165-2-212 are consistent with the calculations in the Engineer Technical Letter (ETL) 1100-2-1, *Procedures to Evaluate Sea Level Change, Impacts, Responses, and Adaptation*, dated June 30, 2014.

To account for the unknowns in sea level change the Corps requires considering “high”, “intermediate”, and” low” estimates of sea level change projections. The estimated values range from 3.18 feet for the local subsidence “high” value to 1.04 feet for the “low” tide gage value for this project area.

In order to assess possible impacts of sea level change for the project the "high" value was evaluated, and it was determined the "high" sea level change scenario will not produce negative impacts on the existing or proposed project. Upland PAs will be armored to withstand the predicted effects of rising sea levels. Minor impacts in the project vicinity would likely occur due to RSLC, but not as a consequence of the proposed project. See Engineering Appendix Section 2.6.4 Sea Level Change for more detailed information.

7.6.5 Study Risks

The Project First Costs include contingency markups on each major feature of work, and to the Preconstruction Engineering, and Design (PED), and Construction Management (CM) phases. Since the Fully Funded Total Project Cost was expected to exceed $40 million, a formal cost risk analysis was required per ER 1110-2-1302 *Civil Works Cost Engineering*. Therefore, the Cost Engineering Mandatory Center of Expertise for Civil Works (located in Walla Walla District) performed a Cost and Schedule Risk Analysis (CSRA). The result was a recommendation of a contingency value of $7 million, or approximately 25 percent of base project cost at an 80 percent confidence level of successful execution to project completion. A detailed Project CSRA Report is attached to the Engineering Appendix.

The CSRA was completed using the nationally recognized software, "Crystal Ball", an Excel-based Monte-Carlo risk simulation software. The CSRA provided a graphic display of the risks associated with the cost estimate and the probability of a cost overrun. The contingency identified is the amount that must be added to reduce the uncertainties to an acceptable level. As a basis for the CSRA, the Project Delivery Team (PDT) first developed a Risk Register once the Recommended Plan was identified. This Risk Register was developed using a Risk Matrix system that assigned Risk Levels to specific areas of concern for each feature of construction work, as well as for the PED and CM phases.

The 25 percent contingency for the Project First cost was applied to the Features of Work listed below:

1. Contract 1, Navigation, Ports, and Harbors (Dredging Flare, Widener, Barge Lane, and Navigation Aids).
2. Contract 1, Navigation, Ports, and Harbors (Placement Area Work).
3. Contract 2, Fish and Wildlife Facilities (Oyster Reef Mitigation).

Some of the risks considered for dredging include unexpected increases in shoaling, market changes in fuel prices, and possible Value Engineering changes to the design during PED.

Uncertainties taken into account in PA work include delays due to adverse weather, fuel price increases, availability of competitive contractors, and changing geotechnical conditions. For oyster bed construction, risk of cost increases considered were subsidence of the cultch layer thickness and market changes in materials and fuel.

7.7 Environmental Effects of Recommended Corrective Action and Impacts

The following is a summary of the environmental impacts of the recommended plan, and compliance with environmental statutes associated with implementing the recommended plan.

7.7.1 NEPA Compliance

In accordance with NEPA, and in compliance with ER 200-2-2, *Procedures for Implementing NEPA*, an EA has been prepared to analyze and document the potential impacts of the proposed project and reasonable alternatives to the natural and human environment. A copy of the EA for the proposed project is included in Appendix A.

7.7.1.1 Affected Environment and Environmental Consequences

Throughout Sections 3.0 and 4.0 of the EA, impacts to resources and any measures proposed to mitigate for significant adverse effects that would be a consequence of project implementation are discussed. These include: physical resources such as geology, bathymetry, oceanographic (e.g. tides, currents), water and sediment quality; biological resources such as aquatic and terrestrial fauna (e.g. benthos, finfish) and habitat (e.g. oyster reef, wetlands), EFH, protected species, and invasive species; and human environment impacts including air quality, noise, socioeconomic, aesthetics, community and recreational resources, infrastructure, and cultural resources.

Since the proposed project consists of new work dredging to correct design deficiencies in an existing navigation channel and O&M of the corrective actions, any new and initial impacts to ecological resources would occur primarily during the new work dredging to construct the project. Maintenance dredging for the modified channel would only occur in areas initially impacted by new work dredging and areas of the existing channel already receiving maintenance dredging. Because the recommended plan is located entirely in open water, at closest 1.3 miles from the mainland, direct impacts of corrective actions are limited to open water and bay bottom habitats. These habitats consist of soft, featureless bottom that is ubiquitous in Galveston Bay and oyster reef, for which several Federal and State laws require mitigation. Impacts to other resources are temporary, minor, or both (e.g. phytoplankton, noise), or will not occur (e.g. wetlands, terrestrial impacts).

Dredged material placement for the plan will involve using the new work material for dike raises at the existing PA 14, the site closest in proximity to the proposed work. The 20-year placement of maintenance dredged material will use the same existing PAs and BU site as currently used for maintenance (PA 15, PA 14, Mid Bay PA, Atkinson Island BU Marsh Cells M7/8/9 and M10, as well as any other existing Atkinson Island BU Marsh Cells requiring renourishment. Therefore, no significant impacts from placement are expected. Specific details for major resource statutes are discussed in the next subsections and Section 2.2.2 through 2.2.8 of the EA. Full details of impacts are discussed in Section 4.0 of the EA.

7.7.1.2 Endangered Species Act

The evaluation of the presence of threatened and endangered (T&E) species is summarized in Section 3.2.4, and the potential project impacts is discussed in Section 4.2.5 of the EA provided in Appendix A to this report. The evaluation for T&E presence included the most recent U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) listings for the subject counties, and coordination through Texas Parks and Wildlife Department (TPWD) to obtain Texas Natural Diversity Database (TXNDD) occurrence listings. A draft Biological Assessment (BA) that discusses the potential impacts to federally listed species in detail is included as Appendix B of the EA in Appendix A of this report. Compliance with the Endangered Species Act (ESA) is discussed in Section 6.8 of the EA.

The federally listed protected species that may occur in the project area are the Green, Kemp's Ridley, and Loggerhead sea turtles. The T&E evaluations and Draft BA conclude that, though the sea turtles may occur in the bay waters in or near the project area as transients, no suitable nesting habit is found in the project area. The Draft BA concludes that the proposed action will have no effect on the listed species. Because no designated critical habitat is involved and the proposed action would not adversely affect the listed species, formal consultation was not initiated with the resource agencies.

7.7.1.3 Fish and Wildlife Coordination Act

As discussed in Section 6.2 of the EA in Appendix A, the USFWS provided a planning aid letter (PAL) to assist with the planning of the proposed project by providing comments and recommendations related to impacts on fish and wildlife resources. The use of the American oyster HSI model, mitigation of the impacted reef, and the continued coordination of the mitigation with the Beneficial Uses Group (BUG) was recommended. Those recommendations are being implemented.

7.7.1.4 Coastal Zone Management Act

Compliance with the Coastal Zone Management Act (CZMA) of 1972 is discussed in Section 6.7 of the EA provided in Appendix A. Because the proposed action exceeded Texas Commission on Environmental Quality (TCEQ) thresholds for referral to the Coastal Coordination Council, the determination of consistency with the TCMP was deferred to determination by the TCEQ under its Section 401 State Water Quality Certification of the proposed action. State Water Quality Certification will be requested from the TCEQ and will be included in the Final EA.

7.7.1.5 Clean Water Act

Section 404 of the Clean Water Act (CWA) regulates dredge and/or fill activities in U.S. waters. Section 404(b)(1) of the CWA, for which the Section 404(b)(1) Guidelines were developed, regulates discharges of dredged or fill material to maintain the integrity of waters of the United States, including activities under the Corps Civil Works Program. The proposed action would require dredging in U.S. waters. The EA was prepared to support the decision-making process implementation of the recommended plan, and the discussion of the impacts of the proposed action has taken into consideration the Section 404(b)(1) Guidelines. The District evaluated the proposed action pursuant to Section 404(b)(1) of the CWA and this analysis is included in Appendix A of the EA.

The TCEQ is responsible for conducting Section 401 certification reviews of proposed Federal actions, including those proposed by the Corps, for the purpose of determining whether the proposed discharge would comply with State water quality standards. A copy of the State Water Quality Certification will be included in Appendix A of the final EA.

Pursuant to the Section 404(b)(1) Guidelines in 40 CFR 230, the suitability of dredged material for placement and the need to test material further was determined. Under 40 CFR 230.60 and USACE Regulatory Guidance Letter (RGL) 06-02, *Guidance on Dredged Material Testing for Purposes of Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972*, dredged material testing under the CWA is based on a reason to believe that contaminants are present in the material proposed for discharge and have the potential to cause an unacceptable adverse impact. An evaluation of dredged material for confined upland placement using a lines-of-evidence (LOE) and weight-of-evidence (WOE) approach was performed by ERDC. The evaluation examined factors for the presence, fate, and transport of contaminants related to the material proposed for dredging and placement. This included identifying potential contaminant sources, pathways, ecological receptors, and chemicals of concern, and an evaluation of past sediment and dredged material testing to develop multiple LOEs for the evaluation of the potential presence of contaminants. Past sediment and dredged material testing included results from recent maintenance material testing in this reach of the HSC conducted from 2009 to 2015, and new work material testing in the BSC conducted in 2014. The LOEs were evaluated under a WOE framework considering spatial, temporal, and other factors such as exposure strength/gradient, plausibility, and specificity of cause. The evaluation resulted in the conclusion that there was no reason to believe that contamination was present that will be mobilized during the dredging or placement to implement the corrective action of the recommended plan, and that further pre-dredge physical and chemical testing of the material proposed to be dredged was not required.

7.7.1.6 Clean Air Act

Coordination and determination of conformity with the relevant State Implementation Plan (SIP) was conducted. The USACE sent a letter requesting a determination of conformity with the SIP to the TCEQ, the agency responsible for the SIP for Texas, via a letter dated August 25, 2015. A copy of this letter is provided in Appendix 2 of this EA. The Draft GCD was publicly coordinated and a public notice of the Draft GCD availability was published concurrent with agency and public review of the Draft PDR and Draft EA, with copies provided to the TCEQ, EPA Region 6, and the HGAC. The TCEQ sent a letter responding to the request dated November 4, 2015, which concluded that the proposed project would conform to the SIP. Compliance with the Clean Air Act (CAA) is discussed in Section 6.6 of the EA.

7.7.1.7 Hazardous, Toxic and Radioactive Waste (HTRW)

HTRW is addressed in Sections 3.3.7 and 4.3.7 of the EA provided in Appendix A. Compliance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Resource Conservation and Recovery Act (RCRA) is discussed in Sections 6.14 and 6.15, respectively of the EA. The proposed action will not involve sites or wastes regulated under CERCLA or RCRA. The proposed action involves dredging of a submerged navigation channel to improve navigability, and inherently does not involve the substances or activities regulated under the Toxic Substances Control Act (TSCA).

7.7.1.8 National Historic Preservation Act (NHPA)

Cultural resource surveys and impacts of the proposed action are discussed in Sections 3.3.10 and 4.3.10, respectively, of the EA provided in Appendix A. Compliance with the NHPA of 1966, as amended, is discussed in Section 6.4 of the EA. Surveys, including those for potential submerged cultural resources, were done in coordination with the Texas State Historic Preservation Officer (SHPO) and in accordance with the Texas State Antiquities Code. Two anomalies warranting further investigation or avoidance were identified in the project's APE. On August 12, 2012, Galveston District provided a letter to the SHPO describing the results of the marine remote sensing survey conducted to investigate the anomalies. Subsequently, the SHPO concurred with these findings on August 22, 2012. A copy of this correspondence in provided in Appendix D of the EA.

Therefore, the recommended corrective action would not have any impacts on historic properties, and no additional surveys are planned for this area. In accordance with regulations in 36 CFR 800.2, promulgated for Section 106 of the NHPA, the Advisory Council on Historic Preservation (ACHP) consults with and comments to agency officials on individual undertakings and programs when they affect historic properties. Since no historic properties were found in the APE, consultation or review by the ACHP was not initiated. No Tribal lands are in the vicinity of the proposed project.

7.7.2 Oysters and Oyster Reef Impacts

Oysters and Oyster Reef Impacts are discussed in Section 3.2.2.2.3 of the EA provided in Appendix A. There are approximately 21.3 acres of oyster reef within the proposed Flare easing, 7.4 acres of reef within the proposed main channel widener, and 8.6 acres of reef within the proposed barge lane relocation. The main channel widener is wholly within the existing barge lane of the HSC. The oyster reef impacts within the existing barge lanes (including those within the proposed main channel widener) were mitigated for permanent impact with approximately 54 acres of oyster reef pad construction by the USACE in 2004, when the barge lanes were dredged as part of the HGNC. The existing barge lanes are to be perpetually maintained. The existing barge lane oyster reef impact and mitigation were documented under the *2005 Record of Environmental Considerations for Houston - Galveston Navigation Channels, Texas Project - Upper Bay Barge Lanes*. Therefore, the 7.4 acres of reef within the proposed main channel widener, which represents regrowth into the existing barge lanes which are periodically dredged for maintenance, have already been mitigated.

A map delineating areas of consolidated oyster reef and areas with high densities of shell hash (i.e. shell-in-mud or shell-on-mud) with or without oysters around the proposed project area is provided in Figure 7-6. In summary, approximately 37.3 acres of oyster reef habitat were found to occur within the footprint of the proposed action, of which 7.4 acres were already previously mitigated, resulting in 29.9 acres of reef impact to mitigate.

7.7.3 Mitigation Requirements Resulting from Implementing Corrective Action

Oyster reef, although not a Federal or State Endangered species, is considered a significant ecological resource under both the USACE Regulatory program and in our Civil Works Planning

Process. In addition, these resources are considered significant and therefore subject to mitigation of unavoidable impacts by USFWS, TPWD (state resource agency; regulates compensation for oyster reef impacts twice in state law), Texas General Land Office (implements the Texas Coastal Management Program under the Federal CZMA; oyster reef is designated as a Critical Natural Resource Area, CNRA, under this program), and NOAA (EFH).

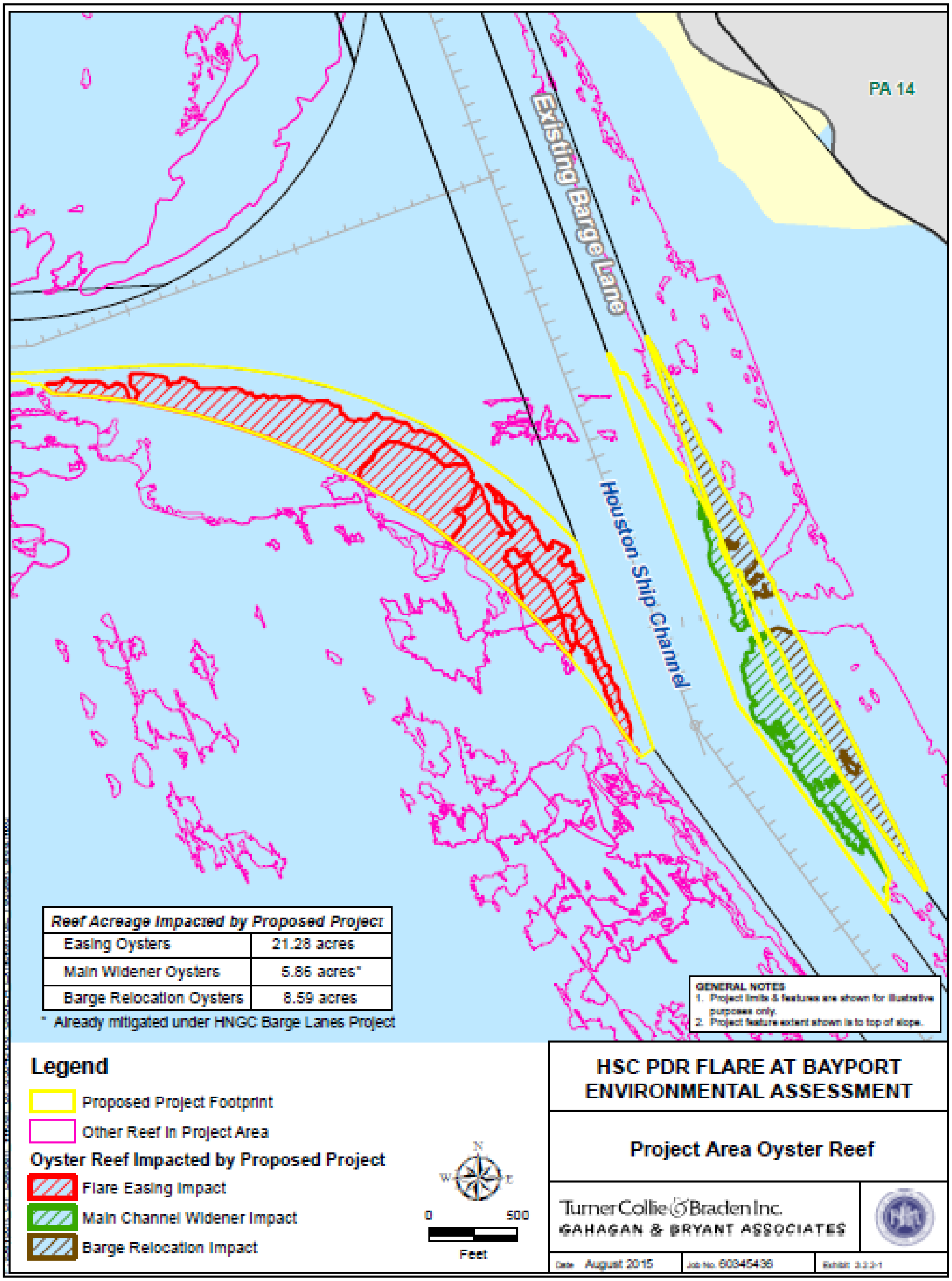

Figure 7-6: Oyster Reef Acreage Impacted by Recommended Corrective Action

The corrective action to the HSC would result in unavoidable, permanent impacts to approximately 29.9 acres of oyster reef. Mitigation for these direct impacts would replace the oyster habitat lost by restoring oyster reef on San Leon Reef in the Clear Lake embayment of Galveston Bay, Chambers County, Texas. The mitigation plan is shown in Figure 7-7 and details of the Mitigation Plan can be found in Section 4.4.1 of the EA included as Appendix A.

The San Leon Reef mitigation area was recommended by TPWD, following assessment of reef impacted by Hurricane Ike-induced sedimentation in 2008. San Leon Reef has approximately 40 acres identified by TPWD for rehabilitation. To determine the amount of mitigation required, a functional assessment model, the USFWS Habitat Suitability Index model for the American oyster was applied, to determine the functional impacts of the proposed project, and the function restored by the proposed mitigation, measured in Average Annual Habitat Units (AAHU). A total of 30.1 acres at San Leon Reef was determined to be necessary to replace the 29.16 AAHUs lost from the impact to the 29.9 acres at the project site.

The mitigation plan proposes to place cultch (limestone, clean, crushed concrete or other suitable material) to 30.1 acres on San Leon Reef to produce a relief of 6-inches above the bay bottom to recruit oysters. The initial construction cost of 30.1 acres of oyster reef is $3.3 million. The mitigation monitoring effort for the oyster reef includes sonar side-scans in Year 1 and Year 10, yearly monitoring (spring and fall) by divers in Years 1, 2, 3, and 10, and report writing. The total cost of initial and follow-up monitoring is $174,684 under O&M.

Figure 7-7: HSCPDR Oyster Mitigation Plan

7.8 Project Operation and Costs

7.8.1 Operation and Maintenance

The O&M phase of the project will be accomplished using the existing procedure for the HSC project. The procedure would be composed of the following steps:

1) Historical records are kept for shoaling rates in various reaches of the navigation channel. The data in the historical records are continually updated based on actual contract dredging volumes for the various reaches.

2) Condition Surveys are conducted twice a year to determine the actual cross-sections at multiple stations along the navigation channel. The cross-sections are used to compute the actual shoaling rate in the various reaches. The actual shoaling rates are compared with the expected rates obtained from the historical data. Historical data are also updated to reflect the actual shoaling rates.

3) Dredging contracts are prepared to restore the channel to its design depth as required for the various reaches of the channel.

4) The Corps performs all the activities indicated above.

5) The structural components are limited to the existing drop-outlet structures used to drain excess water from the PAs. The structures are composed of structural steel members, a steel-reinforced concrete invert slab, steel discharge pipes, and access platforms. Water drainage through the drop-outlet structures are controlled by the use of timber planks (stop-logs). As part of the O&M of the project, these structures will be periodically painted as needed, and the timber planks replaced. As the containment dike elevations are raised and repositioned laterally toward the interior of the PAs the drop-out structures may be moved and or replaced as required by the new dike configurations.

6) The anticipated dredged maintenance material quantities for future O&M are anticipated to increase incrementally for the existing BSC Flare and the HSC project dimensions.

7.8.2 Deficiency Correction Design and Construction Costs

The cost estimate (see Appendix C) for the design and construction of the recommended corrective action was certified on January 12, 2016 and reflects a price level of October 1, 2015. The first cost for the design and construction of the deficiency corrective action is $35,106,000, as detailed in the cost estimates provided in Section 5.0 of the Engineering Appendix. The fully funded cost for the design and construction of the deficiency corrective action is $35,873,000. These costs were developed using Mii Version 4.2 in accordance with guidance in Corps engineering regulations. A summary of the cost is provided in Table 7-5. The cost estimate for the construction contract includes a 25 percent contingency based the formal risk analysis process (Crystal Ball), as directed for this report by the Cost Engineering Directory of Expertise. The cost includes mitigation of oyster impacts under Cost Account 06. A summary of the cost estimate for the 20-Year O&M for the project is provided in Table 7-6. The O&M cost include the approximately $175,000 of periodic mitigation monitoring over 10 years. At October 2015 price levels the first cost of the 20-year O&M for the project is $32,106,000 and the fully funded cost of the 20-year O&M for the project is $42,011,000.

Table 7-5: Project First Cost & Fully Funded Cost for Correction Action ($000)

Cost Account	**Construction General – General Navigation Features (GNF)**		
		Project First Cost *Oct 2015 Price Level*	**Fully Funded Cost** *Oct 2015 Price Level*
12	Navigation Aids (100% Federal-USCG)	$70	$72
12	Navigation Ports & Harbors[1,]	$30,461	$31,142
06	Fish & Wildlife Facilities[1]	$4,550	$4,634
01	Lands and Damages	$25	$25
	Total Correction Action Cost	**$35,106**	**$35,873**

[1]*Includes associated Planning, Engineering & Design and Construction Management costs.*

Table 7-6: 20-Year O&M for Flare and Widener Incremental Dredging ($000)

Cost Account	**Construction General – General Navigation Features (GNF)**		
	20-Year O&M	**Project First Cost**	**Fully Funded Cost**
		Oct 2015 Price Level	
12	Navigation Ports & Harbors	$32,106	$42,011
	Total Correction Action Cost	**$32,106**	**$42,011**

7.8.3 Cost Sharing

For a commercial navigation project, With-Project depths greater than 20 feet but not in excess of 45 feet, the non-federal share for the construction is 25 percent. Lands, easements, rights-of-way, and relocations (LERRs) are 100 percent non-federal costs. O&M of the general navigation features with a 100 percent commercial vessel navigation project are a 100 percent Federal responsibility.

ER-1105-2-100 (Page E-62) states under 2(a) Harbors, General Navigation Features, Section 101 specifies cost shares for general navigation features that vary according to the channel depth: (20 feet or less, greater than 20 feet but not more than 45 feet, and greater than 45 feet). The percentage also applies to mitigation and other work cost shared the same as general navigation features. The cost share is paid during construction. Section 101 also requires the project sponsor to pay an additional amount equal to 10 percent of the total construction cost for general navigation features. This may be paid over a period not to exceed thirty years, and LERRs may be credited against it; however, for this project there are no LERRs.

The recommended plan for corrective action includes mobilization (mob/demob) costs. See Table 7-7 for General Cost Allocation breakout and notes specific to the Recommended Corrective Action.

Table 7-7 – General Cost Allocation

Feature	**Federal Cost %[1]**	**Non-Federal Cost %[1]**
General Navigation Features (GNF)	●90% from 0 feet to 20 feet **●75% from 20 feet to 45 feet** ●50% for 46 feet and deeper	●10% from 0 feet to 20 feet **●25% from 20 feet to 45 feet** ●50% for 46 feet and deeper
Mitigation	**●75%**	**●25%**
Navigation Aids	**●100% USCG**	**●0%**
Operation and Maintenance		
GNF	**●100% except cost share 50**% costs for maintenance > 45 feet.	●0% except cost share 50% costs for maintenance > 50 feet.

[1] The non-Federal sponsor shall pay an additional 10% of the costs of GNF over a period of 30 years, at an interest rate determined pursuant to Section 106 of WRDA 86. Normally, the value of LERR shall be credited toward the additional 10% payment; however, there are no LERRs for this project.

Table 7-8 reflects the cost allocation for the cost of the Recommended Corrective Action at October 2015 price levels.

Table 7-8: Recommended Corrective Action – First Costs Allocation ($000)

Cost Account	**Project Features**	**Federal (75%)**	**Non-Federal (25%)**	**Total**
		October 2015 price levels		
	Construction General – General Navigation Features (GNF)			
12	Coast Guard Navigational Aides	$70	$0	$70
12	Navigation-Deep Draft (75/25)[1]	$22,846	$7,615	$30,461
06	Fish & Wildlife Facilities (75/25)[1]	$3,413	$1,138	$4,550
01	Lands and Damages (Non-Federal 100%)	$0	$25	$25
	Total Correction Action Cost	**$26,328**	**$8,778**	**$35,106**
[1]*Includes associated Planning, Engineering & Design and Construction Management costs.*				

The Cost Apportionment for the cost of the Recommended Corrective Action at October 2015 price levels is presented in Table 7-9.

Table 7-9: Cost Apportionment ($000)

	Construction Item	**Project First Cost ($000's)**	**Project Fully Funded Cost ($000's)**
		Oct 2015 Price Level	
Navigation (other Federal):			
12	Coast Guard Navigational Aides	$70	$72
General Navigation Features			
12	Federal – Deep-Draft Dredging (75%)	$19,315	$19,746
12	Federal – Deep-Draft Dike Work on PA (75%)	$1,478	$1,510
12	Non-Federal Deep-Draft Dredging (25%)	$6,439	$6,582
12	Non-Federal Deep-Draft Dike Work on PA (25%)	$493	504
06	Fish & Wildlife Mitigation (Federal 75%)	$3,105	$3,161
06	Fish & Wildlife Mitigation (Non-Federal 25%)	$1,035	$1,053
30	Planning, Engineering & Design (Federal 75%)[1]	$1,462	$1,476
30	Planning, Engineering & Design (Non-Federal 25%)[1]	$487	$492
31	Construction Management (Federal 75%)[1]	$898	$939
31	Construction Management (Non-Federal 25%)[1]	$299	$313
01	Land & Damages – 100% Non-Federal	$25	$25
Total General Navigation Features Costs and Credits		**$35,106**	**$35,873**
[1]*Planning, Engineering & Design and Construction Management costs for accounts 12 and 06.*			

7.8.4 Project Cooperation Agreement

If the PDR approved by the DCW determines that the issue at the HSC/BSC intersection is a project deficiency, additional authorization is not required for construction and O&M. The authorization is the original project authorization (WRDA 1996) as we are working to achieve the benefits for the authorized project and make it function as originally intended. The project's existing Project Cooperation Agreement (PCA) was signed by the Acting ASA(CW) on June 10, 1998. The District will proceed under the existing PCA as we are still working to achieve the authorized purpose and have not closed out the original project. However, future guidance may prompt a new Project Partnership Agreement (PPA) for the project deficiency fix. The 7001 Report does not automatically assume the proposal will be authorized. It only states the proposal meets the five set deficiency criteria Section 7001. The Port of Houston and the Congressional Committees will determine if this proposal from the PDR will be included into the next WRDA.

7.8.5 View of Non-Federal Sponsor

The PHA fully supports this project both financially through cost sharing and legislatively through the project authorization. The letter of support is included in this Final Report submittal. After the HSC portion of the construction was physically completed in 2005 (fiscally completed in 2007), the sponsor reported issues regarding the navigation risks in the area of concern and has worked diligently to have the problem resolved.

8 PUBLIC INVOLVEMENT AND AGENCY COORDINATION

8.1 Public Involvement Activities

The public was provided an opportunity to comment on the recommended corrective action and proposed mitigation plan during the 30-day public review that started 14 September 2015 for the HSCPDR/EA document. Notification was provided by posting the documents on the District's public document review website: (*www.swg.usace.army.mil/BusinessWithUs/PlanningEnvironmentalBranch/DocumentsforPublicReview.aspx*), postcards mailed to adjacent property owners, and a public Notice of Availability published in the Houston Chronicle on September 14, 2015 and September 15, 2015. Comments submitted during that process were considered and addressed. Public comments were received and responses to them are provided in Appendix 3, Responses to Public Comments, of the EA. The HSCPDR is very limited in scope and non-controversial.

8.2 Coordination of Corrective Action with Federal and State Agencies

The development of the mitigation plan was coordinated with the USFWS, TPWD, and NMFS. The EA and a Draft Findings of No Significant Impact (FONSI) was sent to Federal and State agencies including the following:

Environmental Protection Agency Region 6
NOAA National Marine Fisheries Service
Texas Commission on Environmental Quality
Texas General Land Office
Texas Historical Commission
Texas Parks and Wildlife Department
U.S. Coast Guard
U.S. Fish and Wildlife Service
Natural Resource Conservation Service
Texas Parks and Wildlife Department
Texas Water Development Board
Texas Office of State-Federal Relations
Governor's Office of Budget and Planning
Railroad Commission of Texas
Honorable John Cornyn
Texas Department of Transportation

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9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

As demonstrated in Section 2, the project meets all five criteria for a design deficiency. AIS data analysis proves the project does not function as initially intended, in a safe, viable, and reliable manner. Fact is that at least 80 percent of the time, the passing of the class of vessels for which the channel was designed for violates the minimum clearances stipulated for safe navigation. In other words, the project does not function as intended 80 percent of the time. The recommended plan for corrective action meets the planning objectives by allowing for safe navigation in the area of safety concern in the vicinity of the HSC and BSC intersection. The channel design for the WRDA 1996 project did not fully account for the impacts of the channel improvements in the project area. A hazardous and unacceptable navigation condition has resulted. The recommended corrective action can alleviate the ongoing navigation concerns in the vicinity of the HSC and BSC intersection.

9.2 Recommendations

I hereby recommend construction of the Alternative 3 recommended design deficiency corrective action. The corrective action consists of increasing the existing 3,000 feet southern radius of the Flare to 4,000 feet, widening the HSC by a maximum 235 feet to the east between about HSC Station 26+484 and HSC Station 30+090, and relocating the existing barge lane to accommodate the widened HSC. The barge lane will be relocated to the east of the HSC widening and will be consistent with the original design.

Dredging will be accomplished using a hydraulic dredge with cutterhead and pumping the dredged new work materials to PA 14, located about one-half mile northeast of the project. The upland confined Mid Bay PA would be considered an alternate location for new work placement for this project should unforeseen circumstances occur prior to construction precluding the use of or limiting the capacity of PA 14. However, the material must be similarly placed within the upland confined Mid Bay PA, on the interior slope of the existing perimeter dike to form a berm, whereupon it may also be used for future dike raising construction.

The project would result in increased maintenance volumes on the order of about 204,000 CY annually from the Flare and 23,000 CY annually from the HSC Widener. The resulting 20-year maintenance increment, taking into account dredging cycle lengths and number of cycles anticipated, would be about 4.58 MCY. Approximately 30.1 acres of oyster habitat would be restored at the San Leon Reef to compensate for the 29.9 acres of direct oyster impacts in the project footprint.

The estimated Project First Cost of the corrective action at October 2015 price levels is (a) $35,106,000, including a 100 percent federal share of (b) $70,000 and non-Federal share of (c) $25,000, an estimated 75 percent Federal share of (d) $26,259,000, and an estimated 25 percent non-Federal share of (e) $8,753,000. The Fully Funded Cost of the project, which includes Project Costs and expected escalation totals, is $35,873,000. The 20-year O&M for the Flare and Widener incremental dredging is estimated at a Project First cost of $32,106,000 and a Fully Funded cost of $42,011,000.

This recommended corrective action would alleviate the ongoing navigation safety concerns at the intersection of the HSC and BSC and allow the project to function as originally intended. The construction and O&M of the recommended corrective action can be implemented under the WRDA 1996 project authority, subject to modification of the authorization for the HGNC project to address the Section 902 cost limit.

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels with the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorizations and implementation funding. However, prior to transmittal to the Congress, the non-Federal sponsor, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

22 MARCH 2016
Date

Richard P. Pannell
Colonel, U.S. Army
Commanding