U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas

Final Integrated Feasibility Report – Environmental Impact Statement

December 2019

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DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
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Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas

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RECORD OF DECISION

Houston Ship Channel Expansion Channel Improvement Project
Harris, Chambers, and Galveston Counties, Texas

The Final Integrated Feasibility Report and Environmental Impact Statement (FIFR/EIS) dated **DATE OF FEIS**, for the **Houston Ship Channel Expansion Channel Improvement Project** addresses **deep draft navigation** opportunities and feasibility in the Harris, Chambers, and Galveston Counties, **Texas**. The final recommendation is contained in the report of the Chief of Engineers, dated **DATE OF CHIEF'S REPORT**. Based on these reports, the reviews by other Federal, State, and local agencies, Tribes, input of the public, and the review by my staff, I find the plan recommended by the Chief of Engineers to be technically feasible, economically justified, in accordance with environmental statutes, and the public interest.

The Final IFR/EIS, incorporated herein by reference, evaluated various alternatives that would to provide an efficient and safe navigation channel while contributing to the National Economic Development (NED) consistent with protecting the nation's environment in the study area. The recommended plan is the Locally Preferred Plan (LPP) and includes:

- Four bend easings on main HSC channel with associated relocation of barge lanes (Segment 1);
- Widening the HSC main channel between Bolivar Roads and BCC from the existing 530-foot width to 700 feet with associated relocation of barge lanes (Segment 1);
- Widen BSC on north side of channel to 455 feet (Segment 2);
- Widen BCC on north side of channel 455 feet (Segment 3);
- Widen BCC flare on north and south to create a 1,800-foot diameter turning basin (Segment 3);
- Deepen the HSC main channel from Boggy Bayou to Hunting Turning Basin up to 46.5 feet (Segment 4);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (Segment 4);
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge up to 41.5 feet (Segment 5);
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin up to 41.5 feet (Segment 6);
- Improve Brady Island turning basin to 900-foot diameter (Segment 6);
- Inclusion into the Federal Project, the Greens Bayou Channel, a 1.6-mile-long combination 41.5-feet and 16.5 feet deep channel (Segment 1);
- Inclusion into the Federal Project, the BSC dimensions of 46.5-feet deep by 400-feet wide from the HSC to the Land Cut and 350-feet wide from the Land Cut to Turning Basin (Segment 2);
- Inclusion into the Federal, the BCC dimensions 46.5-feet deep by 300-feet wide (Segment 3);
- Inclusion into the Federal Project, the Jacintoport Channel measuring 0.76-mile long by 41.5 feet deep (Segment 4); and Inclusion into the Federal Project, the Jacintoport Channel measuring 0.76-mile long by 41.5 feet deep (Segment 4)
- Implementation of the environmental compensatory mitigation and associated monitoring and mitigation area adaptive management plan. Monitoring will continue until the mitigation is determined to be successful based on the identified criteria within the Mitigation Plan for Oyster Reef Habitat included in Appendix P-1. Monitoring is expected to last 3 years, but no more than 10 years. Mitigation for wetland impacts would occur through purchase of wetland mitigation bank credits at a bank approved by the USACE Galveston District.

In addition to a "no action" plan, eight alternatives were evaluated. The alternatives included Alternative 1 - Minimum System Wide Plan, Alternative 2 - Bay Plan, Alternative 3 - Suezmax Plan, Alternative 4 - Aframax Plan, Alternative 5 - Bulkers, Tankers, and Vehicle Carriers Plan, Alternative 6 - Bay Mooring Plan, Alternative 7 - Upper Channel Mooring Plan, Alternative 8 - The Comprehensive Plan. Non-structural measures were considered and not selected because they have been historically used to manage safe vessel transit of the HSC system and are already practiced to the greatest extent practicable; however, they are not sufficient to alleviate the existing inefficiencies, and would not provide some of the positive environmental impacts for air emissions reduction or beneficial use (BU) that structural alternatives could provide. Alternative 8 was selected for refinement into the NED Plan and the LPP. The LPP impacts 410 acres of oyster reef compared to 88 acres by the NED Plan, and both plans impact approximately 72 acres of terrestrial wetlands. However, the LPP would provide approximately 4 times the reduction of in-port operational emissions and hours of delay, reduce the risk of vessel incidents by providing greater two-way vessel meeting opportunities in one of the highest traffic ports in the Nation, and would provide more BU material to construct an additional 445 acre marsh cell M11 and a shoaling attenuation feature to reduce the largest source of channel maintenance material that requires long-term placement capacity. The LPP was recommended for implementation and was identified as the environmentally preferable alternative.

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the recommended plan are listed in Table 1:

Table 1: Summary of Potential Effects of Recommend Plan

	Significant adverse effect	Insignificant effects due to mitigation	Insignificant effects	Resource unaffected by action
Aesthetics	☐	☐	☒	☐
Air quality	☐	☐	☒	☐
Aquatic resources/wetlands	☐	☒	☐	☐
Invasive species	☐	☐	☒	☐
Fish and wildlife habitat	☐	☒	☐	☐
Threatened/Endangered species	☐	☒	☐	☐
Historic properties	☐	☐	☒	☐
Other cultural resources	☐	☐	☒	☐
Floodplains	☐	☐	☒	☐
Hazardous, toxic & radioactive waste	☐	☐	☒	☐
Hydrology	☐	☐	☒	☐
Land use	☐	☐	☒	☐
Navigation	☐	☐	☐	☐
Noise levels	☐	☐	☒	☐
Public infrastructure	☐	☐	☒	☐
Socio-economics	☐	☐	☒	☐
Environmental justice	☐	☐	☒	☐
Soils	☐	☐	☒	☐
Tribal trust resources	☐	☐	☐	☒
Water quality	☐	☐	☒	☐
Climate change	☐	☐	☒	☐

All practicable means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the IFR/EIS will be implemented to minimize impacts. Oyster reef and wetland impacts would be adverse and significant if not mitigated, and will require execution of the mitigation plans summarized in Section 7.5 and detailed in Appendix G (Section 3.5) and Appendix P. Their impacts are summarized in Sections 7.2.1.2 and 7.2.2.4, and detailed in Appendix G (Sections 3.2.1.2 and 3.2.2.3) and Appendix P. Practices for construction air emissions are being determined through the ongoing General Conformity Determination process. Construction of upland PAs will follow applicable local noise ordinances. Construction of BU oyster reef pads will employ submerged diffuser technology to minimize turbidity to nearby reef. Channel maintenance using hopper dredging with placement at the offshore site ODMDS No. 1 will follow the current best management practices (BMP) currently employed for the existing channel maintenance. Construction of upland PAs, or new ones adjacent to existing PAs would consider scheduling to minimize impacts during nesting seasons, and employ nesting surveys as necessary.

The recommended plan will result in unavoidable adverse impacts to oyster reef and wetlands. To mitigate for these unavoidable adverse impacts, the U.S. Army Corps of Engineers will require construction of oyster reef mitigation and purchase of wetland mitigation bank credits. The oyster reef mitigation will require construction of 358.3 acres of reef pads at the San Leon and Dollar Reef areas in Galveston Bay, and 18.1 acres of oyster reef wave trip/shore protection features at the three BU sites in Galveston Bay. Wetland mitigation will require purchase of approximately 18.1 biota and 14.7 chemical functional capacity units (FCU) for construction of new work placement PAs E2 Clinton and BW8, and 34.8 biota and 25.4 chemical FCUs for future construction of the Rosa Allen Expansion maintenance PA, at an approved mitigation bank. The details of the acreage and credit types are provided in Section 7.5 and Appendix G (Sections 3.2.1.2 and 3.2.2.3) and Appendix P.

Public review of the draft IFR/EIS was completed on 13 November 2017. The public review began on 1 September 2017, was extended an additional 30 days because much of the interested public had been affected or displaced by Hurricane Harvey. The public review closed for comments on and closed for comments on 13 November 2017. All comments submitted during the public comment period were responded to in the Final IFR/EIS. A 30-day waiting period and state and agency review of the Final IFR/EIS was completed on **29 February 2020**. Comments from state and federal agency review did not result in any changes to the final IFR/EIS.

Pursuant to Section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers determined that the recommended plan may affect but is not likely to adversely affect the following federally listed species or their designated critical habitat: endangered green, loggerhead, and Kemp's ridley sea turtles, Giant manta ray, and West Indian manatee. The National Marine Fisheries Service (NMFS) concurred with the Corps' determination on 27 November 2019. The U.S. Fish and Wildlife Service (FWS) concurred with the Corps' determination on 10 December 2019.

Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, the U.S. Army Corps of Engineers determined that historic properties may be adversely affected by the recommended plan. The Corps and the Texas State Historic Preservation Office (SHPO) entered into a Programmatic Agreement (PA), dated 1 February 1988. All terms and conditions resulting from the agreement shall be implemented in order to minimize adverse impacts to historic properties. The USACE intends to execute a new PA, in consultation with the Advisory Council on Historic Preservation (ACHP), the Texas SHPO, and Tribal Nations, that will include the Houston Ship Channel Expansion Channel Improvement Project. The new PA will be executed within two years of the Record of Decision and replace the 1988 PA.

Pursuant to the Clean Water Act of 1972, as amended, all discharges of dredged or fill material associated with the recommended plan have been found to be compliant with the section 404(b)(1) Guidelines (40 CFR 230). The Clean Water Act Section 404(b)(1) Guidelines evaluation is found in Appendix H of the IFR/EIS.

A water quality certification pursuant to section 401 of the Clean Water Act was obtained from the Texas Commission on Environmental Quality. All conditions of the water quality certification shall be implemented in order to minimize adverse impacts to water quality.

A determination of consistency with the Texas Coastal Zone Management program pursuant to the Coastal Zone Management Act of 1972 was obtained from the Texas General Land Office. All conditions of the consistency determination shall be implemented in order to minimize adverse impacts to the coastal zone.

All applicable environmental laws have been considered and coordination with appropriate agencies and officials has been completed. Impacts to resources under other statutes have been considered including the Clean Air Act, Section 103 of the Marine Protection, Research, and Sanctuaries Act, Magnuson-Stevens Fishery Conservation and Management Act, Fish and Wildlife Coordination Act, Marine Mammal Protection Act, Farmland Protection Policy Act of 1981 and Prime and Unique Farmlands, Executive Order 12898 for Environmental Justice, and the Migratory Bird Treaty Act.

Technical, environmental, and economic criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on the review of these evaluations, I find that benefits of the recommended plan outweigh the costs and any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

_____ _____

Date **R. D. James**

Assistant Secretary of the Army (Civil Works)

EXECUTIVE SUMMARY* (NEPA required)

STUDY DESCRIPTION

This Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS) documents the formulation and evaluation of plans for modification to the existing Houston Ship Channel System conducted under the Houston Ship Channel Expansion Channel Improvement Project (HSC ECIP) Feasibility Study. The report has undergone public review, policy review, agency technical review (ATR), and Independent External Peer Review (IEPR) processes. The U.S. Army Corps of Engineers (USACE) Project Delivery Team (PDT), inclusive of the non-Federal sponsor (NFS), addressed all review comments, presented a recommended plan, conducted additional modeling, including feasibility-level ship simulations to refine the recommended plan and now presents the Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS).

AUTHORITY

The study was performed under the standing authority of Section 216 of the Flood Control Act of 1970 Public Law 91-611, as amended.

STUDY PURPOSE

The purpose of this feasibility study was to evaluate Federal Interest in alternative plans (including the No-Action Plan) for reducing transportation costs while providing for safe, reliable navigation on the HSC system. The study has assessed the effects of the alternatives on the natural system and human environment, including the economic development effects of existing inefficiencies. Economic conditions have changed significantly since the last HSC study (completed in 1995) for both the container and bulk industry. An increase in throughput tonnage and a significant shift in average fleet size render current channel dimensions incapable of accommodating the forecasted commodity and fleet growth without significant and system-wide inefficiencies. The study evaluates and recommends measures that address current and expected inefficiencies.

STUDY SCOPE

The scope of the study area included the entire HSC, which was evaluated for current and projected vessel size and traffic. Beginning at the seaward end of the HSC (Bolivar Roads at the Galveston Entrance Channel), the study examined possible moorings and bay widening to provide for safe and efficient meeting opportunities in the Bay Reach, as well as study the following side channels: Bayport Ship Channel (BSC), Barbours Cut Channel (BCC), Jacintoport Channel, and Greens Bayou Channel. The study also investigated deepening opportunities and widening where

practicable in the upper reach of the HSC between Boggy Bayou and the Main Turning Basin. Further analysis was conducted during feasibility-level design, during which a dredged material management plan (DMMP) was developed. Placement opportunities that were evaluated included a suite of upland confined placement areas (PA), beneficial use (BU) sites, and offshore placement at the existing Ocean Dredged Material Disposal Site (ODMDS No. 1).

The HSC ECIP study scope did not include the Galveston Entrance Channel, Galveston Channel, Texas City Ship Channel, or the Cedar Bayou Navigation Channel. The Galveston Entrance Channel provides access to these channels, inclusive of the HSC, from the Gulf of Mexico and its depth is sufficient since the HSC main channel from Bolivar Roads to Boggy Bayou would remain at its existing -46.5-feet mean lower low water (MLLW). All depths in this report are referenced to the MLLW datum unless specifically stated otherwise.

LOCATION

The HSC provides access to various private and public docks and berthing areas associated with Port Houston. The HSC system is located in southeast Texas and spans Harris, Chambers, and Galveston Counties, Texas.

The study area was divided into the following six study segments, as shown in **Figure ES-1** and the bullets below.

Segment 1	**Bay Reach**
Segment 2	**Bayport Ship Channel**
Segment 3	**Barbours Cut Channel**
Segment 4	**Boggy Bayou to Sims Bayou**
Segment 5	**Sims Bayou to I-610 Bridge**
Segment 6	**I-610 Bridge to Main Turning Basin**

STUDY SPONSOR

The NFS is the Port of Houston Authority (PHA). PHA is providing the majority of the environmental analyses and engineering products as Work-In-Kind (WIK) products.

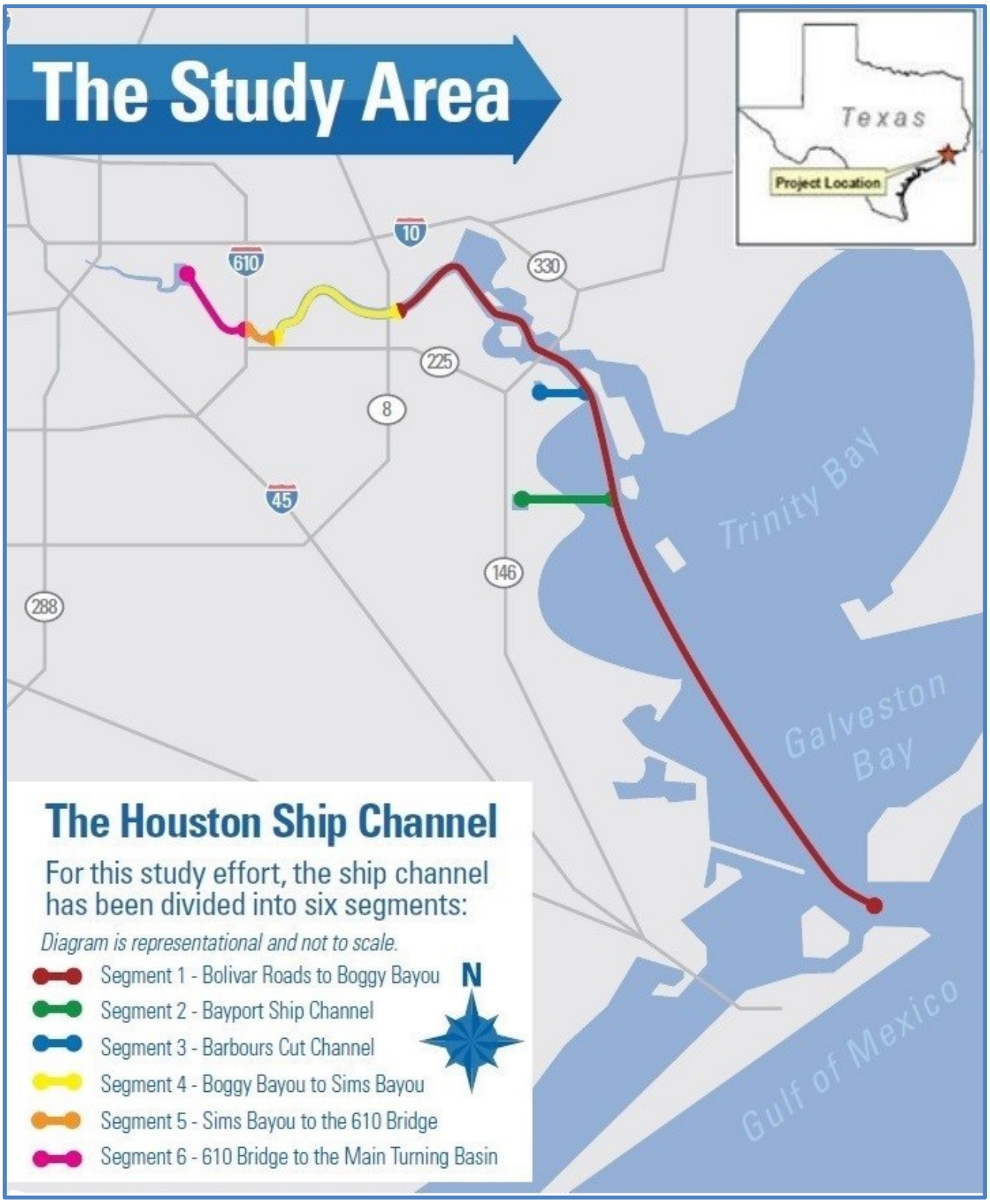

Figure ES-1 - Six Study Segments for the HSC ECIP Feasibility Study

PROBLEMS AND OPPORTUNITIES

The problems identified in the HSC study area are (1) navigation safety concerns for deep and shallow-draft vessel traffic, (2) inefficient vessel utilization, and (3) lack of environmentally acceptable dredged material placement.

Navigation Safety. The HSC is one of the busiest waterways in the United States (U.S.) with over 9,000 deep-draft and 200,000 barge transit per year [**Segment 1-6**]. The U.S. Coast Guard Port and Waterway Safety Assessment (PAWSA) assigned the HSC the highest baseline risk level for economic loss and assigned an unacceptable baseline risk for HSC's channel dimension and configuration, safety, potential for discharges, and volume of ship traffic.

Inefficient vessel utilization. Existing channel depth, width, and configuration cause inefficiencies for shallow and deep-draft vessels. Average vessel size and traffic volume at the HSC continue to increase, leading to thousands of hours of delays for vessels transiting the HSC. With projected increases in trade volume and vessel size, more delays can be expected. Design Vessels for the study are provided in **Table ES-1**. The major inefficiencies include:

- Four undersized bends [**Segment 1**] and insufficient channel width at BSC [**Segment 2**] and BCC [**Segment 3**] prevent Gen III Containerships (1,100- by 158-feet) from calling Port Houston. The width of the BSC also restricts Suezmax tanker transits.
- The current depth and width of **Segment** 4 limits traffic to Panamax-sized vessels and reduces loading efficiency for both tankers and bulkers.
- Channel depth in **Segment** 5 and **Segment** 6 also prevent efficient loading of tankers and bulkers, and turning basin dimensions in **Segment 6** limit effective transit of the design fleet.

Table ES-1 – HSC ECIP Design Vessels

Segment and Vessel Type/Class		LOA	Beam	Draft
		(feet)		
1,2,3	Containership/Gen III	1,100	158	49
1,2,3	Containership/ Gen III	1,200	140	49
1,2	Tanker (Suezmax)	935	164	54
3,4	Tanker (Aframax)	850	138	54
4	Bulk Carrier (Panamax)	810	106	44
5	Tanker (Panamax size)	610	106	44
5	Vehicle Carrier (Ro-Ro)	640	106	34
6	Bulk Carrier (70k-110k Bulker	750	106	45

Lack of environmentally acceptable dredged material placement (PA/BU). Current PA/BU capacity is insufficient for the future needs of the system [**Segments 1-6].**

PLANNING OBJECTIVES

The overall study goal is to provide an efficient and safe navigation channel while contributing to the National Economic Development (NED) consistent with protecting the nation's environment. The following planning objectives were used in formulation and evaluation of alternative plans:

- Reduce navigation transportation costs by increasing economies of scale for vessels to and from HSC over the period of analysis (starting in the base year for 50 years)
- Increase channel efficiency, and maneuverability in the HSC system for the existing fleet and future vessels through the 50-year period of analysis
- Develop environmentally suitable placement for dredged material and maximize use of BU of dredged material for placement over the 50-year period of analysis
- Increase channel safety for vessels utilizing the HSC, BSC, and BCC; and
- Reduce high shoaling at BSC Flare to reduce dredging frequency

ALTERNATIVES

The final array of alternatives consisted of a No-Action Alternative and eight action alternatives developed from the remaining measures to address issues such as congestion, vessel delays, inefficient vessel loading practices, and inefficient vessel fleet utilization throughout the channel targeting different segments, with the ultimate goal of increasing navigation efficiencies throughout the entire HSC system.

SMART Planning is:
S: Specific
M: Measurable
A: Attainable
R: Risk Informed
T: Timely

Table ES-1 shows the costs and benefits for each alternative at the time of screening. The final array was screened based on the economic benefits of each alternative. The costs for all alternatives in the table are inclusive of the measures identified for further evaluation in regards to safety. As shown in **Table ES-1**, Alternative 8 provides the highest **net benefits** of all the alternatives and best meets the study objectives. Alternative 8 is the NED Plan (inclusive of aforementioned measures). As shown in **Table ES-2** the width for the bay widening in this alternative was evaluated for the range of 650 feet to 820 feet. The use of feasibility-level ship simulations was used to address the uncertainty surrounding the width in the bay.

Net Benefits
Benefits minus Cost

Alternatives 4 and 5 display higher BCRs than Alternative 8. These alternatives would result in less cost but are limited in scope. Alternative 4 would provide for deepening and some widening to allow the Aframax design vessel in Segment 4, provide turning basin improvements and allow vessel meeting for beams wider than the current guideline. Alternative 5 would allow for larger tanker vessels in Segments 4, 5, and 6 and increase loading efficiencies and vessel meeting for

beams wider than 105 feet in Segment 4. However, Alternative 8 would provide improvements for all six design vessels across all study segments, and it maximizes net benefits. **Section 5.6.2** provides detailed evaluation of each alternative before the final recommendation in **Section 6**.

Table ES-2 - Final Screening of Alternative Plans ($000)

Alt	First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
	(October 2016 Price Levels, 2.875 Percent Discount Rate)					
No Action	This alternative does not meet the study objectives. This alternative forms the baseline to which all other alternatives are compared. The No-Action Alternative would not result in additional costs for construction and operations and maintenance (O&M), would not provide additional benefits, and would not result in environmental impacts.					
1	$513,900	$848,900	$27,700	$59,700	$32,000	2.2
2	$706,300	$1,304,300	$40,800	$47,700	$6,900	1.2
3	$527,000	$1,018,300	$31,300	$26,100	$(5,200)	0.8
4	$129,900	$312,900	$8,500	$60,700	$52,200	7.1
5	$98,400	$126,700	$4,600	$36,800	$32,200	8.0
6	$94,600	$164,100	$5,200	$2,100	$(3,100)	0.4
7	$47,600	$116,200	$3,300	$3,300	$-	1.0
8(650')	$950,000	$1,849,700	$56,800	$123,100	$66,300	2.2
8(820')	$1,451,800	$2,727,200	$84,700	$123,100	$38,400	1.5

FEASIBILITY-LEVEL EVALUATIONS TO REFINE RECOMMENDED PLAN

Engineering and environmental evaluations were conducted during feasibility-level design and analysis to refine the width of Alternative 8 and to determine which features would remain and which features would be eliminated from the NED Plan. The NED Plan provides opportunities for the containership design vessel to meet or pass between Bolivar Roads and Redfish Reef. However, the NFS desires channel-widening throughout the bay reach of Segment 1. Therefore, the NFS has requested a Locally Preferred Plan (LPP). With approval from the Assistant Secretary of the Army (Civil Works), the LPP is the Recommended Plan.

RECOMMENDED PLAN

The Recommended Plan shown in **Figure ES-2** includes the following features (by study segment) deemed necessary for safe and efficient navigation in the HSC. Additional details are available in **Section 6** of this FIFR-EIS.

Segment 1 – Bolivar Roads to Boggy Bayou

- Four bend easings on main HSC channel with associated relocation of barge lanes
- Widen HSC from Bolivar Roads to BCC to 700 feet with barge lane relocation

Segment 2 – Bayport Ship Channel

- Widen BSC to 455 feet

Segment 3 – Barbours Cut Channel

- Widen BCC to 455 feet
- BCC Combined Flare and Turning Basin

Segment 4 – Boggy Bayou to Sims Bayou

- Deepen HSC from Boggy Bayou to Hunting Turning Basin to 46.5 feet
- Widen HSC from Boggy to Greens Bayou up to 530 feet
- Improvements to Hunting Turning Basin

Segment 5 – Sims Bayou to I-610 Bridge

- Deepen HSC from Sims Bayou to I-610 Bridge up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin

- Deepen HSC from I-610 Bridge to Main Turning Basin up to 41.5 feet
- Improvements to Turning Basin near Brady's Island

Federalization of Non-Federal Improvements (located in Segments 1, 2, 3 and 4)

- Previous improvements made by the non-Federal sponsor (PHA) to the Jacintoport Channel (Segment 1), BSC (Segment 2), BCC (Segment 3), and Greens Bayou Channel (Segment 4) (locations shown in **Figure ES-2**) were recommended for Federalization as part of the TSP. There were previously determined to be in the Federal Interest and are being included into the authorization; these features are assumed part of the FWOP and necessary to realize the benefits of the recommended plan.

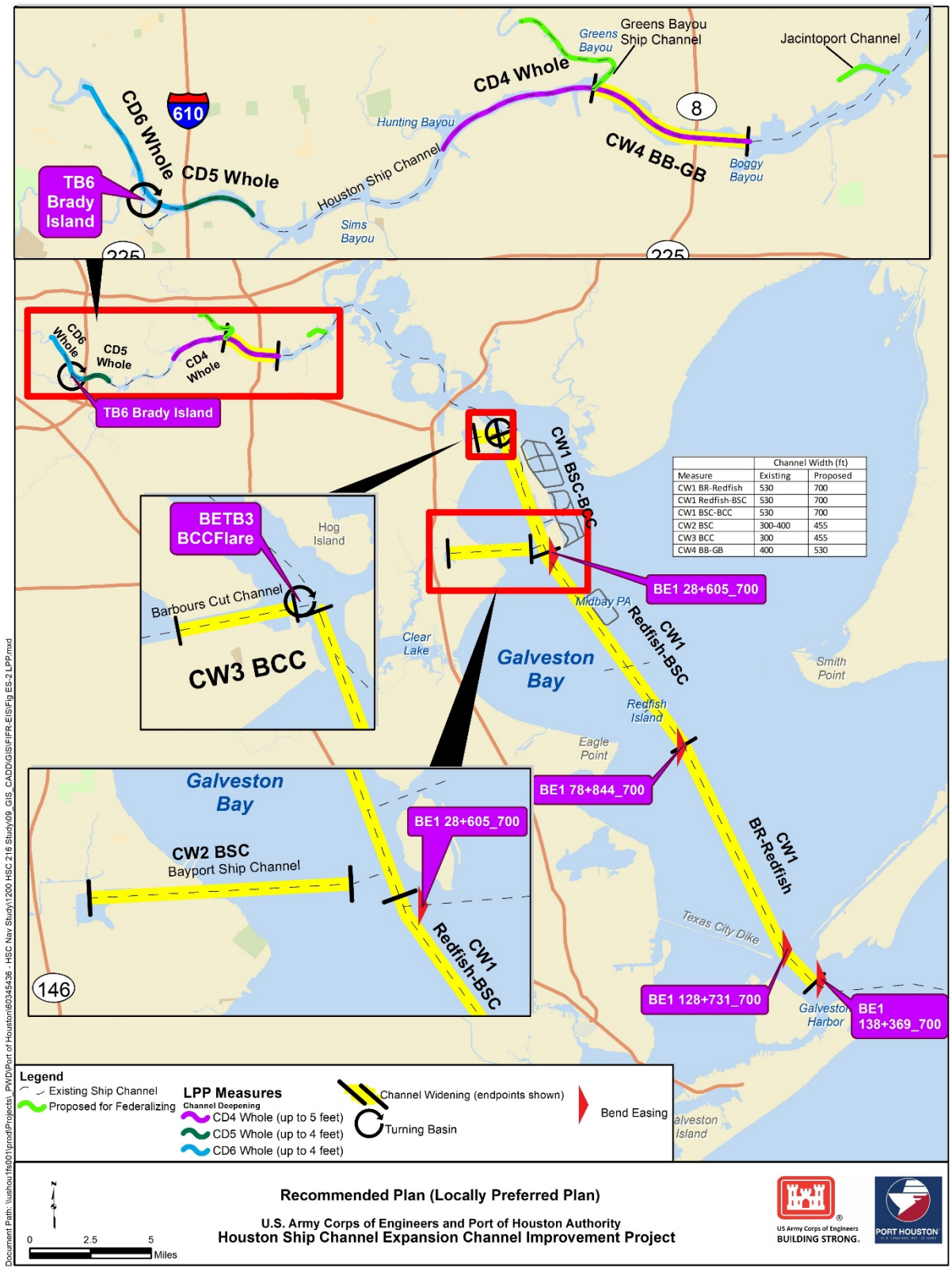

Figure ES-2 – HSC ECIP Recommended Plan

ENVIRONMENTAL COMPLIANCE

The main Environmental Quality effects of the Recommended Plan on significant natural resources would be unavoidable temporary impacts to unvegetated estuarine Bay and river bottom and permanent impacts to oyster reef. These effects of the Recommended Plan are detailed in **Section 7** of the main report. It is estimated that 88.3 acres for the NED Plan and 409.6 acres for the Recommended Plan would be permanently impacted through removal from dredging. However, these impacts would be fully mitigated as discussed in **Section 7.5** and **Appendix P**.

Between approximately 1,190 acres for the NED Plan and 2,133 acres for the Recommended Plan, of estuarine river in the upper HSC and Galveston Bay bottom, which is essential fish habitat, would be temporarily impacted by dredging, and would be expected to recolonize and recover following dredging events. The primary concern is to benthic infauna and use by fish species.

Temporary avoidance and disturbance would occur during construction and maintenance dredging of the Recommended Plan that is similar to routine maintenance effects for the existing channels; these temporary impacts are not anticipated to result in impacts to migratory birds or incidental takes of marine mammals. The Recommended Plan may effect, but is not likely adversely affect endangered sea turtles; a Biological Assessment (BA) is being coordinated with National Marine Fisheries Service and U.S. Fish and Wildlife Service for concurrence with this determination. No specific cultural resource impacts have been identified; cultural resource investigations will be performed during the pre-construction, engineering and design phase. The USACE, having determined that the Recommended Plan has the potential to cause effects on historic properties, and in accordance with the existing Programmatic Agreement will address the identification and discovery of cultural resources, in consultation with the Texas State Historic Preservation Officer (SHPO) and Tribal Nations, prior to the construction and maintenance of the Recommended Plan. The USACE intends to execute a new Programmatic Agreement, in consultation with the Advisory Council on Historic Preservation (ACHP), the Texas SHPO, and Tribal Nations, that will include the HSC ECIP. The new Programmatic Agreement will be executed within the two years of the Record of Decision and replace the existing 1988 Programmatic Agreement.

BENEFITS AND COST OF THE RECOMMENDED PLAN

Benefits were calculated using the USACE certified HarborSym model. Benefits and costs were calculated with a base year of 2029 and a 50-year period of analysis (2029-2078) using the October 01, 2019 (Fiscal Year (FY) 20)) price levels and (FY20) Federal discount rate of 2.75 percent. Construction of the Recommended Plan would generate average annual equivalent (AAEQ) benefits of approximately $133,551,000 with AAEQ costs of approximately $53,251,000, producing AAEQ net benefits (benefits minus costs) of approximately $80,300,000 and a benefit-to-cost ratio (BCR) of 2.51 at the Fiscal Year 2020 discount rate (2.75 percent).

The construction costs were developed using October 01, 2019 price levels (**Table ES-3**). The Project First Cost of all project components totals $876,848,000. The Fully Funded Project Cost of all components totals $996,912,000.

Table ES-3 - Recommended Plan Cost Summary ($000)

Cost Account and Item Descriptions		Project First Cost	Fully-Funded Cost
		October 2019 Price Level	
General Navigation Features (GNF)			
06	Fish & Wildlife Mitigation	$81,758	$91,511
12	Navigation	$638,862	$729,274
30	Planning, Engineering & Design	$66,322	$75,257
31	Construction Management	$37,898	$43,866
	GNF Total	**$824,840**	**$939,908**
LERR (100% Non-Federal Cost)			
01	Lands & Damages (100% non-Federal)	$14,658	$16,077
02	Relocations	$37,350	$40,927
	LERR Total	**$52,008**	**$57,004**
	Project First Cost	**$876,848**	**$996,912**
Associated Costs (Other Federal Cost) [1]			
12	Navigation Aids (100% Federal – USCG) [1]	$4,609	$5,122
	Associated Cost Subtotal (Other Federal Costs) [1]	**$4,609**	**$5,122**
Associated Costs (Non Federal Cost) [2]			
12	Local Service Facilities (100% non-Federal) [2]	$78,204	$87,573
	Associated Cost Subtotal (Other Federal Costs) [1]	**$78,204**	**$87,573**
	Total Associated Costs (Other Federal and Non-Federal) [1,2]	**$82,813**	**$92,696**
	Project Cost plus Associated Costs	**$959,661**	**$1,089,609**

[1] Other non-Federal costs that are not part of the recommended Federal project but are another Federal agency responsibility.
[2] Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.
Note: There may be slight differences due to rounding.

Table ES-4 displays the costs, benefits, and net benefits of the Recommended Plan. Total project construction costs includes all associated costs. The costs of the LPP are greater than the NED Plan. The costs for Operations and Maintenance (O&M) of the LPP are also greater than for the NED Plan. The non-Federal sponsor is willing to pay the difference in the O&M in the future.

Table ES-4 - HSC ECIP Equivalent Annual Costs and Benefits ($000)

Category	NED Plan	Recommended Plan
	October 2019 Price Levels, 2.75% Discount Rate	
Total Project Construction Costs	$746,649	$959,661
Interest During Construction	$12,612	$19,477
Total Investments Cost	**$759,261**	**$979,138**
Construction Average Annual Costs	$28,123	$36,268
OMRR&R	$13,883	$16,983
Total Average Annual Costs	**$42,006**	**$53,251**
Average Annual Benefits	$114,683	$133,551
Net Annual Benefits	$72,677	$80,300
Benefit to Cost Ratio	**2.73**	**2.51**

ER 1105-2-100 defines a separable element as "…any part of a project which has separately assigned benefits and costs, which can be implemented as a separable action (at a later date or as a separate project)…" (Appendix E, Section 3c). The Recommended Plan includes seven separable elements. **Table ES-5** identifies all separable elements and their respective cost benefit summary.

Table ES-5 – Separable Elements Benefit-Cost Summary ($000s) for Recommended Plan

Separable Elements (7)	Measure(s)	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
		(October 2019 Price Level, 2.75% Discount Rate)			
BR-RF[1]	CW1_BR-Redfish	$4,595	$11,276	$6,681	2.45
RF-BSC[1]	CW1_Redfish-BSC	$12,670	$11,248	$(1,422)	0.89
BSC-BCC[1]	CW1_BSC-BCC	$6,858	$7,620	$762	1.11
BSC[2]	CW2_BSC	$4,993	$33,554	$28,561	6.72
BCC[2]	CW3_BCC, BETB3_BCCFlare	$8,086	$19,166	$11,080	2.37
Segment 4 Deepening and Widening[3]	CD4_Whole, CW4_BB-GB, TB4_Hunting	$12,420	$40,249	$27,829	3.24
Segment 5 & Segment 6 Deepening[4]	CD5, CD6	$2,727	$10,438	$7,711	3.83

[1] Analysis assumed deepening in Segments 4 through 6 and full bay widening. Benefits are less for isolated widening.

[2]BSC and BCC both require BE1_078+844_530 and BE1_028+605_530. Analysis assumes BSC bears the costs of bend easings

[3] Analysis assumed that benefits of Segment 4 only accrue with channel deepening and widening to allow design fleet transit

[4] Segment 6 deepening requires equivalent depths in Segment 5. Segment 5 alone is not economically justified

COST APPORTIONMENT

The project cost for determining the cost-sharing requirements is based on the Project First Cost. The Project First Cost for all project components is separated into expected Federal and non-Federal cost shares and detailed in **Table ES-6**. The costs share rates are accurately apportioned

for the channel depths. In **Table ES-6** the cost share for the NED Plan is provided under the columns for the "Project First Cost – NED Plan". The "Federal Cost" column is the cost share for the NED Plan or the Recommended Plan. In addition to their normal cost share, the NFS is responsible for 100 percent of the LPP costs. To determine the non-Federal cost share for the Recommended Plan, the Federal share is subtracted from the LPP Total Project Cost.

Table ES-6 – Comparison of Cost (NED vs LPP) ($000s)

Cost Account and Item Descriptions		Project First Cost – NED Plan			Total Cost	Federal Share	Non-Fed Share
		Federal Cost	Non-Federal Cost	Total	Allocated (LPP Total)	GNF (NED Cost Total)	GNF Difference (LPP-NED)
		October 2019 Price Level					
Construction Item							
01	Lands & Damages (100% non-Federal)	$0	$14,624	$14,624	$14,658	$0	$14,658
02	Relocations	$0	$34,571	$34,571	$37,350	$0	$37,350
06	Fish & Wildlife Mitigation	$40,655	$13,552	$54,207	$81,758	$40,655	$41,103
12	Navigation	$363,071	$121,024	$484,094	$638,862	$363,071	$275,792
	SUBTOTAL	**$403,726**	**$183,771**	**$587,496**	**$772,628**	**$403,726**	**$368,902**
30	Planning, Engineering & Design	$37,595	$12,532	$50,126	$66,322	$37,595	$28,728
31	Construction Management	$21,483	$7,161	$28,644	$37,898	$21,483	$16,415
	SUBTOTAL	**$59,078**	**$19,693**	**$78,770**	**$104,220**	**$59,078**	**$45,143**
	TOTAL PROJECT COSTS	**$462,804**	**$203,464**	**$666,266**	**$876,848**	**$462,804**	**$414,045**

Note: There may be slight differences due to rounding

Table ES-7 provides the Cost Share Apportionment for the Recommended Plan.

Table ES-7 – Recommended Plan Cost Share Apportionment ($000s)

Cost Account and Item Descriptions		Federal	Non-Federal	Total Project First Cost
		October 2019 Price Level		
General Navigation Features (GNF)				
06	Fish & Wildlife Mitigation	$40,655	$41,103	$81,758
12	Navigation	$363,071	$275,792	$638,862
30	Planning, Engineering & Design	$37,595	$28,728	$66,322
31	Construction Management	$21,483	$16,415	$37,898
	GNF Total	**$462,803**	**$362,037**	**$824,840**
LERR (100% Non-Federal Cost)				
01	Lands & Damages (100% non-Federal)	$0	$14,658	$14,658
02	Relocations	$0	$37,350	$37,350
	LERR Total	**$0**	**$52,008**	**$52,008**
	Project First Cost	**$462,803**	**$414,045**	**$876,848**
Associated Costs (Other Federal Cost) [1]				
12	Navigation Aids (100% Federal – USCG) [1]	$4,609	$0	$4,609
	Associated Cost Subtotal (Other Federal Costs) [1]	**$4,609**	**$0**	**$4,609**
	Associated Costs (Non Federal Cost) [2]			
12	Local Service Facilities (100% non-Federal) [2]	$0	$78,204	$78,204
	Associated Cost Subtotal (Other Federal Costs) [1]	**$0**	**$78,204**	**$78,204**
	Total Associated Costs (Other Federal and Non-Federal) [1,2]	**$4,609**	**$78,204**	**$82,813**
	Project Cost plus Associated Costs	**$467,412**	**$492,249**	**$959,661**

[1] Other non-Federal costs that are not part of the recommended Federal project but are another Federal agency responsibility.
[2] Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.
Note: There may be slight differences due to rounding

PUBLIC COORDINATION

The **Notice of Intent (NOI)** to "*Prepare a Draft EIS for the Houston Ship Channel 45-Foot Expansion Channel Improvement Project (HSC ECIP), Harris, and Chambers Counties, Texas"* was prepared by the USACE and published in the Federal Register, Volume 81, No. 60, on Tuesday, March 29, 2016. On May 17 and 19, 2016, public scoping meetings were held to provide the public with study information.

An initial interagency workshop took place on May 3, 2016, at the USACE Galveston District to gain early agency stakeholder input on the problems and opportunities related to improving deep draft navigation in

The **Notice of Intent (NOI)** to prepare a Draft Environmental Impact Statement for this study published in the **Federal Register** on Tuesday, March 29, 2016 (81 FR 17450) cited the project title as the "Houston Ship Channel 45-Foot Expansion Channel Improvement Project (HSC ECIP), Harris and Chambers Counties, Texas".

The study title has been slightly modified to better reflect Corps vertical datum policy and the planning geography involved to ***"Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas."*** This document is for the same project in the cited NOI.

the planned reaches of the HSC. Letters inviting stakeholder agencies to participate as cooperating agencies were distributed on April 19, 2016. The EPA accepted by letter dated May 23, 2016. Texas Water Development Board accepted by letter dated June 1, 2016. Follow up meetings were held on February 16, 2017 and May 17, 2017 in conjunction with regularly scheduled Beneficial Uses Group (BUG) Meetings. Topics covered included an introduction to the study, measures, and alternatives being considered, options for the BU of dredged material, potential oyster impacts, proposed mitigation, and updates to the study schedule, and the TSP.

In order to focus on specific issues identified by the resource agencies, BUG subcommittees were created for Oyster/Habitat Modeling, Hydrodynamic Modeling, hazardous, toxic, and radioactive waste (HTRW) and Sediment, and the BU of Dredged Material (BUDM). The intent of a subcommittee is to meet with a focus on specific issues identified by the resource agencies to allow PDT technical staff to discuss with interested agencies how impacts for those issues are planned to be analyzed, and to obtain input from those agencies to help inform the analysis of those issues. Meetings for each subcommittee will be held as needed throughout the four-year study for the HSC-ECIP, as specific analyses and planning activities involved occur.

For this study phase, the Oyster/Habitat Modeling subcommittee met on January 19, 2017, March 24, 2017, and June 29, 2017 to discuss impact assessment, habitat modeling, and mitigation for oyster reef that would be impacted by the proposed TSP.

The public was provided with the opportunity to comment on the TSP during the 75-day public review of the DIFR-EIS. The public review began on September 1, 2017, was extended an additional 30 days because much of the interested public had been affected or displaced by Hurricane Harvey. The public review closed for comments on and closed for comments on November 13, 2017. Comments submitted during that process have been considered and addressed.

NON-FEDERAL SPONSOR SUPPORT

PHA, the NFS for the HSC ECIP Feasibility Study, was actively engaged in the formulation of the Recommended Plan and fully supports the project and is willing to sponsor project construction in accordance with the items of location cooperation set forth in this report. The PHA believes this plan represents the most effective implementation of features to economic growth and safe, efficient navigation, while protecting environmental resources. The NFS has indicated financial capability to satisfy its obligations for the construction of the Recommended Plan.

DREDGED MATERIAL MANAGEMENT PLAN (DMMP)

During feasibility-level analysis and design, a detailed DMMP was developed for both the NED Plan and the Recommended Plan. The intent of the DMMP is to cover all placement needs for the entire HSC System. The existing HSC system is governed under at least seven separate authorities and agreements. With one DMMP to cover the full HSC system under one single study, all future channel construction and maintenance would be governed under the same rules. The resulting DMMP would be more effectively managed by the government than the current segmented system and instead of multiple agreements could be covered under one Project Partnership Agreement. **Appendix R – HSC System DMMP** provides the least cost placement plan for the NED Plan and the Recommended Plan.

MAJOR FINDINGS AND CONCLUSIONS

The proposed actions described in this report are in the national interest. The recommendations contained herein reflect the information available at the time the report was prepared.

The NFS prefers a plan that is more costly than the NED Plan and the increased scope of the plan is not sufficient to warrant full Federal participation. By letter dated August 5, 2019, the Assistant Secretary of the Army (Civil Works) granted an exception to recommend a Locally Preferred Plan (LPP), with the additional costs (Project First Cost and future O&M costs) above the NED plan being the sole responsibility of the sponsor.

This Recommended Plan is in support of two of the four goals for USACE contained in the latest (as of June 1, 2017) USACE Campaign Plan (FY18-22). Specifically, the Recommended Plan supports Goal 2 (Deliver Integrated Water Resource Solutions) and Goal 4 (Prepare for Tomorrow). The USACE Campaign Plan is available on the Headquarters Webpage at the following address: *http://www.usace.army.mil/about/campaignplan.aspx*.

Table of Contents

*** SECTIONS REQUIRED FOR NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE (***Required by Council on Environmental Quality (CEQ) Regulations 40 CFR 1502.10***)**

FIGURES

TABLES

APPENDICES*

***Note**: Italicized Reference Documents are available upon request to the Galveston District Project Management.*

List of Acronyms

AAHUs	Average Annual Habitat Units
AAEQ	Average Annual Equivalent
ACHP	Advisory Council on Historic Preservation
ACS	American Community Survey
ADCIRC	Advanced CIRCulation
ADM	Agency Decision Milestone
ALU	High Aquatic Life Use; Water Quality Classification
AMM	Alternatives Milestone Meeting
AOC	Area of Concern
AOM	Assumption of Maintenance
APE	Area of Potential Effect
ATR	Agency Technical Review
BA	Biological Assessment
BCC	Barbours Cut Channel
BCR	Benefit-to-Cost Ratio
BMP	Best Management Practice
BP	Before Present
BSC	Bayport Ship Channel
BU	Beneficial Use
BUG	Beneficial Uses Group
CAA	Clean Air Act
CBIA	Coastal Barrier Improvement Act
CBRA	Coastal Barrier Resources Act
CBRS	Coastal Barrier Resources System
CCAC	Coastal Coordination Advisory Committee
CCC	Coastal Coordination Council
CDF	Confined Disposal Facility
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CNRA	Coastal Natural Resource Areas
CO-OPS	Operational Oceanographic Products and Services
CTR1	Coastal Texas Ecosystem Protection and Restoration, Texas, Feasibility Study, Region 1
CWA	Clean Water Act

CY	Cubic Yards
CZMA	Coastal Zone Management Act
DA	Department of Army
DDNPCX	Deep-Draft Navigation Planning Center of Expertise
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
DMMP	Dredged Material Management Plan
DO	Dissolved Oxygen
DoD	Department of Defense
DSHS	Department of State Health Services
DWT	Dead Weight Tons
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice
EM	Engineer Manual
EOP	Environmental Operating Principles
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EQ	Environmental Quality
ER	Engineer Regulation
ERL	Effects Range Low
ERM	Effects Range Meridian
ERDC	Engineer Research and Design Center
ESA	Endangered Species Act
ETL	Engineer Technical Letter
ºF	Degrees Fahrenheit
FCA	Flood Control Act
FCSA	Feasibility Cost Sharing Agreement
FCU	Fish Consumption Use; Water Quality Classification
FEMA	Federal Emergency Management Agency
FIFR-EIS	Final Integrated Feasibility Report and Environmental Impact Statement
FMC	Fishery Management Councils
FMP	Fishery Management Plan
FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without-Project
FY	Fiscal Year
GBANS	Galveston Bay Area Navigation Study

GC	General Conformity
GCD	General Conformity Determination
GHP	Greater Houston Partnership
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GMFMC	Gulf of Mexico Fishery Management Council
GNF	General Navigation Feature
GOM	Gulf of Mexico
GRBO	Gulf Regional Biological Opinion
GRP	Gross Regional Product
GU	General Use; Water Quality Classification
HGB	Houston-Galveston-Brazoria
HGNC	Houston-Galveston Navigation Channels
HHS	U.S. Department of Health and Human Services
HQ	Headquarters
HSC	Houston Ship Channel
HSC ECIP	Houston Ship Channel Expansion Channel Improvement Project
HTRW	Hazardous, Toxic and Radioactive Waste
IEPR	Independent External Peer Review
ITA	Incidental Take Authorization
LERRs	Lands, Easements, Rights-of-Way, and Relocations
LERRDs	Lands, Easements, Rights-of-Way, and Relocations and Disposal Areas
LOA	Length Overall
LOOP	Offshore crude terminal
LRR	Limited Reevaluation Report
LSF	Local Service Facilities
MII or Mii	MII is the Second Generation of MCACES
MBTA	Migratory Bird Treaty Act
MCACES	Micro Computer Aided Cost Engineering System
Ug/kg	Microgram/kilogram
MCY	Million Cubic Yards
Mg/kg	Milligram/kilogram
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLT	Mean Low Tide
MMPA	Marine Mammal Protection Act

MM/YR	Millimeters per Year
MOU	Memorandum of Understanding
MPRSA	Marine Protection, Research, and Sanctuaries Act
MSA	Metropolitan Statistical Area
MSC	Major Subordinate Command
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
NAA	Nonattainment Area
NAAQS	National Ambient Air Quality Standards
NED	National Economic Development
NEPA	National Environmental Policy Act
NFS	Non-Federal Sponsor
NMFS	National Marine Fisheries Service
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_x	Nitrogen Oxide
NPL	National Priorities List
O&M	Operations and Maintenance
ODMDS	Ocean Dredged Material Disposal Site
OSE	Other Social Effects
OWPR	Office of Water Project Review
OWU	Oyster Waters Use; Water Quality Classification
P&G	Principles and Guidelines
PA	Placement Area
PAH	Polycyclic Aromatic Hydrocarbons
PAL	Planning Aid Letter
PCB	Polychlorinated Biphenyls
PB	Planning Bulletin
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PHA	Port of Houston Authority
P.L.	Public Law
PMP	Project Management Plan
PPT	Parts Per Trillion
PPTH	Parts Per Thousand

RCRA	Resource Conservation and Recovery Act
RECONS	USACE Online Regional Economic System
RED	Regional economic development
REP	Real Estate Plan
RFMC	Regional Fishery Management Councils
RGL	Regulatory Guidance Letter
RHA	Rivers and Harbors Act
ROD	Record of Decision
RSLC	Regional Sea Level Change
RU	Recreation Use; Water Quality Classification
S&A	State and Agency
S2G	Sabine Pass to Galveston Bay, Texas, Feasibility Study
SAV	Submerged Aquatic Vegetation
SH	State Highway
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SJRWP	San Jacinto River Waste Pits
SMMP	Site Monitoring and Management Plan
SWD	Southwestern Division
T&E	Threatened and Endangered
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Program
TDSHS	Texas Department of State Health Services
TEU	Twenty-Foot Equivalent Units
TMDL	Total Maximum Daily Load
TPWD	Texas Parks and Wildlife Department
TSP	Tentatively Selected Plan
TWDB	Texas Water Development Board
TXGLO	Texas General Land Office
USACE	United States Army Corps of Engineers
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VLCC	Very Large Crude Carriers
VOC	Volatile Organic Compound
WIK	Work in Kind

WIIN Act	Water Infrastructure Improvements for the Nation Act
WMA	Wildlife Management Area
WRDA	Water Resources Development Act
WRRDA	Water Resources Reform and Development Act
Zone AE	One Percent Annual Chance Event (FEMA Code)
Zone VE	Coastal Flood Zone with Velocity Hazard (FEMA Code)

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1 STUDY INFORMATION*

1.1 INTRODUCTION

This Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS) documents the planning process undertaken for the Houston Ship Channel Expansion Channel Improvement Project (HSC ECIP) Feasibility Study. The study has investigated channel improvements to the Houston Ship Channel (HSC) system, located in Harris, Chambers, and Galveston Counties, Texas. The study alternatives have been screened, resulting in identification of the Recommended Plan. The Port of Houston Authority (PHA) and U.S Army Corps of Engineers (USACE) propose to modify the HSC to reduce transportation costs and address navigation safety issues on the HSC.

1.2 STUDY AUTHORITY

1.2.1 General Authority

The study is being performed under the standing authority of Section 216 of the Flood Control Act (FCA) of 1970 Public Law (P.L.) 91-611, as amended:

> *"The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operations of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due [to] significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest."*

All proposed actions under this study would be under the Section 216 authorization.

1.3 NON-FEDERAL SPONSOR

PHA, the non-Federal Sponsor (NFS), is providing the majority of the environmental and engineering products as Work-In-Kind (WIK) products.

1.4 STUDY PURPOSE AND SCOPE*

The purpose of this report is to present findings of the feasibility investigations and analyses conducted to determine if there is a Federal Interest for navigation improvements to the HSC system. This FIFR-EIS describes the problems and opportunities of the existing HSC, and

* In this Report Sections denoted with an asterisk (*) are required by CEQ Regulations 40 CFR 1502.10

identifies the alternatives and analyses conducted to meet the planning objectives of the study. Navigation improvements are needed to reduce transportation costs while providing for safe, reliable navigation on the HSC system. The study evaluates an array of alternatives and assesses the effects of the alternatives on the natural system and human environment, including the economic development effects of existing inefficiencies. Economic conditions have changed significantly since the last HSC study (completed in 1995) for both the container and bulk industry. An increase in throughput tonnage and a significant shift in average fleet size renders current channel dimensions incapable of accommodating the forecasted commodity and fleet growth without significant and system-wide inefficiencies. The FIFR-EIS tells the story surrounding the selection of the Recommended Plan in the chronological order in which it occurred. The FIFR-EIS provides all the information normally included in an EIS and meets the requirements of the National Environmental Policy Act (NEPA), comparing the environmental impacts of the Final Array of Alternatives (including the No-Action Plan) and fully describing the impacts of the Recommended Plan.

The scope of the study area includes the entire 52-miles of the HSC, which has been evaluated for current and projected vessel size and traffic. The study examined possible moorings and channel widening to provide for safe and efficient meeting opportunities as ships transit the channel through Galveston Bay from Bolivar Roads at the Galveston Entrance Channel to Boggy Bayou. Additionally, the study looked at deepening and widening opportunities where practicable in the upper reaches of the HSC between Boggy Bayou and the Main Turning Basin. The study evaluated Bayport Ship Channel (BSC), Barbours Cut Channel (BCC), Jacintoport Channel, and Greens Bayou Channel, which are side channels of the HSC that provide access to important container and petro-chemical facilities of Port Houston. Modifications are not being considered for Greens Bayou and Jacintoport Channel; only federalization of the existing navigation features for which USACE has already assumed maintenance. Dredged material placement has been evaluated for possible upland confined placement areas (PAs), beneficial use (BU) sites, and offshore placement in the existing Ocean Dredged Material Disposal Site (ODMDS No. 1).

The scope of this study did not include the Galveston Entrance Channel, Galveston Channel, Texas City Ship Channel, or the Cedar Bayou Navigation Channel. These channels are integrally connected to the overall navigation system of the Galveston Bay area; however, each has their own independent sponsor.

1.5 STUDY AREA

The HSC system is located in southeast Texas and spans Harris, Chambers, and Galveston Counties, Texas. The HSC project consists of an existing 52-mile long navigation channel, four tributary side channels and one shallow draft tributary channel (Buffalo Bayou Light Draft

Channel). Several other minor tributary channels also intersect the HSC, including South Boaters Cut, North Boaters Cut, and Five Mile Cut. The HSC provides access to numerous private and public docks and berthing areas, including those associated with Port Houston. The upper reach of the channel is located within a highly developed industrialized urban area of Houston where few tracts of vacant undeveloped land remain and potential impacts could include residential, business, pipeline, roadway, and railroad relocations. Based on past environmental analyses the portions of the study (BSC, BCC, possible mooring in bay, and placement options) within the bay reach of the HSC would likely involve benthic and oyster impacts and pipeline(s) may need to be relocated.

Although the Texas City Channel, Galveston Harbor and Channel, and the Cedar Bayou Navigation Channel Projects are located in the same bay system, as mentioned previously, they are not part of the HSC ECIP Feasibility Study. The Galveston Entrance Channel provides access to these channels, inclusive of the HSC, from the Gulf of Mexico and its depth is sufficient since the HSC main channel from Bolivar Roads to Boggy Bayou would remain at its existing -46.5-foot Mean Lower Low Water (MLLW) depth. Just beyond Galveston Harbor, the HSC and the Texas City Ship Channel intersect at Bolivar Roads. Additionally, on the northern end of the Atkinson Island Marsh, the HSC intersects with the Cedar Bayou (shallow draft) Federal Navigation Channel.

The study area has been divided into the following six study segments, as shown in **Figure 1-1** and the bullets below.

Segment 1	**Bay Reach** (Bolivar Roads to Boggy Bayou)
Segment 2	**Bayport Ship Channel**
Segment 3	**Barbours Cut Channel**
Segment 4	**Boggy Bayou to Sims Bayou**
Segment 5	**Sims Bayou to I-610 Bridge**
Segment 6	**I-610 Bridge to Main Turning Basin**

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

Senator John Cornyn
Senator Ted Cruz
Representative Brian Babin (TX-36)
Representative Dan Crenshaw (TX-02)
Representative Lizzie Fletcher (TX-07)
Representative Al Green (TX-09)
Representative Randy Weber (TX-14)
Representative Sheila Jackson-Lee (TX-18)
Representative Pete Olson (TX-22)
Representative Sylvia Garcia (TX-29)

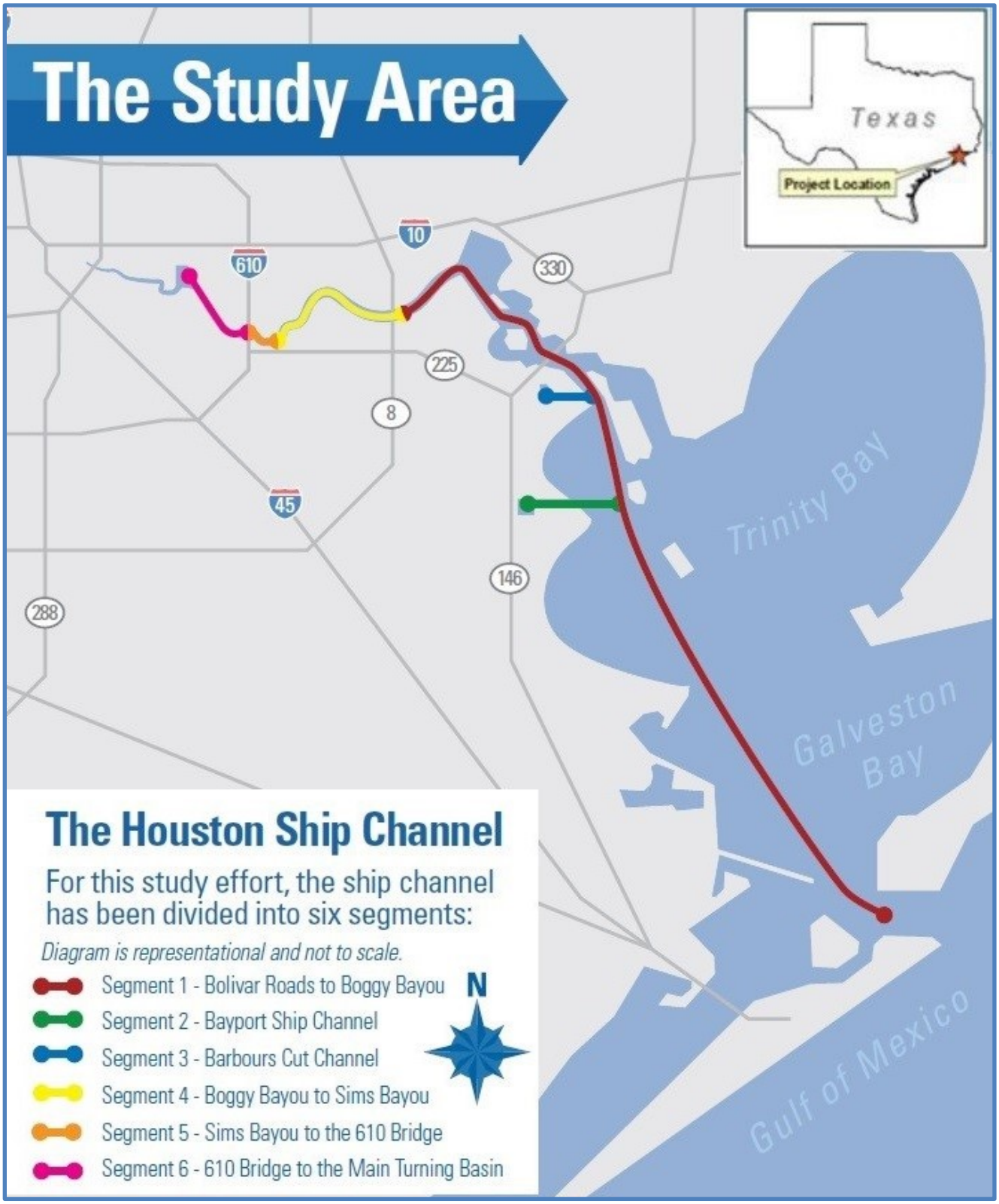


Figure 1-1 - Six Study Segments for the HSC ECIP Feasibility Study

1.6 HISTORY OF THE INVESTIGATION

A reconnaissance study was undertaken to determine if there was a Federal Interest in a cost-shared feasibility study to evaluate the need for channel improvements to the HSC system. The *Houston Ship Channel Expansion, Texas, Section 905(b) of the Water Resources Development Act (WRDA) of 1986 Analysis Report* (905(b) Report), approved September 22, 2014, demonstrated that channel improvements may be needed to improve the efficiency and maneuverability of the HSC system and supported initiation of a cost-shared feasibility-level study. The Feasibility Cost Sharing Agreement (FCSA) was signed on November 13, 2015. The Notice of Intent (NOI) to prepare an EIS was published in the Federal Register on March 28, 2016. Two public scoping meetings were held on May 17 and 19, 2016.

1.7 PRIOR STUDIES, REPORTS, AND EXISTING WATER PROJECTS

1.7.1 Prior Studies and Reports

A resolution of the House Committee on Public Works, adopted October 19, 1967, authorized a review of the reports on the Galveston Harbor and Channel, the HSC, and the Texas City Channel, Texas. These reports are published as: House Document No. 350, 85th Congress, 2nd Session; and House Document No. 427, 86th Congress, 2nd Session. The reconnaissance report for this study was completed in 1980. Additional feasibility studies followed.

The feasibility study for the Texas City Ship Channel was completed in 1982. The report recommended enlarging the project from its existing dimensions of -40 feet mean low tide (MLT) and 400 feet wide to -50 feet MLT and 600 feet wide as well as deepening the Galveston Entrance Channel. These improvements were authorized for construction by P.L. 99-662, WRDA 1986.

The following list is a compilation of studies involving the HSC that have been completed or are currently in process.

- *Galveston Bay Area Navigation Study (GBANS) Feasibility Report and Environmental Impact Statement, USACE – Galveston District*, July 1987. The GBANS report recommended a - 50-foot MLT channel. However, the GBANS report recommendation was superseded by the report addressed in the following bullet.
- *Houston-Galveston Navigation Channels (HGNC), Texas, Limited Reevaluation Report* (LRR) *and Final Supplemental Environmental Impact Statement, USACE, Galveston District, November 1995* (1995 LRR). The 1995 LRR recommended plan was authorized under WRDA 1996. The plan extended and deepened the Galveston Entrance Channel, enlarged and deepened the Galveston Harbor Channel excepting the last 2,571 feet at the most westward end (to -45 feet MLT), and enlarged and deepened the HSC (-45 feet MLT)

up to Boggy Bayou. An Environmental Restoration Plan through BU of dredged material was also authorized for the HSC portion of the HGNC. The constructed project is referred to throughout the report as the HGNC Project.

- *The Houston-Galveston Navigation Channels, Texas, Final Limited Reevaluation Report, USACE, Galveston District*, dated May 2007 (2007 LRR). The 2007 LRR involved an economic update for the 1995 LRR.
- *Bayport Ship Channel Improvements and Barbour's Cut Channel Improvement Projects, Section 204(f) Assumption of Maintenance Assessment (AOM) Report for Harris and Chambers Counties, Texas*, dated 23 December 2013; USACE.
- *Jacintoport Ship Channel at Houston Ship Channel, Houston, Texas, Assumption of Maintenance Report*, dated January 2015, provided for the Federal AOM for non-Federal improvements made to the Jacintoport Channel.
- *Houston Ship Channel, Texas, Preliminary Assessment*, dated December 5, 2017. This Preliminary Assessment utilized alternative placement in existing PAs for placement of dredged material from the HSC to attain 20-year dredged material placement capacity.
- *Houston Ship Channel Expansion, Texas Navigation Improvement Reconnaissance Report, Section 905(b) Analysis*, approved on September 22, 2015, confirmed Federal Interest in continuing a feasibly study to evaluate the need for channel improvements to the HSC system.
- *Houston-Galveston Navigation Channel, Texas, Final Post Authorization Change Report, and Section 902 Cost Limit Determination, USACE Galveston District*, dated March 2016 (Revised April 2016) (HGNC 902 PACR). Director's Report was signed May 13, 2016.
- Houston Ship Channel Project Deficiency Report (Flare at the Intersection of the Houston Ship Channel and Bayport Ship Channel), Houston-Galveston Navigation Channels, Texas – Galveston District, dated March 2016 (HSC PDR). Addressed a safety issue and recommended an interim corrective action at the HSC/BSC intersection with the ultimate fix requiring a study of the Bay Reach of the HSC under this Section 216 feasibility study. During this study, the following two reports were developed:
    - USACE Engineer Research and Development Center (ERDC) 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 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 in the 1995 LRR, 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.
- *Galveston Harbor Channel Extension Project, Feasibility Study, Houston-Galveston Navigation Channels, Texas, Feasibility Report and Environmental Assessment,* dated September 2016. Recommended deepening the last 2,571 feet at the most westward end of Galveston Channel to match depth from 1995 LRR. The Chief's Report was signed on August 8, 2017.

1.7.2 Existing Water Projects

Federal involvement with the future HSC began as early as 1870 when the Buffalo Bayou Ship Channel Company improved the channel and subsequently persuaded Congress to make Houston a port of delivery in 1870. This resulted in the USACE surveying the channel and making a recommendation to dredge the channel to 100-feet wide and six-feet deep.

Interest in improving the HSC for deep-draft commercial shipping has continued since that time. The HSC is now a blend of channels providing for shallow-draft and deep-draft vessel traffic, constructed under the authorizations of the Houston Ship Channel, Texas and the Houston-Galveston Navigation Channels, Texas Projects. The Rivers and Harbors Acts (RHAs) of 1905 and 1919 started with the easing of sharp bends and deepening to 30 feet. Dates of the authorizing acts, work authorized, and the pertinent authorizing documents are provided in **Tables 1-2 through 1-3.**

Table 1-1 – Work and Authorizations under HSC, Texas Project

Date Authorizing Act	Project and Work Authorized for HSC	Documents
Mar 5, 1905	Easing or cutting off sharp bends and construction of pile dike (Deauthorized[1])	Rivers & Harbors Committee Document 35, 61st Congress, 2nd Session
Mar 2, 1919	A channel 30 feet deep, widen bend at Manchester and enlarge turning basin	House Document 1632, 65th Congress, 3rd Session
Mar 3, 1925	A light-draft extension of channel to mouth of White Oak Bayou *(Hill Street Bridge to mouth of White Oak Bayou deauthorized[1])*	House Document 93, 67th Congress, 1st Session
Jul 3, 1930	Widen channel through Morgans Point and to a point 4,000 feet above Baytown and widen certain bends.	House Document 13, 71st Congress, 1st Session
Aug 30, 1935	Deepen to 32 feet in main channel and turning basin, and a 400-foot width through Galveston Bay (*Previously authorized Sep 6, 1933 by Public Works Administration)*	Rivers & Harbors Committee Document 28, 72nd Congress, 1st Session
Aug 30, 1935	Deepen to 34 feet in main channel and widen from Morgans Point to turning basin	Rivers & Harbors Committee Document 58, 74th Congress, 1st Session
Mar 2, 1945	Branch channel 10 by 60 feet behind Brady Island.	House Document 226, 76th Congress, 1st Session
Mar 2, 1945	Widen channel from Morgans Point to lower end of Fidelity Island with turning points at mouth of Hunting Bayou and lower end of Brady Island.	House Document 226, 76th Congress, 1st Session
Mar 2, 1945	Widen channel from lower end of Fidelity Island to Houston turning basin and dredge off-channel silting basins.	House Document 737, 79th Congress, 2nd Session
Jun 30, 1948	Deepen to 36 feet from Bolivar Roads to and including main turning basin at Houston, Texas, including turning points at Hunting Bayou and Brady Island.	House Document 561, 80th Congress, 2nd Session
Jul 3, 1958[1]	Deepen to 40 feet from Bolivar Roads to Brady Island, construct Clinton Island turning basin, a channel 8 by 125 feet at Five Mile Cut, and improve shallow draft channel at Turkey Bend *(Deepening channel to 40 feet from Southern Pacific Slip (mile 47) to Brady Island deauthorized[1])*.	House Document 350, 85th Congress, 2nd Session
Jul 14, 1960	Barbour Terminal at Morgans Point	Section 107, PL 86-645
Oct 27, 1965	Restoring existing locally dredged channel from Mile 0 to 0.34 to 36 feet deep and dredging a 15-12 foot channel from Mile 0.34 to 2.81 in Greens Bayou *(The 12-foot channel from mile 1.65 to mile 2.81 deauthorized[1])*.	House Document 257, 89th Congress, 1st Session
Nov 17, 1986	Maintenance of Greens Bayou, Barbour Terminal Channel, and Bayport Ship Channel to forty-foot depths at Federal Expense.	Section 819, PL 99-662

[1]*Deauthorizations under Section 12 of PL 93-251 (1975 Deauthorization List)*

Table 1-2 – Work/Authorizations under HGNC, Texas Project

Date Authorizing Act	Project and Work Authorized for HSC under HGNC[1]	Documents
Oct 12, 1996	Provides for navigation and environmental restoration improvements. The navigation improvements consist of deepening and widening the Entrance Channel to 47 feet deep and 800 feet wide; the Houston Ship Channel to 45 feet deep and 530 feet wide; and the Galveston Channel to 45 feet deep. The environmental restoration portion consist of initial construction of marsh habitat and a colonial water bird nesting island through the beneficial use of new work dredged material, and incremental development (deferred construction) of additional marsh over the life of the navigation project through the beneficial use of maintenance material dredged from Galveston Bay. The project is referred to as Houston-Galveston Navigation Channels.	Section 101 (30) PL 104-303
Oct 27, 2000	Provides for barge lanes immediately adjacent to either side of the Houston Ship Channel, from Bolivar Roads to Morgans Point, to a depth of 12 feet.	Appendix B, PL 106-377

[1]*Dimensions for HGNC authorized project in MLT datum.*

2 EXISTING CONDITIONS *

2.1 GENERAL

The HSC is a high use channel and one of the busiest waterways in the United States (U.S.) with over 9,000 deep draft and 200,000 barge transits per year. The HSC system is currently suffering inefficiencies due to the high vessel transit count and congestion within the current channel configuration (**Figure 2-1**). The system has constrained vessel sizes, draft restricted areas in the upper channel, and inadequate channel configurations for vessels currently using the channel. The *Houston Pilots Working Rules* incorporated into this study were dated October 24, 2018. The *Houston Pilot Working Rules* are available at the following link: http://www.houston-pilots.com/documents/pdf/NavigationSafetyGuidelines.pdf. Note, these rules are subject to change.

Vessels calling at Port Houston experience inefficient vessel utilization due to channel depth and width constraints and thus the maximum cargo capacity afforded by the vessel size is not realized. The **light loading** of vessels prevents them from utilizing their optimal draft. One-way traffic is required for vessels with wide beams and lengths in excess of 1,000 feet, causing time delays in vessel transit as other vessels wait for the largest vessels to clear the channel. Existing channel configurations require slowing and tug assistance for larger vessel classes.

Light loading is the practice of loading a vessel below its optimum storage capacity. This practice allows vessels (not all) to transit the channel; however, it limits the vessels full draft capability leading to more overall vessel calls. This contributes to congestion in the channel.

Total vessel calls to HSC have grown in four of the last five years with available data (**Section 2.7.3 and Table 2-8**). This increase in vessel calls has been accompanied by growth in average vessel size (**Appendix B, Section 4**). With more total vessel calls made by a larger fleet, HSC has experienced increased delays throughout the system that will be exacerbated by the projected commodity and fleet forecast (**Appendix B, Section 4**).

An established safety issue was addressed under the HSC PDR, approved in May 2016, which recommended an interim corrective action at the HSC/BSC intersection with the ultimate fix requiring further evaluation as part of this 216 Feasibility Study.

Figure 2-2 illustrates existing PAs, inclusive of BU for the HSC system. **Table 2-1** provides the dimensions (depth, width, and length) for the HSC, its tributary channels, and turning basins. All depths in this report are referenced to the MLLW datum unless specifically stated otherwise.

* Required by CEQ Regulations 40 CFR 1502.10

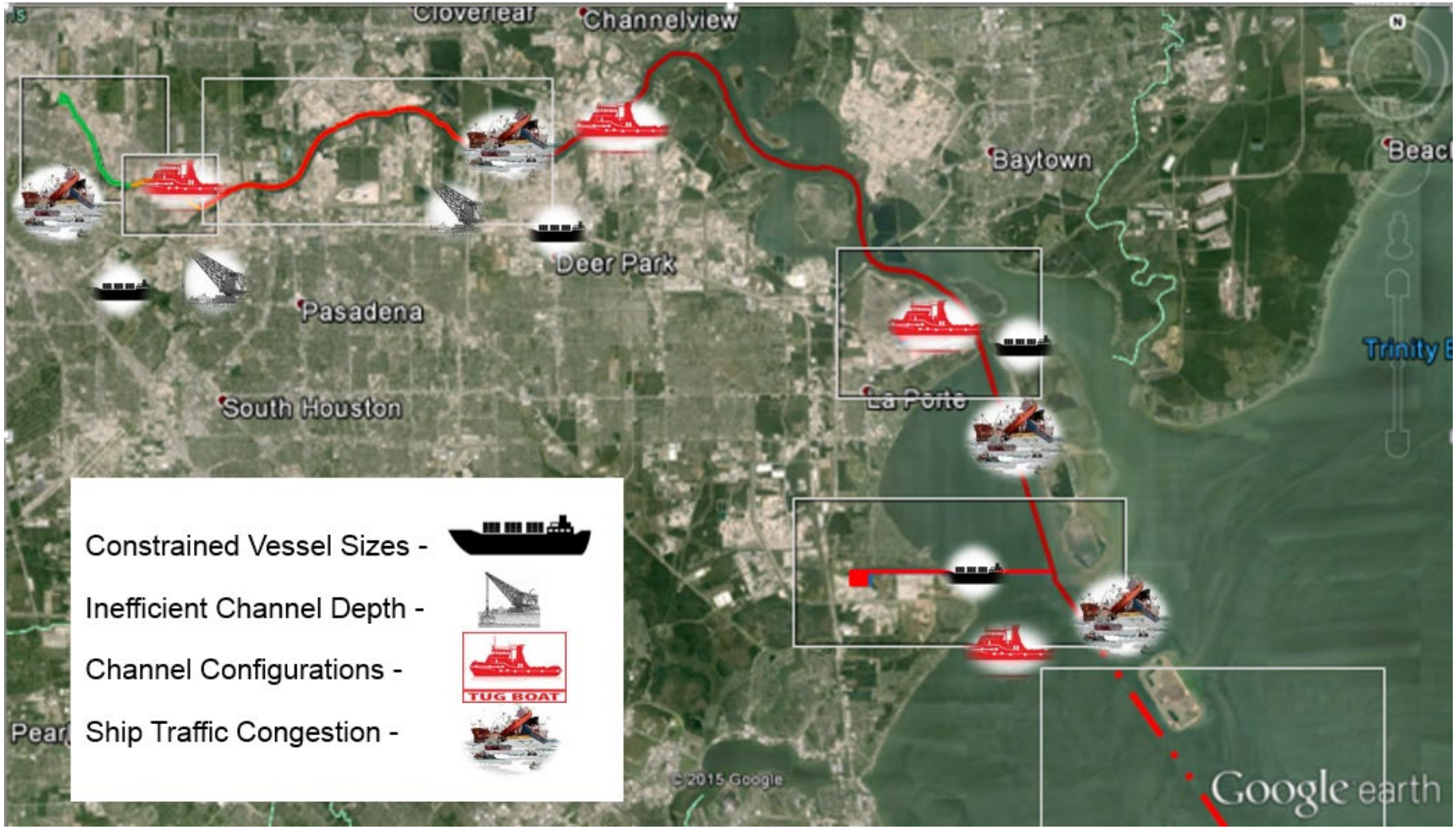


Figure 2-1 – Existing Conditions in the HSC System

* Required by CEQ Regulations 40 CFR 1502.10

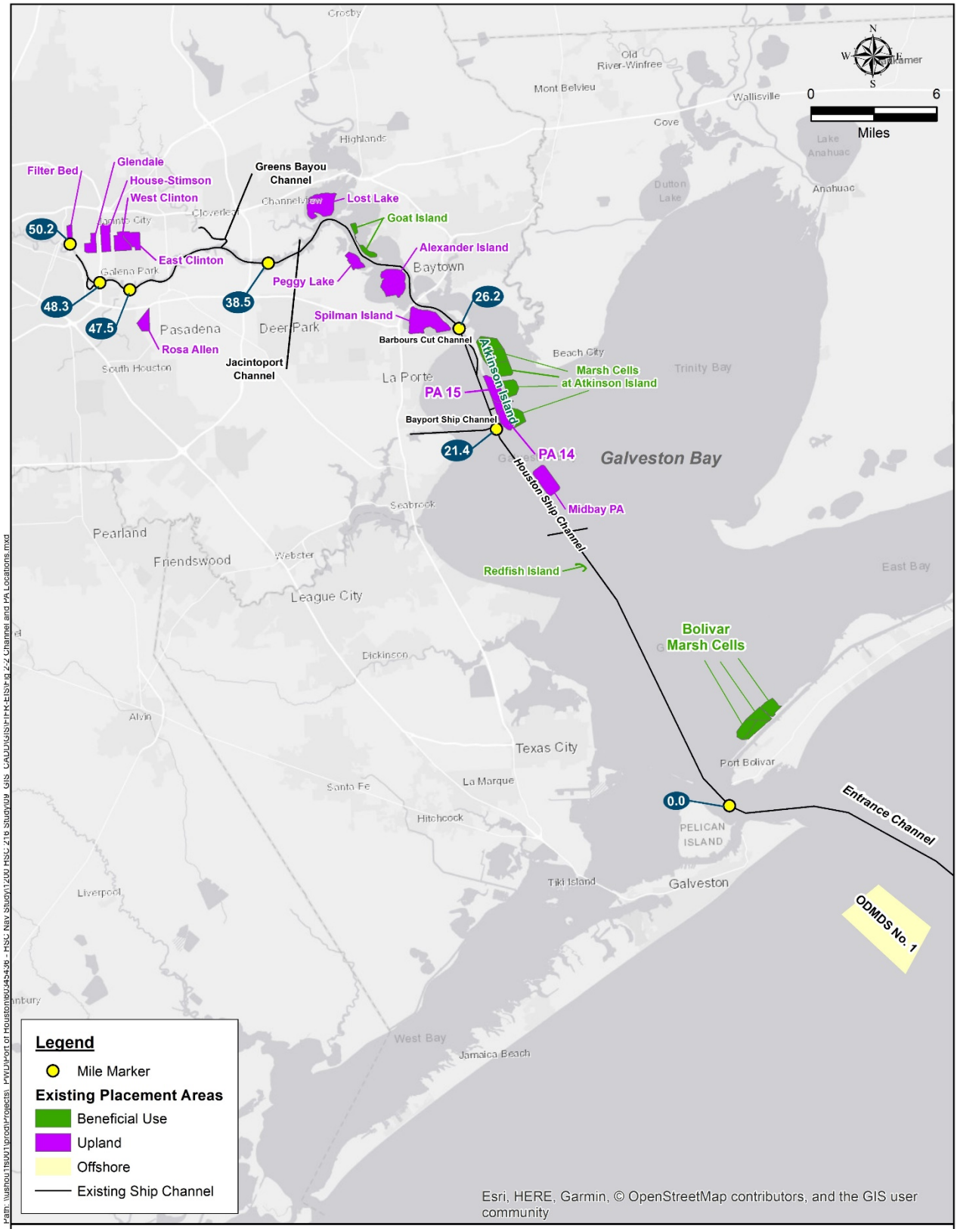


Figure 2-2 – Existing Placement Area Map

* Required by CEQ Regulations 40 CFR 1502.10

Table 2-1 - Channel Dimensions for HSC and Tributaries

Houston Ship Channel Section of Waterway	Authorized Dimensions			
	Depth (feet)		Width (feet)	Length (miles)
	MLT	MLLW		
SEGMENT 1 – HSC-BAY REACH SAFETY AND EFFICIENCY ENHANCEMENTS				
-Bolivar Roads (Mile 0) to Morgans Point (Mile 26.2)[1]	-45	-46/ -46.5	530	26.2
-Barge Lanes (adjacent to and on each side from Mile 0 to Mile 26.2)	-12	-13	125	26
-Morgans Point (Mile 26.2) to Boggy Bayou (Mile 38.5)	-45	-46.5	530-600	12.3
-South Boaters Cut @ Mile 15.3	-8	-9	300	1.9
-North Boaters Cut @ Mile 18.7	-8	-9	100	2.1
-Five Mile Cut Channel @ Mile 20.9	-8	-9	125	1.9
SEGMENT 2 – BAYPORT SHIP CHANNEL				
-Bayport Ship Channel (Mile 21.4 at intersection with HSC)[2]	-40	-41.5	300	3.8
Turning Basin	-40	-41.5	300-1,600	0.3
SEGMENT 3 – BARBOURS CUT CHANNEL				
-Barbours Cut Channel (Miles 26.3 at intersection with HSC)[2]	-40	-41.5	300	1.1
Turning Basin	-40	-41.5	300-1,600	0.3
SEGMENT 4 – HSC-BOGGY BAYOU TO SIMS BAYOU				
-Boggy Bayou (Mile 38.5) to Greens Bayou (Mile 42.0)	-40	-41.5	300	3.5
Jacintoport Channel	-40	-41.5	200	0.7
-Greens Bayou (Mile 42.0) to Sims Bayou (Mile 47.5)	-40	-41.5	300	5.5
Hunting Bayou Turning Basin	-40	-41.5	948-1,000[3]	0.3
Clinton Island Turning Basin	-40	-41.5	965-1,070[3]	0.3
-Greens Bayou Channel Mile 0.0 to Mile 0.36	-40	-41.5	175	0.4
-Greens Bayou Channel Mile 0.36 to Mile 1.65	-15	-16.5	100	1.3
SEGMENT 5 – HSC-SIMS BAYOU TO I-610 BRIDGE				
-Sims Bayou (Mile 47.5) to I-610 Bridge (Mile 48.3)	-36	-37.5	300	0.8
SEGMENT 6 – HSC-I-610 BRIDGE TO MAIN TURNING BASIN				
-I-610 Bridge (Mile 48.3) to Houston (Main) Turning Basin (Mile 50.2)	-36	-37.5	300	1.9
Houston (Main) Turning Basin	-36	-37.5	400-932	0.6
Upper Turning Basin	-36	-37.5	150-527	0.2
Brady Island Channel	-10	-11	60	0.9
Brady Island Turning Basin	-36	-37.5	300-722	0.2
-Buffalo Bayou Light Draft Channel (part of HSC beyond Segment 6; no improvements planned)				
Upper Turning Basin to Jensen Drive	-10	-11	60	4.1
Turkey Bend Channel	-10	-11	60	0.8
Jensen Drive to White Oak Bayou[4]	-10	-11	60	1.5

[1] Per the MLT to MLLW Datum Conversion, the split occurs at Beacon 76.
[2]PHA received approval to deepen channel to -45 feet (mean low tide (MLT))/ -46.5 feet (mean lower low water (MLLW)) and subsequent Federal assumption of maintenance under Section 408/204(f). BSC deepening was completed in Fall of 2016 and BCC was completed in August 2015. The BSC was widened from 300 feet to 400 feet from the flare to the land cut and from 300 feet to 350 feet from the land cut to the BSC Turning Basin. The BCC is 300 feet wide.
[3] Includes 300-foot channel width

2.2 PHYSICAL DESCRIPTION OF THE EXISTING PROJECT

The existing project is comprised of the dimensions previously provided in **Table 2-1**. The HSC is a 52 mile-long channel that is predominantly 46.5 feet deep through approximately 39 miles of its length from Bolivar Roads near Galveston Island and the Bolivar Peninsula to Boggy Bayou (Segment 1). Beyond Boggy Bayou to just downstream of the east part of Beltway 8 in east Houston, the channel is 41.5 feet deep for the next 8 upstream miles (Segment 4), and 37.5 feet deep for the remaining 5 upstream miles ending at the Main Turning Basin (Segments 5 and 6).

2.2.1 Channels Where the Government Has Assumed Maintenance

Federal AOM was assumed by USACE for maintenance of the PHA improvements to the BSC and the BCC Improvement Projects under Section 204(f) of WRDA 1986, as amended. The federally authorized BSC (Segment 2) is approximately 4.1-mile-long, 300-feet-wide, and authorized to 41.5-feet deep. The NFS deepened and widened the bay portion of the channel by 100-feet and widened the constricted portion of the channel within the land cut by 50-feet, and deepened the BSC to 46.5-feet deep.

The federally authorized BCC (Segment 3) is approximately 1.5 miles-long, 300 feet wide, and authorized to 41.5-feet deep. The NFS improvements shifted the entire channel and centerline of the BCC 75 feet to the north, maintaining the 300-foot channel bottom width to accommodate a wider berthing area. The NFS also deepened the authorized depth of the BCC from 41.5 feet to 46.5-feet deep.

Federal AOM was assumed for the approximately 0.76-mile long Jacintoport Channel (Segment 1) under Section 5001(a)(9) of WRDA 2007. Federal AOM of Greens Bayou Channel (Segment 4), a 1.6-mile long channel (combination of 41.5 feet and 16.5 feet) was conducted under WRDA 1986.

2.3 PHYSICAL RESOURCES

2.3.1 Project Area

The project area is located in southeast Texas and includes Chambers, Harris, and Galveston Counties. Chambers County consists mostly of agriculture, open water, and wetlands. Harris County is mostly developed and includes open space developments, agriculture, forests, wetlands, grasslands, and includes open water. Most of Galveston County in the project area is open water (NOAA 2017). The project area includes Galveston Bay and the greater Houston area along the HSC upstream of Galveston Bay. Galveston Bay is a 600 square-mile estuary where freshwater mixes with saltwater from the Gulf of Mexico, with generally shallow depths ranging from 5 to 12 feet except around dredged navigation channels located throughout the bay system. Galveston

Bay consists of several bays: Trinity Bay, East Bay, San Jacinto Bay, upper Galveston Bay, and West Bay. The project area also includes the HSC above Morgans Point, within the most-downstream segment of Buffalo Bayou at the confluence with the mouth of the San Jacinto River just upstream of Galveston Bay.

2.3.2 Climate

The climate for the Greater Houston area is classified as humid subtropical. Temperatures on average range from a low of 43 degrees (º) Fahrenheit (F) in January to a high of 95º F in August with an average yearly precipitation of 50 inches (NOAA 2016). The prevailing wind in Galveston Bay is from the southeast. The Greater Houston area and Galveston Bay region in general are susceptible to tropical cyclones during hurricane season (June through November). Storm tide heights recorded near the City of Galveston have ranged from 6.29 to 15.69 feet above MLLW (5.7 to 15.1 feet above mean sea level (MSL)). The last major hurricane to impact the area was Hurricane Ike in 2008. It should be noted that Hurricane Harvey had decreased in strength to a tropical storm by the time it impacted the Houston-Galveston region, but the flooding impact from precipitation was widespread due to its slow moving and dwelling nature in the area.

2.3.3 Topography, Soils, Geology, and Groundwater

The majority (90 percent) of the project area is in open water. The topography of land adjacent to the general area of the project is relatively flat and is located on the Gulf Coastal Plain, which consists of flat lowlands. Elevation in the vicinity of the project, according to U.S. Geological Survey (USGS) topographic maps, ranges from sea level within Galveston Bay to approximately 30 feet on the surrounding lands. The mapped soils on the nearest adjacent land in the project area (Harris County) are mixtures of loams, clays, sands, and urbanized soil units. Soil types and characteristics are listed and described in detail in **Appendix G, Table G1-1**. Subsidence data closest to the project area shows subsidence generally leveling off by 1990, with the exception for an abrupt short-term increase between the 2010 to 2013 drought years (USGS 2016). More detail on the topography, soils, geology, and groundwater of the project is discussed in **Appendix G, Section 1.3.3**.

2.3.4 Physical Oceanography

Galveston Bay is characterized as a relatively large shallow bay with an extensive interconnected system of deeper navigation ship channels. With the exception of ship navigation channels and the Mid Bay constriction caused by Redfish Bar, both natural and anthropogenic oyster reefs constitute the largest physiographic feature in Galveston Bay as remaining portions are comprised of shell, sand, mud, silt and clay particles with little bottom relief. Galveston Bay is dominated by tidal mixing and, to a lesser degree, freshwater input, and wind driven circulation.

2.3.4.1 Tides, Currents, and Water Level

The project area experiences semi-daily tides with two high and two low tidal periods, each with an average range of approximately one foot. Elevated tidal surge is experienced in Galveston Bay during storms and high spring tide events. High rain-driven freshwater inflows during May to September from the Trinity and San Jacinto Rivers, and Buffalo Bayou, typically result in formation of a fresh/saltwater wedge in deeper areas and navigation channels (e.g. HSC and BSC) of Galveston Bay. Currents are also affected by prevailing winds, especially in shallower areas. Prevailing winds from the south and southeast from spring through fall force water against the mainland, creating countercurrents in near-shore areas, while prevailing north and northwest winds in winter push bay water against Galveston Island and Bolivar Peninsula.

2.3.4.2 Salinity

The dimensions of the Galveston Entrance Channel and Jetties generally control the saltwater inflows and outflows of the Galveston and Trinity Bay Systems. The BSC is a tributary channel to the HSC with a closed terminus that runs east-west essentially along the same isohaline (contour with the same salinity). Freshwater inflows are generally controlled by the San Jacinto and Trinity River as well as various local flood-control district outflows and surface runoff. The salinity in the Bay is highly variable with the diurnal tidal and seasonal changes in seawater and freshwater but average from near-ocean salinity (approximately 35 part per thousand (ppth)) in the lower part of the Bay to much fresher values between 5 and 10 ppth in the upper part of the Bay. Texas Commission on Environmental Quality (TCEQ) and the Texas Water Development Board (TWDB) data show decreasing salinity as one moves upstream toward the upper limit of the project area at the HSC Main Turning Basin where TCEQ historical monthly averages range between 3.7 ppth to 7.6 ppth (see **Appendix G, Section 1.3.4.2** and **Appendix P**). As discussed earlier in this section, salinity can vary greatly with seasonal changes, especially low salinity during high flow, long duration freshwater pulse events from intense and prolonged rainfall events. These can be either extreme spring rainfall events such as those that occurred in 2015 and 2016, or tropical events such as Hurricane Harvey, which was a stalled tropical storm when it arrived in Galveston Bay. These typically result in filling up Addicks and Barker flood risk management reservoirs upstream of the HSC, which then have to be emptied over a long period (many weeks) due to risk management operation, depressing salinity in the Bay. Hurricane Harvey provided a third straight year of a long duration of depressed salinity that cause large scale reef mortality discussed in **Section 2.4.2.3**.

2.3.4.3 Relative Sea Level Change

Rising sea levels due to changes induced by climate change are an impact of the environment on coastal project performance of increasing concern to the USACE. Relative Sea Level Change (RSLC) was evaluated using the current USACE guidance and policy in Engineer Regulation (ER)

1100-2-8162, *Incorporating Sea Level Change In Civil Works Programs*, dated December 2013, and Engineering Technical Letter (ETL) 1100-2-1, *Procedures To Evaluate Sea Level Change: Impacts, Responses, And Adaptation*, dated June 2014. These projections depend in part on historic rates, which were obtained from NOAA Center for Operational Oceanographic Products and Services (CO-OPS) data. The longest-running (1908 to present) tide gage at Pier 21 (NOAA 8771450) in Galveston was used, which meets the minimum 40-year span of data required by policy. The MSL trends presented are local relative trends referenced to a fixed level on land, which accounts for effects of subsidence, and represents a combination of the global sea level change rate and local vertical land motion, also known as RSLC.

The MSL trend from 1908 to 2013 date was estimated to be an increase of 6.39 mm/yr with a 95 percent confidence interval of ± 0.24 mm/yr. Comparing this to the global sea level rise derived from the rate curves in USACE policy, the observed subsidence rate would be approximately 4.69 mm/yr. However, by using NOAA's estimate RSLC, which encompasses two more years of gage data than the USACE estimate, subsidence in this area may be slowly decelerating at the rate of 0.01mm/yr^2. The RSLC trends derived from the tidal gage data were used to project low, intermediate, and high rates of future change in sea level for the Future Without-Project Condition discussed in detail in **Engineering Appendix, Attachment C (Relative Sea Level Change)**.

2.3.5 Water and Sediment Quality

2.3.5.1 Water Quality

The TCEQ establishes, reviews, and revises water quality standards for all surface waters within the state to comply with the Federal Clean Water Act (CWA). A list of impaired waters required by Section 303(d) must be prioritized to identify waters targeted for Total Maximum Daily Load (TMDL) standard development. The TMDL defines an environmental target by determining how much a certain pollutant must be reduced to attain and maintain the affected use designated by the State, such as use by aquatic life, and the State develops an implementation plan to mitigate pollution sources in the watershed and restore full use of the water body (TCEQ 2007).

The HSC encompasses three separate classified water quality segments within Basin 10 of the San Jacinto River Basin: HSC/San Jacinto River Tidal (Segment 1005), HSC Tidal (Segment 1006), and HSC/Buffalo Bayou Tidal (Segment 1007). The HSC ECIP study limit also includes several water quality Segments in Basin 24 of the Bays and Estuaries. These segments have multiple designated uses including High Aquatic Life Use (ALU), Recreation Use (RU), General Use (GU), Fish Consumption Use (FCU), and Oyster Waters Use (OWU). Their classifications and impairments are identified in **Appendix G, Table G-1-2**.

Overall, segments with an Aquatic Life Use Designation meet minimum Dissolved Oxygen (DO) levels. All segments have nutrient concerns (e.g. nitrate-nitrite, ammonia, or phosphorus), which

exceed state screening levels but do not meet the definition of "impaired." Seven of twelve segments list Chlorophyll α as a concern. Two segments do not meet OWU designation due to bacteria levels, while another segment partially meets the OWU designation. This does not mean that oysters cannot be harvested or consumed from these areas. It means that after certain weather events like heavy rain that certain health department restrictions apply on harvested oysters before being sold for consumption. None meets FCU as the Texas Department of State Health Services (DSHS) has imposed fish consumption advisories. These advisories are due to high levels of either polychlorinated biphenyls (PCB) and/or dioxins in edible fish tissue. This does not mean that all fish have consumption advisories; only that certain fish like catfish have recommended limits for weekly or month consumption. In conclusion, the only impairments in the study area are the OWU and FCU. All other parameters used to assess the designated uses of each segment, particularly DO, have met the minimum levels established in the State standards.

2.3.5.2 Sediment Quality

Sediment quality has been characterized in various reaches of the HSC for nearly every dredging project on the waterway. Sampling has been conducted as part of research studies, as part of Federal maintenance dredging characterization in accordance with the joint Environmental Protection Agency (EPA)/USACE *Inland Testing Manual*, for new work dredging projects, and even private berth dredging. These sampling events have typically characterized both sediment chemistry and sediment elutriates, the latter of which simulates chemical leaching, resulting when material is agitated, as it is during dredging. These events test for metals, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), among others. The results of these sampling events are compared to several different standards and criteria, one of which is the Effects Low Range (ERLs) (Buchman, 2008). This is a method of statistical analysis of sediment chemical concentrations with biological responses using only effect data. This method is essentially an estimation of probability of the sediment causing harm to benthic organisms. The ERL is the concentration below which negative impacts to these organisms is not expected, while the Effects Range Medium (ERM) is the concentration above which negative effects are predicted (Long, et. al., 1995). While use of the ERL guidelines is useful in estimating sediment toxicity, they are not enforceable sediment quality standards, and do not represent hard and fast toxicity thresholds. Refer to the **Engineering Appendix (Section 8)**, for a complete discussion of sediment quality in the HSC.

In general, sediments with constituents of concern can be found in all reaches of the HSC, in various concentrations. Shoaled material in the Galveston Channel/Bolivar Roads rarely exceed ERLs for any the hundreds of constituents tested, and those that do fall well below the applicable ERM (USACE, 2015). The most recent data show no ERL exceedances in shoaled material from Redfish Reef to the BCC, and only two marginal ERL exceedances of nickel (21 and 24 milligram/kilogram (mg/kg) vs. 20.9 mg/kg ERL and 51.6 mg/kg ERM) in shoaled material from

Exxon to Carpenter's Bayou (USACE, 2015). Data from the 2015 maintenance dredging cycle shows several ERLs exceeded for a variety of contaminants (copper, mercury, and three PAHs) in shoaled material between Carpenters Bayou and Greens Bayou. However, these exceedances fell far below applicable ERMs, as shown in **Table 2-2** (USACE, 2015).

Table 2-2 – HSC 2015 Maintenace Dredging Record of Contaminant Exceedances

Analyte	Highest Measured Concentration	ERL	ERM	Percent of ERM (%)
Copper	44.9 mg/kg	34.0 mg/kg	270 mg/kg	16.6%
Mercury	0.190 mg/kg	0.15 mg/kg	0.71 mg/kg	26.7%
Acenaphthene	111 ug/kg	16 ug/kg	500 ug/kg	22.2%
Fluorene	103 ug/kg	19 ug/kg	540 ug/kg	19.0%
Phenanthrene	526 ug/kg	240 ug/kg	1500 ug/kg	35.0%

Milligram/kilogram (mg/kg)
Microgram/kilogram (ug/kg)

The 2015 maintenance data shows only two ERL exceedances in shoaled material from Greens Bayou to Sims Bayou, and no ERMs were exceeded. Several ERLs and ERMs were exceeded in shoaled material from Sims Bayou to the Main Turning Basin. The most recent maintenance data shows that chemical concentrations in shoaled sediment increase as one travels up the HSC. However, historical data has shown an overall decrease in sediment concentrations in the upper reaches of the HSC over the last 20 years, and in general, chemical concentrations in shoaled sediment in the HSC are either decreasing towards the ERL, or are already well below the ERL.

Dioxins and furans can also be found in nearly all sediment samples taken of shoaled material from the HSC. While USACE has consistently found similar concentrations in estuaries across the country, one reach of the HSC is immediately downstream from the San Jacinto Waste Pits Superfund Site. Listed on EPA's National Priorities List (NPL) in 2008, the San Jacinto Waste Pits is a series of impoundments that served as a dumping ground for pulp waste material containing dioxin/furans and other constituents of concern. Due to the continued discovery of dioxin in the estuary as well as continuing cleanup efforts at the site, a public notice was released in 2009 establishing an Area of Concern (AOC) and requiring that certain sampling take place for any dredged material projects in that AOC (EPA et al., 2009). A part of the HSC reach between Exxon and Carpenter's Bayou is in this AOC, and the appropriate coordination and sampling will be conducted at the appropriate time in the dredge planning process.

Extensive sediment testing has also been conducted as part of characterization for dredging of new work material, most recently in the BSC and in the BCC. In 2001, sediment and elutriate sampling at six planned berth and terminal locations in the BSC showed no presence of most constituents of concern, with the exception of metals, which appeared to be in line with natural background

concentrations. A follow up sampling event in 2004 at seven locations in the BSC showed only one ERL exceedance (total chlordane) out of 18 tested parameters. In 2010, sampling conducted at similar BSC locations showed similar results, with only two ERL exceedances (phenanthrene) out of 20 tested parameters. Finally, in 2014, a sampling event for new work dredging in the BSC showed several marginal ERL exceedances that were in line with background concentrations for those parameters. New work sediment in BCC has shown similar concentration trends, with the few marginal ERL exceedances falling in line with background values.

Sediment throughout the HSC shows the presence of constituents of concern. However, extensive historical sediment testing has shown ERL exceedances to be relatively rare, and concentration trends have been decreasing. Sediment testing will continue to be conducted in accordance with the joint EPA/USACE *Inland Testing Manual*, with handling requirements and selection of placement areas to be further refined during feasibility-level analysis, with final design in PED

2.3.6 Energy and Mineral Resources

The study area is home to the nation's and one of the world's largest centers of petroleum refining with numerous refining facilities served by the HSC, and product pipelines present throughout the area. Additionally, oil and gas field development and extraction continues on land and through shallow offshore drilling in various parts of the study area. No other major mineral resource extraction occurs in the vicinity of the HSC system. Active shallow offshore drilling activity is mostly clustered around several major fields with the south-most major activity near the HSC occurring near Bolivar Peninsula and around Texas City in the North Point Bolivar Field. North of that, a major cluster of activity occurs in the Redfish Reef Field on either side of HSC at Redfish Reef, and some active drilling to the west of the HSC just south of Mid Bay PA. Further north in the Bay, all activity occurs east of the HSC between Mid Bay PA to the Fred Hartmann Bridge in the major fields of Cedar Point and Goose Creek, east of Atkinson Island and Hog Island, respectively. Upstream of the Fred Hartmann, not much active shallow offshore or land-based drilling takes place near the HSC.

2.3.7 Hazardous, Toxic, and Radioactive Waste (HTRW)

In order to complete a feasibility-level Hazardous Toxic Radioactive Waste (HTRW) evaluation for the HSC ECIP, a report was completed following the rules and guidance of ER 1165-2-132: *HTRW Guidance for Civil Works Projects*, and ASTM E1527-13: *Standard Practice for Environmental Site Assessment: Phase 1 Environmental Site Assessment Process*. The full detailed HTRW evaluation can be found in **Appendix G, Section 1.3.7**.

The following sites have been identified as HTRW sites of concern. **Table 2-3** lists these sites along with the site location, details of the site, and the action recommendation.

Table 2-3 – Summary of HTRW Sites of Concern in the Project Area

Site	Location	Recognized Environmental Condition (REC)	Action Recommendation
Patrick Bayou	1.8 mi E of Beltway 8 bridge, Harris County	NPL site, sediment contaminated with PAHs, metals, and PCBs	Avoidance of widening measures in this area of HSC
San Jacinto Waste Pits	Immediately N of I10 bridge @ San Jacinto River, Channelview	NPL site, sediment contaminated with dioxin	Chemical sediment quality sampling within HSC portion of AOC, in accordance with 2009 EPA public notice
Pasadena Refining System	0.25 mi E of Washburn Tunnel, Pasadena	Past RCRA investigations and corrective actions, TSDF, active institutional controls	Avoidance of widening measures in this area of HSC
South Coast Terminals	0.1 mi E of I610 bridge, Houston	Past state enforcement orders, active VCP remediation ongoing, soil and GW contaminated with VOCs, BTEX, and PAHs	Avoidance of widening measures in this area of HSC
Lone Star Industries	0.1 mi E of Brady Island, Houston	Active VCP investigation ongoing, soil and GW contaminated with VOCs, SVOCs, metals, and TPH	Avoidance of widening measures in this area of HSC
Pasadena Terminal	0.4 mi S of Hunting Bayou, Pasadena	Past state enforcement orders, active institutional controls	Avoidance of widening measures in this area of HSC
Oxid, LP	0.1 mi E of I610 bridge, Houston	Active VCP remediation ongoing, soil and GW contaminated with solvents and metals	Avoidance of widening measures in this area of HSC

2.3.8 Air Quality

The Clean Air Act (CAA), as amended in 1990, regulates air emissions from area, stationary, and mobile sources, and requires the EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. Currently, there are air quality standards for six "criteria" pollutants designated by EPA; carbon monoxide, nitrogen dioxide, ozone, lead, sulfur oxides, and inhalable and fine airborne particulate matter (**PM_{10} and $PM_{2.5}$** respectively) [EPA, 2011]. These standards are summarized in more detail in **Appendix G, Table G1-7**.

Particle Pollution, also called Particulate Matter or PM references a mixture of solids and liquid droplets floating in the air.

PM_{10} - Coarse dust particles (2.5 to 10 micrometers (µm) in diameter) such as dust, pollen, mold, etc.

$PM_{2.5}$ – Fine particles (2.5 µm or smaller diameter) produced by combustion, organic compounds, metals, etc. https://airnow.gov/index.cfm?action=aqibasics.particle

The HSC ECIP study area is located within the Houston-Galveston-Brazoria (HGB) nonattainment area (NAA) regulated under the CAA, consisting of Harris, Montgomery, Liberty, Chambers, Galveston, Brazoria, Fort Bend, and Waller Counties. The HGB NAA currently meets all of the EPA NAAQS, except for ozone, which it is designated as being in moderate nonattainment. The current designation of moderate nonattainment changed recently from marginal nonattainment, in December 2016. The attainment status of the HGB area is detailed in **Appendix G, Table G1-8**.

The existing air quality in the study area, although improving, is still impaired for ozone. The nitrous oxide (NO_x) and volatile organic compounds (VOC) emissions that produce ozone come from many different sources in an urban and industrial environment. These sources include vehicle traffic, power generation, construction activity, and transportation (i.e. aircraft, truck, rail, and marine cargo), oil and gas production, refining and industrial processes, recreational equipment, and lawn and garden equipment.

To comply with the CAA, the State of Texas develops State Implementation Plans (SIP) that contain emissions inventories which comprehensively estimate emissions from all pollutant sources in a NAA to aid in demonstrating how compliance with the NAAQS will be achieved. More details can be found in **Appendix G, Section 1.3.7**.

2.3.9 Noise

2.3.9.1 Airborne Noise

The existing sound environment of the area surrounding the HSC ECIP study segments is influenced by numerous noise generating sources, from transportation (e.g. waterways, roadways) like ships, barges, commercial fishing vessels, and sport and recreational boats or marine terminal-related (e.g. docks, cranes), or terminal activity consists such as operation of cranes, pumps, trucks, or other equipment (e.g. loaders, forklifts). Typical maximum instantaneous sound levels of these sources at several distances, and comparison to typical noise levels of common indoor and outdoor activities are shown in **Appendix G, in Tables G1-9 and G1-10**. Traffic noise from numerous roadways traversing the mainland portion of the study area adjacent to the channels also influences the existing sound environment.

2.3.9.2 Underwater Noise

The Port of Houston has functioned as a commercial port since the late 1800's and as a deep water port since 1914. The Port of Houston has evolved over the last 105 years to accommodate a growing city, State and shipping industry with ever larger vessels calling. Recreational and commercial vessel traffic, and other industrial noise has also continued to increase adding to the underwater soundscape. Several ambient noise sources are also present at the Port of Houston and in Galveston Bay. These include natural sources such as wind waves, tidal currents, fish, and mammals, and manmade sources such as the aforementioned vessel traffic, periodic dredging, and harbor construction (pile driving etc.). Tidal currents can produce hydrodynamic sounds, most significantly at very low frequencies (< 100 Hz). Vessel traffic generates sounds that can travel considerable distances, in frequencies ranging from 10 to 1000Hz. Wind-driven waves also produces ambient sounds in the frequency range of 500 to 100,000 Hz and can be expected to constitute the main underwater sound source in the Bay.

The Port of Houston and Galveston Bay has the typical noise characteristics of a busy port and highly used recreational water. Noise sources for commercial vessels include cranes, whistles and propulsion and auxiliary engines. Dockside noise sources include cranes, pumps, and loading and unloading equipment. Recreational vessel sound sources are predominantly outboard motors. Noise has been documented to influence fish behavior. Fish detect and respond to sound by utilizing cues to hunt for prey, avoid predators, and for social interaction. Fish produce sound when swimming, mating, or fighting and also noise associated with swimming. Given the number and ubiquity of natural and manmade sound sources, and level and frequency of vessel and construction activity, marine species are likely adapted to the current underwater soundscape, typical of a very busy port.

2.4 ECOLOGICAL AND BIOLOGICAL RESOURCES

2.4.1 Habitats

2.4.1.1 Terrestrial

The study area is located within the Gulf Coast Prairies and Marshes Natural Region as mapped by the Texas Parks and Wildlife Department (TPWD) [TPWD 2011]. The region has flat to very gently rolling topography along the Gulf Coast from Louisiana to Mexico and includes coastal features such as barrier islands, beaches, estuarine lagoons, tidal marshes, inland prairies, and woodlands of various sorts (Poole et al. 2007).

Most of the area directly adjacent to the HSC, BSC, and BCC is heavily developed, primarily with industrial development. Terrestrial conditions in the areas within 500 feet of the existing HSC toes were defined by TPWD land-cover classification data supplemented by 2014 aerial photography. Almost 70 percent of landside cover within 500 feet of the existing HSC, are mapped as high and low intensity urban, occurring mostly upstream of Morgans Point. Potential wetland areas total less than six acres and comprise less than one percent. More detail on these areas is provided in **Table G1-11, Appendix G.**

Twenty-seven existing PAs have been identified in the study area that could be used for the HSC ECIP project. These areas are listed in **Table 2-4** and shown previously in **Figure 2-2**. **Appendix G, Section 1.4.1.1** describes the PA vegetation in more detail. All upland disposal areas are periodically filled with additional material from current and future dredging activities.

Table 2-4 –Existing Dredged Material Placement Areas

Name	Placement Type Proposed
ODMDS No. 1	Ocean Disposal
Bolivar Marsh Cells 1 through 3	Renourishment Placement
Bolivar 288-acre marsh	Renourishment Placement
Redfish Island	Renourishment Placement
Mid Bay PA	Upland Placement
PA 14	Upland Placement
PA 14/15 Connection*	Upland Placement
PA 15	Upland Placement
Atkinson Island Cell M5/M6	Beneficial Use Placement
Atkinson Island M10	Beneficial Use Placement
Atkinson Island M 7/8/9	Beneficial Use Placement
Atkinson Island M11*	Beneficial Use Placement
Atkinson Island M1/M2	Renourishment Placement
Atkinson Island NW	Renourishment Placement
Atkinson Island M3	Renourishment Placement
Atkinson Island M4	Renourishment Placement
Spilman	Upland Placement
Alexander Island	Upland Placement
Goat Island	Renourishment Placement
Peggy Lake	Upland Placement
Lost Lake	Upland Placement
East Clinton	Upland Placement
West Clinton	Upland Placement
Rosa Allen	Upland Placement
House-Stimson	Upland Placement
Glendale	Upland Placement
Filter Bed	Upland Placement

**Denotes a partially complete or future cell already planned and approved under a previous Federal project.*

2.4.1.2 Wetlands

Two basic types of wetlands are common in the study area: depressional and estuarine wetlands. Depressional wetlands typically occur in depressed locations on the landscape, usually receive moisture from rainfall, and are poorly drained. Estuarine wetlands are typically saline, located in the transition between freshwater and saltwater marshes.

Only 5.7 acres of potential wetland areas were identified along the shoreline adjacent to the HSC in the few areas noted upstream of Morgans Point. No wetlands or vegetated shallows are located directly along the BCC or BSC channel margins. Fringe wetlands may be present in a low-lying slope bench behind the rip rap and foreshore of the northern shore of the BSC in the land cut where development outside of the HSC ECIP continues. Outside of the eastern containment dikes of PA 14 and 15, tidal marsh has developed on dredged material that migrated prior to the closure of the

dikes in 2002 and these wetland areas were mitigated as per the PA 14/15 enclosure. Within two terrestrial tracts (BW8 and East-east Clinton) proposed for project new work dredged material placement, there are approximately 22.7 acres of mostly forested, and 8.7 acres of mostly scrub shrub palustrine wetlands. Approximately 40.7 acres of mostly palustrine forested wetlands are found in the Rosa Allen Expansion tract that would be proposed for future maintenance placement. All of these wetlands are dominated by invasive or fast-growing species such as Chinese tallow (*Triadica sebifera*), and cattails (*Typha latifolia*).

2.4.1.3 Bays and Deepwater Habitats

The open-bay bottoms in Texas bay systems include all unvegetated subtidal areas with various sediment types. They are open systems that greatly interact with the overlying waters and adjacent habitats (Armstrong et al., 1987; Tunnel and Judd, 2002). The Galveston-Houston area bay system includes the Galveston, Trinity, East, and West bays. Mud and sandy mud are the dominant sediment types in this system, with sand at bay margins. Sandy sediments are associated with flood-tidal deltas at Bolivar Roads and San Luis Pass and with modern barrier islands.

2.4.2 Wildlife

2.4.2.1 Terrestrial

The wildlife in the project area includes species typical of the Gulf Coast Plain and the Galveston Bay system. More detail and species can be found in **Appendix G, Section 1.4.2.1**.

Birds

The project area is located in a region along the Gulf of Mexico known for year-round bird watching, with 139 bird species associated with Galveston Bay wetlands and open-bay habitats observed. These can be grouped into wading birds who feed along the shoreline and marshes such as herons and egrets, and those who primarily feed on fish caught in open water habitats including terns, gulls, and pelicans (GBEP 2011). Many species of waterfowl use the coastal prairies of the upper Texas coast as a vital winter foraging area as they migrate along the Central Mississippi flyways each year, with species such as blue winged teal (*Anas acuta*), American widgeon (*Anas americana*), northern shoveler (*Anas clypeata*), and snow goose (*Chen caerulescens*) observed (GBEP 2011). The Galveston Bay system is also an important site for migrating shorebirds such as the American avocet (*Recurvirostrata americana*), sanderling (*Calidris alba*), and the black-bellied plover (*Pluvialis squatarola*) (GBEP 2011).

Reptiles and Amphibians

Reptiles and amphibians known to occur in the counties adjacent to Galveston Bay include the Texas rat snake (*Elaphe obsolete*), western ribbon snake (*Thamnophis proximus*), Gulf Coast toad (*Bufo valliceps*), western cottonmouth (*Agkistrodon piscivorus*), box turtle (*Terrepene*

carolinensis), green tree frog (*Hyla cinerea*), and five lined skink (*Eumeces fasciatus*), among others. The American alligator (*Alligator mississippiensis*) is known to inhabit the fresh and brackish waters and wetlands and can be found in the bayous and rivers that flow into the bay.

Mammals

Common terrestrial mammals that inhabit the general region include, but are not limited to, the swamp rabbit (*Sylvilagus aquaticus*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*Sciurus niger*), Virginia opossum (*Didelphis virginiana*), nine-banded armadillo (*Dasypus novemcintus*), eastern cotton tail (*Sylvilagus floridanus*), roof rat (*Rattus rattus*), hispid cotton rat (*Sigmodon hispidus*), Norway rat (*Rattus norvegicus*), nutria (*Myocastor coypus*), raccoon (*Procyon lotor*), coyote (*Canis latrans*), striped skunk (*Memphitis memphitis*), white tailed deer (*Ordocoileus virginianus*), and feral hogs (USACE 2003a).

2.4.2.2 Aquatic

Fish and Nekton

The open bay habitat contains nekton species (able to swim independently of currents) comprised mostly of crustaceans and finfish species. The diversity and distribution of fish species can be affected at any time during the year by migrations and spawning cycles (Armstrong, 1987). Newly spawned fish species begin migrating into the Bay in winter and early spring, with maximum biomass observed during the summer (Armstrong et al., 1978; Parker, 1965). Dominant finfish species inhabiting and caught in Galveston Bay include Atlantic croaker (*Micropogonias undulatus*), Gulf menhaden (*Brevoortia patronus*), bay anchovy (*Anchoa mitchilli*), sand seatrout (*Cynoscion arenarius*), gizzard shad (*Dorosoma cepedianum*), spot (*Leiostomus xanthurus*), and hardhead catfish (*Arius felis*). More detail on the fish and nekton species is provided in **Appendix G, Section 1.4.2.2**.

Benthos

The benthic (bottom) habitats within Galveston Bay have been previously surveyed, and common assemblages that occur within the areas of soft bottom (those areas comprised of sand, silt, or clay) are detailed in **Appendix G, Table G1-13**. Common dominants include species of polychaetes, mollusks, and crustaceans. Silty clay (or muddy) sediments tend to support a community dominated by polychaetes, while more sandy (coarse grained) sediments are primarily dominated by crustaceans (GBEP 2002). The assemblages within the project area are a combination of several of these, depending on channel extent and current depth of water. Benthic invertebrate abundance generally increases north to south in the Bay below Morgans Point, and seasonally peaking in spring, between February and May, and decreasing in October and November.

Macrofaunal diversity within Galveston Bay is considered to be low or moderate compared to other estuaries in the Gulf of Mexico, with the highest diversity in areas with stable salinity regimes

(e.g., near inlets such as Bolivar Roads and Rollover Pass). The HSC area generally has a lower species diversity compared to the more open bay stations (GBEP 2002). The highest densities of oligochaetes (pollution tolerant species) are found in the HSC upstream of Morgans Point. All other areas in the Bay have low densities of oligochaetes, including other tributaries. More detail on the assemblages in Galveston Bay is discussed in **Appendix G, Section 1.4.2.2**.

Plankton

The benthic and nekton species depend on the food web provided by planktonic species. Phytoplankton in the Bay is dominated by diatoms, which constitute over 40 percent of all phytoplankton, including species such as *Skeletonema costatum* and *Navicula abunda*, all of which exhibit peak abundance in the early spring. Blue-green algae *Oscillatoria* species dominate this community in the summer, while green algae *Ankistrodesmus* species dominate in the late summer and early fall months (Texas Department of Water Resources 1981). Zooplankton (not including meroplankton) in the Bay is primarily comprised of copepods, cladocerans, and chaetognaths, with species such as *Acartia tonsa,* and *Oithona* species. Meroplankton are early planktonic stages (eggs and/or larvae) of organisms such as fish and benthic invertebrates. In Galveston Bay, zooplankton abundance is closely linked to water temperatures and inversely related to salinity levels (Armstrong 1987), peaking in April with high freshwater input into the bay and late summer with elevated water temperatures. The increased zooplankton population observed in summer have the capacity to severely limit phytoplankton abundance through intensive grazing, leaving the less palatable cyanobacteria (blue green algae) as the dominant phytoplankton group (Ornolfsdottir 2003).

2.4.2.3 Oyster Reef

Oyster reefs are present in many areas of the Galveston Bay system and provide ecologically important functions. Two species inhabit Texas coastal waters. Eastern oysters (Crassostrea virginica) are the dominant bivalve species in shallow saltwater bays, lagoons, and estuaries; in water 8 to 25 feet (2.5 to 7.5 m) deep and between 28 and 90 °F. Crested oyster (*Ostrea equestris*) is less common in Texas and limited to higher salinity waters. Therefore, it is not expected to be abundant in the project area.

The project area encompasses a large portion of the HSC with varying degrees of salinity and dissolved oxygen. It is expected that live oysters will be limited to the areas of the channel with suitable habitat. While oysters can survive in salinities from 5 to 40 ppth (Cake, 1983), they grow and spawn most successfully in salinity between 10 and 30 ppth, and dissolved oxygen greater than 5 parts per million (ppm) (Natural Resources Conservation Service (NRCS) 2011, Volety et al 2009, Cake, 1983, Butler, 1954)).

American oyster reef has been documented to occur as deep as anywhere between 40 feet and 100 feet, but are known to thrive in depths less than 15 feet (SCDNR 2015, NOAA Fisheries Eastern Oyster Biological Review Team 2007, Kilgen and Dugas 1989). Local, recent side-scan imagery and mapping for the NFS's BSC Improvements Project, and from recent TPWD mapping discussed in the next paragraph, indicate reef signature on the HSC side slopes at depths between 15 and 20 feet, and in the existing HSC barge lane bottom at approximately 12 feet. Factors such as periodic maintenance dredging of the channels limits presence at depth, and other factors like local DO and phytoplankton (oyster's food source) also limit growth deeper in the navigation channels. The presence of reef at 20 feet of depth and shallower along the HSC is consistent with observations in the 1995 LRR (Appendix E, USACE 1995).

Reef within Galveston Bay was last mapped comprehensively on a Bay-wide basis during the surveys conducted by Texas A&M for the Galveston Bay National Estuary Program (now Galveston Bay Estuary Program), surveyed in 1991 and reported in 1997 (Powell et al. 1997). This mapping (reference **Figure 2-3**) shows that the largest extent of concern to the project occurs directly lining the HSC essentially from the Redfish Reef area northward to Morgans Point and along the BSC. Very little to no reef is seen along the HSC south of Redfish Reef to the southern end of the study. TPWD surveyed major reef complexes in the Bay to assess damage from sedimentation produced by Hurricane Ike in 2008. They estimated between 50 percent of the oyster reef in the Bay was damaged or destroyed (Rohrer et al. 2010, Hons and Robinson 2010, Drake 2012). Areas along or in close proximity to the HSC had less impact than complexes further away from the channel. The resulting TPWD mapping, also shown in **Figure 2-3**, indicates a relatively solid extent along the HSC margin.

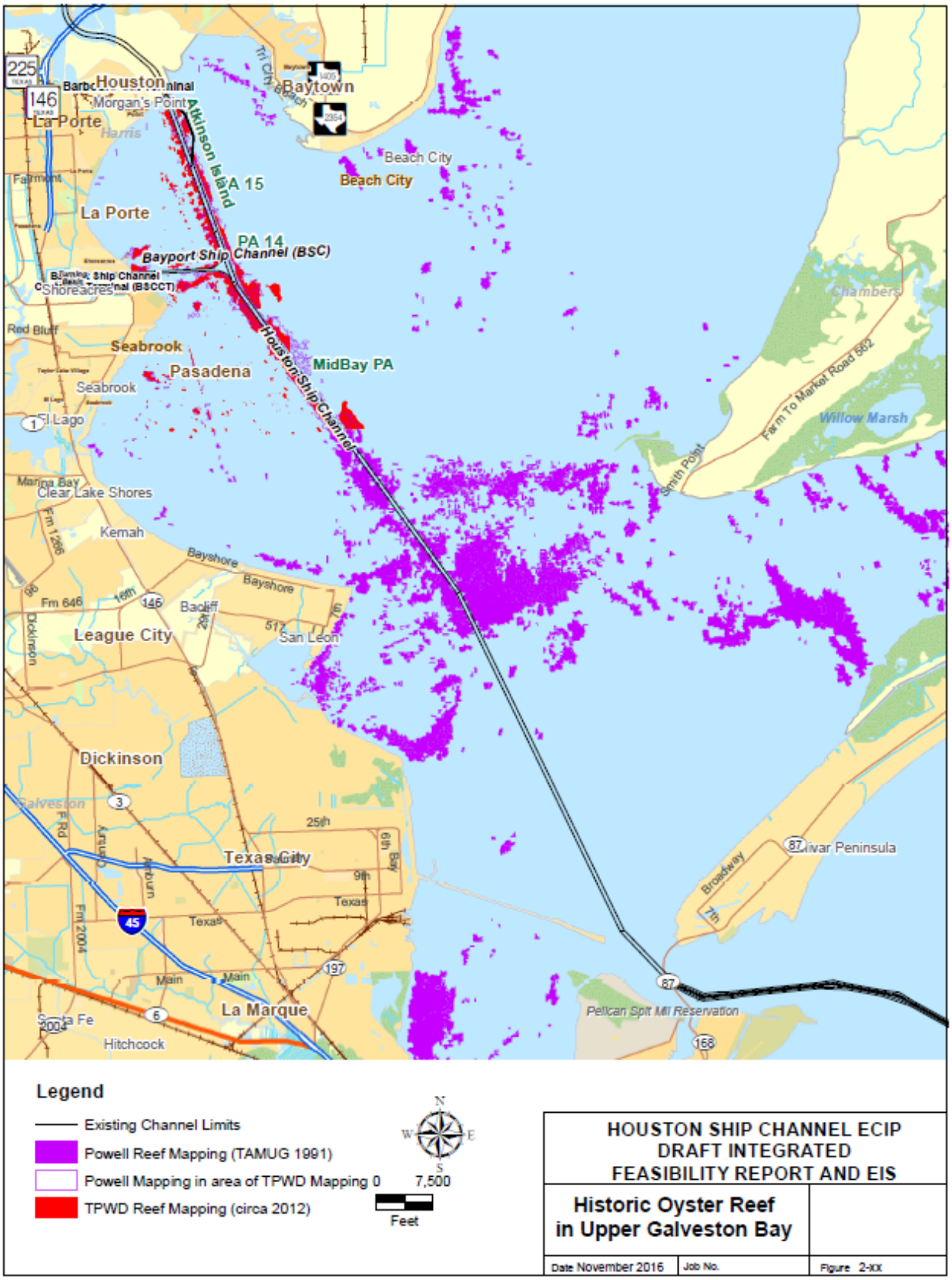


Figure 2-3 – Oyster Reef Mapping in the Study Area (Source: TPWD)

The 2011 BSC project side scan data discussed in the previous paragraph also indicated solid reef coverage around the HSC margins that did not appear to have been significantly impacted by burial of sediment from Hurricane Ike in 2008. Surveys to determine detailed extent within specific proposed plan footprints where only older Powell mapping was available were conducted during feasibility-level analysis in 2018 using new side scan sonar surveys and groundtruthing through sample dredging. The survey is described in detail in **Appendix G, Section 3.2.2.3** and **Appendix P-1, Mitigation Plan for Oyster Reef Habitat Project** reef mapping would be further refined during preconstruction engineering and design (PED) for the navigation project.

Neither the Powell historical mapping nor the recent TPWD mapping included areas of the HSC above Morgans Point. The deepened navigation channel and the adjacent deep draft berths receive periodic maintenance dredging, and would not be expected to support reef development. These deepened parts of the navigation system cover most of the open water area above Carpenter's Bayou. Between Morgans Point and Carpenter's however, Buffalo Bayou and the San Jacinto River has a wider, greater extent of shallower undredged bathymetry outside of the main channel that could support reef growth given the appropriate salinity. Sidescan sonar data and low tide observations in the shallow bay south of Alexander Island for a recent proposed liquid natural gas terminal project indicated reef growth on the shallow bottom. Salinity data, channel bathymetry, and berth presence were reviewed in the channel footprint above Morgans Point to determine the likelihood that reef could develop or not, to determine areas to prioritize for local reef surveillance during the feasibility-level design and analysis phase. This data is summarized and discussed in **Section 5.2 of Appendix P, Mitigation Plan for Oyster Reef Habitat**. The review indicates salinity is too low above Vince Bayou to routinely support growth, is not in the preferred range between Greens Bayou and Vince Bayou, and relatively few and small areas in the channel footprint above Morgans Point that would be expected to support growth compared to reef in the Bay portion of the HSC. The salinity and bathymetry information and areas prioritized for survey were coordinated with the resource agencies to determine final survey areas to address during the feasibility-level design and analysis phase. Other information from private terminal project permits was consulted for proposed widening further upstream between Boggy Bayou to Greens Bayou that did not indicated likelihood of substantial reef. The aforementioned 2018 survey and groundtruthing covered the channel measures remaining in plan formulation above Morgans Point that had sufficient salinity and more substantial shallow bathymetry to warrant surveillance. These were HSC widening above BCC, the combination turning basin/flare at the BCC, HSC widening along Hog Island, a proposed mooring near the San Jacinto Monument.

While reef extent depends on hard substrate to build the base for a living reef, the living portion depends on repeated and seasonal spawning and settling of live oysters dependent on appropriate salinity to trigger spawning and sustain growth. The productivity and density is subject to the highly variable salinity that occurs with drought and flood cycles in an estuary. Prolonged salinity

below 5 ppt results in mass oyster mortality, while too high a salinity that favors oyster predators, parasites, and diseases may also decimate populations (Cake 1983, Buzan et al 2009, Rybovich 2014). Droughts such as the severe one in 2011, decrease freshwater inflow that can result in the higher salinities that allow oyster predators and pests to thrive. Long-term high freshwater inflows into estuaries from prolonged rain events ("freshets"), such as the 2015 and 2016 spring floods, and most recently Hurricane Harvey in 2017, periodically cause mass mortalities from depressed salinities, especially when conditions below 2 ppt persists for more than a month; however, they will normally recover to pre-flood productivity in 2-3 years (Cake 1983).

The prolonged fresh water inflow from surface runoff and reservoir releases following Hurricane Harvey was the third year in a row that abnormally high freshwater inflow resulted in prolonged low salinity. It took approximately two months for normal salinity levels to recover (Du *et al.* 2018). The previous 2015 and 2016 events resulted in reef mortality, observed in the oyster reef monitoring conducted for the Bayport Ship Channel Improvements. The third consecutive event from Harvey resulted in high mortality of live reef varying between 20 percent in the middle of the Bay to greater than 90 percent in East Bay and Dollar Reef near the western shoreline of Galveston Bay, according to TPWD (Bay Group Media 2017).

2.4.3 Essential Fish Habitat

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) set forth a new mandate for the National Marine Fisheries Service (NMFS), regional Fishery Management Councils (FMC), and other Federal agencies to identify and protect important marine and anadromous fisheries habitat, referred to as Essential Fish Habitat (EFH). It also required that EFH consultation be conducted for any activity that may affect important habitats of federally managed marine and anadromous fish species. These designations and supporting regulations are described in more detail in **Appendix G, Section 1.4.3**. NOAA Fisheries and Gulf of Mexico Fishery Management Council (GMFMC) is responsible for the creation of Fisheries Management Plans (FMPs), which results in identifying the following EFH for the study area: Red drum (*Sciaenops ocellatus*), Gray snapper (*Lutjanus griseus*), Spanish mackerel (*Scomberomorus maculatus*), brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*F. duorarum*), and white shrimp (*Litopenaeus setiferus*)

Only the following have EFH within the open water area in Galveston Bay from the BSC and points south (not applicable to the remainder of the project area). These are the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), Blacktip shark (*Carcharinus limbatus*), Bonnethead shark (*Sphyrna tiburo*), Bull shark (*Carcharhinus leucas*), and the Scalloped hammerhead shark (*Sphyrna lewini*).

The project area is located within GMFMC Ecoregion 4, with relevant categories of EFH in the project area including estuarine emergent marsh, estuarine shell substrate, estuarine mud substrate,

and estuarine water column. For more information on the EFH categories in Galveston Bay see **Appendix G, Section 1.4.3.**

2.4.4 State Managed, Commercial, and Recreational Fisheries

The finfish and shellfish resources in Galveston Bay support the most lucrative commercial and recreational fisheries of all the major ports in Texas and annually constitute approximately 33 percent of the total commercial revenue and 50 percent of the total recreational revenue for the entire State (Lester 2002). From 1997 to 2001, landings of white shrimp from Galveston Bay comprised 62 percent of the landings from Texas bay systems, valued at $5.7 million in 1999, while brown and pink shrimp landings in Galveston comprised the majority (36 percent) for these species in Texas bays, estimated at $2.5 million in 1999 (Culbertson et. al. 2004). Galveston Bay also supports a robust live and dead bait shrimp fishery responsible for over 50 percent of coastal Texas landings worth $1.6 million in 2001 (Culbertson et. al. 2004).

Other important shellfish in Galveston Bay's commercial harvest include blue crab and Eastern oyster, which accounts for 91 percent of Texas oyster landings from 1997-2001 worth an estimated $13.2 million in 1999. Recreational fishing in the Galveston Bay system accounts for almost 40 percent of this coastal fishing and 35 percent of the landings (TPWD 2000). The primary species targeted and landed by recreational fishermen include Atlantic croaker, sand sea trout, southern flounder, red drum, and spotted seatrout.

2.4.5 Protected Species

The U.S. Fish and Wildlife Service (USFWS) and NMFS have responsibilities under the Endangered Species Act of 1973 to protect species federally designated as threatened or endangered. Threatened and endangered (T&E) species are known to occur in the study area. Other Federal acts afford specific protection for species relevant to the study area.

2.4.5.1 Threatened and Endangered Species

USFWS and NMFS were consulted to develop a list of T&E species present in the subject counties of the HSC ECIP study area. These are listed in **Table G1-10 of Appendix G**. Habitat types and critical habitat designations within 500 feet of the current HSC, and in existing placement areas adjacent to the channel study segments, were reviewed. Of the Federally listed species, only the sea turtles are likely to occur within the project area. Three T&E sea turtle species known to use the bay as a seasonal foraging area include the Kemp's ridley sea turtle (*Lepidochelys kempii*), the green sea turtle (*Chelonia mydas*), and the loggerhead sea turtle (*Caretta caretta*) (GBEP 2011, USACE 2003a). However, piping plover and red knot, may be found at the far southern end of the study, but more than a mile away from the study area footprint. There is no designated critical

habitat for any species located directly within the 500-foot buffer of the project area of the HSC, BSC, and BCC.

2.4.5.2 Migratory Birds

The Migratory Bird Treaty Act of 1918 states that it is unlawful to kill, capture, collect, possess, buy, sell, trade, or transport any migratory bird, nest, or egg in part or in whole, without a Federal permit issued in accordance with the Act's policies and regulations. The majority of the project area is located in a marine habitat, and the majority of the adjacent terrestrial area is industrially developed; therefore, there are limited areas for nesting and rookeries directly near the channel project area. The Texas General Land Office (TXGLO) in cooperation with TPWD and USFWS mapped colonial waterbird rookeries including in Galveston Bay using generalized boundaries that identified portions of several existing active dredged material PAs or other dredge material placement islands adjacent to the HSC. These include Atkinson Island, Alexander Island, and Goat Island. The USFWS also listed 41 migratory birds that may utilize other land areas or islands near the project area. Thirteen of the 41 are year-round residents and may utilize the dredge placement areas and the limited sand beaches, mud or sand flats that are adjacent to the Project Area such as the American oystercatcher (*Haematopus palliatus*) or Sandwich tern (*Thalasseus sandvicensis*). A more detailed discussion and list of migratory birds is provided in **Appendix G**, **Section 1.4.5.2**.

2.4.5.3 Marine Mammals

The Marine Mammal Protection Act (MMPA) was passed in 1972. It establishes a moratorium on the taking and importation of marine mammals and marine mammal products, with certain exceptions. Consultation for the MMPA is conducted when proposed project effects would result in takes of protected marine mammal species. The only marine mammals covered under the MMPA that are expected to be regularly present in Galveston Bay are bottlenose dolphins (*Tursiops truncatus*). The West Indian manatee, (*Trichechus manatus*), is only rarely present as a transient when they wander or are displaced from their normal range in Florida and northern Mexico.

2.4.6 Protected/Managed Lands

2.4.6.1 Wildlife Management Areas

Atkinson Island is located approximately 0.7 miles east of the project area and abuts the existing PAs and BU marsh cells proposed for continued use in this project. The northern end just beyond PA 16 is listed as a wildlife management area (WMA) managed by the TPWD. Wildlife on the island includes shore and wading birds, raccoons, and rattlesnakes. All other WMAs are located farther than 10 miles away around Galveston Bay.

2.4.6.2 Critical Habitat Areas

Loggerhead critical habitat (Sargassum habitat Unit LOGG S-02) was designated in offshore waters of the Gulf of Mexico, approximately 6 miles from the proposed TSP's southern limit. An existing offshore dredged material disposal site (ODMDS No. 1) is located in the designated waters and is currently permitted for placement of maintenance material from of the lower segment of the HSC. Further discussion of the Loggerhead critical habitat can found in the BA (**Appendix K**)

2.5 CULTURAL RESOURCES

The HSC is located along the upper Texas coast and has been occupied by humans since the Paleoindian period dating to around 11,500 **Before Present (BP)**. The study area is characterized by upland coastal prairies dissected by streams and rivers and an extensive bay and estuarine systems along the coast. The study area is primarily drained by the Trinity River, the San Jacinto River, and Buffalo Bayou. Sediments in the region are generally fluvial sandy and silty clays overlying Pleistocene aged clay. Prehistoric sites are commonly found within these upper sediments along streams and rivers and along the shorelines of the bays and gulf coast, close to prime areas for resource exploitation. These sites include campsites, dense shell middens, and cemeteries, containing projectile points, stone, bone, and shell tools, aquatic and terrestrial faunal remains, hearth features, ceramics, and in some cases human remains and associated funerary objects. Historic aged resources in the region consist of farmsteads and ranches, houses, buildings, bridges, tunnels, oil industry structures, cemeteries, lighthouses, shipwrecks, and the ruins of these buildings and structures. Although historic resources can occur anywhere, these sites tend to be concentrated in small towns and urban areas, along roads, and within current and historic navigation paths. Shipwrecks may also occur in numerous locales due to the dynamic nature of the sea floor and bay bottoms and the lack of navigation improvements until the latter part of the 19th century. These dynamic conditions can result in shifting shoals and reefs that endanger ships as well as bury their wrecks as shorelines and bars migrate through time.

Before Present (BP) is a time scales used by scientific disciplines. The standard practice is to use January 1, 1950 as the start date. Radiocarbon dating became practical in the 1950s. https://en.wikipedia.org/wiki/Before_Present accessed on 31 July 2017.

There are an estimated total of 194 cultural resources located within one mile of the Houston Ship Channel. These cultural resources include two National Historic Landmarks, four National Register of Historic Places listed properties, 143 archeological sites, 16 cemeteries, and 29 shipwrecks and submerged resources. The two National Historic Landmarks in the study area include the San Jacinto Battlefield and the Battleship Texas. The four National Register Properties are generally located in urban areas and consist of historic houses, commercial and government buildings, and structures represented by the Morgans Point Historic District, Pomeroy Homestead, Ross S. Sterling House, and the Washburn Tunnel.

The primary considerations concerning cultural resources are threats to submerged resources from dredging, wake-induced erosion of shoreline sites, and from construction of new dredged material placement areas. A large portion of the study area, especially along the margins of the ship channels, has been altered for industrial and commercial use. As such, in upland areas, the probability for intact prehistoric archeological sites to occur is low. However, there is a moderate to high potential for encountering historic age archeological sites, as well as historic age structures and buildings. For the marine portions of the study area, the potential for encountering submerged cultural resources, such as shipwrecks, is moderate. Although much of the area has been dredged in years past, the very dynamic nature of the study area means that submerged resources may occur anywhere.

2.6 SOCIOECONOMIC CONSIDERATIONS

2.6.1 Population, Employment, and Income

The project area is located in the Houston-Sugar Land-Baytown metropolitan statistical area (MSA), which is the sixth most populous MSA, and where Houston is the fourth most populous city in the nation. The proposed project is located in Chambers, Galveston, and Harris counties, and is located within or adjacent to the city limits of Baytown, Deer Park, Galena Park, Galveston, Houston, La Porte, Morgans Point, Pasadena, Seabrook, Shore Acres, and Texas City. The majority of the project area is located within the open water of Buffalo Bayou and Galveston Bay; therefore, it is not located within City limits. U.S. census population and demographic, and Texas Workforce Commission labor data for the counties, cities, and the 20 census tracts lining the project area were obtained for 2000, 2010, and 2014. This data is presented in detail in **Appendix G, Tables G1-12 through 14** and summarily discussed here.

Between 2000 and 2014, the population for Chambers, Galveston, and Harris counties is estimated to have increased by approximately 49, 29, and 33 percent, respectively. Chambers, the least populated county, grew from 26 thousand to 38 thousand, Galveston from 250 thousand to 322 thousand, and Harris from 3.4 million to 4.5 million. Harris County is the third most populous county in the nation. The civilian labor force in Chambers, Galveston, and Harris Counties is 18,244; 159,958; and 2,275,980; respectively, with unemployment rates of 6.8, 5.9, and 5.8 percent, respectively (TWC 2016). The 2014 average median household income for the Chambers, Galveston, and Harris counties was $72,239; $61,744; and $53,822; respectively. The average median household income within the 20 census-tract area ranges from a low of $27,321 to a high of $77,470 in Tract 3416.00 with an average of $48,874.

2.6.2 Demographics

Census data for the study area counties indicate a percent ethnic minority for Chambers, Galveston, and Harris Counties of 29 percent, 41 percent, and 61 percent respectively, with the Hispanic ethnicity being the major component of the minority population. The minority percentages for the 11 cities associated with the project area have a percent minority ranging from 21.4 percent for Shoreacres to 88.6 percent for Galena Park. The 20 census-tract percent minority is 32 percent. The full demographic numbers for the counties, cities, and census tracts are provided in **Appendix G, Table G1-18**.

2.6.3 Community Resources and Facilities

Within the half mile buffer used for project area community resources, there are two fire stations operated by the Port of Houston, two schools (De Zavala and J.R. Harris Elementary schools) Four cemeteries (Glendale, Crow Hill, De Zavalla, and Lynchburg Cemetery), and thirty-eight places of worship. A majority of these resources are located in neighborhoods adjacent to HSC from the Turning Basin to the Boggy Bayou.

2.6.4 Recreational Resources

Recreational activities in the vicinity of the project area includes duck hunting, saltwater fishing, swimming, sailing, nature viewing, pleasure boating, camping, picnicking, and sightseeing. Ecotourism, or tourism that is based on nature rather than manmade attractions, is the tourist industry's most rapidly expanding sector. Greater than 20 percent of the region's population participates in saltwater fishing and the use of open space, and about 15 percent enjoys saltwater boating (GBEP 2011). Various recreational use surveys indicate that more than 30 percent of the region’s households likely use the Bay once a year recreationally. Tourism in the Gulf Coast region creates notable economic benefit to the community and provides employment, of which Galveston Bay-related activity is important. Approximately nine parks, seven colonial water bird rookeries (used by birdwatchers), and five public boat ramps are within 0.5 mile of the HSC. Three rookeries and one boat ramp (currently inactive and no longer publicly accessible) are within a 500-foot buffer of the HSC.

About 90,000 pleasure boats are registered in Galveston Bay (TCEQ 2007). Galveston Bay has the third highest concentration of privately owned marinas in the U. S. (TCEQ 2007). There are many popular boating and yacht clubs, located within the Galveston Bay area, that utilize the bay for their boating activities. These include but are not limited to the Houston Yacht Club and the Seabrook Sailing Club. The existing HSC also has three existing boater’s cuts crossing the HSC Bay Reach study Segment 1 that were excavated as crossings for deeper-drafting recreational vessels across previous spoil banks at the margins of the current HSC. These are South Boaters Cut, North Boaters Cut located south and north of Mid Bay PA, and Five Mile Cut, just south of

the BSC. These are used by the sailing community to access Trinity Bay coming from Galveston Bay west of the HSC, where the major recreational marinas are located.

2.7 ECONOMIC CONDITIONS

2.7.1 Commodities Overview

The HSC services containerships, tankers, Ro-Ro vessels, bulk carriers, general cargo vessels, vehicle carriers, and barges. Users of the channel face depth, width, and other operating constraints throughout the channel.

The HSC handles more foreign waterborne trade than any other port in the U.S. Petroleum and petroleum products comprise the most tonnage, but chemicals and manufactured goods are also a significant driver of port traffic. **Table 2-5** summarizes import tonnage in HSC from 2013 through 2017. Overall import tonnage has fallen in HSC since 2013 due to falling petroleum and petroleum product imports.

Table 2-5 – 2010-2015 Import Tonnage (000s), WCSC

Commodity	2013	2014	2015	2016	2017
Coal, Lignite & Coal Coke	2	1	1	1	1
Petroleum and Petroleum Products	46,782	42,272	37,013	40,616	38,847
Chemicals and Related Products	6,326	5,796	5,915	5,194	5,202
Crude Materials, Inedible Except Fuels	2,658	3,915	3,664	2,492	2,889
Primary Manufactured Goods	9,102	11,423	11,686	8,278	11,410
Food and Farm Products	1,615	1,616	1,846	1,858	1,927
All Manufactured Equipment	2,285	2,973	3,633	3,413	3,990
Unknown or Not Elsewhere Classified	583	1,575	1,004	844	1,402
All Commodities	**69,353**	**69,571**	**64,762**	**62,695**	**65,667**

Table 2-6 summarizes exports moved through HSC from 2013 through 2017. Over that period, export grew by 16 million tons led by rapid growth in petroleum and petroleum product exports.

Table 2-6 – 2010-2015 Export Tonnage (000s), WCSC

Commodity	2013	2014	2015	2016	2017
Coal, Lignite & Coal Coke	2,738	1,927	469	176	303
Petroleum and Petroleum Products	43,780	46,974	56,685	57,963	62,659
Chemicals and Related Products	15,321	13,302	14,308	14,630	15,579
Crude Materials, Inedible Except Fuels	1,570	1,304	1,062	655	889
Primary Manufactured Goods	956	857	691	746	827
Food and Farm Products	7,315	7,210	6,027	8,096	6,636
All Manufactured Equipment	2,725	2,755	2,635	2,258	2,571
Unknown or Not Elsewhere Classified	986	1,738	1,605	1,546	2,003
All Commodities	**75,389**	**76,066**	**83,482**	**86,070**	**91,467**

2.7.2 Trade Volumes and Trends

Maritime trade including containership cargo at HSC has generally been increasing over time. Like most ports, the economic downturn from 2007-2009 substantially reduced growth of tonnage and the number of twenty-foot equivalent units (TEUs) handled at HSC. However, tonnage, TEUs, and vessel sizes have been steadily increasing since 2009. In terms of average international TEU throughput from 2013 through 2017, the HSC was the 5th largest container port in the U.S. and the largest on the Gulf Coast (**Table 2-7**).

Table 2-7 – Loaded TEU Throughput (2013-2017), WCSC

Rank	Port Location	Average Annual Foreign TEUs (2013-2017)
1	Los Angeles	5,823,343
2	Long Beach	4,915,324
3	New York (NY and NJ)	4,378,937
4	Savannah	2,764,739
5	Houston	1,747,982
6	Oakland	1,608,589
7	Charleston	1,521,269
8	Tacoma	1,346,199
9	Port of Virginia	1,248,784
10	Seattle	872,417

Figure 2-4 shows the historical tonnage shipped through HSC from 2005 through 2014. With the notable exception of the economic downturn from 2007 through 2009 and a drop in tonnage in 2011 and 2013 caused by significant reduction in petroleum product imports, throughput tonnage at HSC has steadily increased over the past decade.

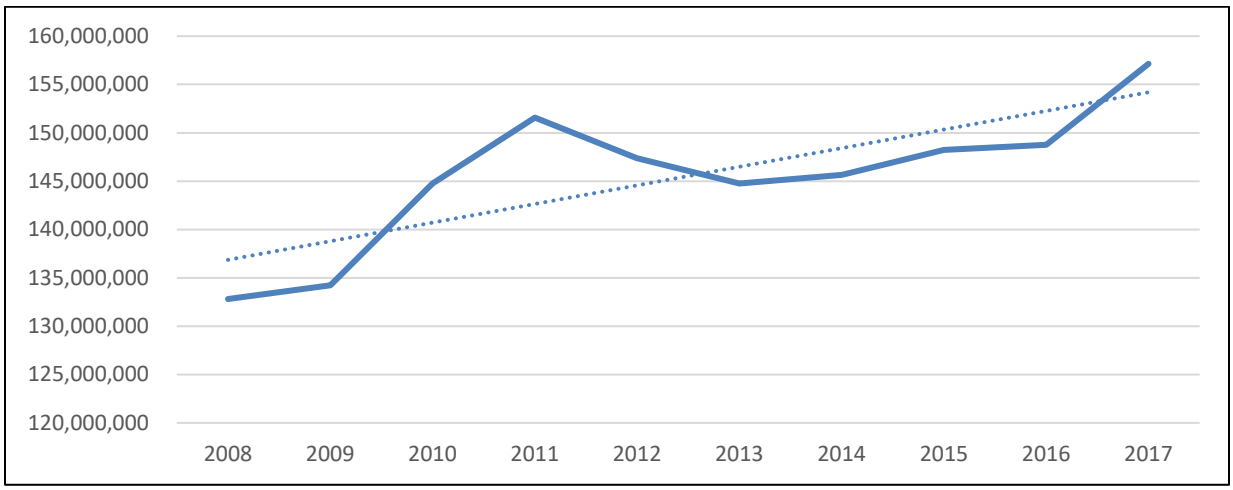


Figure 2-4 – Historical Commodity Growth for HSC (2008-2017)

2.7.3 Vessel Traffic

HSC is the most congested port in the U.S. in terms of total vessel traffic. The 50 mile-long channel accommodates 10 percent of all calls made by oceangoing vessels of 10,000 Dead Weight Tons (DWT) or greater at U.S. ports. **Table 2-8** provides an overview of total vessel calls. From 2011 to 2016, HSC averaged more than 7,500 vessel calls a year. This total does not include barge movements or the over 1,000 interport movements that take place in HSC annually.

Table 2-8 - Port Calls (2011-2016)

Vessel Type	2011	2012	2013	2014	2015	2016
Bulk Carrier	858	946	1,083	1,344	1,020	999
Containership	1,015	985	944	948	946	909
General Cargo	1,163	1,254	1,271	1,301	1,099	945
RoRo	221	264	205	193	198	151
Tanker	4,139	4,140	4,146	3,990	3,952	5,302
Grand Total	**7,396**	**7,589**	**7,649**	**7,776**	**7,215**	**8,306**

RORO refers to roll-on/roll-off ships. These vessels carry wheeled cargo including cars, trucks, semi-trailer truck, trailers, and railroad cars. These vessels are driven off the ship on their own wheels or through use of a platform vehicle. https://en.wikipedia.org/wiki/Roll-on/roll-off (last accessed on 8/10/2017).

High numbers of total vessel traffic cause extreme congestion along HSC. The current depth and width of the channel also leads to inefficient vessel loading and movement within the channel. Pilot rules along the system are reflective of the complexity of vessel traffic. Rules established for passing and meeting throughout the channel cause significant vessel delays compounded by increasing vessel traffic.

3 FUTURE WITHOUT-PROJECT CONDITIONS (FWOP)*

The USACE is required to consider the Future Without-Project (FWOP) conditions relevant to the problems and opportunities under consideration in the planning area during the planning process to comply with USACE regulation and guidance for planning. In the FWOP conditions, it is assumed that no project would be implemented by the Federal Government or by local interests to achieve the planning objective. The FWOP condition will form the basis against which all other alternative plans are measured, and is focused on how changes in economic and other conditions are likely to have an impact on the problems and opportunities. National Environmental Policy Act (NEPA) also requires consideration of the "No Action" alternative during assessment of impacts. In the No Action alternative, it is assumed the project being recommended by the feasibility study would not be implemented, but impacts to environmental resources by human or other activity expected to be ongoing outside of the project, would be considered.

One anticipated change related to this project that would occur without the project is the USACE's planned use of Bay Aquatic Beneficial Use Sites (BABUS) in the upper half of Galveston Bay, east of the HSC, for long-term maintenance of the HSC for 50 years and beyond. Long-term maintenance placement capacity is forecasted to be greatly constrained by the limited options near the HSC, especially in the landlocked segment above Morgans Point, due to development, distance, and other factors. In order to provide long-term capacity, the USACE proposes a series future BU cells in the bay created by dredging bay bottom material to create confining dikes that would provide the platforms for creating aquatic habitat such as tidal marsh and oyster reef. The dikes would form cells around the dredged area that would provide maintenance material placement capacity that would be filled with HSC maintenance material over a period of time until filled. Once filled, the interior would be converted to marsh or other desirable habitat. The planned use of BABUS in the FWOP condition was incorporated into the dredge material management plan (DMMP) developed for the HSC ECIP.

The FWOP condition is equivalent to the No Action alternative. To meet both the USACE planning and NEPA purposes, this section describes the FWOP condition and No Action alternative together.

3.1 PHYSICAL RESOURCES / FWOP

3.1.1 Project Area

The project area itself will not change in the FWOP. Various resources described below will undergo changes.

* Required by CEQ Regulations 40 CFR 1502.10

3.1.2 Climate

Climate-change predictions are both variable (depending on the model deployed) and usually small (again, depending on the model used) with the 2041-2070 lifetime used in a variety of reports. The predicted changes in heavy-precipitation days are in the single digits and are generally less than one day per year. For more details, see **Appendix G, Section 2.1.**

3.1.3 Topography, Soils, Geology, and Groundwater

The general characteristics of terrestrial soils would not change in the FWOP condition, as these are consequences of long-term geologic processes. Similarly, the geologic condition of the project area would not change in the FWOP condition. The hydrogeological setting of the project area would not be expected to change in the FWOP condition, though groundwater level changes would be expected to change year to year with changes in withdrawal and drought conditions. However, the trend in curtailing withdrawal discussed in **Section 2**, and the associated leveling off of subsidence, save for drought events, would be expected to continue, since the switch to surface sources for water supply would continue and the existing reliance on surface sources already implemented around most of the study area would continue too.

3.1.4 Physical Oceanography

3.1.4.1 Tides, Currents, and Water Level

Relative Sea Level Change is the sum of the following three components:

- Subsidence
- Eustatic or worldwide water-elevation change, and
- Local water-elevation change

The astronomical tidal range is expected to remain nearly the same, although it is acknowledged that minor changes will occur. Due to predicted sea level change however, the tide range will be between higher sea level elevations. For feasibility level analysis, the assumption that tides and waves will not change is acceptable. This is an approximation, and fully dynamic models will be used in PED to account for these nonlinearities. No major changes in the circulation pattern and current magnitude are expected under the FWOP Condition. The wind and wave climate in the study area is expected to remain the same. Long-term changes in water level due to relative sea level change area discussed in **Section 2.3.1.4.3**. One impact Hurricane Harvey had bay-wide on the physical characteristics of Galveston Bay was sediment deposition from stream flow, following several days of inland flooding and runoff. Approximately 4 inches (10 cm) on average was deposited bay-wide according to one estimate (Du *et al.* 2018). Deposition varied and was estimated to be greatest near river mouths (i.e. San Jacinto/HSC) or right behind the Texas City Dike. While channel shoaling was addressed through emergency dredging, and Harvey is not expected to impact channel shoaling rates long-term, the bay-wide deposited material adds inches of bathymetric elevation in the Bay.

3.1.4.2 Salinity

Hydrodynamic modeling provides information on environmental impacts (e.g., salinity effects on oysters, vegetation types, etc.) and input (e.g., currents, water levels, waves at the entrance channel) to ship simulations. Initial modeling (including salinity) will be conducted on the present condition without the project to provide a baseline for comparison and to provide input on the ultimate width dimension in the bay. Hurricane Harvey depressed salinity for the 3rd consecutive year. However, this is expected to be a seasonally-related event, but not a permanent change, since recovery to normal salinity occurred within two months.

3.1.4.3 Relative Sea Level Change

In addition to the project 50-year period of analysis and the RSLC planning horizon of 100 years, RSLC for the 25-year period was calculated, per ETL 1100-2-1. The following paragraphs present the predicted rates of RSLC for the 25-year, 50-year, and 100-year periods.

Predicted Future Rates of RSLC for 50-Year (Project Design) Period of Analysis - The computed future RSLC for a 50-year period of analysis is based on the predicted change between the years 2029 and 2079 for Galveston Bay. Relative sea level change values for the 50-year period are shown in **Figure 3-1** and **Table 3-1**.

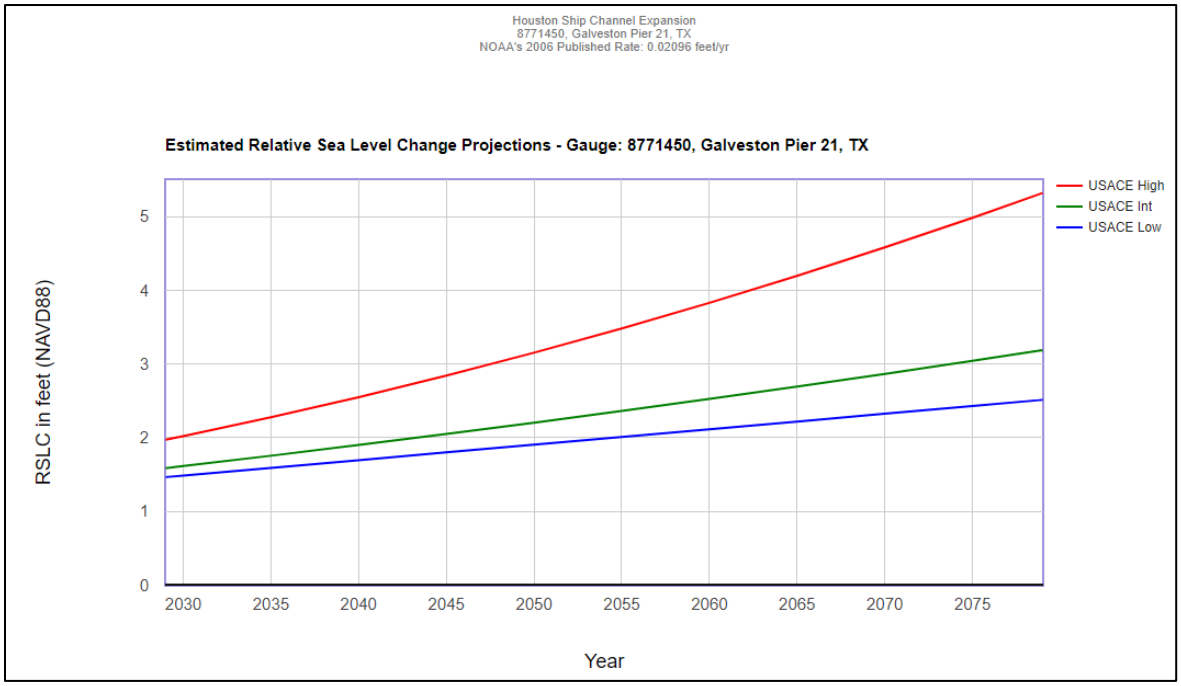


Figure 3-1 – Estimated RSLC for 50-Year Project Life (2029-2079)

Table 3-1 – SLC for 50-Year Period of Analysis

Houston Ship Channel Expansion
8771450, Galveston Pier 21, TX
NOAA's 2006 Published Rate: 0.02096 feet/yr
All values are expressed in feet relative to NAVD88

Year	USACE Low	USACE Int	USACE High
2029	1.47	1.59	1.97
2030	1.49	1.62	2.02
2035	1.59	1.76	2.28
2040	1.70	1.90	2.55
2045	1.80	2.05	2.84
2050	1.91	2.21	3.15
2055	2.01	2.36	3.48
2060	2.12	2.53	3.83
2065	2.22	2.69	4.20
2070	2.33	2.87	4.58
2075	2.43	3.04	4.98
2079	2.51	3.19	5.32

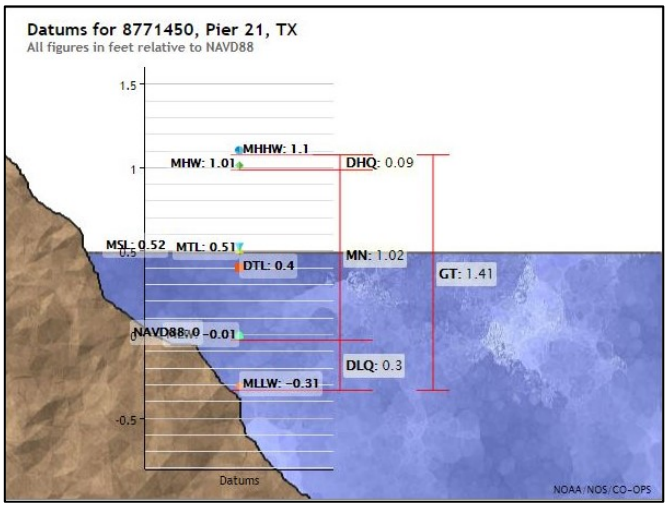


Figure 3-2 – Datums for Galveston Pier 21
(From NOAA Tides & Currents)

Table 3-2 provides a summary of the RSLC from the base year when the anticipated project construction would occur, 25-years, 50-years, and 100-years; all levels are relative to **NAVD88**. Low, intermediate, and high projections of RSLC at the end of the 50-year period of analysis are estimated to be 1.68 feet, 2.36 feet, and 4.49 feet, respectively. For the complete report, see the **Engineering Appendix, Attachment E (Sea-Level Rise)**. In **Table 3-2** the values are expressed as MLLW in NAVD88. The WRDA 1996 authorization for HSC was expressed in Mean Low Tide (MLT); however, Galveston District has since then converted the HSC to the MLLW datum.

Table 3-2 – Summary of Relative Sea-Level Change Estimates (MLLW)

Summary of Relative Sea-Level Change Estimates (MLLW) *(Levels are relative to 1992 Zero)*			
Year	**Low (feet)**	**Intermediate (feet)**	**High (feet)**
2023	0.51	0.60	0.87
	The anticipated project construction start year		
2029 (0 years)	0.64	0.76	1.14
	The anticipated project construction completion year		
2054 (25 years)	1.16	1.50	2.59
2079 (50 years)	1.68	2.36	4.49
2129 (100 years)	2.73	4.40	9.69

3.1.5 Water and Sediment Quality

3.1.5.1 Water Quality

Operations and maintenance (O&M) dredging in the HSC are expected to continue to cause temporary effects along and adjacent to the HSC with respect to turbidity and DO. Existing Section 401 water quality certification processes would continue in accordance with regulations requiring that water quality standards not be violated during dredging operations. Designated uses not met in the water quality segments within the project area would continue to be stressed by the existing causes such as elevated bacteria levels and nutrients, resulting from increased development and urbanization throughout the various watersheds. Continued management of resources through point, and non-point source regulation within the water quality segments will continue to minimize the potential long-term impacts of development in the future.

3.1.5.2 Sediment Quality

In the absence of the proposed project, existing conditions of chemical concentrations in shoaled sediment within the HSC would persist and concentrations would continue to vary greatly across the full length of the channel.

3.2 BIOLOGICAL NO ACTION / FWOP

3.2.1 Habitats

As the study area is in the highly urbanized Houston metropolitan region, land use surrounding the channels of the HSC system is highly developed with limited areas of undeveloped land that are not part of parks or conserved land (e.g. nature centers, WMAs etc.). Only small incremental changes in habitats as the few remaining tracts become developed would occur. Bay habitats would largely remain the same, as the same uses would continue. However, responses to changes such as salinity from periodic drought and flood cycles and gradual stream inflow changes, or hurricanes would produce some changes such as reef extent growing and shrinking accordingly.

3.2.1.1 Terrestrial

Terrestrial habitat is not expected to change significantly compared to the predominant developed land use that characterizes the project area. The few remaining channel-side, undeveloped uplands in the upper channel, would be expected to be developed with the planned petrochemical terminal facility expansions discussed in the Reasonably Foreseeable actions discussed in **Appendix G, Section 3**. O&M of the HSC are expected to continue to cause temporary effects to the pioneer herbaceous vegetation within the existing PAs caused by the periodical disturbance from the deposition of dredged material during channel maintenance cycles or earthwork to de-water and manage these PAs.

3.2.1.2 Wetlands

O&M dredging for the existing HSC is expected to continue with little to no impacts to existing wetlands associated shoreline adjacent to HSC upstream of Morgans Point. Potential wetland areas along the HSC could become developed by private users with future projects that construct bulkheaded docks along these shoreline margins; however, it is expected they would be mitigated through the Regulatory Permit process for elsewhere in the watershed. It is not expected that the small, scattered wetlands adjacent to the north shore of the BSC would be developed since they are on PHA land. Wetland future conditions are not expected to affect the deep draft problems and opportunities being addressed in this deep draft navigation study.

3.2.1.3 Bays and Deepwater Habitats

Benthic Habitat

Continued O&M dredging at the currently authorized depths would result in direct but temporary impacts to the benthic substrate. The substrate would be expected to recover from organisms recolonizing disturbed areas from the adjacent undisturbed areas as well as through recruitment. In the FWOP condition, a greater number of smaller vessels would be required to traverse the HSC in order to convey the same amount of goods that fewer, larger vessels could. This may translate into additional scour from propeller wash to benthic habitat in the FWOP condition, but given the ubiquity of habitat and fecundity of species, would not be expected to significantly impact populations.

3.2.2 Wildlife

3.2.2.1 Terrestrial

O&M dredging in the HSC would be expected to continue with little to no impacts to existing terrestrial animals. As terrestrial areas adjacent to the project area are highly developed, habitat would continue to be scarce and fragmented, and fauna characteristic of this landscape would continue to inhabit remaining areas. Any future development of remaining adjacent land by others would be subject to the existing regulations and permit requirements including mitigation to any impacts to waters of the U.S.

3.2.2.2 Aquatic

Fish and Other Pelagic Fauna

In the FWOP condition, it is expected that the fish currently utilizing the HSC as habitat, would continue to utilize this habitat and no significant change in the basic assemblage of fish would occur. Continued O&M dredging at the currently authorized depths would result in direct but temporary impacts to the benthic substrate with indirect, temporary impacts due to localized turbidity and associated vessel activity. O&M dredging may temporarily impact the amount of

food available for foraging and may cause fish to evacuate the area temporarily during the maintenance dredging. However, the availability of food in the surrounding, undisturbed area will remain the same, and it is unlikely that any significant changes in fish populations would occur as displaced fish would likely return once dredging is completed.

Plankton

The FWOP condition is not expected to appreciably impact the plankton community. Continued O&M dredging at the currently authorized depths would result in indirect impacts due to localized turbidity and associated vessel activity. The associated vessel activity may lead to additional entrainment/impingement of plankton into seawater ballast intakes and screens as vessel activity increases with increased shipping demand. However, due to the localized nature of the entrainment/impingement and ubiquity of plankton, impacts to plankton populations due to increased activity from growth in vessel traffic forecasted to occur in the existing HSC system under FWOP conditions are anticipated to be negligible.

3.2.2.3 Oyster Reef

Historical mapping of oyster habitat is difficult to compare to more recent mapping due to improvements in technology capable of discerning more information from deeper areas. Some oyster reefs in Galveston Bay have persisted since documentation began, while others exhibit considerable flexibility, changing shape and position in response to natural and manmade changes to the ecosystem. Over 2,500 acres of reef has developed along the HSC due to previous widening efforts, which exposed suitable substrate for oyster spat settlement (GBEP 2011). It is likely that without additional widening or deepening this accretion of oyster reef habitat would continue to accrete. It is expected that periodic extreme high flow events or drought, such as the 2016 flood and 2011 drought events discussed in **Section 2.4.2.3**, would continue to periodically occur, and cause fluctuations in living oyster density and productivity on these accreted reefs in Galveston Bay. As discussed in **Section 2.4.2.3**, the last high freshwater inflow event from Hurricane Harvey resulted in variable live reef mortality ranging from 20 percent to greater than 90 percent, depending on the part of the Bay affected. Also as discussed, recovery after such events usually occurs within a few years with normal salinity, due to the time involved for oyster growth to reach maturity. Therefore, in the future, effects from Harvey and the previous two years should fade, as successive spat seasons and growth allow reefs to recolonize and reach maturity.

3.2.3 Essential Fish Habitat

It is expected that the Galveston Bay and tidal channels flowing into it would continue to have designated EFH, as this estuary system would continue to be important to sustaining Gulf of Mexico fisheries. The fisheries would continue to be managed and protected by the existing regulations codifying the MSFCMA, and specific FMPs, which would be updated and changed in

response to changes in fish populations and fishing activity. Oyster reef, being an EFH, would change as described in the preceding section. Remaining tidal marsh in the study area, which is another EFH, would continue to be protected by CWA regulations, but would be subject to changes induced by RSLC and subsidence. This could result in losses if subsidence is sudden enough, or shifts in the location of the marsh boundary upward as marsh plant communities and inundated areas move upward in response.

3.2.4 State Managed, Commercial, and Recreational Fisheries

The FWOP condition will not appreciably affect the suitability of fish habitat for most state managed, commercial and recreational species found in the HSC. O&M dredging will continue to have temporary, minor effects on fish distribution as mobile adults and juvenile fish would be expected to vacate the area during construction. Relatively immobile benthic mollusk species would be expected to encounter injury or mortality if within the dredge footprint. The FWOP condition would continue to have consumption restrictions as currently recommended by the TDSHS, and would be revised as appropriate in response to changing contaminant conditions.

3.2.5 Protected Species

3.2.5.1 Threatened & Endangered

O&M dredging in the HSC are expected to continue with little to no impacts to existing T&E species, except when hopper dredging is used. Any future development of adjacent land by others would be subject to existing regulations and permit requirements including those associated with protecting T&E species. Certain types of maintenance dredging, such as hopper dredging, would continue to have a potential for impact for any sea turtles that may be in the area. However, hydraulic dredging, not known to take turtles, would primarily be used, and provisions required for using hopper dredges, would be exercised when used.

3.2.5.2 Migratory Birds

Landside development in remaining areas in metropolitan Houston and Galveston would continue to be developed, decreasing stopover habitat. Islands that provide stopover habitat that were dredged material placement sites that have been completed and filled, including those purpose-built as bird islands, would remain however. When BU marsh cells are filled and fully developed into marshes, these would also provide some other stopover habitat.

3.2.5.3 Marine Mammals

Bottlenose dolphins are highly mobile species readily able to avoid existing dredging activities and vessels. O&M dredging in the HSC would be expected to continue with little to no impacts to existing bottlenose dolphin populations.

3.2.6 Protected/Managed Lands

3.2.6.1 Wildlife Management Areas

The study area is highly developed, and the WMAs already in place are surrounded by water or other land uses. No significant change or impact from the FWOP condition is expected.

3.2.6.2 Critical Habitat Areas

Critical habitat in the study area would continue to be protected until the benefiting species recovers. As the area is highly developed, and most relevant species to this study are marine, no new critical habitat designations are anticipated.

3.3 HUMAN ENVIRONMENT/ FWOP

3.3.1 Socioeconomic Considerations

The following describes the No Action alternative and FWOP condition for socioeconomic considerations.

3.3.1.1 Population, Employment, and Income

Based on TWDB's 2016 Regional Water Plan population projections and listed in **Appendix G**, **Table G2-5**, the three counties, cities, and Census Designated Places are forecasted to continue to have an increase in population in the 60 years between 2010 (year of the last official census) and 2070. Galveston Count would be expected to grow the fastest at 60 percent, followed by Chambers at 56 percent. Texas City would be expected to grow the fastest at 56 percent followed by Houston at 50 percent.

3.3.1.2 Demographics

According to projections by the Greater Houston Partnership (GHP), Houston's racial and ethnic composition will shift dramatically (GHP 2014). Population growth will come from the natural increase (births minus deaths) and from "net immigration", which is people moving into the region minus people moving out. Two growth scenarios were evaluated for the Houston-The Woodlands-Sugar Land, and Texas MSA, the Fast and Moderate Growth scenarios.

According to these projections, Anglo populations are projected to decrease between 23 and 18 percent for the Fast and Moderate growth scenarios, respectively. The percentage comprised of Black populations, are projected to decrease, but population numbers would are projected to stay relatively the same. The Hispanic population is projected to increase to be over 50 percent of the population for both growth scenarios. The Other population category will also increase but not at the rate of the Hispanic population.

3.3.1.3 Community Resources and Facilities

Because the vicinity of the project area is already well developed, the condition of community resources such as Police, Fire, and Emergency Services; School and Educational Facilities; and Cemeteries, Historical Markers, and Places of Worship would remain unchanged in the FWOP Condition.

3.3.1.4 Recreational Resources

Recreational uses of the Bay are well established and would not be expected to change in the future. Fishing and pleasure craft use would be expected to continue to predominate and grow with changes in the population. Bird watching may constitute a greater percentage of recreational activity in the future, as it has been a growing sector of outdoor recreation.

3.3.2 Energy and Mineral Resources

In the FWOP Condition, drilling activity near the HSC system is expected to continue or decrease, considering these are mature oil fields. No significant increase in activity is expected.

3.3.3 Air Quality

As discussed in the **Existing Conditions**, air quality has improved markedly in the HGB NAA as a result of SIP actions and improved national emissions standards. The 2015 NAAQS for Ozone continues the trend of improvement in standards, and as discussed, they will begin taking effect in the near future. Considering this, it is expected that improvements to air emissions controls implemented as a result of these SIP requirements, and improving national emission standards for on-road and non-road sources, will continue resulting in gradual air quality improvements. Outside of regulated pollutants, other regional trends are also contributing to reduced emissions. Power generation (e.g. electric utilities), which is a major part of the point source category, is increasingly coming from renewable or non-fossil fuel sources (e.g. wind, nuclear, solar). The increasing percentage of non-combustion power reflects the significant increase in renewable energy, most notably, wind power in Texas, with the percent of Texas power generated by non-combustion sources increasing from approximately 6 percent to 17 percent between 1990 and 2013 (EIA 2015). The HGB region's power grid is interconnected and managed at the state-level by the Electric Reliability Council of Texas power management region, and therefore, local power demands would increasingly use statewide additions of wind turbine and other renewable generation. This trend would also be expected to contribute to gradual air quality improvements.

With respect to vessel activity associated with the HSC system, recent changes in national and international marine emissions standards will help reduce future marine vessel emissions, as specific requirements become applicable, or vessel replacement of older vessels occurs. These

changes include more stringent emissions standards that went into effect for various categories of newly manufactured engines in 2011, and 2016, and should gradually be reflected in the future fleet. Also lower sulfur fuel standards went into effect in 2015, and lower international maritime emission standards that apply to the US Coast went into effect in 2016.

It is expected that these ongoing improved emissions controls would contribute to the continuing trend of regional air quality improvement in the FWOP Condition. It is not anticipated that FWOP conditions of air quality will affect the problems and opportunities being specifically addressed by this deep draft navigation study.

3.3.4 Noise

3.3.4.1 Airborne Noise

The existing environment surrounding the channels are already heavily developed with long-standing land uses and very limited land available for development, and are expected to retain the same land uses. Therefore, the future airborne sound environment is expected to remain largely the same, with a wide variety of the same industrial, commercial, and recreational marine noise sources described in the existing condition.

3.3.4.2 Underwater Noise

Similar to airborne noise, the future underwater sound environment is expected to remain largely the same, with a wide variety of the same natural, industrial, commercial, and recreational marine noise sources described in the existing condition, due to the long-standing water-side uses and limited land available for development adjacent to the channel.

3.3.5 Hazardous, Toxic, and Radioactive Waste Concerns

The HTRW situation on the HSC will most likely stay the same in the FWOP condition. The upper HSC is located in one of the largest petrochemical complexes in the world, and the manufacturing of chemicals, complex compounds, and other hazardous materials will continue in the project vicinity with or without the ship channel expansion. The upper channel is also extremely urbanized, so contamination related to urbanization can be expected as well. The extent to which HTRW sites continue to be created and discovered is impossible to predict, current existing HTRW sites can be expected over time to be remediated. The HSC will always be a global center for petrochemical manufacturing and this activity will continue even without the channel expansion.

The potential for drastic changes to the HTRW existing condition as a result of dramatic weather events, such as Hurricane Harvey, cannot be discounted. Catastrophic weather events have the

potential to affect previously controlled HTRW sites and release contaminates into receiving waters such as the HSC. While the specific effect of the most recent event cannot be fully quantified yet, catastrophic weather events can dramatically destabilize the HTRW context of the proposed project. New HTRW sites may be identified once the impact of Hurricane Harvey is fully realized.

3.3.6 Cultural Resources

There are an estimated 194 cultural resources located within and along the HSC and the formation processes that currently affect these sites will continue into a future without the project. Undiscovered submerged cultural resources could be at risk from future maintenance dredging activities and shifting bars if these resources were to migrate into the channel. This could potentially occur if these resources are located outside of surveyed areas along channel margins, and migrate into the channel due to erosion or sloughing of channels at the side slope margins, or movement from other events such as storms. Upland historic and prehistoric sites will continue to be at risk from shoreline erosion and commercial, industrial, and residential development. These formation processes may result in partial or total loss of historic properties.

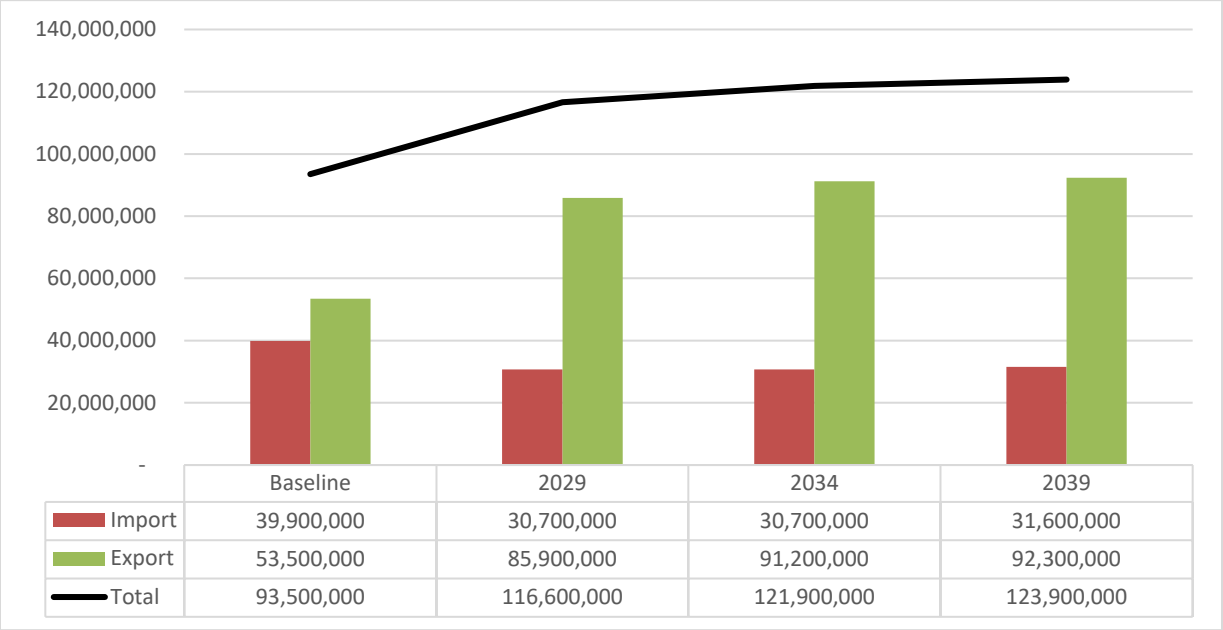
3.4 ECONOMIC CONDITIONS/ FWOP

The study assumes that the improvements of the HSC will not alter the total commodity throughput (see **Appendix B, Section 5**), therefore, the future with-project and future without-project conditions use the same cargo forecast. Additional information on forecasting is provided in **Appendix B, Economic Appendix**.

3.4.1 Commodity Forecast

Projected annual commodity tonnage growth rates were developed through a world trade-forecasting model provided by Global Insight for the period from 2029 to 2078 as well as growth rate estimates from the U.S. Department of Energy and U.S. Department of Agriculture. The commodity forecast baseline based on commodity throughput for 2014 through 2017. The forecasted growth rates were applied to the baseline to forecast annual commodity tonnage through the end of the available forecast (2039). From 2040 to 2078, all tonnage was held constant.

Figure 3-3 through **Figure 3-6** present the results of the bulk and containerized trade forecasts. **Figure 3-3** provides a summary of the trade forecast for Petroleum Products. Overall petroleum product trade grows over the study period led by export growth of 2.5 percent from the baseline through 2039. Imports of petroleum and petroleum products decrease at 1.5 percent annually from the baseline through 2039.



	Baseline	2029	2034	2039
Import	39,900,000	30,700,000	30,700,000	31,600,000
Export	53,500,000	85,900,000	91,200,000	92,300,000
Total	93,500,000	116,600,000	121,900,000	123,900,000

Figure 3-3 - Petroleum Products Trade Forecast

Figure 3-4 outlines the commodity forecast for bulk imports at HSC, excluding petroleum products. Non-petroleum bulk cargo imports are expected to experience compound average annual growth of 1.6 percent through 2039 with the majority of growth coming from primary manufactured goods and chemicals.

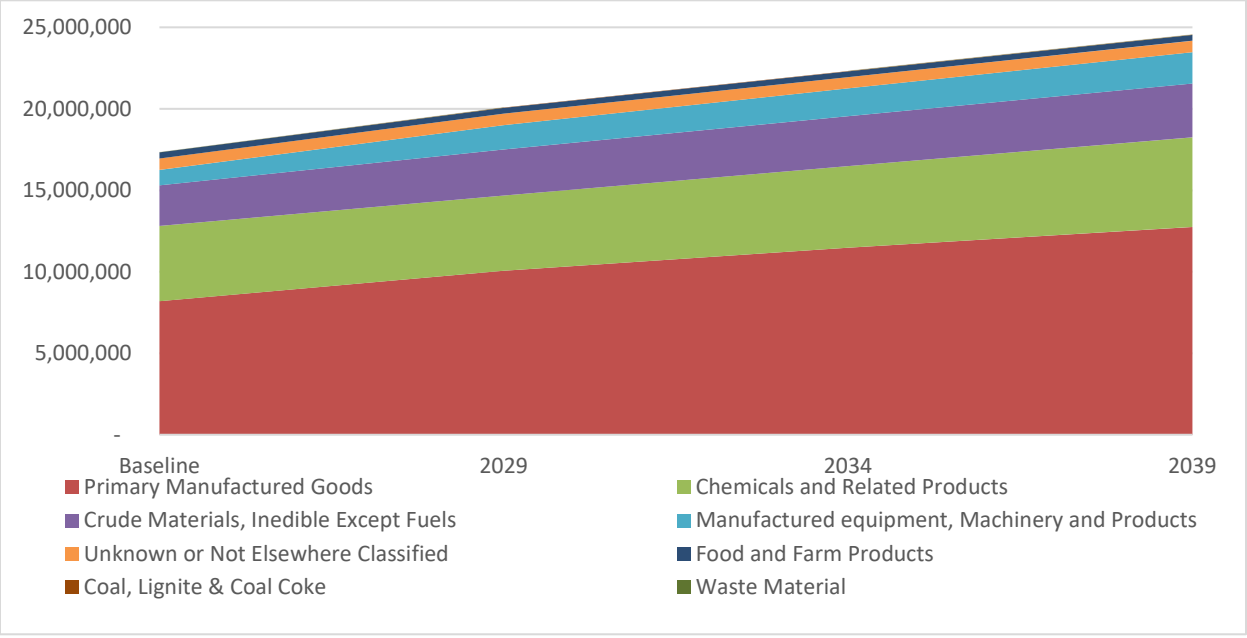


Figure 3-4 - Bulk Imports Forecast

Figure 3-5 outlines the bulk export forecast, excluding petroleum products. Compound annual growth in non-petroleum products from the baseline through 2039 is estimated at 2.5 percent with most the majority of growth in the Chemicals and Food and Farm categories.

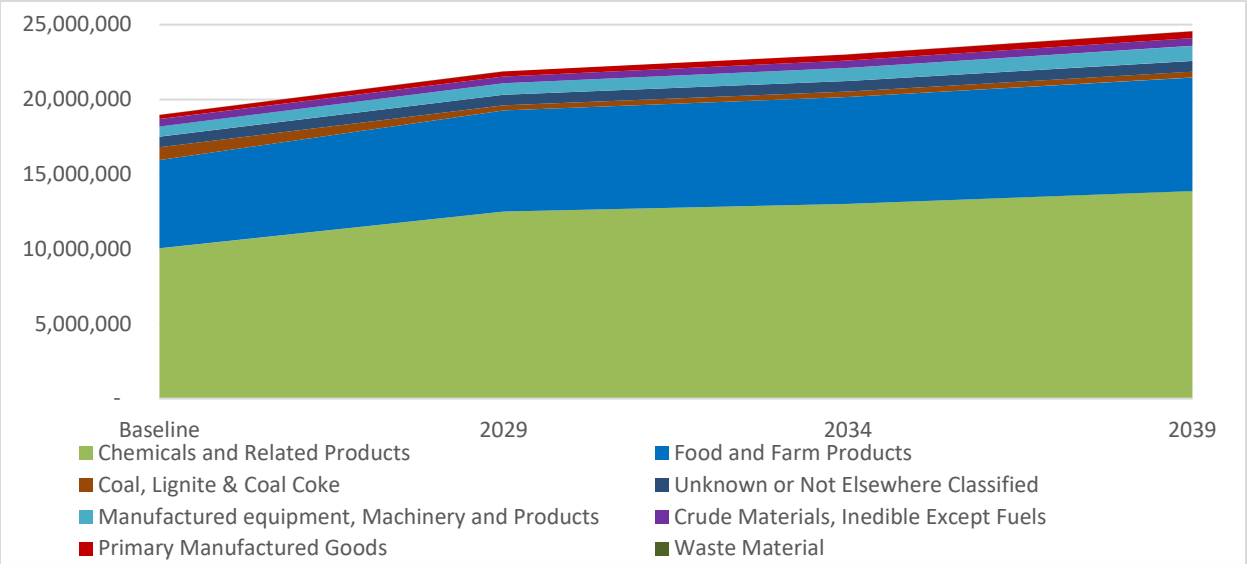
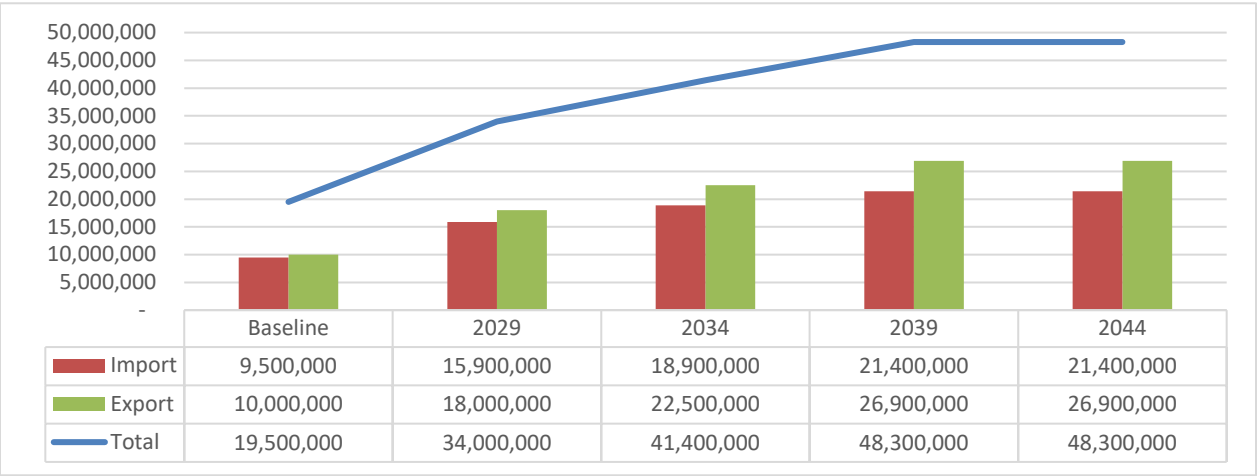


Figure 3-5 – Bulk Export Forecast

The study assumes strong containerized import and export growth through 2039. Containerized trade is expected to grow by 3.1 percent for imports, 3.7 percent for exports, and 3.4 percent for all containerized trade. This leads to more than doubling in containerized trade by 2034. The containerized forecast holds tonnage constant after 2039, however, the analysis continues to transition the containerized vessel fleet through 2044. **Figure 3-6** summarizes the results of the containerized trade forecast.



	Baseline	2029	2034	2039	2044
Import	9,500,000	15,900,000	18,900,000	21,400,000	21,400,000
Export	10,000,000	18,000,000	22,500,000	26,900,000	26,900,000
Total	19,500,000	34,000,000	41,400,000	48,300,000	48,300,000

Figure 3-6 – Containerized Trade Forecast

3.4.2 Future Vessel Traffic

3.4.2.1 Fleet Forecast Summary

To meet the forecasted commodity growth at HSC, a fleet forecast was completed. The forecast assumes both growth in total vessel traffic and an increase in the average size of vessels transiting HSC. This will further congest the channel and lead to additional vessel delays through the navigation system. **Figure 3-7** shows the unconstrained fleet forecast for HSC over the study period in the future without-project condition by vessel type.

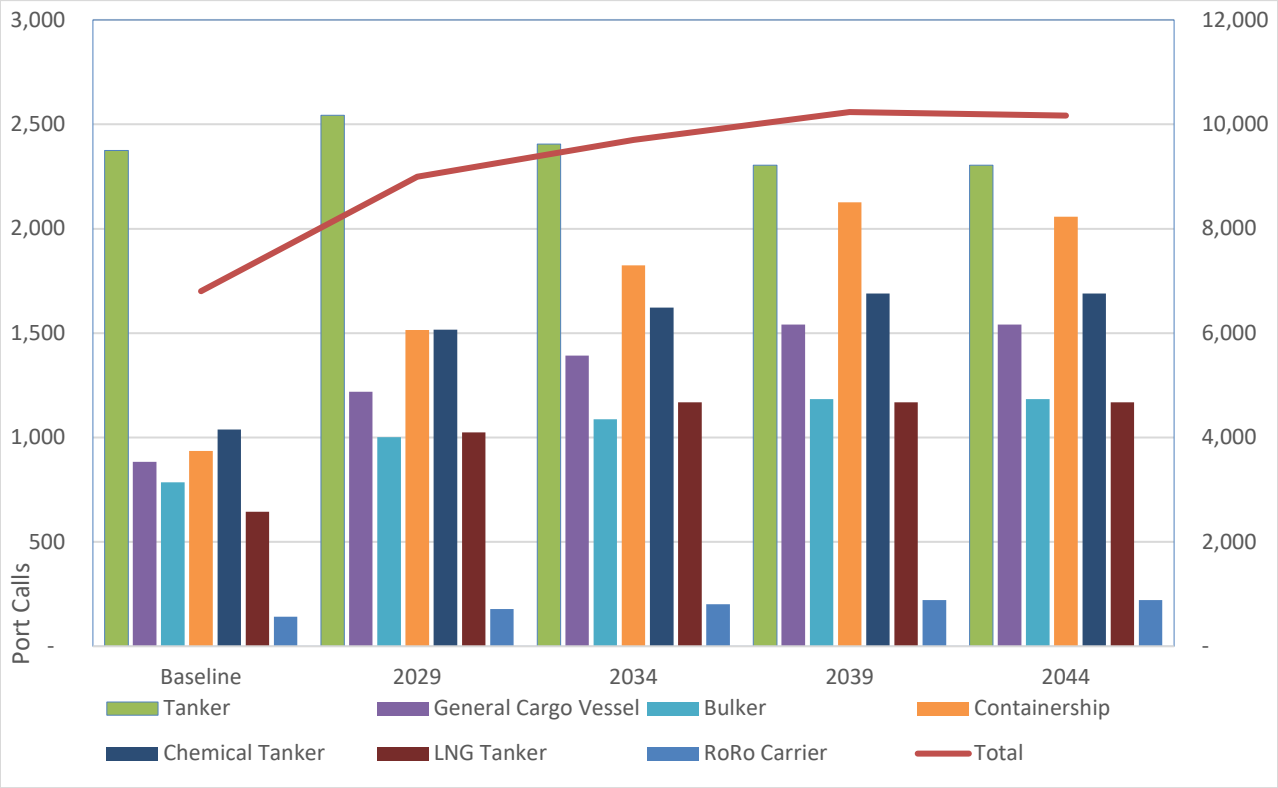


Figure 3-7 – FWOP Port Calls (All)

The economic analysis developed a containerized and non-containerized fleet forecast. The containerized fleet forecast was developed using an MSI container fleet forecast. This forecast applies in-depth analysis of macroeconomic indicators coupled with analysis of the vessel fleet order book to estimate a future world fleet. This world fleet is specific to trade regions and service routes which can then be used to forecast the future containerized fleet for HSC.

The non-containerized fleet forecast is based on a similar methodology as the containerized fleet forecast. First, a world order book of vessels by vessel type was developed using IHS Maritime Seaweb vessel fleet data. Vessel sized growth by vessel type was calculated for the study period. This vessel sized growth was applied to the existing condition vessel fleet at HSC. For certain vessel types, there is limited growth in size given the constraints of the FWOP and Future With-Project channel dimensions; however, tanker fleet size is expected to continue to grow at HSC as more Aframax and Suezmax tankers transit the channel. **Appendix B** provides a more detailed explanation of the methodology and result of the fleet forecasts.

4 PROBLEMS AND OPPORTUNITIES

4.1 PROBLEMS

The problems identified in the HSC study area are (1) navigation safety concerns for deep and shallow-draft vessel traffic, (2) inefficient vessel utilization, and (3) lack of environmentally acceptable dredged material placement. These are discussed below and are referenced on the study segment map provided for convenience in **Figure 4-1.**

Navigation Safety. The HSC is one of the busiest waterways in the United States (U.S.) with over 9,000 deep-draft and 200,000 barge transit per year [**Segment 1-6**]. The U.S. Coast Guard Port and Waterway Safety Assessment (PAWSA) assigned the HSC the highest baseline risk level for economic loss and assigned an unacceptable baseline risk for HSC's channel dimension and configuration, safety, potential for discharges, and volume of ship traffic. The intent is not to overstate safety; however, with the increasing number of vessels (deep-draft and barge), number of transits and increasing vessel sizes there is increasing safety risk on the HSC in terms of close vessel interactions and close proximity to channel edges. Safety, managed by the U.S. Coast Guard (USCG) and the Houston Pilots rules mitigate safety risk but contribute to the delays in the channel.

Inefficient vessel utilization. Existing channel depth, width, and configuration cause inefficiencies for shallow and deep-draft vessels. Average vessel size and traffic volume at the HSC continue to increase, leading to thousands of hours of delays for vessels transiting the HSC. With projected increases in trade volume and vessel size, more delays can be expected. The major inefficiencies include:

- Four undersized bends [**Segment 1**] and insufficient channel width at BSC [**Segment 2**] and BCC [**Segment 3**] prevent Gen III Containerships (1,100- by 158-feet) from calling Port Houston. The width of the BSC also restricts Suezmax tanker transits.
- The current depth and width of **Segment** 4 limits traffic to Panamax-sized vessels and reduces loading efficiency for both tankers and bulkers.
- Channel depth in **Segment** 5 and **Segment** 6 also prevent efficient loading of tankers and bulkers, and turning basin dimensions in **Segment 6** limit effective transit of the design fleet.

Lack of environmentally acceptable dredged material placement (PA/BU). Current PA/BU capacity is insufficient for the future needs of the system [**Segments 1-6].**

More specific problem statements regarding inefficient vessel utilization, safety, and PAs are:

* Required by CEQ Regulations 40 CFR 1502.10

- Very Large Crude Carriers (VLCC) require lightering in order to economically move products to Port of Houston refineries [**Segment 1**];
- Barges have inefficient movement due to the shallow draft of the barge lanes. Barges may run aground due to the drawdown of the surrounding water when faster deep-draft traffic passes. Due to this risk of drawdown, barges many times utilize the deep draft channel for transit, thus reducing vessel speeds in the deep draft channel, increasing congestion and decreasing safety [**Segment 1**]
- An established safety concern exists near the intersection of the HSC and BSC as confirmed in the HSC PDR, which recommended an interim corrective action; however, a more complete corrective action under this 216 Study is needed [**Segments 1-2**];
- Channel configurations cause slowing and tug assistance for larger vessel classes [**Segments 1-3**];
- Vessels longer than 1200-feet length overall (LOA) cannot transit the HSC due to four undersized bends between Bolivar Roads and Morgans Point [**Segments 1-3]**;
- Vessels longer than 1100-feet LOA are restricted to one-way traffic due to the undersized bends and narrow width of the channel [**Segments 1-4];**
- Containership movements are width-restricted by narrow channels at the BSC and BCC. Significant tug assistance is required for Post Panamax Containerships, and some larger Post Panamax vessels (beams exceeding 141 feet) are not allowed to transit the channel. Vessel movements can also face delays while Post Panamax vessels are at berth due to the width constraints of the channel [**Segments 1-3**];
- A loaded Suezmax tanker may not meet any vessel with a beam greater than 106-feet **[Segments 1-4]**;

During the HSC PDR study, the 2016 AIS Report (discussed previously **Section 1.7.1, Prior Studies and Reports)** provided an analysis of the existing 530-foot channel to determine whether it adequately supported two-way traffic for the class of vessels it was designed for in the 1995 LRR, using the design guidance in place at the time of the study. The 530 foot channel was designed to accommodate two-way passage by vessels having a combined beam width of 280 feet, while allowing for minimum bank-to-ship clearances of 60 feet and a minimum ship-to-ship clearance of 80 feet per USACE design guidelines. Specifically, beam combinations of 140 feet/140 feet and 106 feet/156 feet were cleared for safe two-way passage in the ship navigation study conducted at WES.

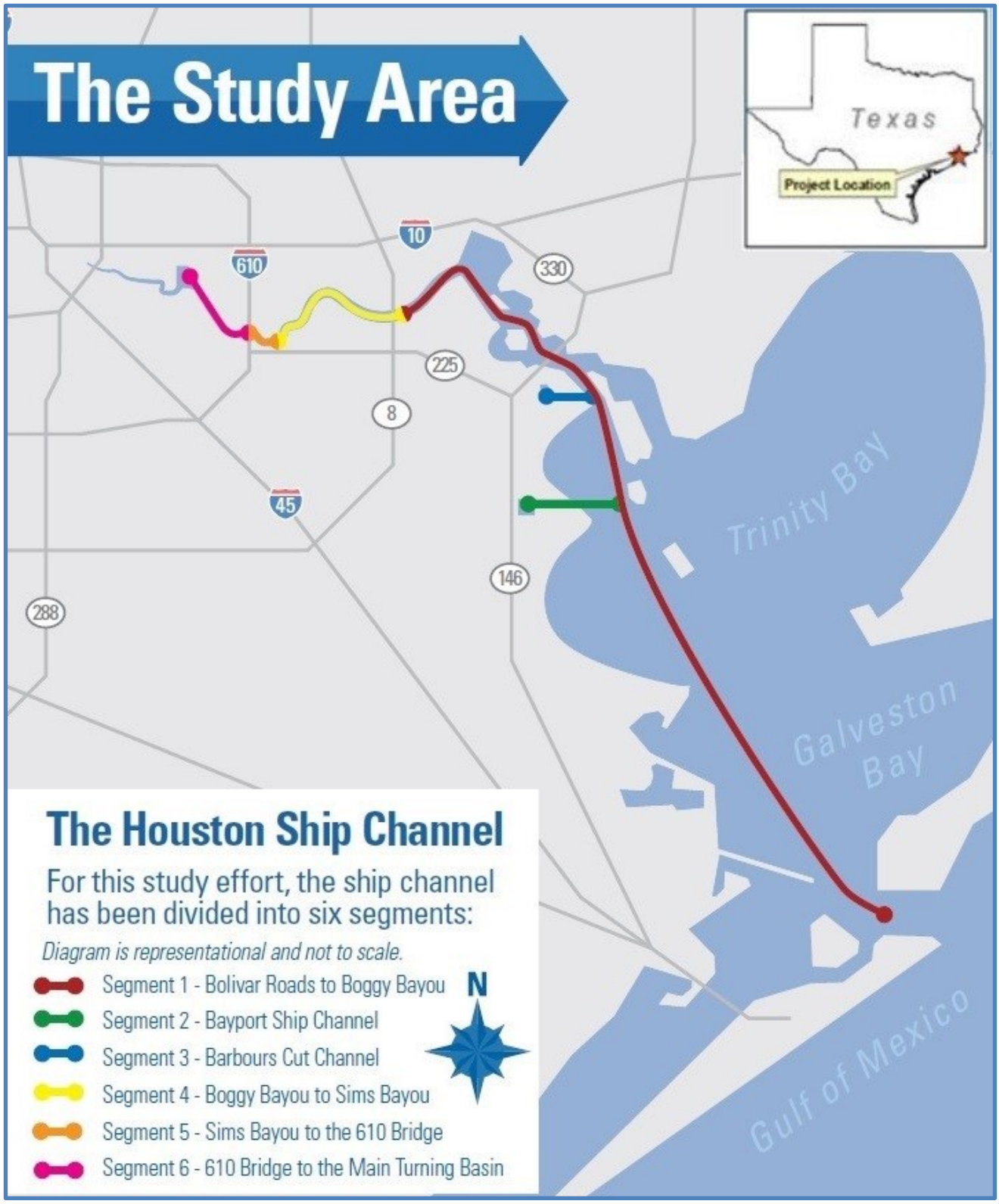


Figure 4-1 – Six Study Segments

- Channel depth constraint of 41.5 MLLW (40 MLT) feet in the Boggy Bayou to the Main Turning Basin reach results in inefficient vessel operations with associated impacts that ripple through the U.S. economy [**Segments 4-6**];
- One way traffic is required for vessels with large beams causing time delays in the Boggy Bayou to Turning Basin reach [**Segments 4-6**];
- Much of the upper reach of the HSC is in a highly industrialized area that is constrained and almost fully developed; leaving little to no new areas for development or creation of new dredged material areas [**Segments 4-6**];
- The volume of petroleum product, chemical trade, and bulk materials at HSC continues to increase, and vessels are forced to operate at drafts constrained by channel depth limitations [**Segments 1-6**];
- Higher than average wait times are being experienced as well a high rate of utilization at the Galveston and Bolivar Anchorages [**Segments 1-6**]; and
  Daylight only transit for vessels with beams greater than 138 feet [**Segments 1-6**];

4.2 OPPORTUNITIES

Opportunities in the HSC study area are:

- Reduce transportation cost of forecasted commodity volume at HSC;
- Eliminate or reduce navigation inefficiencies at HSC for existing and forecasted fleet (i.e., reduce delay times, interport movements, and transit times);
- Eliminate or reduce beam, length, and draft restrictions at HSC for forecasted fleet;
- Optimize channel configuration/design in a cost effective and environmentally acceptable manner that improves safety (e.g. final corrective action for design deficiency at HSC/BSC intersection);
- Establish environmentally suitable PAs/BU sites for new work dredged material, as well as maintenance-dredged material;
- Reduce the risk of adverse environmental impacts from a new project, or protect or improve environmentally sensitive areas in the vicinity of the Federal project through BU of dredge materials; and
- In separate legislation the Energy and Water Development Appropriations Act, 2001, as enacted by Section 1(a)(2) of P.L. 106-377, authorized Barge Lanes to be constructed on either side of the HSC. The barge lanes were not studied in detail for design or economics. Additional review and study of the barge lanes may help to optimize channel configurations to improve safety of the system; however, this analysis was determined to be outside the scope of this study

The HSC PDR, approved in May 2016, outlined a recommended corrective action to provide interim relief for an established design deficiency and lessen navigational safety concerns at the flare and the bend in the HSC near BSC. A report documenting the safety issue in the vicinity of the intersection of the HSC and BSC channels was developed and approved with the understanding that it was an interim fix to a safety issue and that this Section 216 study would evaluate the final corrective action for this problem.

4.3 PLANNING OBJECTIVES

The overall study goal is to provide an efficient and safe navigation channel while contributing to the NED consistent with protecting the nation's environment. The following planning objectives were used in formulation and evaluation of alternative plans:

- Reduce navigation transportation costs by increasing economies of scale for vessels to and from HSC over the period of analysis (starting in the base year for 50 years);
- Increase channel efficiency, and maneuverability in the HSC system for the existing fleet and future vessels through the 50-year period of analysis;
- Develop environmentally suitable placement for dredged material and maximize use of BU of dredged material for placement over the 50-year period of analysis;
- Increase channel safety for vessels utilizing the HSC, BSC, and BCC; and
- Reduce high shoaling at BSC Flare to reduce dredging frequency

4.4 PLANNING CONSTRAINTS

Constraints are restrictions/limitations. Plan formulation involves meeting the study objectives while not violating constraints. The study takes into account all applicable county, state, and Federal laws, permitting requirements, regulations, and environmental guidance. Specific study constraints include:

- Impacts to social, environmental, and cultural resources will be avoided or minimized to the extent practicable;
- Height restrictions due to road/bridge crossings over the HSC limit the air draft of vessels transiting the HSC and pose improvement and cost constraints. Deepening the upper channel [**Segments 4-6**] would allow the existing vessel fleet to load deeper. Deepening is not being considered for Segment 1; it is not in the scope of this study. Each crossing is listed with the common name underlined, the air draft in parenthesis, and study segment location:

> **"Air draft** is the distance from the surface of the water to the highest point on a vessel. This is similar to the draft of a vessel which is measured from the surface of the water to the deepest part of the hull below the surface, but air draft is expressed as a height, not a depth."
> https://en.wikipedia.org/wiki/Sam_Houston_Ship_Channel_Bridge

  - Fred Hartman Bridge or Baytown Bridge (175 foot air draft Mean High Water (MHW)) in **Segment 1** – HSC-Bay Reach;
  - Sam Houston Ship Channel Bridge or Beltway 8 Bridge (formerly known as Jesse H. Jones Memorial) (175 foot air draft MHW) in **Segment 4** - Boggy Bayou to Sims Bayou);
  - Sidney Sherman Bridge or I-610 Bridge (135 foot air draft MHW) in **Segment 6** – HSC I-610 Bridge to Main Turning Basin;
- Lynchburg Ferry (owned by Harris County) in **Segment 1** – HSC-Bay Reach, does not have room for channel improvements, such as widening; therefore, no improvements in the vicinity of the Lynchburg Ferry are being considered. Ferry landings exist on either side of the HSC;
- Coastal Water Authority pipeline crossings (three) are located in vicinity of Lynchburg Ferry in **Segment 1**. These 108-inch diameter pipelines cross under the channel and are just cleared for the current project (with two foot advanced; one foot allowable overdepth). These crossings would be impacted with any channel improvements, such as widening in this area. Deepening in Segment 1 is not under consideration for this study. No improvements in this area are being considered;
- Washburn Tunnel is located in **Segment 5** – HSC Sims Bayou to I-610 Bridge where the project depth of the HSC is 41.5 feet plus 2 feet advanced maintenance and 1-foot allowable overdepth. At the tunnel crossing, the channel is maintained at 40.5 feet plus 1-foot allowable overdepth. Any improvements in this area would have to avoid impacts to the Washburn Tunnel;
- Other various permitted crossings at 175 foot air draft (power lines);
- Alternative plans should not cause or amplify problems in other areas;
- Due to previous oyster shell mining in the Bay Reach of the HSC **(Segment 1)**, there are geographical constraints for the development of new PA/BU sites in close proximity to the channel. Previous construction (e.g. Mid Bay PA and Atkinson Island Marsh BU) in this reach has experienced foundation failure issues resulting in substantial cost increases; and
- Hardened development, including major refineries, docks, and other industrial development, situated directly adjacent to the channel limit potential widening opportunities

4.5 RELATED ENVIRONMENTAL DOCUMENTS

The proposed action is included in sections of this FIFR-EIS in order to satisfy the requirements of NEPA. Other NEPA documents (EA/EIS) prepared by the USACE related to the HSC include:

U.S. Army Corps of Engineers (USACE). 1987. Final feasibility Report and Environmental Impact Statement, Galveston Bay Area Navigation Study. Volume 1, Main Report. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

1995. Houston-Galveston Navigation Channels, Texas. Limited Reevaluation Report and Final Environmental Impact Statement. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

1999. Environmental Assessment for Changes in Bolivar Beneficial Use Placement Area, Safety Zone Construction, Changes in the Offshore Placement Area, and Centerline Offset-Lower Bayou Reach, Houston-Galveston Navigation Channels, Texas, Project. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2001. Record of Environmental Considerations for Environmental Restoration of Redfish Reef and San Jacinto State Park Shoreline Protection, Houston-Galveston Navigation Channels, Texas, Project. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2003. Final Environmental Assessment, Houston-Galveston Navigation Channels, Texas, Project, Upper Bay Barge Lanes.

2005. Record of Environmental Considerations for Houston-Galveston Navigation Channels, Texas Project - Upper Bay Barge Lanes. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2006. Final Environmental Assessment, Houston-Galveston Navigation Channels, Texas, Project -Mining Barbours Terminal Channel for Dike Repair and Construction. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2010. Final Environmental Assessment, Expansion of Placement Areas 14 and 15, Houston Ship Channel Chambers County, Texas.

2014. Final Environmental Assessment for 33 U.S.C Section 408 Approval Request and Section 204(F) Assumption of Maintenance Report Bayport Ship Channel Improvements, Harris and Chambers Counties, Texas. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2014. Final Environmental Assessment for 33 U.S.C Section 408 Approval Request and Section 204(F) Assumption of Maintenance Report Barbours Cut Channel Improvement Project, Harris County, Texas. U.S. Army Corps of Engineers, Galveston District, Galveston, Texas.

2015. Final Environmental Assessment for the Federal Assumption of Maintenance of the Jacintoport Channel as Part of the Houston Ship Channel Project, Harris County, Texas. U.S. Army Corps of Engineers, Galveston District, Texas.

2016. Final Environmental Assessment for the Houston Ship Channel Project Deficiency Report (Flare at the Intersection of the Houston Ship Channel and Bayport Ship Channel), Houston-Galveston Navigation Channels, Texas

4.6 DECISIONS TO BE MADE

This FIFR-EIS will determine whether navigation improvements are recommended to accommodate current and future vessel traffic during the 50-year period of analysis in the HSC System. Various alternatives were evaluated and specific measures were suggested to minimize, or avoid, adverse effects to local resources.

4.7 AGENCY GOAL OR OBJECTIVE

The overall Federal objective related to water and related land resources project planning is to contribute to NED, consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders (EOs), and other Federal planning requirements. Water resources project plans are formulated to alleviate problems and take advantage of opportunities in ways that contribute to this objective. Additional information about contributions to NED is provided in **Section 5, Plan Formulation** and in **Appendix B, Economics**.

To determine whether there is a Federal Interest in implementing navigation improvements recommended in the HSC ECIP, the expected return to the national economy on the total investment to construct and maintain the improvements over a 50-year study (period of analysis) must be calculated. Like most USACE navigation studies, the return to the national economy would be generated by reducing transportation costs by addressing inefficiencies in the existing transportation system. For there to be a Federal Interest, the NED benefits must exceed the cost to construct and maintain the project over the period of analysis. The NED benefits associated with each of the alternatives considered are compared with the costs to implement and maintain the improvements. The results, including recommendations, are summarized in this FIFR-EIS and the supporting appendices.

5 FORMULATION AND EVALUATION OF ALTERNATIVE PLANS*

5.1 PLAN FORMULATION RATIONALE

Features can be a structural element that requires construction or a nonstructural action.

Plan formulation is the process of building alternative plans that meet the planning objectives of the study within the planning constraints. First, management measures are formulated. These measures are **features** that can be implemented at a specific geographic site to address the planning objective(s). Then alternative plans are developed, comprising a set of one or more management measures functioning together to address the planning objective. Prior to the development and presentation of measures and subsequently alternatives, the existing Federal channels were divided into six study segments (shown previously in **Figure 1-1**). Those segments are as follows:

Segment 1	**Bay Reach** (Bolivar Roads to Boggy Bayou)
Segment 2	**Bayport Ship Channel**
Segment 3	**Barbours Cut Channel**
Segment 4	**Boggy Bayou to Sims Bayou**
Segment 5	**Sims Bayou to I-610 Bridge**
Segment 6	**I-610 Bridge to Main Turning Basin**

Initial study efforts involved a determination of the magnitude and extent of the problems along the HSC in order to develop and evaluate an array of alternative solutions that meet the existing and long-range future needs of the Federal Channel. At the initiation of the feasibility phase of the project, lines of communication were opened with Federal, state, and local agencies, private groups, and the affected public. Public Involvement activities are discussed in **Section 9**.

5.2 MANAGEMENT MEASURES

As stated in **Section 4.1** there are navigation inefficiencies in the existing HSC system due to the current channel configuration. The system has constrained vessel sizes, draft restricted areas in the upper channel, inadequate channel configurations for vessels currently using the channel, including the width and size of channel bends and turns, and these inefficiencies are contributing to congestion along the waterway, especially with the high volume of barge and deep-draft vessel traffic on the HSC. Nonstructural and structural measures were developed to address at least one of the planning objectives, alone or in combination with other measures.

* Required by CEQ Regulations 40 CFR 1502.10

5.2.1 Nonstructural Measures

Non-structural measures included:

- Adjust vessel speed – to alleviate maneuverability or meeting issues;
- Increase tug boat assistance – to overcome maneuvering, passing, turning, or other movement restrictions;
- Traffic controls – to schedule/manage channel entry/exit more efficiently;
- Changes to operating procedures (tides, lightering, etc.) – to overcome draft restrictions; and
- Changes to Shipper Association Operating Procedures – to schedule/manage channel entry/exit or berthing more efficiently

Non-structural measures have been employed historically to allow vessel transit of the HSC system; however, they are not sufficient to alleviate the existing inefficiencies and they are already practiced to the greatest extent practicable. Therefore, non-structural measures were not carried forward for further analysis beyond the initial screening of the measures.

5.2.2 Structural Measures

Structural measures included:

- Channel deepening – deepening to alleviate light-loading of vessels, allow more efficient loading practices, and use of fewer larger ships;
- Channel widening (including meeting areas) – widening to allow more efficient and safe meeting of vessels, alleviate one-way traffic restrictions;
- Other channel configurations (bend easing/flares) – to ease sharp turns and associated vessel slow down, maneuverability issues, and/or tug assist;
- Multipurpose mooring areas – areas to tie up to for temporary harbor for layover (e.g., layberth), or disabled vessels (refuge), reducing anchorage transits to Bolivar Roads or offshore (Sea Buoy). Moorings are considered to be local service facilities (LSF);
- Turning basins – to provide more efficient locations and size for vessel(s) to turn around in one-way channels;
- Sediment Barrier/Shoaling attenuation structures – structures (breakwaters/jetty) to alleviate wave energy or excessive shoaling in problem spots and reduce O&M; and
- Offshore crude terminal (LOOP) – terminals for offloading fully loaded vessels in waters deeper than current channels and pipelining product to shore

Of these structural measures, several increments were evaluated that resulted in the following measures, three channel deepening locations, ten channel widening locations, nine bend easing or flare locations, five mooring locations, eleven turning basin locations, and one sediment barrier/shoaling attenuation feature location. Regarding the nonstructural measures previously identified, these measures are already in place and are a regular part of HSC operations. Modifying these practices would not provide transportation cost savings; therefore, these measures were not carried forward for further analysis. The LOOP Terminal is a lightering area where very large crude carriers and ultra large crude carriers that are typically too large to access a harbor, load and unload liquid bulk. These carriers have beams that often exceed 200 feet, LOA of over 1,500 feet, and drafts often exceeding 66 feet. Most tankers of this size are not able to enter the HSC. No measure being considered in this study will allow vessels this size to call at HSC. Therefore, the LOOP terminal was eliminated for further evaluation early in the study process. Additional detailed information including the development of the alternatives and screening to the Final Array is provided in **Appendix A, Plan Formulation (Appendix A).**

5.3 Initial Screening of Measures Based on Contribution to Objectives

The initial screening of the measures was based on whether a measure would address one or more of the planning objectives alone or in combination with other measures. If a measure could not meet at least one objective, the measure was dropped from further consideration in plan formulation. Screening of the overall non-structural and structural concept measures is provided in **Table 5-1 and further described in Appendix A**. As shown in **Table 5-1**, the nonstructural measures do not contribute to the planning objectives. While these measures are already employed, will continue to be employed and improved where practicable, they do not alleviate the problems or meet the planning objectives and therefore are not evaluated further. All of the general structural measures will contribute to the planning objectives (except the LOOP) and are further evaluated on various increments as described later in this section.

Table 5-1 – Initial Screening of Measures Based On Contribution to Objectives

Measure	Notes	Contributes to Objective				
		Obj 1*	Obj 2*	Obj 3	Obj 4	Obj 5
		*Primary NED Objectives				
Non-Structural Measures						
Adjust vessel speed	Already at the slowest speed possible without affecting maneuverability	No	No	No	Yes	No
Additional Tug Assist	Standard tug operations are sufficient and additional tugs would not improve transportation efficiency. In some cases, tugs are an interim risk reduction.	No	No	No	No	No
Traffic Management (Vessel Traffic System or VTS)	USCG and Pilots collaborate for effective traffic management. VTS Houston/Galveston exists to prevent groundings, allisions, and collisions by sharing information and implementing appropriate traffic management measures.	No	Yes	No	Yes	No
Use tides, lightering	The tidal range for Galveston Bay at NOAA Pier 21 is diurnal maximum 1.75 feet at MLLW, minimum -0.63 feet MLLW; therefore, it does not really make a difference in time or transit. Lightering is already common practice.	No	No	No	No	No
Terminal improvements	Projected terminal improvements are included in the without-project condition; would not substantially improve transportation efficiency.	No	No	No	No	No
Structural Measures						
Channel Deepening	Inclusive of deepening of berthing areas, projected to improve transportation efficiency.	Yes	Yes	Yes	No	No
Channel Widening	Widening to create meeting area(s) may improve transportation efficiency and safety.	Yes	Yes	Yes	Yes	No
Other Channel Configurations	Bend easing and flares are insufficient to address existing safety concerns and assure safe and efficient maneuverability	Yes	Yes	Yes	Yes	No
Shoaling Attenuation Feature/ Sediment Barrier	Construction of breakwater/jetty to function as shoaling attenuation features to assist in the reduction of shoaling.	No	No	No	No	Yes
Improve existing or create additional turning basins	Reduce inefficiencies created by requiring channel closures or other restrictions while operating vessels in areas without adequate turning opportunities.	Yes	Yes	No	Yes	No
Create multipurpose moorings for layover mooring and disabled vessels	Improve safety and environmental impacts by limiting transits of vessels outside of immediate service area. Ships have to move down channel to Bolivar Roads Anchorage or Sea Buoy Anchorage.	Yes	Yes	No	Yes	No
LOOP	We do not expect that deepening would result in Larger Tankers (70 foot draft) being able to transit HSC.	No	No	No	No	No

Obj 1 - Reduce navigation transportation costs by increasing economies of scale for vessels to and from HSC;
Obj 2 - Increase channel efficiency, and maneuverability in the HSC system for the existing fleet and future vessels;
Obj 3 - Develop environmentally suitable placement for dredged material and maximize use of BU of dredge material;
Obj 4 – Increase channel safety for vessels utilizing the HSC, BSC, and BCC;
Obj 5 - Reduce high shoaling at BSC Flare to reduce dredging frequency.

5.4 Secondary Screening of Measures

The study scope does not consider deepening beyond 46.5 feet. Deepening greater than 46.5 feet is expected to be cost prohibitive due to the significant environmental and engineering challenges

as well as high costs associated with project depth below 46.5 feet. The NFS supports this study scope and is not in support of an expanded analysis of deeper depths.

Without bay deepening and significant channel modifications that would be required for the transit of a VLCC, it is assumed that VLCCs would not enter HSC and current lightering practices at the LOOP would continue. The project makes no change to these practices.

Barge lane relocation is assumed under all widening scenarios. Barge lanes would be replaced to the specifications of P.L. 106-377 as an associated cost of the project.

5.4.1 Criteria for Secondary Screening of Measures

The following criteria were used to evaluate and conduct a second iteration of screening of the remaining structural measures prior to developing the alternatives:
Environmental issues – any measure that would negatively affect a WMA or Bird Rookery will be eliminated from further study;
Engineering issues – if it was determined that 1) insufficient space is available for a measure or 2) a measure is already appropriately sized for the design vessel(s) it will be eliminated from further evaluation;
Infringement on another Federal Project – any measure that would negatively affect or overlap with another Federal project will be eliminated. The HSC is adjacent to the Texas City Ship Channel, Cedar Bayou Navigation Channel, the Gulf Intracoastal Waterway (GIWW), and the Galveston Harbor and Channels;
Regulatory Permit issued – if a Department of the Army (DA) Regulatory Permit has been issued for proposed work the expectation is that work will be conducted; and
Houston Pilots Input – To date, three different meetings (25 July 2016, 14 March 2017, and 19 April 2017) were held with the Houston Pilots to determine which measures would result in lifting pilot restrictions or meet objectives If a measure is determined to not improve safety or lift a pilot restriction in whole or in part, it will be eliminated.

Based on these secondary screening criteria, all three channel deepening locations, ten channel widening locations, nine bend easing or flare locations, three mooring locations, six turning basin locations, and one sediment barrier/shoaling attenuation feature location were carried forward. The size and increments of these measures are further described in **Section 5.5** below, in **Appendix A**, and in **Sections 3 and 4 of Appendix C, Engineer Appendix**.

5.5 Initial Array of Alternative Plans

In this phase, comprehensive alternative plans were formulated for the HSC system and specific needs for different design vessels used within the system through a combination of structural

measures. The alternatives are meant to be standalone plans that can be directly compared to one another. Some alternatives were intended to provide all-inclusive plans to address inefficiencies of the total HSC system and others were drafted to focus more closely on specific problems. Based on the measures previously identified, eight structural alternatives and a no-action alternative were included in the Initial Array. A range of widths and depths for the structural alternatives were evaluated for their economic merit of generating transportation cost savings using the HarborSym model and then evaluated against costs to determine the average annual equivalent (AAEQ) benefits (benefits minus costs) and a Benefit-to-Cost Ratio (BCR).

These plans were formulated in consideration of the four criteria (completeness, effectiveness, efficiency, and acceptability) described in the *Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, dated March 1983 (P&G). These plans were then screened and further refined to identify the TSP.

- Completeness: Extent to which the plan provides and accounts for all necessary investments or actions to ensure realization of the planning objective
- Effectiveness: Extent to which the plan contributes to achieving the planning objective
- Efficiency: Extent to which the plan is the most cost-effective means of addressing the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment
- Acceptability: Workability and viability of the alternative plan with respect to acceptance by Federal and non-Federal entities and the public, and compatibility with existing laws, regulations, and public policies

Preliminary plans were formulated by combining management measures. Based on the economic and cost analyses some of the measures included in the preliminary plans were eliminated on this basis or recommended for further engineering safety evaluation.

Future Without-Project Condition (No Action Alternative)

As previously stated in **Section 3**, the FWOP condition would retain the existing depths and widths of the HSC and its tributary channels, previously shown in **Table 2-1**. Navigation inefficiencies of the HSC system would continue due to the existing restrictive channel dimensions and users would not be able to take advantage of economies of scale experienced with the growing world fleet. Although the volume of product and chemical trade continues to increase, vessels would continue to be forced to operate at drafts constrained by channel depth and width limitations. Inefficient channel maneuvers and traffic congestion would continue and increase over time. Additionally, the established safety issue in the vicinity of the HSC/BSC intersection would not

be addressed beyond the interim corrective action. A final corrective action was recommended in the HSC PDR, referenced in the last bullet under **Prior Reports and Existing Water Projects**. This alternative would result in no environmental impacts.

Initial Alternatives

Eight design vessels were identified within the six study segments. The alternatives target channel improvements that would result in the reduction or elimination of travel restrictions for those different design vessels throughout the HSC system allowing for two-way traffic. **Table 5-2** provides the design vessels for each study segment. All non-containerized vessels are consistent in the FWOP and FWP. The study assumes that the Recommended Plan will allow for a containerized fleet transition to a Post-Panamax Generation III vessel. Additional detail on the design fleet is available in the **Appendix B, Economic Appendix**.

Table 5-2 – Design Vessels per Study Segment

Segment	Type	Class	LOA	Beam	Draft
			(feet)		
1,2,3	Containership	Gen III	1,100	158	49
1,2,3	Containership	Gen III	1,200	140	49
1,2	Tanker	Suezmax	935	164	54
3,4	Tanker	Aframax	850	138	54
4	Bulk Carrier	Panamax	810	106	44
5	Tanker	Panamax size	610	106	44
5	Vehicle Carrier	Ro-Ro	640	106	34
6	Bulk Carrier	70k-110k Bulker	750	106	45

Measures were evaluated and screened on their ability to meet the study objectives. Hydrodynamic modeling and ship simulation results were not available until the feasibility-level analysis phase of the study. In the evaluation of the Initial Array, eight alternative plans were developed to address issues such as congestion, vessel delays, inefficient vessel loading, and inefficient vessel fleet utilization throughout the channel. The alternatives targeted different segments of the HSC system. However, the ultimate goal of the study is to increase navigation efficiencies throughout the entire HSC system. To that end, the alternatives became additive in nature in that a combination of alternatives best meets the study planning objectives for the HSC system.

The PDT evaluated the need of selectively widening the existing 530-foot wide HSC to facilitate two-way traffic meeting by large vessels as well as the easing of the channel bends and turns associated with transit restrictions, slowdowns, and additional tug assist. The PDT used three methods to determine the range of widths considered for widening the channel in the bay. The first width was established using recommendations from the Engineer Manual (EM) 1110-2-1613, *Hydraulic Design of Deep-Draft Navigation Projects,* The EM recommended a 902-foot (rounded down to 900 feet) channel to allow two Suezmax design vessels to meet in the Bay. In many cases,

the channel dimensions recommended by EM 1110-2-1613 may not be feasible due to physical, engineering, environmental impacts, cost, and economic constraints. The second width was established using a standard pilot rule of thumb of "2.5 times the combined beam width". This would allow for a smaller channel widening of 820 feet. The third width was determined based on discussions with the Houston Pilots Association, in which a bare minimum of an additional 100 feet of channel width, for a total 650-foot width, was considered necessary for two-way traffic of wide-body vessel meeting opportunities in the Bay Reach below Morgans Point and/or to revise the current vessel transit conditions.

Based on the aforementioned considerations, the PDT assumed that a channel at some dimension between 650-feet and 900-feet would allow for safe, efficient meeting opportunities. General guidance presented in EM 1110-2-1613, is based on "average" navigation conditions and situations with the expectation that the design will be adapted to meet the local, site-specific conditions of the project. The final project design generally incorporates real-time ship simulations with local professional pilots.

The PDT planned for feasibility-level ship simulations to be conducted subsequent to public review to better determine the feasible (safe and efficient) dimensions of the channel. Therefore, the PDT determined the need to treat any channel widening in the bay as a range between the 650-foot and 900-foot wide dimensions until the dimension for safe, efficient transit is verified. In this way, the maximum environmental impacts can be coordinated through the NEPA process and once ship simulations establish the true dimension needed, the actual impacts will be reduced and the project design will be further refined.

The analysis additionally considered construction of a multipurpose mooring area in or near Galveston Bay to reduce congestion in the channel from multi-anchorage transits to and from Bolivar Roads or offshore (Sea Buoy) while a vessel is waiting between facilities. The PDT also measures for widening in the side channels (BSC and BCC), flare modifications, and turning basins. Additional bend easing, channel widening, and turning basins were investigated in addition to deepening of the upper channel segments beyond Boggy Bayou, the limit of the 46.5-foot channel.

The measures within each alternative were assessed for environmental impacts (bay bottom and oysters) to assess mitigation costs, pipeline relocation costs, estimated quantities of new work dredging, shoaling, estimated placement costs using historical information from the HSC system, and maintenance dredging costs to estimate costs for Project First Costs and O&M. These costs were then used to assess the economic benefits for each of the alternative plans and combination of plans to maximize the net benefits.

Eight structural alternatives were formulated subsequent to the secondary screening of management measures. Those alternatives are outlined below. Later in the report, under Comparison of Alternatives and subsequent to the final screening, **Table 5-15** and **Table 5-16** lay out the specific pilot rules and restrictions from the *Houston Pilot Working Rules (Updated October 24, 2018)* that were targeted by each alternative. The tables provide a comparison between the current working rules and the anticipated change to the rules and restrictions for each of the alternatives. All measures were sized for the design vessel that the measures are addressing; however, the ability to confirm whether these restrictions can be alleviated and or reduced will be dependent upon the results of the feasibility-level ship simulations that will be conducted in coordination with the Houston Pilots Association with oversight by ERDC.

Pilot Rule Restrictions are navigation safety guidelines established in the interest of safety in the navigation channel. They do not limit, hinder, or override the on-scene discretion of individual pilots, as there may be situations where actions that depart from or conflict with the guidelines "restrictions" may be necessary to react to specific circumstances or avoid danger. On the HSC, traffic density and location are dynamic factors that can change from minute to minute.
http://www.houston-pilots.com/workingRules.pdf

ALTERNATIVE 1 – Minimum System Wide Plan (No Bay Widening)

This alternative focused on modifications in Segment 1 to allow the design vessels, particularly Generation III design vessel Containerships (1100- by 158 feet and 1200- by 140 feet), into the Bay Reach beyond the four undersized bends. Additionally, Segments 1, 2, and 3 modifications would provide for Generation III design vessel Containerships to enter the BSC and BCC channels to call on the associated terminals. Widening the BSC and BCC channels would allow maximum vessel sizes beyond the current 1,000- by 138-foot maximum vessel size restriction and ease congestion when large vessels are at berth and allow for the Suezmax (935- by 164-feet) to call on the BSC. Widening the BSC and BCC channels would allow smaller vessels to continue transiting the channel once larger vessels are at berth. Note that residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR need a final corrective action. A shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. A multipurpose Bay mooring would address the lack of a dedicated waiting area that results in increased transit time and cost inefficiencies because vessels (Tankers and Chemical Tankers at BSC) are required to go to the anchorage at Bolivar Roads or offshore (Sea Buoy) while a vessel is waiting between facilities. Deepening Segments 4-6 would allow for an increased efficiency in loading practices for all design vessels except the vehicle carrier that drafts 34 feet when calling on the upper channel. Drawings of the eight alternatives are provided in the **Appendix A** for reference. Alternative 1 includes:

- Four bend easings on the main HSC channel in the Bay reach with associated relocation of barge lanes (**Segment 1**);
- New turning basin near entrance of the land cut (**Segment 2**);
- Flare expansion on BSC (**Segment 2**);
- Widen BSC from existing 300-400 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure around BSC Flare (**Segment 2**);
- Bay multipurpose mooring at BSC (**Segment 2**);
- Combination flare and turning basin on BCC near the entrance (**Segment 3**);
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**);
- Channel deepening from the existing channel depth of 41.5 feet to a maximum depth of 46.5 feet as much as possible upstream of Boggy Bayou (**Segment 4**); and
- Channel deepening from the existing channel depth of 37.5 feet to a maximum depth of 41.5 feet as much as possible upstream of Boggy Bayou (**Segments 5, and 6**)

ALTERNATIVE 2 – Bay Plan

This alternative focused on modifications in Segment 1 to get the design vessels, particularly Generation III design vessel Containerships (1100- by 158-feet and 1200- by 140-feet) into the Bay Reach beyond the four undersized bends. Channel widening increments between Bolivar Roads and BCC to alleviate one-way traffic in and out of the HSC system and lift daylight restrictions for wide body vessels and vessels exceeding an LOA of 1100-feet. Modifications in Segments 1, 2, and 3 would provide for Generation III design vessel Containerships to enter the BSC and BCC channels and pass the berths with other ships moored to call on the associated terminals and allow for the Suezmax (935- by 164-feet) to call on the BSC. Note that residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR need a final corrective action. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 2 includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530 foot width to between 650 to 900 feet with associated relocation of barge lanes (**Segment 1**);
- New turning basin near entrance of the land cut (**Segment 2**);
- Flare expansion on BSC (**Segment 2**);
- Widen BSC from existing 300 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure near the BSC Flare to reduce heavy shoaling (**Segment 2**);
- Combination flare and turning basin on BCC (**Segment 3**); and
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**)

ALTERNATIVE 3 – Suezmax Plan

This alternative focused on modifications in Segment 1 to get the design vessels into the Bay Reach beyond the four undersized bends and channel widening increments between Bolivar Roads and BCC to allow two-way traffic for Suezmax vessel as well as container vessels and to alleviate daylight restriction in and out of the HSC system. Additional bend easings and selective widening would provide opportunities between Morgans Point and Boggy Bayou for design vessel meeting in the Bayou portion of the Bay Reach and would alleviate one-way traffic restrictions for widebody vessels, particularly the Suezmax vessels (935- by 164-feet). Widening the BSC would allow Generation III design vessel Containerships (1100- by 158-feet and 1200- by 140-feet) and the Suezmax Tanker to enter the BSC and pass the berths with other ships moored to call on the terminals. Lastly, a shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 3 includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widen (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC between the existing 530 foot width to between 650 to 900 feet with associated relocation of barge lanes (**Segment 1**);
- Two bend easings in the Bayou Portion of the HSC main channel above Morgans Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (**Segment 1**);
- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from San Jacinto Monument to Boggy Bayou from the existing 400 foot width to 530 feet for approximately 1.3 miles (**Segment 1**);
- Widen BSC from existing 300-400 feet to 455 feet (**Segment 2**);and
- A shoaling attenuation structure near the BSC Flare to reduce heavy shoaling (**Segment 2**)

ALTERNATIVE 4 – Aframax Plan

This alternative focused on modifications to allow for efficient use of the channel for vessels larger than the pilot rules maximum vessel size (750- by 116-feet) and up to the Aframax design vessel (850-by 138-feet) primarily for Segment 4. This would include widening the last 1.3 miles of Segment 1 and Segment 4 from 400-feet wide to approximately 530-feet through centerline shifts to the extent practicable. Deepening the channel in Segment 4 would allow for increased loading efficiencies and widening would allow vessel meeting for beams wider than the current guideline.

A new turning basin and the expansion of an existing turning basin would provide future Aframax vessels going further up in this segment a turning basin of sufficient size to turn. Additionally, this would provide for more turning opportunities for smaller vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 4 includes:

- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from the San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet approximately 1.3 miles to remove a neck-down in the channel (**Segment 1**);
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou beyond 41.5 feet as much as possible up to 46.5 feet deep (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot width up to 530 feet (**Segment 4**);
- New turning basin in the Boggy Bayou to Greens Bayou Segment near Pasadena docks (**Segment 4**); and
- Expand Hunting Bayou Turning Basin (**Segment 4**)

ALTERNATIVE 5 – Bulkers, Tankers, and Vehicle Carriers Plan

This alternative focused on modifications to enable tanker vessels larger than the current guideline and up to the design vessel for this segment to allow from efficient use of the channel by the tanker fleet. Deepening the channel in Segments 4, 5, and 6, would allow for increased loading efficiencies and widening would allow vessel meeting for beams wider than the 105-feet in Segment 4. Expansion of existing turning basins would provide for more turning opportunities for the design vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 5 includes:

- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (**Segment 4**);
- Expand Hunting Bayou Turning Basin (**Segment 4**)
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet (**Segment 5**);
- Expand Brady Island Turning Basin (**Segment 6**); and
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin from the existing 37.5-foot depth up to 41.5 feet (**Segment 6**);

ALTERNATIVE 6 – Bay Mooring Plan

This alternative focused on reducing congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in increased transportation costs. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 6 includes:

- The addition of a new multipurpose mooring in the BSC to be located just outside the land cut (Segment 2).

There are no specific pilot rules targeted for this alternative. A lack of sufficient layberthing space (e.g. sitting at someone's dock) leads to the need for anchorage transits to Bolivar Roads or offshore (Sea Buoy) until a berth comes available.

ALTERNATIVE 7 – Upper Channel Mooring Plan

This alternative focused on reducing congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in additional transportation costs. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 7 includes:

- Two new multipurpose moorings in the HSC upper channel; one mooring would be located near Alexander Island and the other mooring would be located near the San Jacinto Monument (Segment 1).

There are no specific pilot rules targeted for this alternative. This alternative is to address a lack of sufficient layberthing space (e.g. sitting at someone's dock) for vessels when a berth is not available. This lack of layberthing for vessels leads to the need for anchorage transits to Bolivar Roads or offshore (Sea Buoy) until a berth comes available, contributing to increased transportation costs and congestion in the channel.

ALTERNATIVE 8 – The Comprehensive Plan

This alternative focused on modifications that alleviate as many problems and restrictions practicable for all design vessels, system wide. Modifications in Segment 1 were combined to allow the design vessels, particularly Generation III design vessel Containerships (1100- by 158-feet and 1200-by 140-feet) and the Suezmax Tanker (935-by 164-feet) to transit into the Bay Reach beyond the four undersized bends. Channel widening increments between Bolivar Roads and BCC would alleviate one-way traffic in and out of the HSC system for Gen III Container vessel transits

and meeting of two-way wide body vessels such as the Suezmax (935- by 164-feet), reduce combined beam and draft restrictions, and lift daylight restrictions. Bend easings and selective widening would provide opportunities between Morgans Point and Boggy Bayou for design vessel meeting in the Bayou portion of the Bay Reach and would alleviate one-way traffic restrictions for widebody vessels. Multi-purpose moorings in would reduce congestion in the channel caused by multiple inter-channel vessel movements between facilities out to the anchorage while waiting to transit between docks. These transits result in additional transportation costs and time. Modifications in Segments 1, 2, and 3 would provide for Generation III design vessel Containerships (1100- by 158-feet and 1200-by 140-feet) and Suezmax to enter the BSC and BCC channels and pass moored vessels to call on the associated terminals. Note that residual safety issues remaining after construction of the interim corrective action recommended by the HSC PDR need a final corrective action. Widening the BSC and BCC channels would allow maximum vessel sizes beyond the current 1,000- by 138-foot maximum vessel size restriction and ease congestion when large vessels are at berth.

A shoaling attenuation structure would reduce the dredging frequency around the flare; high shoaling within the BSC flare area results in increased maintenance dredging, strains placement area capacity, and increases maintenance costs. Deepening the channel in Segments 4, 5, and 6, would allow for increased loading efficiencies and widening in Segment 4 would allow vessel meeting for beams wider than the current pilot's guideline of 105 feet. New turning basins and the expansion of existing turning basins would reduce the distance future vessels are required to transit before reaching a turning basin of sufficient size to turn and provide more turning opportunities for smaller vessels such as tankers and bulk carriers, alleviating the need to transit all the way to the Main Turning Basin. See **Plan Formulation Appendix** for drawings of the Alternatives. Alternative 8 includes:

- Four bend easings on the main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widening (in whole or in part) the HSC main channel for meeting between Bolivar Roads and BCC from the existing 530-foot width to between 650 to 900 feet with associated relocation of barge lanes (**Segment 1**);
- Two bend easings in the Bayou Portion of the HSC main channel above Morgans Point. The first easing near Fred Hartman Bend and the second easing near Alexander Island Turn (**Segment 1**);
- Minor widening of the channel in the Bayou portion of the HSC main channel in the Hog Island Stretch and from the San Jacinto Monument to Boggy Bayou from the existing 400-foot width to 530 feet approximately 1.3 miles to remove a neck-down in the channel (**Segment 1**);

- Two new multipurpose moorings in the HSC upper channel with one mooring located near Alexander Island and the other mooring located near the San Jacinto Monument (**Segment 1**);.
- New turning basin near entrance of the land cut (**Segment 2);**
- Flare expansion on BSC (**Segment 2**);
- Widen BSC from existing 300 feet to 455 feet (**Segment 2**);
- Shoaling attenuation structure near the BSC Flare (**Segment 2**);
- A new multipurpose mooring in the BSC just outside the land cut (**Segment 2**)
- Combination flare and turning basin on BCC (**Segment 3**);
- Widen BCC from existing 300 feet to 455 feet (**Segment 3**);
- Deepen the HSC main channel from Boggy Bayou to Sims Bayou from the existing 41.5-foot depth up to 46.5 feet (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (**Segment 4**);
- New turning basin in the Boggy Bayou to Greens Bayou Segment near Pasadena docks (**Segment 4**);
- Expand Hunting Bayou Turning Basin (**Segment 4)**
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet (**Segment 5**);
- Expand Brady Island Turning Basin (**Segment 6**); and
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin from the existing 37.5-foot depth up to 41.5 feet deep (**Segment 6**)

5.6 Evaluation Array of Alternative Plans

5.6.1 Screening Criteria

To evaluate and screen the initial array of alternative plans to determine those that best meet the study objectives and avoid the study constraints, an initial screening matrix was developed.

The following information was assessed to provide the cost of each measure within the alternatives: New work dredging construction costs, PA construction costs, impacted oyster area (acreage) and its associated mitigation unit costs, real estate costs, relocation costs, mooring structure construction costs, sheet pile wall construction costs, shoaling attenuation feature costs, and contingencies. Total project cost and economic benefits are presented in AAEQ values. AAEQ values are calculated by discounting the benefit stream, deferred installation costs, and Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs to the beginning of the period of analysis using the existing FY20 discount rate (2.75 percent). Installation expenditures are brought forward to the end of the period of installation by charging

compound interest at the project discount rate from the date the costs are incurred. Using AAEQ values allows for a direct comparison of costs and benefits over the 50-year study period. The BCR is calculated by dividing AAEQ Benefits by AAEQ costs and is used to determine if the project is justified (BCR ≥ 1.0). These criteria are shown in **Table 5-3**.

Table 5-3 – Criteria for Screening Initial Array

Criteria	Metric	Inventory
Costs	Dollars	New work dredging construction costs, placement area construction costs, impacted oyster area (acreage), mitigation unit costs, real estate costs, relocation costs, mooring structure construction costs, sheet pile wall construction costs, shoaling attenuation feature costs, contingencies, local service facilities, and 50-year maintenance.
Economic Benefits	Dollars	Assessment of transportation cost savings

5.6.2 Evaluation of Each Alternative Plan

Once the alternatives were developed, the PDT evaluated the impacts, and estimated costs for the measures within each of the alternatives. **Tables 5-4 through 5-11** summarize the results of the economic cost benefit analysis. Measures that produced the highest net benefits (green) were carried forward. Measures not economically justified but that may be required for engineering safety concerns (gray with an asterisk (*) beside the measure name) were also carried forward. Measures that were not economically justified, and did not require ship simulation for engineering safety evaluation, were screened out (gray). Measures that were economically justified, but did not produce the highest net benefits (white), were screened out.

For the largest design vessels (Container and Suezmax) several measures must be combined to allow for efficient design vessel transit. These measures include the easing of the four undersize bends between Bolivar Roads and Morgans Point, the Bayport Flare easing, Barbours Cut Flare Easing combined with a Turning Basin, widening of both the BSC and BCC and the shoaling attenuation feature north of the BSC. The shoaling attenuation feature is necessary for efficient vessel movement due to the high level of shoaling in that vicinity, thus reducing draft restrictions and regular occupation of the flare by a dredge.

5.6.2.1 Alternative 1 Evaluation

Table 5-4 presents the benefit cost summary for Alternative 1. All measures are economically justified except for the BSC RoRo Turning Basin (TB_RORO_1800). This measure is not economically justified alone; however, it requires ship simulation to confirm whether it is required to realize benefits at BSC. The remaining measures for the design vessel transit and the Bayou Deepening (Segment 4-6) shown in green are economically justified and carried forward as Alternative 1 to the final screening of alternatives. Refer to **Table 5-2** for a listing of the design vessels per study reach.

Table 5-4 – Alternative 1 – Minimum System-Wide Plan (No Bay Widening) ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
Measures for Design Vessel Transit	BE1_138+369_530	Bend easing in Bay	$5,200	$5,200	$21,600	$21,500	$(100)	1.00
	BE1_128+731_530	Bend easing in Bay	$5,500	$7,600				
	BE1_078+844_530	Bend easing in Bay	$24,600	$58,800				
	BE1_028+605_530	Bend easing in Bay	$23,000	$36,200				
	BE2_BSCFlare	Flare Expansion post HSC PDR plan	$21,600	$139,900				
	SA2_BSCFlare	Shoaling attenuation structure near BSC Flare	$22,300	$22,300				
	CW2_BSC_455	Widen BSC up to 455 feet wide	$153,800	$254,100				
	CW3_BCC_455	Widen BCC up to 455 feet wide	$104,200	$109,500				
	TB3_BCCFlare_1800NS	Ease flare and create turning basin	$24,900	$44,000				
BSC TB	*TB2_BSCRORO_1800	Turning Basin/Flare at BSC	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
Bayou Deepening	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet.	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
	CD5_Whole + CD6_Whole	Deepen beyond 37.5 feet up to 41.5 feet.	$19,900	$19,900	$800	$11,400	$10,600	14.3
		Total[1,2]	**$513,900**	**$848,900**	**$27,700**	**$59,700**	**$32,000**	**2.2**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs (~%500k AAEQ Costs)*

5.6.2.2 Alternative 2 Evaluation

Table 5-5 provides the analysis for Alternative 2 – Bay Plan. Alternative 2 considered increments of widening in the Bay to provide for vessel meeting opportunities. Three widths (650, 820, and 900 feet) were evaluated in different combinations for the Bay widening as follows:

1. Widening from Bolivar Roads to Redfish Reef;
2. Widening from Redfish Reef to BSC;
3. Widening from BSC to BCC; and
4. Widening from Bolivar Roads to BCC

The widening analysis of Alternative 2 is assumed the same for Alternative 2, 3, and 8. If Alternative 2 or 3 were carried forward, additional analysis would be required to estimate widening benefits without all Alternative 8 features. The 900-foot wide channel is not economically justified for any increment and is eliminated from further evaluation. The 820-foot width is economically justified from Bolivar Roads to Redfish Reef; however, the evaluation showed channel widening to be economically justified at the 650-foot width from Bolivar Roads up to the BCC. Additionally, though the increments are economically justified individually at 650 feet, they have a higher net benefit for the combined widening from Bolivar Roads to the BCC. However, as discussed earlier in **Section 5.5**, the widening component would be treated as a range (650-820 feet) until the dimension for safe, efficient transit is verified. The measures for design vessel transit were also carried forward including the BSC RORO turning basin, as explained for Alternative 1.

Table 5-5 – Alternative 2 – Bay Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900	Widen to 900 feet from Bolivar Roads to Redfish Reef	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
	CW1_Redfish-BSC_900	Widen to 900 feet from Redfish Reef to BSC	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
	CW1_BSC-BCC_900	Widen to 900 feet from BSC to BCC	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	Widen to 900 feet from Bolivar Roads to BSC	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	Widen to 900 feet from Bolivar Roads to BCC	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820	Widen to 820 feet from Bolivar Roads to Redfish Reef	$186,200	$210,000	$8,100	$8,600	$500	1.1
	CW1_Redfish-BSC_820	Widen to 820 feet from Redfish Reef to BSC	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
	CW1_BSC-BCC_820	Widen to 820 feet from BSC to BCC	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	Widen to 820 feet from Bolivar Roads to BSC	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
	*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	Widen to 820 feet from Bolivar Roads to BCC	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
Bay Widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650	Widen to 650 feet Bolivar Roads to Redfish Reef	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
	CW1_Redfish-BSC_650	Widen to 650 feet from Redfish Reef to BSC	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
	CW1_BSC-BCC_650	Widen to 650 feet from BSC to BCC	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	Widen to 650 feet from Bolivar Roads to BSC	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	Widen to 650 feet from Bolivar Roads to BCC	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
Measures for Design Vessel Transit	BE1_138+369_530	Bend easings (530 feet) between Bolivar Roads and BCC	$5,200	$5,200	$21,600	$21,500	$(100)	1.0
	BE1_128+731_530		$5,500	$7,600				
	BE1_078+844_530		$24,600	$58,800				
	BE1_028+605_530		$23,000	$36,200				
	BE2_BSCFlare	Expansion of Flare post HSC PDR plan	$21,600	$139,900				
	SA2_BSCFlare	Shoaling attenuation structure near BSC Flare	$22,300	$22,300				
	CW2_BSC_455	Widen BSC up to 455 feet wide	$153,800	$254,100				
	CW3_BCC_455	Widen BCC up to 455 feet wide	$104,200	$109,500				
	BETB3_BCCFlare_1800NS	Ease flare and create turning basin	$24,900	$44,000				
BSC TB	*TB_BSCRORO_1800	Turning Basin at BSC	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
		Total[1, 2]	**$706,300**	**$1,304,300**	**$40,800**	**$47,700**	**$6,900**	**1.2**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

5.6.2.3 Alternative 3 Evaluation

Table 5-6 provides the analysis for Alternative 3 – Suezmax Plan. Alternative 3 only showed increments of widening in the Bay to provide for vessel meeting opportunities at 650 feet, to be economically justified. Measures carried forward in grey as part of "Bay Bend Easing," "Upper Bay Bend Easing," and "BSC Widening" measure groups require ship simulation to determine whether they are needed to realize widening benefits. San Jacinto Monument to Boggy Bayou Widening (CW3_SJM to BB) lacks economic justification but is included for additional ship simulation to determine whether it is necessary for the design vessel to transit through Boggy Bayou to realize benefits associated with new terminals near BW8.

Table 5-6 – Alternative 3 – Suezmax Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
Bay Widening for Widebody Meeting (900 foot width)	CW1_BR-Redfish_900	Widen to 900 feet from Bolivar Roads to Redfish Reef	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
	CW1_Redfish-BSC_900	Widen to 900 feet from Redfish Reef to BSC	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
	CW1_BSC-BCC_900	Widen to 900 feet from BSC to BCC	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900	Widen to 900 feet from Bolivar Roads to BSC	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
	CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	Widen to 900 feet from Bolivar Roads to BCC	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
Bay Widening for Widebody Meeting (820 foot width)	CW1_BR-Redfish_820	Widen to 820 feet from Bolivar Roads to Redfish Reef	$186,200	$210,000	$8,100	$8,600	$500	1.1
	CW1_Redfish-BSC_820	Widen to 820 feet from Redfish Reef to BSC	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
	CW1_BSC-BCC_820	Widen to 820 feet from BSC to BCC	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
	CW1_BR-Redfish_820 CW1_Redfish-BSC_820	Widen to 820 feet from Bolivar Roads to BSC	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
	*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	Widen to 820 feet from Bolivar Roads to BCC	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
Bay Widening for Widebody Meeting (650 foot width)	CW1_BR-Redfish_650	Widen to 650 feet from Bolivar Roads to Redfish Reef	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
	CW1_Redfish-BSC_650	Widen to 650 feet from Redfish Reef to BSC	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
	CW1_BSC-BCC_650	Widen to 650 feet from BSC to BCC	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650	Widen to 650 feet from Bolivar Roads to BSC	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
	CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	Widen to 650 feet from Bolivar Roads to BCC	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
Bay Bend Easing	*BE1_138+369_530	Bend easing (530 feet) between Bolivar Roads and BCC	$5,200	$5,400	$3,400	N/A	$(3,400)	N/A
	*BE1_128+731_530	Bend easing (530 feet) between Bolivar Roads and BCC	$5,500	$7,600				
	*BE1_078+844_530	Bend easing (530 feet) between Bolivar Roads and BCC	$24,600	$58,800				
	*BE1_028+605_530	Bend easing (530 feet) between Bolivar Roads and BCC	$23,000	$36,200				
Upper Bay Bend Easing	*CW1_HOG_600	Widen Hog Island reach	$10,300	$21,700	$1,900	N/A	$(1,900)	N/A
	*BE1_153+06	Bend easing at Fred Hartman Bend	$10,500	$30,400				
	*BE1_246+54	Bend easing Alexander Island	$6,000	$14,200				
SJM-BB Widening	*CW3_SJM-BB	Widening at transition from 400 to 530 feet.	$17,800	$56,400	$1,500	$200	$(1,300)	0.1
BSC Widening	*CW2_BSC_455	Bayport Ship Channel Widening for Suezmax Transit	$153,800	$254,100	$8,300	$1,100	$(7,200)	0.1
		Total[1,2]	**$527,000**	**$1,018,300**	**$31,300**	**$26,100**	**$(5,200)**	**0.8**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

5.6.2.4 Alternative 4 Evaluation

Table 5-7 provides the analysis for Alternative 4 – Aframax Plan. Deepening of Segment 4 and widening from Boggy Bayou to Greens Bayou in Segment 4 were economically justified. The turning basin measures would be carried forward for engineering safety evaluation.

Table 5-7 – Alternative 4 – Aframax Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
To Accommodate Aframax Design Vessel	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
	CW4_BB-GB_530	Widen Boggy Bayou to Greens Bayou to 530 feet	$22,900	$112,600	$2,700	$35,100	$32,400	13.0
	*TB4_775+00	Create new turning Basin for Aframax	$30,300	$67,100	$2,000	$-	$(2,000)	0.0
	*TB4_Hunting	Expand existing Hunting Bayou Turning Basin	$900	$17,900	$400	$-	$(400)	0.0
SJM-BB Widening	*CW3_SJM-BB	Widening at transition from 400 to 530 feet.	$17,800	$56,400	$1,500	$200	$(1,300)	0.1
		Total[1,2]	**$129,900**	**$312,900**	**$8,500**	**$60,700**	**$52,200**	**7.1**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

5.6.2.5 Alternative 5 Evaluation

Table 5-8 provides the analysis for Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan. Deepening of Segments 4, 5, and 6 was determined to be economically justified, whereas, the turning basin measures would be carried forward for further evaluation as engineering safety concerns.

Table 5-8 – Alternative 5 – Bulkers, Tankers, and Vehicle Carriers Plan ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
To Accommodate Bulker, Tanker, and Vehicle Carrier Design Vessel	CD4_Whole	Deepen beyond 41.5 feet up to 46.5 feet	$45,400	$45,400	$2,200	$25,400	$33,600	16.3
	*TB4_Hunting	Expand Hunting Bayou Turning Basin	$900	$17,900	$300	$ -	$(300)	0.0
	CD5_Whole + CD6_Whole	Deepen beyond 37.5 feet up to 41.5 feet	$19,900	$19,900	$800	$11,400	$15,900	20.9
	*TB6_Brady_900	Expand Brady Island Turning Basin	$19,600	$30,900	$1,000	$ -	$(1,000)	0.0
		Total[1]	**$98,400**	**$126,700**	**$4,600**	**$36,800**	**$32,200**	**8.0**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

5.6.2.6 Alternative 6 Evaluation

Table 5-9 provides the analysis for Alternative 6 – Bay Mooring, which is not economically justified, and would not be carried forward for further evaluation as an engineering safety concern.

Table 5-9 – Alterantive 6 – Bay Mooring ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
Bay Mooring	MM2_BSC_1800	Multipurpose mooring outside BSC land cut	$94,600	$164,100	**$5,200**	**$2,100**	**$(3.100)**	**0.4**
		Total[1]	-	-	**-**	**-**	**-**	**-**

[1]*Measure was not economically justified, nor was it carried forward for safety validation via ship simulation*

5.6.2.7 Alternative 7 Evaluation

Table 5-10 provides the analysis for Alternative 7 – Upper Channel Moorings, one of which is economically justified while the other was eliminated.

Table 5-10 – Alternative 7 – Upper Channel Moorings ($000)

Measure	Measure	Description of Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
Bay Mooring	MM1_AI(d)	Multipurpose mooring near Alexander Island	$124,900	$212,500	$6,800	$3,000	$(3,800)	0.4
	MM1_520+00*	Multipurpose mooring near San Jacinto Monument	$47,600	$116,200	$3,300	$3,300	$-	1.0
		Total[1,2]	$47,600	$116,200	$3,300	$3,300	$-	1.0

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*
[2] *Total include costs associated with pipeline relocations and real estate costs*

5.6.2.8 Alternative 8 Evaluation

Table 5-11 provides the analysis for Alternative 8 – The Comprehensive Plan. In Alternative 8, the measures for the design vessels transits were economically justified, as was bayou deepening. The increments of widening in the Bay to provide for vessel meeting opportunities were considered most economical for 650 feet, although the 820 feet width is economically justified from Bolivar Roads to Redfish Reef. Channel widening in Segment 4 from Boggy Bayou to Greens Bayou is economically justified. One bayou mooring is economically justified while the bay mooring and one bayou mooring were not and will be eliminated. Measures that were not economically justified but were carried forward for further evaluation as engineering safety concerns until feasibility-level ship simulations could be conducted included the widening from San Jacinto Monument to Boggy Bayou where the channel necks down, limited widening and bend easing in the bayou portion of Segment 1, and the three turning basins.

Table 5-11 – Alternative 8 – The Comprehensive Plan ($000)

Alt	Alternative	Measure	Project First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
			October 2016 Price Level, 2.875 % Discount Rate					
1, 2	Measures for Design Vessel Transit	BE1_138+369_530	$5,200	$5,200	$21,600	$21,500	$(100)	1.0
		BE1_128+731_530	$5,500	$7,600				
		BE1_078+844_530	$24,600	$58,800				
		BE1_028+605_530	$23,000	$36,200				
		BE2_BSCFlare	$21,600	$139,900				
		SA2_BSCFlare	$22,300	$22,300				
		CW2_BSC_455	$153,800	$254,100				
		CW3_BCC_455	$104,200	$109,500				
		BETB3_BCCFlare_1800NS	$24,900	$44,000				
1	*BSC TB	TB2_BSCRORO_1800	$50,800	$93,400	$2,900	$1,400	$(1,500)	0.5
1, 2, 6	Bay Mooring	MM2_BSC_1800	$89,700	$159,300	$5,200	$2,100	$(3,100)	0.4
1, 4, 5	Bayou Deepening	CD4_Whole	$45,400	$45,400	$1,900	$25,400	$23,500	13.4
		CD5_Whole + CD6_Whole	$19,900	$19,900	$800	$11,400	$10,600	14.3
2, 3	Bay Widening_900	CW1_BR-Redfish_900	$281,200	$311,400	$12,100	$8,600	$(3,500)	0.7
		CW1_Redfish-BSC_900	$463,800	$973,200	$29,100	$7,800	$(21,300)	0.3
		CW1_BSC-BCC_900	$310,200	$585,800	$18,200	$2,500	$(15,700)	0.1
		CW1_BR-Redfish_900 CW1_Redfish-BSC_900	$745,000	$1,284,600	$41,200	$17,900	$(23,300)	0.4
		CW1_BR-Redfish_900 CW1_Redfish-BSC_900 CW1_BSC-BCC_900	$1,055,200	$1,870,400	$59,400	$24,800	$(34,600)	0.4
2, 3	Bay Widening_820	CW1_BR-Redfish_820	$186,200	$210,000	$8,100	$8,600	$500	1.1
		CW1_Redfish-BSC_820	$343,500	$742,400	$22,000	$7,800	$(14,200)	0.4
		CW1_BSC-BCC_820	$242,400	$458,200	$13,600	$2,500	$(11,100)	0.2
		CW1_BR-Redfish_820 CW1_Redfish-BSC_820	$529,700	$952,500	$30,100	$17,900	$(12,200)	0.6
		*CW1_BR-Redfish_820 *CW1_Redfish-BSC_820 *CW1_BSC-BCC_820	$772,100	$1,410,700	$43,700	$24,800	$(18,900)	0.6
2, 3	Bay Widening_650	CW1_BR-Redfish_650	$44,600	$54,300	$2,000	$8,600	$6,600	4.3
		CW1_Redfish-BSC_650	$119,500	$283,700	$8,200	$7,800	$(400)	1.0
		CW1_BSC-BCC_650	$106,200	$195,200	$6,100	$2,500	$(3,600)	0.4
		CW1_BR-Redfish_650 CW1_Redfish-BSC_650	$164,100	$338,000	$10,200	$17,900	$7,700	1.8
		CW1_BR-Redfish_650 CW1_Redfish-BSC_650 CW1_BSC-BCC_650	$270,300	$533,200	$16,300	$24,800	$8,500	1.5
3	SJM-BB Widening	*CW1_SJM-BB_530	$17,800	$56,400	$1,500	$200	$(1,300)	0.13
3	Upper Bay BE Suezmax	*CW1_HOG_600	$10,300	$21,700	$1,900	$-	$-	0.0
		*BE1_153+06	$10,500	$30,400				
		*BE1_246+54	$6,000	$14,200				
4	Aframax Widening	CW4_BB-GB_530	$22,900	$112,600	$2,700	$35,100	$32,400	13.0
4, 5	Bayou TB	*TB4_775+00	$30,300	$67,100	$2,000	$-	$(2,000)	0.0
		*TB4_Hunting	$900	$17,900	$400	$-	$(400)	0.0
5	Brady Island TB	*TB6_Brady_900	$19,600	$30,900	$1,000	$-	$(1,000)	0.0
7	Bayou Mooring	MM1_AI(d)	$120,000	$207,600	$6,800	$3,000	$(3,800)	0.4
		MM1_520+00*	$47,600	$116,200	$3,300	$3,300	$-	1.0
Total (650')			**$950,000**	**$1,849,700**	**$56,800**	**$123,100**	**$66,300**	**2.2**
Total (820')			**$1,451,800**	**$2,727,200**	**$84,700**	**$123,100**	**$38,400**	**1.5**

[1] *Totals include measures that are economically justified (green) plus measures requiring safety validation via ship simulation (*gray). Total excludes measures without economic justification or that do not maximize net benefits in comparison to an alternative measure (white)*

[2] *Total include costs associated with pipeline relocations and real estate costs*

5.7 COMPARISON OF FINAL ARRAY OF ALTERNATIVE PLANS AND DECISION CRITERIA

The final array was screened based on the economic benefits of each alternative. Table 5-12 shows the costs and benefits for each alternative. The costs for all the alternatives are inclusive of the measures identified for further evaluation in regards to safety. As shown in **Table 5-12**, Alternative 8 provides the highest **net benefits** of all the alternatives and best meets the study objectives. Alternative 8 is the NED Plan (inclusive of aforementioned measures). As shown in **Table 5-12** the width for the bay widening in this alternative was evaluated for the range of 650 feet to 820 feet. The use of feasibility-level ship simulation addresses the uncertainty surrounding the width in the bay, after which, the NED Plan will be refined.

Net Benefits
Benefits minus Cost

Alternatives 4 and 5 display higher BCRs than Alternative 8. These alternatives would result in less cost. Additionally, the net benefits of the two alternatives are competitive with Alternative 8. Alternative 4 would provide for deepening and some widening to allow the Aframax design vessel in Segment 4, provide turning basin improvements and allow vessel meeting for beams wider than the current guideline. Alternative 5 would allow for larger tanker vessels in Segments 4, 5, and 6 and increase loading efficiencies and vessel meeting for beams wider than 105 feet in Segment 4. However, Alternative 8 would provide improvements for all six design vessels and it reasonably maximizes the net benefits. Alternative 8 provides for a full system plan.

Table 5-12 – Final Screening of Alternative Plans ($000)

Alt	First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
	October 2016 Price Level, 2.875 % Discount Rate					
No Action	This alternative does not meet the study objectives. This alternative forms the baseline to which all other alternatives are compared. The No-Action Alternative would not result in additional costs for construction and O&M nor would it provide additional benefits; however, it would not result in environmental impacts.					
1	$513,900	$848,900	$27,700	$59,700	$32,000	2.2
2	$706,300	$1,304,300	$40,800	$47,700	$6,900	1.2
3	$527,000	$1,018,300	$31,300	$26,100	$(5,200)	0.8
4	$129,900	$312,900	$8,500	$60,700	$52,200	7.1
5	$98,400	$126,700	$4,600	$36,800	$32,200	8.0
6	$94,600	$164,100	$5,200	$2,100	$(3,100)	0.4
7	$47,600	$116,200	$3,300	$3,300	$-	1.0
8 (650')	$950,000	$1,849,700	$56,800	$123,100	$66,300	2.2
8 (820')	$1,451,800	$2,727,200	$84,700	$123,100	$38,400	1.5

Final Comparison of Alternatives – **Tables 5-13 and 5-14** provide a list of the pilot rules the PDT has targeted for the study. The alternatives are identified with a "Y" where a rule could be eliminated or reduced in theory. Ship simulations will be performed during the feasibility-level analysis phase of the study and will be used to define the future with-project footprint to provide the dimensions for safe and efficiency transit of vessels. In this comparison, Alternative 8 either eliminates or alleviates all target Pilot Rules.

Telling the Story Chronologically

The story surrounding the selection of the Recommended Plan is provided in the order in which it occurred.

- **Tentatively Selected Plan (TSP)**. Early on we refer to the selection of the TSP, subject to review and analysis. This is the plan provided for Public Coordination with a range of 650-820 feet to cover maximum impacts of channel widening in the Bay Segment and DMMP.
- **NED Plan**. Subsequent to the TSP we arrive at the NED Plan. This plan reflects the outcome of reviews and additional analysis.
- **LPP**. Subsequent to the determination of the NED Plan the NFS decided to pursue a LPP. This is the prerogative of the NFS so long as it's within Policy.
- **Recommended Plan**. This is the final determination of the plan to be recommended for authorization.

Table 5-13 – Pilot Rules Targeted by Each Alternative

Comparison of Alternatives and How they Change Pilot Rules and Practices									
Current Working Rules and Practices (530 foot Channel)	Anticipated Change to Working Rules and Practices	Alternatives							
		1	2	3	4	5	6	7	8
Maximum vessel size 1000-by 138-feet Bolivar Road to Barbours Cut.	Increase vessel LOA to 1200 feet.	Y	Y	Y					Y
Two widebodies meeting in the HSC between Buoy 18 and Beacons 75/76 restricted to 310 combined beam and 85 feet combined draft	Eliminate restriction by widening channel.		Y	Y					Y
Any widebody tanker proceeding with cargo will be daylight restricted above Buoy 18	Eliminate restriction to Beacon 75/76 (Bayport) by widening.		Y	Y					
	Eliminate restriction to Morgans Point by widening								Y
Two widebodies meeting in the HSC between Beacons 75/76 and Boggy Bayou restricted to combined beam of 272 feet and combined draft of 77 feet	No combined beam restriction or combined draft restriction in the widened channel from Beacons 75/76 to Morgans Point. Extend the outbound sailing restriction from the upper reaches by 2 hours.								Y
Containerships with dimensions equal to or greater than 1150-by 141-feet will not be met by any vessel in HSC	Eliminate restriction by widening channel.								Y
Loaded Suezmax tankers will not meet any vessel with a beam above 106 feet above Beacon 18	Loaded Suezmax tankers will meet vessels greater than 106-feet beam in the widened channel to from Beacon 18 to Morgans Point.								Y
Loaded Aframax tankers (approximately 135-by 850-feet) will not meet a larger, loaded vessel	Loaded Aframax tankers will meet larger vessels from Beacon 18 to Morgans Point.								Y
No vessel meeting in Bayport Ship Channel	Combined beam restriction of approximately 212 feet		Y						Y
Containerships with dimensions equal to or greater than 1160-by 150-by 45-feet will transit Bayport Ship Channel and make berth at Dock 1	Containerships with dimensions equal to or greater than 1160-by 150-by 45-feet will berth at all Bayport Container Terminal Docks		Y						Y
Maximum vessel size permitted to transit to Barbours Cut Number 1 is 1158-by 142-feet. When this vessel is at berth, no vessel transits the channel.	The design containership will berth at all Barbours Cut Docks		Y						Y

Table 5-14 – Pilot Rules Targeted by Each Alternative

Comparison of Alternatives and How they Change Pilot Rules and Practices (Continued)									
Current Working Rules and Practices (530 foot Channel)	**Anticipated Change to Working Rules and Practices**	**Alternatives**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
The maximum vessel size of 1158 feet LOA-by 142-feet beam and above docked at Barbours Cut Number 1 will restrict all movement of vessels with beams greater than 106 feet.	All vessels transit the channel when the maximum vessel size (1158-feet LOA-by 142-feet beam and above) is berthed at Docks 1-6.		**Y**						**Y**
Maximum draft above Boggy Bayou to Sims Bayou is 41.5 feet.	Maximum draft increased up to 46.5 feet.	**Y**			**Y**				**Y**
Maximum vessel size from Boggy to Sims Bayou is 750-feet LOA-by 116-feet beam and draft restricted to 41.5 feet.	Increase maximum vessel size to 850-feet LOA-by 138-feet beam and draft up to of 46.5 feet.				**Y**				**Y**
Vessels with > 105-feet beam shall not meet any ship vessel of any size above Boggy Bayou.	Allowable meeting of vessels with >105-feet beam from Boggy to Greens Bayou.				**Y**				**Y**
All vessels > 750-feet LOA and a draft > 39 feet are daylight restricted above the Beltway 8 Bridge.	Allow for vessels of 850-feet LOA-by 138-feet beam feet and draft up to 46.5 feet to move from (Shell) to Greens Bayou without daylight restriction. (Needs widening from CW1_SJM-BB_530)				**Y**				**Y**
Maximum draft from Sims Bayou to Turning Basin is 37.5 feet.	Maximum draft from Sims Bayou to Turning Basin up to 41.5 feet	**Y**				**Y**			**Y**
No car carrier of any size or any other vessel of 325-feet LOA or longer will arrive/depart City Docks #20-32 when required to turn at Brady Island Turning Basin when there is a vessel docked or encroached into City Dock #27. No vessel 580-feet LOA or longer loaded to more than 30-feet draft when required to turn at Brady Island Turning Basin will arrive/depart City Dock #20-32 when there is a vessel docked or encroached into City Dock # 27.	Lift part of all restriction for turning at Brady Island Turning Basin and allow for use of City Dock #27. (Measure TB6_Brady_900 needs further evaluation.					**Y**			**Y**

Appendix G, Table G3.1-1 provides a summary of the environmental impacts of the eight alternatives for comparison.

Each Alternative was formulated in consideration of the four criteria in the P&G: completeness, effectiveness, efficiency, and acceptability as presented in **Table 5-17** and **Table 5-18**. With the exception of the No-Action Alternative, each alternative in the Final Array is considered acceptable. While all of the alternatives which improve the channel in some fashion while avoiding and minimizing environmental impacts to the greatest extent possible during the 50-year period of analysis, only two alternatives (Alternative 1 and 8) would provide system-wide benefits. The plan with the greatest net excess benefits is considered the most complete, efficient, and effective plan. Therefore, Alternative 8 is the plan that best meets the four P&G criteria.

Table 5-15 - Comparison of P&G Evaluation Criteria (Part 1)

Alternative #	No Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Criteria	**FWOP**	**Minimum System Wide Plan**	**Bay Plan**	**Suezmax Plan**	**Aframax Plan**	**Bulkers, Tankers, and Vehicle Carriers Plan**	**Bay Mooring Plan**	**Upper Channel Mooring Plan**	**The Comprehensive Plan**
Acceptability (meets all laws, regulations and guidance)	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Completeness (provides and accounts for all necessary investments or other actions to ensure the realization of the planning objective)	● No Action is an Incomplete solution to all planning objectives	● Minimally complete solution; does not address congestion. ● Provides second most improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Incomplete solution ● Provides improvement in navigation efficiency over No Action ● Does not maximize transportation benefits throughout the entire HSC System.	● Most complete solution ● Provides most improvement in navigation efficiency over all other alternatives ● Maximizes transportation benefits throughout entire HSC System.

Table 5-16 - Comparison of P&G Evaluation Criteria (Part 2)

Alternative #	No Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Criteria	**FWOP**	**Minimum System Wide Plan**	**Bay Plan**	**Suezmax Plan**	**Aframax Plan**	**Bulkers, Tankers, and Vehicle Carriers Plan**	**Bay Mooring Plan**	**Upper Channel Mooring Plan**	**The Comprehensive Plan**
Efficiency (extent to which an alternative plan is the most cost effective means of achieving the objective)	● No Action does not address the planning objective	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Less costly than TSP ● Does not address objective as effectively ● Net excess benefits not maximized and are less than the TSP	● Most costly alternative ● Addresses objectives most effectively ● Highest net excess benefits
Effectiveness (extent to which the alternative plans contribute to achieve the planning objective)	● Ineffective for improving navigational efficiencies	● Second most effective plan for improving navigation efficiency ● This is a minimally system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Not effective as TSP for improving navigation efficiency ● Not a system wide improvement	● Most effective alternative for improving navigation efficiency ● This is a system wide improvement

5.8 PLAN SELECTION (DRAFT REPORT)

Alternative 8 was identified as the TSP in the DIFR-EIS and was selected based upon limited detailed information; the general understanding of the transit restrictions that could be reduced by channel improvements to increase transportation cost savings; the current vessel fleet forecast; historical information regarding environmental conditions requiring mitigation; generalized type of dredged material placement; and general assumptions regarding channel improvement design. Additional economic, engineering, and environmental evaluation is necessary to confirm the final NED Plan. As previously stated, ship simulations were performed during the feasibility-level design and analysis phase of the study to confirm the engineering assumptions made and determine the feasible dimensions of the channel. Final channel dimensions will be refined through more in-depth ship simulations during PED.

Additional Features for Inclusion into Alternative 8 for Further Evaluation and Ship Simulation

Bay Widening for Meeting – As discussed previously in Section 5.5 under Initial Alternatives, the PDT evaluated three methods to determine the range of widths that would be considered for widening the channel in the bay and elected a lesser width than recommended by EM 1110-2-1613. The bay widening was considered in three increments: Bolivar Roads to Redfish, Redfish to BSC, and BSC to BCC. These widths were determined to be of adequate length for meeting and passing of the design vessels in the bay reach. Because limited ship simulation would not possible until after pubic review, the PDT determined that Alternative 8 would be evaluated for a width ranging from 650-feet to 820-feet. This would allow for maximum impacts to be coordinated through the NEPA process. It was agreed that once the limited ship simulations were conducted to establish the necessary dimensions of width required for the meeting and passing of the design vessels in the bay reach, that width would be carried forward and impacts would be reduced while project design was further refined. To assess the range, the impacts were presented for the 650-foot and 820-foot widths.

Further Evaluation of Measures – A limited number of measures listed below were added to be further evaluated as part of the Alternative 8. These features were determined likely to be necessary for the design vessels safe and efficient transit; however, until limited ship simulations could be conducted the PDT determined to include those features until they could be validated as necessary for transit and economically justified. Ultimately, any features not economically justified would be eliminated from Alternative 8.

1. Minor widening of the channel in the bayou portion of the HSC main channel in the Hog Island stretch and two bend easings for maneuverability (**Segment 1);**

2. A turning basin requested by the pilots to provide for additional turning opportunities at the BSC at the mouth of the BSC land-cut (**Segment 2)**;
3. Turning Basin at Station 775+00 would be the most upstream location for Aframax vessels to turn (**Segment 4)**;
4. Hunting Turning Basin to ensure continued Federal maintenance (**Segment 4)**;
5. The alleviation of a channel restriction by widening from the existing 400-feet to 530-feet for a distance of approximately 1.3 miles from just west of the San Jacinto Monument and Boggy Bayou (**Segment 4)**; and
6. Improvement of and consideration of federalizing an existing turning basin located near Brady's Landing (**Segment 6)**

As per Planning Bulletin (PB) 2017-01, paragraph 6.e., there is typically not enough detailed information to conclude that the TSP will ultimately be the NED Plan. Once feasibility-level ship simulations are conducted, a determination of which features and their dimensions that will provide for the safe and efficient navigation of vessels in the channel can be established.

Table 5-13 provides the estimated range of costs for the features included in the TSP. First Cost of the TSP is estimated to range between $950,000,000 and $1,451,800,000.

Table 5-17 – TSP (Inclusive of Features to be Further Evaluated) ($000)

Alt	First Cost	O&M	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits*	Net Benefits*	BCR*
	October 2016 Price Level, 2.875 % Discount Rate						
8(650)[1]	$950,000	$899,700	$1,849,700	$56,800	$123,100	$66,300	2.2
8(820)[2]	$1,451,800	$1,275,400	$2,781,600	$84,700	$123,100	$38,400	1.5

[1] Alternative 8 includes bay widening to 650 feet plus measures for further evaluation; lower range.
[2] Alternative 8 includes bay widening to 820 feet plus measures for further evaluation; higher range.

Table 5-14 provides the estimated range of costs for the TSP less the measures that are carried forward for further engineering safety analysis. The widening range of 650-820 feet is included.

Table 5-18 – TSP (Less Features to be Further Evaluated) ($000)

Alt	First Cost	O&M	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits*	Net Benefits*	BCR*
	October 2016 Price Level, 2.875 % Discount Rate						
8(650)[1]	$804,000	$714,000	$1,517,600	$47,100	$121,500	$74,400	2.6
8(820)[2]	$1,310,000	$1,089,500	$2,395,100	$75,000	$121,500	$46,500	1.6

[1] Alternative 8 includes bay widening to 650 feet less measures for further evaluation; lower range.
[2] Alternative 8 includes bay widening to 820 feet less measures for further evaluation; higher range.

Federalization of Non-Federal Improvements for which USACE has Assumed Maintenance

Concurrent with the development of the TSP, improvements to the Jacintoport Channel, BSC, BCC, and Greens Bayou Channel by the NFS are also being recommended for federalization. A

review of the non-Federal improvements will be conducted to determine whether it is in the Federal interest to include the existing improved dimensions as part of this recommendation for Federal authorization.

- AOM for the Jacintoport Ship Channel was conducted under Section 5001(a)(9) of WRDA 2007 (**Segment 1**); and

- The Federal Government authorized the assumption of O&M of the BSC and BCC Improvement Project under Section 204(f) of WRDA 1986, as amended (**Segments 2 and 3, respectively**);
- AOM of Greens Bayou Channel by the Federal Government was conducted under WRDA 1986 (**Segment 4**)

Federalization of these improvements would be to the dimensions provided below. These improvements are included in the FWOP condition. For the BSC and BCC, the additional modifications recommended under the TSP are noted in the second bullets.

Jacintoport Channel (**Segment 1**): This study also recommends federalization of the Jacintoport channel (a side channel of the HGNC Federal navigation project) to a depth of 41.5 feet. The analysis completed under Section 5001 of WRDA 2007 confirmed the Federal interest of this channel.

Bayport Ship Channel (**Segment 2**):

- The NFS improvements resulted in a channel 46.5-feet deep by 400-feet wide from the HSC to the Land Cut and 350-feet wide from the Land Cut to Turning Basin; and
- The TSP recommends further modification to widen the entire BSC 46.5-feet deep channel from 400 feet wide to 455-feet wide.

Barbours Cut Channel (**Segment 3**):

- The NFS improvements resulted in a channel 46.5-feet deep by 300-feet wide; and
- The TSP recommends further modification to widen the BCC 46.5-feet deep channel from 300 feet wide to 455- feet wide.

Greens Bayou Channel (**Segment 4**) is 1.6-mile long combination deep (41.5 feet) and shallow draft (16.5 feet) that serves multiple facilities adjacent to the HSC. This study includes Greens Bayou Channel and confirms the economic benefits of maintaining this channel at the aforementioned depths.

Benefit of Federalizing non-Federal Improvements

The existing HSC system is currently governed under at least seven separate authorities and agreements. The intent of including all components of the system under a single study is to synergize the system; federalization of these features does not result in additional project costs as the Government has already assumed the maintenance for these improvements. By authorizing the system in its entirety, all future channel construction and maintenance activities would be governed under the same rules. The resulting DMMP would be more effectively managed by the Government than the current segmented system and instead of multiple agreements could be covered under one PPA. Ultimately the following channels (and associated features) and maintenance would come under one single authorization: HSC main channel (**Segments 1, 4, 5 and 6**), Jacintoport Channel (connects to **Segment 1**), BSC **(Segment** 2), and BCC (**Segment 3**), and Greens Bayou Channel (connects to Segment 4). The location of these channels is shown later in the report in **Figure 6-1**.

5.8.1 NED Benefits

For the purposes of Deep Draft Navigation Economic Analysis per ER 1105-2-100, an NED benefit may include the following:

1) Reduced cost of transportation through use of vessels (modal shift) , through safer or more efficient operation of vessels and/or use of larger and more efficient vessels (channel enlargement), and through use of new or alternate vessel routes (new channels or port shift)
2) Increased net return to producers from access to new sources of lower cost materials, or access to new and more profitable markets (shift of origin or destination)
3) Increased production through new or greater production opportunity (commercial fishing and offshore minerals), or new economic activities involving new commodity movements (induced movements)

NED benefits are estimated by calculating the total costs to transport the forecasted cargo through the unmodified (without project) harbor system and through each alternative scenario using the HarborSym Modeling Suite of Tools. Benefits for each alternative are calculated by subtracting the total transportation costs for that alternative, from the total transportation costs for the same cargo under the without-project conditions. Net benefits are then calculated by subtracting the total costs to implement each alternative from the benefits that would result from implementing that alternative. Positive net benefits (where cost savings exceed implementation costs) are considered contributions to the NED account. NED benefits are normally expressed in terms of average annual net benefits that are calculated over the 50-year period of analysis. The calculations consider the timing of the expenditures and benefits by applying a discount rate that converts the dollar value of costs and benefits received at different time-periods to present value.

NED benefits include origin-to-destination benefits, meeting area benefits, moorage benefits, and tide delay reduction benefits. Origin-to-destination benefits are primarily derived "at-sea" based on the ability to utilize different vessels or to load more cargo onto them based on differing harbor condition scenarios. For deepening alternatives, most origin-to-destination benefits result from efficiencies related to the ability to use the additional draft to deploy larger, more efficient vessels and/or to transport more cargo on the same vessels and reducing the total number of trips needed to transport a given volume of cargo. Meeting area, moorage, and tide delay reduction benefits are derived near and within the harbor and result from a reduction in transit times needed to navigate the harbor. These benefits are normally smaller than the associated origin-to-destination benefits and are attributable to increased flexibility of harbor operations resulting from fewer tide delays, less concentrated traffic during high tides, and the ability of vessels to pass within the harbor (minimizing or eliminating the need for one-way traffic restrictions).

Refer back to **Table 5-10** for information on benefits for each of the alternatives. Refer back to **Table 5-11** for an analysis for each of the measures within Alternative 8, the TSP, including those carried forward for further evaluation in regards to safety. Engineering and environmental evaluation will be conducted during the feasibility-level analysis phase of the study to determine whether these features remain, or are eliminated from the TSP.

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6 RECOMMENDED PLAN

6.1 Refined NED Plan

Engineering and environmental evaluation was conducted during the feasibility-level design and analysis phase to refine Alternative 8 and to determine which features would remain and which features would be eliminated from the NED Plan. Feasibility-level ship simulations conducted in cooperation and oversight by ERDC estimated that channel widening in the bay for meeting and passing opportunities should be 700 feet. The Bolivar Roads to Redfish Reef increment is economically justified. The other two increments in the bay reach (Redfish Reef to BSC and BSC to BCC) are not included in the NED Plan. Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less. Therefore, the other two widening increments in the bay were eliminated from the NED Plan. Additionally, after further evaluation, other features determined not to be economically justified were eliminated. These features include:

- TB2_BSCRoRo: Ship simulation and engineering design showed that the existing turning basin at BSC could be designed to accommodate the design vessel. The additional turning basin (TB2_BSCRoRo) was not economically justified or necessary to realize benefits at BSC; therefore, it was removed from the NED plan.
- Upper Bay Bend Easings (CW1_Hog_600, BE1_153+06, and BE1_246+54): Ship simulation showed that these bend easings are not necessary for design vessel transit and are not economically justified; therefore, they were removed from the NED plan.
- SJM-BB Widening: Ship simulation showed that channel widening from SJM-BB would not be necessary for design vessel transit. The measure is not economically justified and was removed from the NED plan.
- TB4_775+00: Additional analysis completed post-TSP determined that this turning basin was not required to realize economic benefits given that docks in the study area include and will include T-Slips, allowing for turning without the need for a turning basin. TB4_Hunting will also be improved and will replace any need for TB4_775+00

Further investigations also confirmed that the turning basins at Hunting Bayou and Brady Island were authorized as part of the 36-foot Federal project under House Document 561, 80th Congress, 2nd Session, on 30 June 1948. Therefore, these two turning basins have been retained in the NED plan. **Table 6-1** provides the features of the NED Plan. **Table 6-2** displays the updated benefit-cost comparison of the eight alternatives. The results affirm that Alternative 8 maximizes net benefits and is the NED plan.

Table 6-1 – Description of the HSC ECIP NED Plan per Segment

Segment 1 – Bolivar Roads to Boggy Bayou

- Widen 11 miles of lower bay channel from 530 feet to 700 feet (Bolivar Roads to Redfish Reef) with associated barge lane relocations
- Bend easing in four locations with associated barge lane relocations

Segment 2 – Bayport Ship Channel

- BSC flare expansion
- Widen BSC from existing 300-400 feet to 455 feet

Segment 3 – Barbours Cut Channel

- BCC combined flare and turning basin
- Widen BCC from existing 300 feet to 455 feet

Segment 4 – Boggy Bayou to Sims Bayou

- Deepen HSC from Boggy Bayou to Hunting Turning Basin from the existing 41.5-foot depth up to 46.5 feet
- Widen HSC from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet
- Improvements to Hunting Turning Basin

Segment 5 – Sims Bayou to the I-610 Bridge

- Deepen HSC from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin

- Deepen HSC from I-610 Bridge to Main Turning Basin from existing 37.5-foot depth up to 41.5 feet deep
- Improvements to Brady Island Turning Basin

Table 6-2 - Final Screening of Alternative Plans ($000)

Alt	First Cost	Project Cost + OMRR&R	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
	October 2016 Price Levels, 2.875 % Discount Rate					
No Action	This alternative does not meet the study objectives. This alternative forms the baseline to which all other alternatives are compared. The No-Action Alternative would not result in additional costs for construction and operations and maintenance (O&M), would not provide additional benefits, and would not result in environmental impacts.					
1	$441,400	$615,638	$21,100	$58,300	$37,200	2.8
2	$438,371	$626,666	$21,200	$30,100	$8,900	1.4
3	$313,771	$517,524	$16,900	$9,700	$(7,200)	0.6
4	$81,829	$188,603	$5,000	$35,100	$30,100	7.0
5	$98,405	$126,677	$4,400	$36,800	$32,400	8.4
6	$94,572	$164,125	$5,200	$2,100	$(3,100)	0.4
7	$47,644	$116,240	$3,300	$3,300	$-	1.0
8	$634,051	$1,048,607	$33,700	$79,900	$46,200	2.4

6.2 NFS Locally Preferred Plan

The PHA decided to move forward with a Locally Preferred Plan (LPP). On May 31, 2019, the PHA provided a letter of support for an LPP. The District submitted the request to the ASA(CW) for approval to recommend a LPP as the Recommended Plan. The ASA(CW) granted approval to recommend a LPP in a memorandum dated August 5, 2019. In accordance with ER 1105-2-100, study recommendations may deviate from the NED plan if requested by the NFS and approved by the ASA(CW). If the sponsor prefers a plan more costly than the NED plan and the increased scope of the plan is not sufficient to warrant full Federal participation, the ASA(CW) may grant a waiver from the requirement to recommend the NED Plan as long as the sponsor pays the

difference in cost between the NED Plan and what is known as the LPP. In this case, the LPP must have similar outputs in kind, and equal to or greater than the outputs of the NED Plan. It may also have other outputs. The incremental benefits, impacts, and cost of the LPP, beyond the NED Plan, must be analyzed and documented in the FIFR-EIS.

6.3 Deviation from the NED Plan – Reasons for the LPP

PHA desires two-way traffic throughout the Bay from Bolivar Roads to BCC. While the NED plan provides opportunity for meeting and passing between Bolivar Roads and Redfish; the additional increments of widening (Redfish-BSC and BSC-BCC) of the desired LPP would allow two-way traffic of the design vessel up to BCC. The PHA has formally requested that the LPP plan be considered the Recommended Plan and is willing to pay 100 percent of the cost for the increment over the cost of the NED Plan. **Table 6-3** provides the features of the LPP.

Table 6-3 - Description of the HSC ECIP LPP per Segment (LPP features in Italics)

Segment 1 – Bolivar Roads to Boggy Bayou
- Widen 11 miles of lower bay channel from 530 feet to 700 feet (Bolivar Roads to Redfish Reef) with associated barge lane relocations
- Widen *approximately 10 miles of channel from 530 feet to 700 feet (Redfish Reef to Bayport Ship Channel) with associated barge lane relocations.*
- *Widen approximately 5 miles of channel from 530 feet to 700 feet (Bayport Ship Channel to Barbours Cut Channel) with associated barge lane relocations.*
- Bend easing in four locations with associated barge lane relocations

Segment 2 – Bayport Ship Channel
- Widen BSC from existing 300-400 feet to 455 feet

Segment 3 – Barbours Cut Channel
- BCC combined flare and turning basin
- Widen BCC from existing 300 feet to 455 feet

Segment 4 – Boggy Bayou to Sims Bayou
- Deepen HSC from Boggy Bayou to Hunting Turning Basin from the existing 41.5-foot depth up to 46.5 feet
- Widen HSC from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet
- Improvements to Hunting Turning Basin

Segment 5 – Sims Bayou to the I-610 Bridge
- Deepen HSC from Sims Bayou to I-610 Bridge from the existing 37.5-foot depth up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin
- Deepen HSC from I-610 Bridge to Main Turning Basin from existing 37.5-foot depth up to 41.5 feet deep
- Improvements to Brady Island Turning Basin

6.4 Comparison between the NED Plan and LPP

Details concerning the formulation and screening process to determine the least cost DMMP for the NED Plan and the LPP can be found in **Appendix R – HSC System DMMP, Section 5.8.** Descriptions, plans and cross-sections for the DMMP features (e.g. long bird island, oyster reef pad construction, etc.) are available in the **Engineering Appendix, Section 4.8**. Various strategies and dredging methodologies are discussed for the placement of dredged materials in the **DMMP, Section 5.2**. Figures of the NED and LPP DMMPs (new work and O&M) are provided in **Appendix R, Section 5.10**.

6.4.1 Dredged Material Management Plan for NED Plan and LPP

Table 6-4 provides the least cost dredge material placement plan for the NED Plan. More details are provided in **Appendix R, Table 5-6.**

Table 6-5 provides the least cost dredge material placement plan for the LPP. More details are provided in **Appendix R, Table 5-7**. The DMMPs for the NED Plan and LPP handle the dredge material in Segments 3, 4, 5, and 6 the same. The difference between the plans are in Segments 1 and 2.

Table 6-4 – NED Placement Plan

Dredge Material Management Plan for the HSC ECIP NED Plan									
Segment and Features		**PA/BU Site**	**Stations**	**NW Plan Description**	**NW Req. (KCY)**	**NW Avail. (KCY)**	**First Cost ($000's)**	**O&M Plan Description**	**50-YR Total Incremental Cost ($000's)**
1	BE1_138+369_700 BE1_128+731_700 BE1_078+844_700 CW1_BR-Redfish_700	B18a B18b ODMDS	138+369 - 100+00	NW channel widening to Long Bird Island	1,172[1]	1,994	$94,400	BR-RF: ODMDS	$19,400
				NW channel widening to 8-AC Bird Island	910[1]				
			100+000 - 073+934	NW channel widening to ODMDS	3,038	3,038			
1, 2	BE1_028+605_530	B18c ODMDS	031+171 - 028+605	NW bend easing to Bird Island Marsh	4,500[1]	260	$122,400	RF-BSC: B18c, Mid Bay PA, ODMDS	$264,300
			028+605 - 026+028			165		BSC-BCC: PA15, ODMDS	
	CW2_BSC_455		25+58 - 221+00	NW channel widening to Bird Island Marsh		2,108		BSC: PA14, Connection, ODMDS	
	BE2_BSCFlare		203+66 - 239+00	NW flare widening to Bird Island Marsh		1,925		BSC Flare: PA14, Connection, B29	
3	CW3_BCC_455 BETB3_BCCFlare	B6b	08+78 - 67+11	NW channel/flare widening to Atkinson Marsh Cell M12	2,300[1]	2,825	$108,600	BCC & Flare: Spilman, BABUS, B6b, ODMDS	$96,900
4	CW4_BB-GB CD4_Whole	BB1	684+03 - 850+00	NW widening/deepening to even lift on BW8	2,920	3,272	$115,500	BB-GB: Lost Lake, BABUS	$129,800
		BB2	850+00 - 930+00	NW deepening to even lift on E2 Clinton	352			GB-SB: Rosa Allen, Rosa Allen Exp., East Clinton	
5	CD5_Whole	BB9a	1110+78 - 1160+62	NW deepening to even lift on Glendale PA.	176	176	$6,500	Sims to 610: West Clinton, BABUS	$4,500
6	CD6_Whole TB6_Brady_900	BB9a	1160+62 - 1266+49	NW deepening to even lift on Glendale PA.	734	734	$38,800	610 to Main TB: West Clinton, House Tract, BABUS	$27,200
		BB9b	00+00 - 30+95	NW deepening to even lift on Filterbed PA	267	267			
				TOTALS	**15,369**	**16,764**	**$486,200**		**$542,100**

[1]All material is dredged and costs are accounted for in the estimate. Final PA sizes to be determined through additional geotechnical and engineering evaluations in PED

TABLE LEGEND

BE=Bend Easing
CW=Channel Widening
CD=Channel Deepening
NW=New Work
BR-RF=Bolivar Roads to Redfish
BABUS – Bay Aquatic BU Site
B18a – Long Bird Island
B18b – 8 acre Bird Island
B18c - 3-Bird Island Marsh
B6b – Cell M12
BB1 – Develop BW8 site
BB2- Develop E2 Clinton PA
BB9a – Glendale PA
BB9b – Filterbed PA
***B29 is** used in **DMMP Appendix** for Existing ODMDS*

Table corresponds with Table 5-6 from Appendix R, DMMP.

Table 6-5 – LPP Placement Plan

Segment and Features		PA/BU Site	Stations	NW Plan Description	NW Req. (KCY)	NW Avail. (KCY)	First Cost ($000's)	O&M Plan Description	50-YR Total Incremental Cost ($000's)
1	BE1_138+369_700 BE1_128+731_700 BE1_078+844_700 CW1_BR-Redfish_700	B18a B18b ODMDS	138+369 - 100+00	NW channel widening to Long Bird Island	1,172[1]	1,994	$94,400	BR-RF: ODMDS	$19,400
				NW channel widening to 8-AC Bird Island	910[1]				
			100+000 - 073+934	NW channel widening to ODMDS	3,038	3,038			
1, 2	CW1_Redfish-BSC_700	B18c B20 ODMDS	073+794 - 028+605	NW channel widening to ODMDS	2,474	2,474	$172,800	RF-BSC: B18c, ODMDS, Mid Bay PA	$291,100
				NW channel widening to Oyster Mitigation	2,030[2]	2,030			
				NW channel widening to Bird Island Marsh	4,500[1]	3,181			
	CW2_BSC_455		25+58 - 221+000	NW channel widening to Bird Island Marsh		2,108		BSC & Flare: B6a, B6c, PA14, Connection, ODMDS	
1	CW1_BSC-BCC_700	B6c	-3.94 - 28+605	NW channel widening to Atkinson Marsh Cell M11	2,800[1]	2,800	$118,500	BSC-BCC: B6a, B6c, PA15, ODMDS	$115,700
		B6a		NW channel widening to Atkinson Marsh Cell M7/8/9	600[1]	1,000			
		B10		NW channel widening to Sed. Attn. Feature	800[1]	1,541			
3	CW3_BCC_455 BETB3_BCCFlare	B6b	08+78 - 67+11	NW channel/flare widening to Atkinson Marsh Cell M12	2,300[1]	2,825	$108,600	BCC & Flare: Spilman Island, BABUS, B6b, ODMDS	$96,900
4	CW4_BB-GB CD4_Whole	BB1	684+03 - 850+00	NW widening/deepening to even lift on BW8	2,920	3,272	$115,500	BB-GB: Lost Lake, BABUS	$129,800
		BB2	850+00 - 930+00	NW deepening to even lift on E2 Clinton	352			GB-SB: Rosa Allen, Rosa Allen Exp., East Clinton	
5	CD5_Whole	BB9a	1110+78 - 1160+62	NW deepening to even lift on Glendale PA.	176	176	$6,500	Sims to 610: West Clinton, BABUS	$4,500
6	CD6_Whole TB6_Brady_900	BB9a	1160+62 - 1266+49	NW deepening to even lift on Glendale PA.	734	734	$38,800	610 to Main TB: West Clinton, House Tract, BABUS	$27,200
		BB9b	00+00 - 30+95	NW deepening to even lift on Filterbed PA	267	267			
				TOTALS	**25,073**	**27,440**	**$665,100**		**$684,600**

[1] *All material is dredged and costs are accounted for in the estimate. Final PA sizes to be determined through additional geotechnical and engineering evaluations in PED*
[2] Oyster mitigation varies by PA/BU type

TABLE LEGEND
BE=Bend Easing
CW=Channel Widening
CD=Channel Deepening
NW=New Work
BR-Redfish=Bolivar Roads to Redfish
BABUS – Bay Aquatic BU Site
B18a – Long Bird Island
B18b – 8 acre Bird Island
B18c - 3-Bird Island Marsh
B20 – Oyster Mitigation Sites
B10 – Sedimentation Attenuation Structure
B6a – Cell M7/8/9
B6b – Cell M12
BB1 – Develop BW8 site
BB2- Develop E2 Clinton PA
BB9a – Glendale PA
BB9b – Filterbed PA
***B29 is** used in **DMMP Appendix** for Existing ODMDS*

Table corresponds with Table 5-7 from Appendix R, DMMP.

6.4.2 Economic Comparison

The PHA has elected to pay 100 percent of the cost over the NED Plan. **Table 6-6** displays a comparison of the costs and benefits between the NED Plan and the LPP Plan.

Table 6-6 - Equivalent Annual Costs and Benefits for NED Plan and LPP ($000)

Category	NED Plan	LPP
	October 2019 Price Levels, 2.75% Interest Rate	
Total Project Construction Costs	$746,649	$959,661
Interest During Construction	$12,612	$19,477
Total Investments Cost	**$759,261**	**$979,138**
Construction Average Annual Costs	$28,123	$36,268
OMRR&R	$13,883	$16,983
Total Average Annual Costs	**$42,006**	**$53,251**
Average Annual Benefits	$114,683	$133,551
Net Annual Benefits	$72,677	$80,300
Benefit to Cost Ratio	**2.73**	**2.51**

Table 6-7 provides a comparison of the NED Plan and LPP Project First Cost and Fully Funded Cost.

Table 6-7 – Cost Comparison between NED Plan and LPP ($000)

Cost Account and Item Description		NED Plan		LPP Plan	
		Project First Cost	Fully Funded Cost	Project First Cost	Fully Funded Cost
		October 2019 Price levels; FY20 Federal Discount Rate (2.75 %)			
Construction Item					
1	Lands & Damages (100% non-Federal)	$14,624	$16,040	$14,658	$16,077
2	Relocations	$34,571	$37,851	$37,350	$40,927
6	Fish & Wildlife Mitigation	$54,207	$60,960	$81,758	$91,511
12	Navigation	$484,094	$560,580	$638,862	$729,274
30	Planning, Engineering & Design	$50,126	$57,704	$66,322	$75,257
31	Construction Management	$28,644	$34,003	$37,898	$43,866
	Total Project Costs	**$666,265**	**$767,138**	**$876,848**	**$996,912**
Associated Costs					
12	Navigation Aids (100% Federal - USCG) [1]	$3,869	$4,332	$4,609	$5,122
12	Local Service Facilities (100% non-Federal) [2]	$76,516	$85,683	$78,204	$87,573
	Associated Costs Subtotal	**$80,385**	**$90,016**	**$82,813**	**$92,696**
	Total Project Costs plus Associated Costs	**$746,650**	**$857,154**	**$959,661**	**$1,089,608**

[1] Other non-Federal costs that are not part of the recommended Federal project but are another Federal agency responsibility.
[2] Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.

6.4.3 Environmental Comparison

Construction of the NED Plan or LPP would result in dredging impacts to oyster reef and shell hash habit. Oyster mitigation was coordinated with the BUG and would include restoration of healthy oyster reefs that were damaged by Hurricane Ike in 2008. This would be done through construction of reef pads in Galveston Bay. The LPP results in greater impacts to oysters due to the additional two increments of widening in the bay, resulting in about 288 more acres of oyster mitigation required than the NED Plan. **Table 6-8** provides a summary comparison between the NED Plan and LPP. Detailed information regarding the oyster mitigation and the reef surveys conducted during the feasibility phase can be found in **Appendix G, Section 3.2.2.3 and Section 3.5, and in Appendix P-1**.

Table 6-8 – Summary of Oyster Impacts and Mitigation Required for NED and LPP

Oyster Dredging Impact[1]	NED	LPP
	Net Acres Impacted	
Bolivar Roads to Redfish Reef	35[2,3]	35.0[2,3]
Redfish Reef to BSC	17.25[4]	223.0[3]
BSC to BCC	N/A	143.3[3]
HSC Bend Easing 28+605	13.7	N/A
BSC Widening to 455-feet	5.0	5.0
BSC Flare Easing	13.5	N/A
BCC Combo Flare / Turning Basin	3.3	3.3
Totals	**88.3**	**409.6**
Mitigation Required	**85.1**	**376.4**

[1] Impacts after density adjustments (for detailed information see Appendix G, Table G3.2-1 Direct Impacts of NED and LPP Measures with Mapped Reefs or Appendix P, Table 5 for detailed information).
[2] In LPP Version bend easing at 28+605 is within the 700-foot widening whereas in the NED version the bend easing is standalone.
[3] Impacts revised to account for previous Barge Lane Mitigation (see tables in note [1]).
[4] NED Plan requires a transition from 700-feet to 530-feet for the Bolivar Roads to Redfish Reef widening. This transition impacts an additional 17.8 acres of oyster reef.

Additionally, there would be identical wetland impacts for the NED Plan and the LPP during construction of two proposed new work upland PAs and an expansion of the Rosa Allen PA during O&M. Either plan would impact 63.4 acres of forested wetlands for construction of the Beltway 8 PA and the Rosa Allen PA Expansion. Approximately 8.7 acres of emergent wetlands would be impacted for construction of the E2 Clinton PA.

6.5 RECOMMENDED PLAN

The HSC ECIP Recommended Plan to implement navigation improvements is the LPP. The Recommended Plan allows for two-way traffic throughout the Bay and includes additional DMMP features over the least cost DMMP of the NED Plan. Additional oyster mitigation is required for the Recommended Plan to offset environmental impacts. The Recommended Plan meets the objectives of the study (**Section 4-3**) while avoiding the constraints (**Section 4-4**). The PHA has

agreed to pay the additional cost or difference between the NED Plan and the Recommended Plan, including future O&M costs that are greater than the NED Plan.

6.6 RECOMMENDED PLAN COMPONENTS

The Recommended Plan would provide for safe and efficient navigation in the HSC. Additionally, NFS improvements would be added to the Federal Project. Recommended Plan components are provided below. **Figure 6-2** provides an overview of the Recommended Plan.

- Four bend easings on main HSC channel with associated relocation of barge lanes (**Segment 1**);
- Widening the HSC main channel between Bolivar Roads and BCC from the existing 530-foot width to 700 feet with associated relocation of barge lanes (**Segment 1**);
- Widen BSC on north side of channel to 455 feet (**Segment 2**);
- Widen BCC on north side of channel 455 feet (**Segment 3**);
- Widen BCC flare on north and south to create a 1,800-foot diameter turning basin (**Segment 3**);
- Deepen the HSC main channel from Boggy Bayou to Hunting Turning Basin up to 46.5 feet (**Segment 4**);
- Widen the HSC main channel from Boggy Bayou to Greens Bayou from the existing 400-foot wide channel up to 530 feet (**Segment 4**);
- Deepen the HSC main channel from Sims Bayou to I-610 Bridge up to 41.5 feet (**Segment 5**);
- Deepen the HSC main channel from I-610 Bridge to Main Turning Basin up to 41.5 feet (**Segment 6**);
- Improve Brady Island turning basin to 900-foot diameter (**Segment 6);**
- Inclusion into the Federal Project, the Greens Bayou Channel, a 1.6-mile-long combination 41.5-feet and 16.5 feet deep channel (**Segment 1**); and
- Inclusion into the Federal Project, the Jacintoport Channel measuring 0.76-mile long by 41.5 feet deep (**Segment 4**)

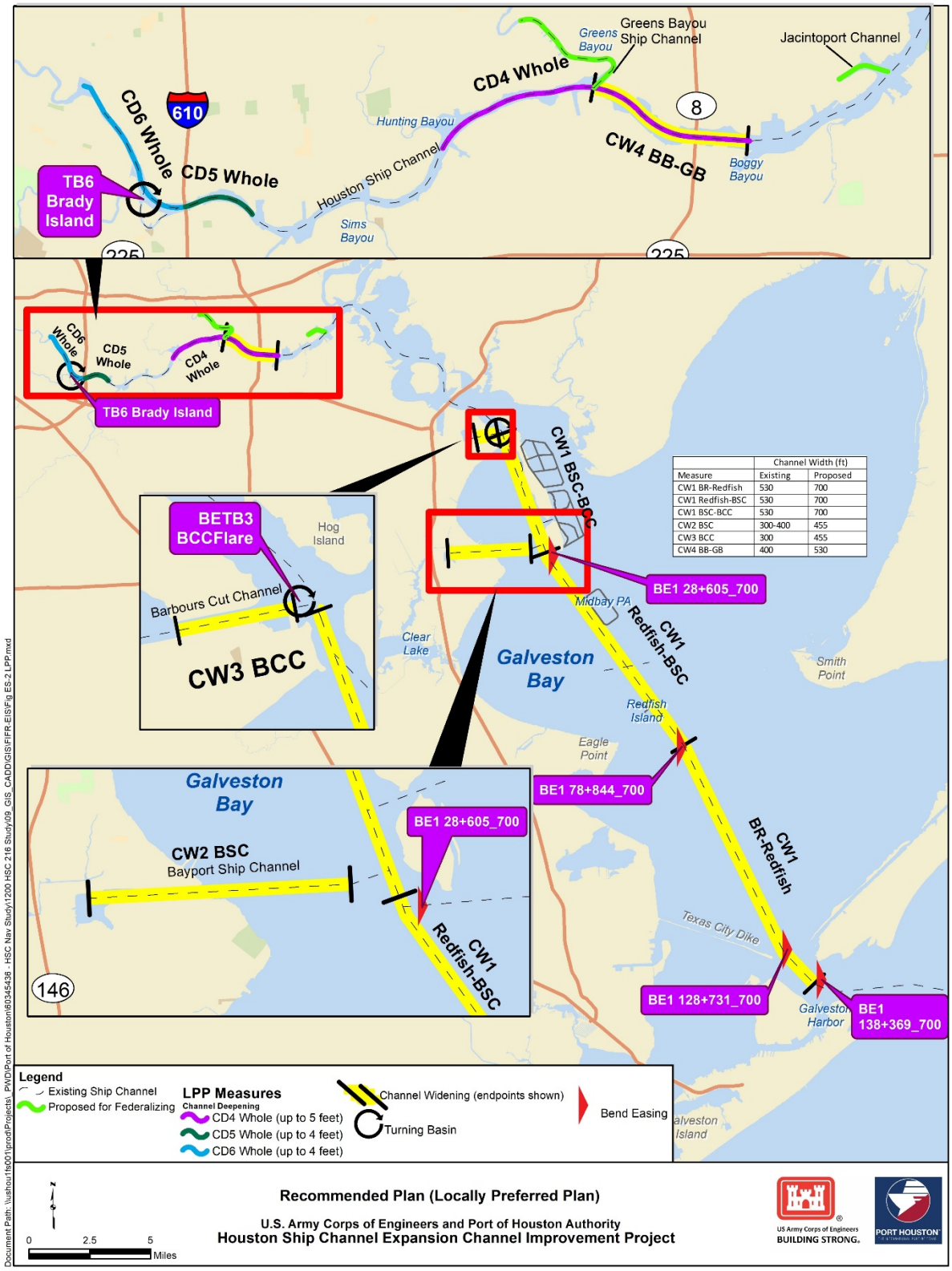

Figure 6-1 – Recommended Plan

6.6.1 Dredged Material Management for Recommended Plan

The estimated quantities of new material from construction of the Recommended Plan and the resulting incremental shoaling of those features in addition to the expected O&M shoaling of the existing HSC system are shown in the **Table 6-9**.

For specific information regarding how the new work and the incremental 50-year shoaling were determined, see **Section 5.1 and Section 5.2 of Appendix C**. Details regarding how the channel might be dredged, specific quantities by reach and section of channel and potential placement strategies are described in the DMMP in **Appendix R, Section 7**. As detailed in **Appendix R, Section 7**, the channel segments and reaches are maintained on varying intervals ranging from 1-6 years. The amount dredged over the 50-year life of the project as detailed in the DMMP may be less than the total shoaling volume in the channel from 2029-2079 depending on the interval of dredging frequency. Shoaling volumes include advanced maintenance and allowable overdepth.

Table 6-9 – Summary of New Work & 50-Year Maintenance Quantities for Recommended Plan

Segment	Recommended Plan	NW (Table 3-2 DMMP)	O&M – 50 Year[2]		
			FWOP[1] (Table 2-7 DMMP)	Incr. (Table 7-2 DMMP)	Total
		(CY)			
1	CW1_BR-Redfish	3,922,000	4,960,000	2,160,000	11,042,000
	CW1_Redfish-BSC	8,794,000	73,446,000	27,635,000	109,875,000
	CW1_BSC-BCC	5,341,000	38,572,000	12,655,000	56,568,000
2	BSC Channel	2,108,000	65,553,000	6,394,000	74,055,000
3	BCC Channel	2,825,000	19,573,000	10,580,000	32,978,000
4	Boggy Bayou – Greens Bayou	2,412,000	5,685,000	5,826,000	13,923,000
	Greens Bayou – Sims Bayou	860,000	10,869,000	988,000	12,717,000
5	Sims Bayou to I-610 Bridge	176,000	2,391,000	212,000	2,779,000
6	I-610 Bridge to Turning Basin	1,000,000	10,726,000	1,330,000	13,056,000
Totals		**27,438,000**	**231,775,000**	**67,779,000**	**326,993,000**

[1] Existing shoaling includes Fed and non-Fed.
[2] These quantities do not include FWOP where modifications to the channel were not made (i.e. Segment 1 from Morgans Point to Boggy Bayou, Jacintoport Channel, Greens Bayou Channel, Turkey Bend Channel, and Light Draft Channel).
Note: Full 700-foot channel widening; no BE1_028+605 or BE2_BSCFlare.

The DMMP for the Recommended Plan was shown previously in **Table 6-5**.

6.6.1.1 Description of System-Wide DMMP

O&M quantities for the entire HSC System are provided in **Table 6-10.** The Study Segments (1-6) covered from Bolivar Roads to the Main Turning Basin. No modifications were considered beyond the Main Turning Basin; however, those sections of channel are part of the HSC System and are included in the table below.

Table 6-10 – HSC System-Wide 50-Year DMMP by Dredging Reach

Study Segment	Reach Description	Placement Area Used	Average Dredging Frequency (Year)	Total Shoaling Rate per Cycle (KCY)	No. of Cycles in 50-Yr Analysis Period	Total 50-Yr Shoaling Volume (KCY)
1	HSC Bolivar Roads to Redfish Reef	ODMDS	4	570	13	7,120
1	HSC Redfish Reef to Bayport	Mid Bay, B.I.M, ODMDS	3	6,065	17	101,081
1	HSC Bayport to Morgans Point	PA15, M7/8/9, M11, ODMDS	3	3,074	17	51,226
2	Bayport Ship Channel & Turning Basin	PA14, Connection, ODMDS	2	1,214	25	30,355
2	Bayport Ship Channel Flare	PA14, Connection, M7/8/9, M11, ODMDS	1	832	50	41,591
3	Barbours Cut Channel	Spilman, M12, BABUS, ODMDS	3	1,809	17	30,153
1	HSC Morgans Point to Exxon	Spilman, Alexander, BABUS	3	3,864	17	64,403
1	HSC Exxon to Carpenters Bayou	Peggy Lake, Lost Lake, BABUS	3	1,405	17	23,418
1	HSC Carpenters Bayou to Boggy Bayou	Lost Lake, BABUS	4	1,328	13	16,605
4	HSC Boggy Bayou to Greens Bayou	Lost Lake, BABUS	4	921	13	11,512
4	HSC Greens Bayou to Sims Bayou	Rosa Allen, Rosa Allen Expansion, BABUS	5	1,186	10	11,856
5	Greens Bayou	East Clinton, BABUS	6	621	8	5,179
5	HSC Sims Bayou to Turning Basin	House Tract, West Clinton, BABUS	6	1,063	9	8,860
6	HSC Main Turning Basin	House Tract, BABUS	3	348	17	5,800
Beyond Segment 6 but included in HSC System	HSC Upper Turning Basin	BABUS	3	106	17	1,761
	Light Draft Channel	BABUS	6	76	8	633
	Turkey Bend Channel	BABUS	6	15	8	126
	Turkey Bend Cut-off Channel	BABUS	6	25	8	206
		TOTAL	-	-	-	**411,884**

Data from Table 7-4 in Appendix R, DMMP

Figure 6-2 shows all placement areas (inclusive of BU) for the HSC System.

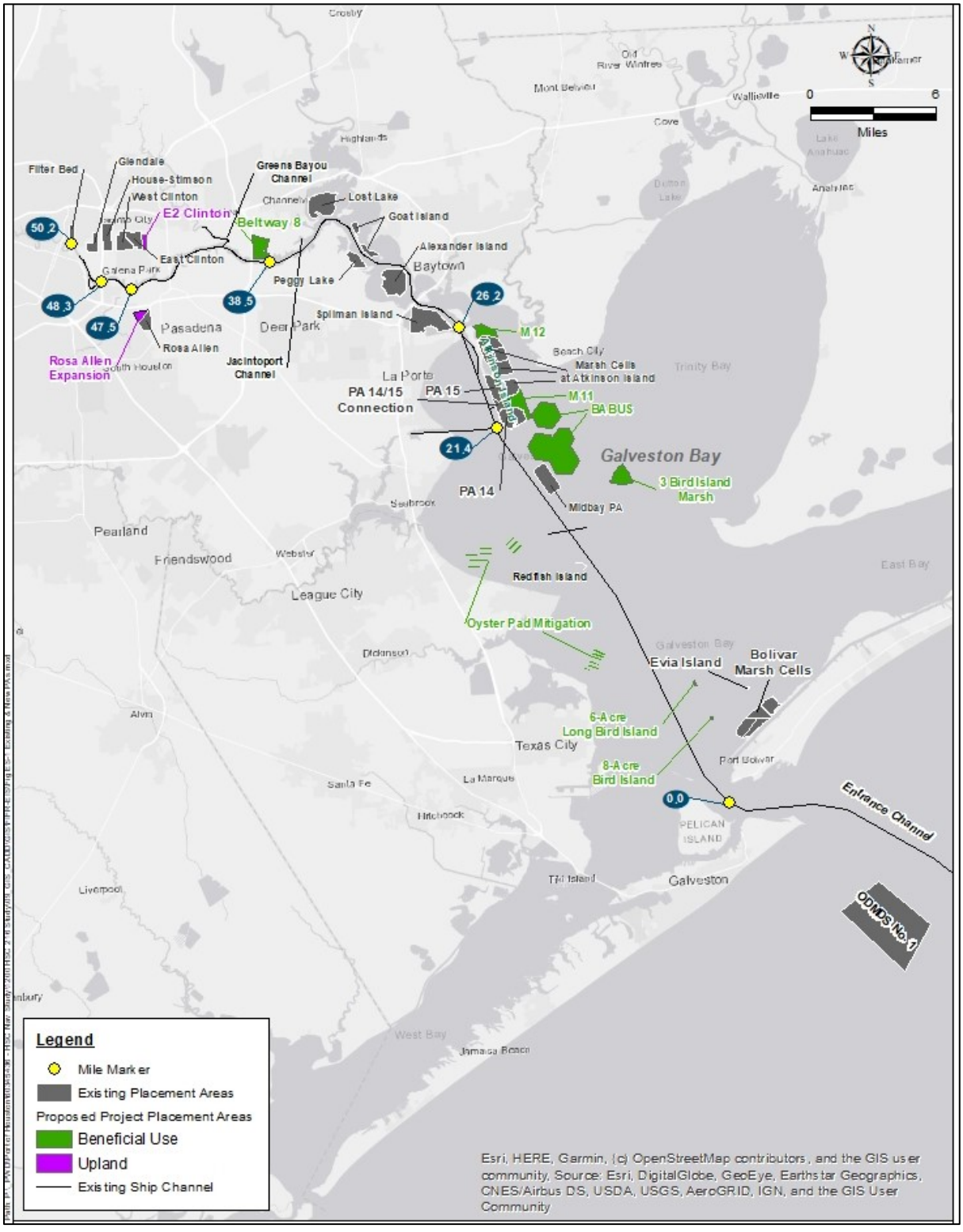

Figure 6-2 – Placement Locations for the HSC System (Future With-Project)

6.6.2 Environmental Impacts

The environmental impact and compliance with environmental statutes for the NED Plan and the Recommended Plan are summarized in **Section 6.4.3** and **Section 6.14**, Environmental Quality effects on significant natural resources most relevant to the project area are summarized in **Section 6.12.3**, and Environmental Consequences for the NED Plan and Recommended Plan are discussed in detail in **Section 7 of the DIFR-EIS** and **Appendix G, Environmental Supporting Document**.

6.7 DETAILED COST ESTIMATES

6.7.1 Cost Estimate for Recommended Plan

Table 6-11 provides the Project First Cost and Fully Funded Cost for the Recommended Plan. The detailed cost estimate for the Recommended Plan was developed using the Microcomputer Aided Cost Estimating System (MCACES). Project costs include associated non-Federal cost for berth and dock modification that would be needed for use of those Segments where channel is deepened (Segments 4, 5 and 6) and any lands, easements, rights-of-way, and relocations (LERR). The Cost and Schedule Risk Analysis provided in **Appendix C, Attachment 1** contains detailed information on the project costs, cost assumptions, and the associated risks that factored into the contingency.

Table 6-11 – Recommended Plan Cost Summary ($000)

Cost Account and Item Descriptions		Project First Cost	Fully-Funded Cost
		October 2019 Price Level	
General Navigation Features (GNF)			
06	Fish & Wildlife Mitigation	$81,758	$91,511
12	Navigation	$638,862	$729,274
30	Planning, Engineering & Design	$66,322	$75,257
31	Construction Management	$37,898	$43,866
	GNF Total	**$824,840**	**$939,908**
LERR (100% Non-Federal Cost)			
01	Lands & Damages (100% non-Federal)	$14,658	$16,077
02	Relocations	$37,350	$40,927
	LERR Total	**$52,008**	**$57,004**
	Project First Cost	**$876,848**	**$996,912**
Associated Costs (Other Federal Cost) [1]			
12	Navigation Aids (100% Federal – USCG) [1]	$4,609	$5,122
	Associated Cost Subtotal (Other Federal Costs) [1]	**$4,609**	**$5,122**
Associated Costs (Non Federal Cost) [2]			
12	$78,204	$87,573	$87,573
	Associated Cost Subtotal (Other Federal Costs) [1]	**$78,204**	**$87,573**
	Total Associated Costs (Other Federal and Non-Federal) [1,2]	**$82,813**	**$92,696**
	Project Cost plus Associated Costs	**$959,661**	**$1,089,609**

[1] Other non-Federal costs that are not part of the recommended Federal project but are another Federal agency responsibility.
[2] Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.
Note: There may be slight differences due to rounding.

Associated financial costs are not part of the Recommended Federal project cost but are a necessary non-Federal or other Federal agency responsibility. The USCG would be responsible for providing and maintaining navigation aids. Costs for modifications to ATON were coordinated with the USCG and are included in the project cost estimate. These other Federal agency costs are 100 percent Federal Cost (USCG). LSF costs are the responsibility of the non-Federal sponsor and will be required as part of the Project Partnership Agreement (PPA) if they are necessary for project benefits to accrue.

General Navigation Features (GNFs) are cost shared between USACE and the NFS during the construction of project. *GNFs include channels, jetties or breakwaters, locks, basins or water areas for vessel maneuvering, turning, passing, mooring or anchoring incidental to transit of the channels and locks, and dredge material placement areas (*except the Gulf Intracoastal Water (GIWW) and Atlantic Intracoastal Waterway*).

Oversimplification: If the vessel is coming into the dock, all the facilities needed to get it from open water to the dock are GNF.

LSFs are features fully funded by non-Federal interests. *LSFs might include such things as piers, wharves, berthing, and mooring.

Oversimplification: Once the vessel stops, everything it touches are the LSF.

*List of features is not all-inclusive
ER 1105-2-100 Planning guidance notebook and oversimplification provided at http://www.iwr.usace.army.mil/Missions/Training/Planning-Associates-Program/PA-Program-2013-Course-Schedule/2013-Deep-Draft-Navigation-Course/

6.7.2 FWP DMMP 50-Year Costs

The total cost of the 50-Year FWP DMMP is described in **Table 6-12**. The analysis discounts Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs to the beginning of the period of analysis using the existing FY19 discount rate (2.875 percent) to develop the benefit-cost summary.

Table 6-12 FWP DMMP Costs/LPP Recommended Plan

Reach Description	Placement Area Used	TOTAL
HSC Bolivar Roads to Redfish Reef	ODMDS	$70,088,000
HSC Redfish Reef to Bayport	Mid Bay, B.I.M., ODMDS	$913,688,000
HSC Bayport to Morgans Point	PA15, M7/8/9, M11, ODMDS	$526,816,000
Bayport Ship Channel & Turning Basin	PA14, Connection, ODMDS	$519,310,000
Bayport Ship Channel Flare	PA14, Connection, M7/8/9, M11, ODMDS	$355,759,000
Barbours Cut Channel	Spilman, M12, M7/8/9, M11, ODMDS	$285,984,000
HSC Morgans Point to Exxon	Spilman, Alexander, BABUS	$553,924,020
HSC Exxon to Carpenters Bayou	Peggy Lake, Lost Lake, BABUS	$245,248,484
HSC Carpenters Bayou to Boggy Bayou	Lost Lake, BABUS	$153,926,502
HSC Boggy Bayou to Greens Bayou	Lost Lake, BABUS	$288,347,000
HSC Greens Bayou to Sims Bayou	Rosa Allen, East Clinton, BABUS	$221,162,000
Greens Bayou	East Clinton, BABUS	$39,984,135
HSC Sims Bayou to Turning Basin	House Tract, West Clinton, BABUS	$155,144,000
HSC Main Turning Basin	House Tract, BABUS	$126,481,000
HSC Upper Turning Basin	House Tract, BABUS	$51,277,993
Light Draft Channel	House Tract, BABUS	$23,349,444
Turkey Bend Channel	House Tract, BABUS	$14,101,962
Turkey Bend Cut-off Channel	House Tract, BABUS	$15,455,043
	TOTALS	**$4,560,046,583**

Costs shown include Existing Federal, Federal Increment, Existing Non-Federal, and Non-Federal Increment
Corresponds to Table 7-13 in Appendix R, DMMP.

6.7.3 Project Schedule and Interest During Construction for Recommended Plan

Interest during Construction (IDC) accounts for the opportunity cost of expended funds before the benefits of the project are available and are included among the economic costs that comprise Recommended Plan costs. The amount of the pre-base-year cost equivalent adjustments depends on the interest rate; the construction schedule, which determines the point in time at which costs occur; and the magnitude of the costs to be adjusted. The current construction schedule assumes authorization of the project in a future WRDA. Assuming Congress provides funding subsequent to authorization of the project in that future WRDA, the proposed schedule of activities would follow, resulting in benefits starting in the base year 2029 for the proposed project. The IDC was computed with the October 01, 2019 (FY20) interest rate of 2.75 percent. Total construction duration is assumed to be 6 years. **Table 6-13** provides the schedule for construction that was used in computing the IDC.

Table 6-13 – Construction Schedule

Cost Account	Segment	Contract	Activity	Duration (Months)	Expected Start	FY
6	Segment 1 (BR-RF Increment)	1	Mitigation-Construct Oyster Reef at San Leon/Dollar Reef	5.0	Year 1; Jan	2023
12		2	NW Dredging - Bolivar Roads to Redfish to 8-Ac B.I.	2.8	Year 1; Jan	2023
12			NW Dredging - Bolivar Roads to Redfish to Long B.I.	3.2	Year 1; Apr	2023
12			NW Dredging - Mech. Dredging to ODMDS	7.6	Year 1; Jan	2023
12	Segment 4	3	Site Preparation - E2 Clinton Tract	2.6	Year 1; Apr	2023
12		4	Site Preparation - Beltway 8 Tract	4.7	Year 1, Apr	2023
12		5	NW Dredging - Greens Bayou to Sims Bayou to E2 Clinton	2.3	Year 1, Jun	2023
12			NW Dredging - Boggy Bayou to Greens Bayou to Beltway 8	7.7	Year 1, Aug	2023
6	Segment 1 (RF-BCC Increment) & Segment 2	6	Mitigation-Construct Oyster Reef at San Leon/Dollar Reef	8.6	Year 2, Jan	2024
12		7	NW Dredging - Mech. Dredging to ODMDS	6.2	Year 2, Apr	2024
12		8	NW Dredging - BSC + HSC to B.I. Marsh	11.3	Year 2, Apr	2024
6	Segment 1 (BSC-BCC Increment) & Segment 3	9	Mitigation-Construct Oyster Reef at San Leon/Dollar Reef	0.3	Year 3, Apr	2025
12		10	NW Dredging - BCC to M12	6.5	Year 3, Apr	2025
12			Sweeping Cedar Bayou	0.7	Year 4, Oct	2026
6		11	NW Dredging - HSC to M7/8/9 & M11	7.3	Year 4, Jan	2026
12			NW Dredging - HSC to BSC Sed. Attn.	7.2	Year 4, Aug	2026
12	Segment 5 & Segment 6	12	Site Preparation - Glendale PA	3.1	Year 5 Apr	2027
12		13	Site Preparation - Filterbed PA	1.5	Year 5, Jul	2027
12		14	NW Dredging - Sims Bayou to Turning Basin to Glendale	3.2	Year 5, Aug	2027
12			NW Dredging - Main Turning Basin to Filterbed	1.6	Year 6, Nov	2028

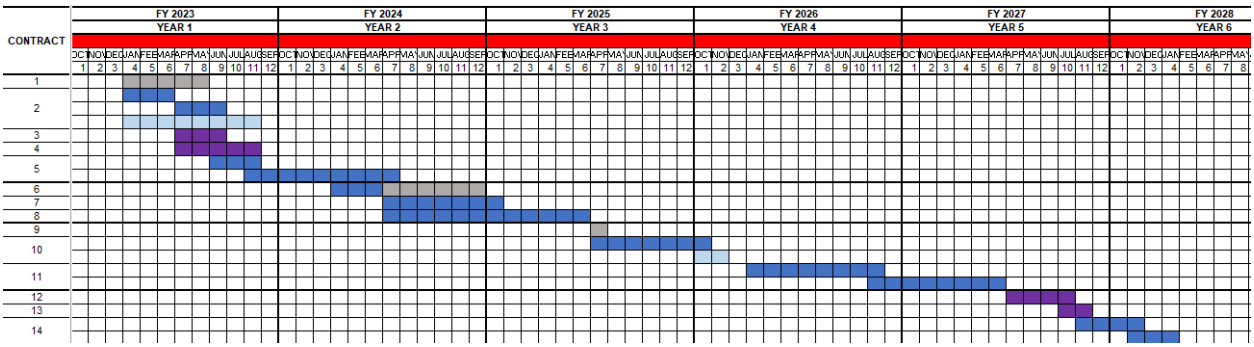

Figure 6-3 – Visual Construction Schedule per Contract

6.7.4 Rationale for Construction Sequencing

The implementation of the construction schedule for the HSC ECIP Study increments considers the most effective sequencing in order to realize the greatest benefits to the nation, state, region, and community in order to provide usable increments of the project in a timely manner. As shown later in **Table 6-18**, Segment 4 provides the highest net benefits at $27.8 million and a BCR of 3.24. Segment 2 (BSC) provides the second greatest net benefit of any one feature at $28.6 million, and a BCR of 6.72. Segment 3 (Barbours Cut Channel) provides the next highest net benefits at $11.1 million with a BCR of 2.37. Segments 5 and 6 provide the fourth highest net benefits at $7.7 million and a BCR of 3.83. Bay widening features provide the three lowest net benefit values at $6.7 million, -$1.4 million, and $0.7 million for Bolivar Roads to Redfish, Redfish to BSC, and BSC-BCC, respectively.

The long length of the HSC affords itself the ability to construct multiple segments at the same time and allowing for safe passage of vessels between dredging activities. The proposed construction schedule (refer back to **Table 6-13**) takes advantage of relieving transportation delays and resulting costs while strategically implementing the project for the benefit of the nation.

Year 1 (Bolivar Roads to Redfish and Segment 4). The first two channel segments in the construction schedule are Boggy Bayou to Sims Bayou (Segment 4) and the Bolivar Roads to Redfish increment in Segment 1. Combined, these features benefit the largest number of users while providing benefits to the remaining segments prior to their construction.

The Bolivar Roads to Redfish increment benefits all users along the HSC by extending the daylight transit rule and synergizes the Federal Government's investment with the investments being made by the non-Federal sponsor and stakeholders in the Redfish to BSC and BSC to BCC increments of widening. Of all the segments in the study, this segment represents the least amount of preparatory work; therefore, construction could be implemented early, allowing some benefits to accrue for the entire system at an earlier stage. Meaning, benefits to Segments 2, 3, and 4 as well

as Segments 5 and 6 can begin to accrue prior to the construction of their overall improvements. Additionally, the design container vessels cannot navigate Bolivar Roads to Redfish without channel modification; consequently, Segments 2 and 3 cannot realize project benefits without Bolivar Roads to Redfish improvements. Without implementing Bolivar Roads to Redfish in the first construction phase, bend easings would need to be made in this segment for Segment 2 and Segment 3 to realize benefits. This would duplicate construction efforts in the Bolivar Roads to Redfish reach, adding significant cost and time.

The Boggy Bayou to Sims segment realizes the second highest net benefits and allows an entire new class of vessel to transit Segment 4. Pipeline relocations and placement area site preparations are required prior to construction of the channel improvements in Segment 4. These activities are scheduled in Year 1 in concert with the improvements from Bolivar Roads to Redfish. Segment 4 improvements would be finished in Year 2 of construction. Benefits are accrued almost instantly as adjoining property owners in both FWOP and FWP are planning to have their projects online in concert with, and directly following, the Federal improvements.

Year 2 (Segment 4, Redfish to BSC increment, and Segment 2). The construction schedule includes completion of Redfish to BSC widening and improvements to Segment 2 (BSC) in construction Year 2 and Year 3. Segment 2 has the highest net benefits. When coupled with Bolivar Roads to Redfish and Redfish to BSC improvements, containers can transit to the Bayport Container Terminal with minimal restrictions, adding significant benefit to the entire HSC system.

LPP components consisting of widening the channel from Redfish to BSC and BSC to BCC further alleviates pilot restrictions throughout the bay, particularly to Segments 2 and 3, and the costs are borne 100 percent by the non-Federal Sponsor.

Year 3 (Redfish to BSC, Segment 2, BSC-BCC, and Segment 3). Year 3 construction would include completion of Redfish to BSC and Segment 2 improvements as well as beginning of the BSC-BCC increment and Segment 3 construction. Segment 3 (BSC) represents the third highest net benefit feature. When paired with the BSC-BCC increment the design container vessels can reach both Bayport and Barbours Cut Container terminals with minimal restrictions, adding benefit to the entire system.

Year 4 (BSC-BCC, Segment 3). Year 4 includes continued construction of the BSC-BCC increment and Segment 3 project features.

Year 5 (BSC-BCC, Segment 3, and Segments 5 & 6). Year 5 includes completion of BSC-BCC increment and Segment 3 features. Additionally, construction begins on the final project element: Segments 5 & 6. Segments 5 and 6, upstream of Sims Bayou, would experience the longest lead

time to benefits as the non-Federal sponsor is the majority beneficiary. Capital improvements already planned in the FWOP condition were not slated to begin until towards the end of the overall HSC ECIP period of construction. While the BCR of Segments 5 and 6 is considerable, their net benefits are significantly lower than other elements in the system that benefit the majority of ship channel users rather than just the non-Federal. Preliminary investigations of the implementation of features to the upper segments appear to indicate proper utilization of these facilities also requires improvements downstream in the Boggy Bayou to Sims Bayou reach to take full effect. This is predominately due to the existing fleet needing to travel at the existing narrower and shallower depth of Boggy Bayou to Sims Bayou (Segment 4), until improvements are made.

Year 6 (Segments 5 & 6). In the final year of construction, the project expects completion of Segment 5 and Segment 6 improvements.

6.8 DESIGN AND CONSTRUCTION CONSIDERATIONS

Specific design and construction considerations are described in detail in **Appendix C, Sections 3 and 4**, and **Appendix R, Section 7**.

6.8.1 With-Project Sea Level Rise

As a conservative approach (not exaggerating benefits from sea-level rise), the Intermediate Sea-Level Curve at Galveston Pier 21 gauge was used for this project as it provides deeper water which is supported by observation. Including sea-level rise and subsidence in the project design would result in increased channel depth. At the end of the 50-year project life (year 2073), it is anticipated that channel depth would increase by 1.05 feet (**Table 3-2**) from the start year which is year 2023 using historic or Intermediate curve. If sea level rises faster than the historic "Intermediate" rate, then the channel depth would increase even more; the respective values (intermediate and high rate) can be found from **Table 3-2**.

The rise in water surface elevation due to sea level changes as well as a reduction in freshwater inflow for future conditions generates somewhat different salinity magnitudes throughout the analysis year. In most locations the mean salinity is larger for the future conditions with RSLC. However, the variation in salinity between with and without project alternatives is quite small for most locations – generally less than 2 ppt. The largest variation in salinity between with and without project results is in the upstream locations of the HSC. The salinities are almost identical near the entrance but begin to diverge further into the system at Mid Bay Marsh, Morgan's Point, and locations further up the HSC. However, the change in the mean salinity between with and without project remains within 2 ppt.

Some adverse effects due to sea-level rise may also occur within the project especially in the channel and PAs. Examples are: increased erosion, increased ship wakes in barge lanes and mooring areas, and increased wind waves. Appropriate shore protection measures must be taken as sea level rise accelerates.

6.8.2 Storm Surge

The ADvanced CIRCulation (ADCIRC) numerical model is used to simulate storm-surge conditions outside the entrance channel and inside Galveston Bay. ADCIRC is a system of computer programs for solving time-dependent, free surface, circulation, and transport problems in three dimensions. These programs utilize the finite-element method in space (rather than time) allowing the use of highly flexible, unstructured grids.

Figure 6-2 below shows five points which represent potential PA locations in Galveston Bay along the HSC. **Table 6-14** accompanies **Figure 6-2**, and shows without project condition storm surge levels of various recurrence intervals. It can be noted that water surface elevation due to storm surge at the inshore PAs are on average higher than at the PAs closer to the gulf. The average storm surge level of the five PAs from the 10 year recurrence interval was found to be 6.05 feet NAVD 88.

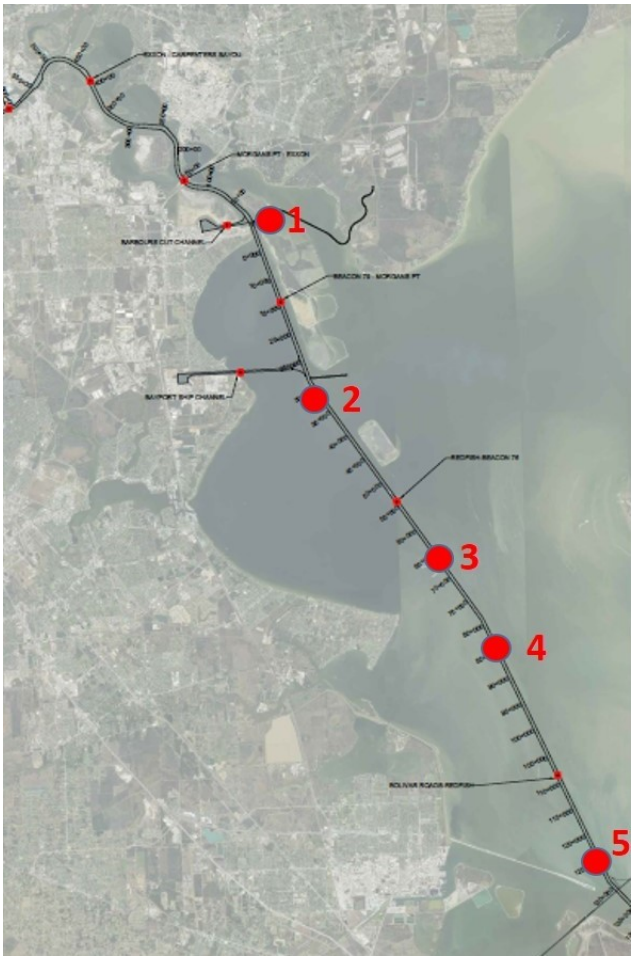

Figure 6-4 - HSC Save Points

Table 6-14 – HSC Storm Surge Levels

Save Point ID	Latitude (deg)	Longitude (deg)	Average Recurrence Interval in years (WL in m, NAVD88) -- Non-exceedance Confidence Limit: 98%												
			1	2	5	10	20	50	100	200	500	1,000	2,000	5,000	10,000
1	29.68979	-94.97024	0.58	1.07	1.70	2.13	2.67	3.80	4.70	5.55	6.52	7.18	7.72	8.30	8.69
2	29.58964	-94.93001	0.57	1.02	1.56	1.92	2.40	3.33	4.16	4.95	5.85	6.45	7.04	7.71	8.10
3	29.52976	-94.87015	0.56	0.97	1.43	1.75	2.17	2.94	3.69	4.50	5.35	5.89	6.45	7.20	7.70
4	29.45972	-94.82003	0.55	0.93	1.37	1.68	2.09	2.82	3.53	4.31	5.04	5.51	5.99	6.67	7.15
5	29.37973	-94.80005	0.55	0.92	1.39	1.75	2.21	2.95	3.77	4.42	5.08	5.54	5.98	6.56	6.97

6.9 REAL ESTATE CONSIDERATIONS

The NFS is responsible for acquiring and furnishing all lands, easements, rights-of-way, relocations (i.e., P.L. 91-646 relocations and utility/facility relocations), borrow material, and dredged or excavated material disposal areas (LERRD) for the project, if required. The real estate requirements for the Project must support construction as well as the continued operation and maintenance of the Project.

6.9.1 Lands, Easements, and Rights-of-Way

This channel improvement project will overlap the existing HSC project as discussed in the "Purpose" section of the Real Estate Plan (REP). The alignment of the NED Plan and LPP is located mostly on open waters of Galveston Bay and HSC. Portions of the additional submerged lands required over Galveston Bay are owned by TxGLO and would be utilized under navigational servitude. A total of 50 TxGLO submerged tracts were identified as being utilized under navigational servitude. These tracts are located in the CW1 BR-BCC measure. A table of these tracts is shown in the **REP, Exhibit D**. A total of 45 Tracts were identified as NFS owned land via patent by the State of Texas. The PHA currently has a development easement extending approximately 230 feet from the improved channel toe along the north side of the BSC for future development. A table of these tracts is shown in the **REP**, **Exhibit E**. These submerged lands are located at the BSC and BCC through the upper bayou of this project.

Segment 6 will include turning basin improvements at Brady Island, which will require the land shaving of 0.096 acres requiring land acquisition in fee. As additional requirement for this feature is a one-acre staging/temporary work area easement on Brady Island situated adjacent to the Brady Island land shaving feature for the term of one year. Access to the staging area will utilize public roads leading into Brady Island.

6.9.2 Facility Removals/ Utility Relocations

An analysis of pipelines crossing the HSC has been conducted using data derived from PHA license data, USACE Regulatory Permit documents, as-built documents, and state and Federal databases. An analysis of the data has resulted in the determination that of the 215 pipelines identified, 14 pipelines would require removal or relocation as a result of the proposed project. These 14 pipelines are located in CW1_BR-Redfish and CD4- whole measures.

The NFS is responsible for performing, or assuring the performance of all pipeline relocations necessary for the project at no cost to the government. Costs borne by the NFS to perform or assure the performance of all utility relocations would be creditable against the NFS's required additional 10 percent repayment requirement at the end of the project. A table of all identified pipelines for this project is shown in the **REP, Exhibit G**.

6.10 OPERATIONS AND MAINTENANCE CONSIDERATIONS

The DMMP documents the dredging and place documents the dredging and placement needs for the Federal project and associated non-Federal facilities, as feasible, for the next 50-years for the HSC complex. The HSC complex includes the HSC main channel from Bolivar Roads to the Upper Turning Basin, BSC, BCC, Greens Bayou Channel, Jacintoport Channel, Buffalo Bayou

Light-Draft Channel, Turkey Bend Channel, and boater cuts and barge lanes. The current and future placement plan for continued O&M of the existing HSC complex is outlined in the December 5, 2017 Preliminary Assessment (HSCPAA) and conceptual 50-year DMMP dated December 18, 2018, as summarized in the **DMMP, Appendix R, Section 2**. This is considered the FWOP condition for the HSC ECIP Study.

Details regarding the calculations of new work dredging quantities resulting from the channel improvements can be found in **Appendix C, Section 5.1**, and **Appendix R, Section 3.2**. Information regarding anticipated incremental shoaling as the result of the channel improvements can be found in **Appendix C, Section 5.2**, and **Appendix R, Section 3.3**. Selection of the least cost environmentally acceptable placement plan selection can be found in **Appendix R, Section 5.9** and is summarized in **Section 6.4.1** of this report.

The study integrates changes to the FWOP conditions by identifying the base plan for placement needs for the increment of new work and maintenance dredging from the recommended modification for Segments 1-6. This includes dredged material originating from the Federal channel, and associated benefitting non-Federal LSFs, for a period of 50-years. This is considered the FWP condition for the HSC ECIP Study. Details regarding the calculations of new work dredging quantities resulting from the channel improvements can be found in **Appendix C, Section 5.1**, and **Appendix R, Section 3.2**. Information regarding the anticipated incremental shoaling as the result of the channel improvements can be found in **Appendix C, Section 5.2** and **Appendix R, Section 3.3**. Selection of the least cost environmentally acceptable placement plan selection can be found in **Appendix R, Section 5.9** and are summarized in **Section 6.4.1** of this report.

Appendix R, Section 7 details the integration of the FWOP condition of the HSC System where there are no improvements (Morgans Point to Boggy Bayou, Jacintoport Channel, Greens Bayou Channel, the Buffalo Bayou Light-Draft Channel, Turkey Bend Channel, and boater cuts) and the portions of the channel receiving improvements in Segments 1-6.

As shown in **Table 6-15**, the FWP condition would create an additional 67,779,000 CY of maintenance materials to be removed during the 50-year study period. The FWP condition would create 34,734,000 CY of new capacity. The remaining 35 321,000 CY of increased maintenance materials would be placed into alternate non-PA sites, either ODMDS or BABUS.

The quantity from the FWOP condition that would go to ODMDS would be 140,647,000 CY and the quantity that would go to BABUS would be 97,543,000 CY. Under the FWP condition, the quantities to non-PA sites are offset in that incremental materials from BCC Flare would be taken to ODMDS, rather than to a BABUS like in the FWOP. Incremental materials from the

BCC and docks would continue to go to BABUS in the FWP like in the FWOP. This ultimately results in a small net decrease of materials that would require placement into a BABUS under the FWP condition. Essentially, impacts to the FWOP BABUS requirement in the FWP are negligible, while increases in the materials going to ODMDS are roughly 50 percent of the total increased O&M requirement. These quantities are summarized in **Table 6-15.**

Table 6-15 – Alternate PA Use and Impact on FWOP DMMP

Description	FWOP	FWP	Difference
	(Quantities in CY)		
Total 50-year O&M quantities[1]	344,105,000	411,884,000	67,779,000
PA Capacity	105,915,000	140,649,000	34,734,000
Quantity to non-PA	238,190,000	273,511,000	35,321,000
To ODMDS	140,647,000	184,040,000	43,392,000
To BABUS	97,543,000	89,472,000	-8,072,000
Total CY to Alternate PAs	238,190,000	273,511,000	35,321,000

Corresponds to Table 7-6 in Appendix R, DMMP

6.11 ECONOMIC ANALYSIS FOR RECOMMENDED PLAN

6.11.1 Depth Optimization

The depth of the proposed channel improvements are optimized to return the greatest excess of benefits over costs with consideration of adverse environmental and social effects. The study evaluated deepening to the intermediate depths of -38.5 feet MLLW in Segments 5 and 6 and -43.5 feet MLLW in Segment 4. The results of the analysis confirmed that the NED plan (-41.5 feet MLLW in Segment 5 through Segment 6 and -46.5 feet MLLW in Segment 4) maximizes net benefits (**Table 6-16**). These optimized measures were included in both the NED and LPP plans and are part of the Recommended Plan.

Table 6-16: Channel Depth Optimization ($000)

Location	Measure	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
October 2018 Price Level, 2.875 % Discount Rate [1]					
Segment 4	CD4_43.5	$490	$16,569	$16,078	33.8
	CD4_46.5	$2,057	$34,966	$32,909	17.0
Segments 5-6	CD5_38.5 & CD6_38.5	$456	$11,141	$10,685	24.4
	CD5_41.5 & CD6_41.5	$914	$16,226	$15,312	17.8

[1] Channel Depth Optimization took place prior to updating the benefit-cost analysis to October 2019 price level and FY20 discount rate. A change in price level and discount rate would not change the NED depths.

Similarly, widening measures defined by safety considerations were through evaluated through Ship Simulation. The assumed channel widening measures and turning basin sizes represent the

best professional judgment of pilots and engineering design criteria. Ship simulation determined the optimal width for Bay widening measures to be 700 feet.

6.12 SUMMARY OF ACCOUNTS

The Federal process incorporates four accounts to facilitate evaluation and display of effects of alternative plans. The four accounts are NED, environmental quality (EQ), regional economic development (RED), and other social effects (OSE). They are established to facilitate evaluation and display of effects of alternative plans.

6.12.1 National Economic Development Benefits

Table 6-17 provides a comparison of cost benefits between the NED Plan and Recommended Plan.

Table 6-17 - HSC ECIP Equivalent Annual Costs and Benefits ($000)

Category	NED Plan	Recommended Plan
	October 2019 Price Levels, 2.75 % Interest Rate	
Total Project Construction Costs	$746,649	$959,661
Interest During Construction	$12,612	$19,477
Total Investments Cost	**$759,261**	**$979,138**
Construction Average Annual Costs	$28,123	$36,268
OMRR&R	$13,883	$16,983
Total Average Annual Costs	**$42,006**	**$53,251**
Average Annual Benefits	$114,683	$133,551
Net Annual Benefits	$72,677	$80,300
Benefit to Cost Ratio	**2.73**	**2.51**

6.12.2 Separable Elements

ER 1105-2-100, Appendix E, Section 3c defines a separable element as "…any part of a project which has separately assigned benefits and costs, and which can be implemented as a separate action (at a later date or as a separate project)…". The Recommended Plan includes seven separable elements. **Table 6-18** identifies all separable elements and their respective cost-benefit summary. All separable elements are economically justified except for channel widening from Redfish Reef to BCC (CW1_Redfish-BSC and CW1_BSC-BCC), which is included in the Recommended Plan as part of a LPP.

Table 6-18 – Separable Elements Benefit-Cost Summary ($000s) for Recommended Plan

Separable Elements (7)	Measure(s)	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
		(October 2019 Price Level, 2.75% Discount Rate)			
BR-RF[1]	CW1_BR-Redfish	$4,595	$11,276	$6,681	2.45
RF-BSC[1]	CW1_Redfish-BSC	$12,670	$11,248	$(1,422)	0.89
BSC-BCC[1]	CW1_BSC-BCC	$6,858	$7,620	$762	1.11
BSC[2]	CW2_BSC	$4,993	$33,554	$28,561	6.72
BCC[2]	CW3_BCC, BETB3_BCCFlare	$8,086	$19,166	$11,080	2.37
Segment 4 Deepening and Widening[3]	CD4_Whole, CW4_BB-GB, TB4_Hunting	$12,420	$40,249	$27,829	3.24
Segment 5 & Segment 6 Deepening[4]	CD5, CD6	$2,727	$10,438	$7,711	3.83

[1] Analysis assumed deepening in Segments 4 through 6. Separable benefits of widening alone would likely be higher.

[2] BSC and BCC both require BE1_078+844_530 and BE1_028+605_530. Analysis assumes BSC bears the costs of bend easings.

[3] Analysis assumed that benefits of Segment 4 only accrue with channel deepening and widening to allow design fleet transit.

[4] Segment 6 deepening requires equivalent depths in Segment 5. Segment 5 alone is not economically justified.

6.12.3 Environmental Quality

In accordance with ER 1105-2-100, and the Water Resources Council Principles and Guidelines, the EQ account displays non-monetary effects on significant natural and cultural resources. The effects of the NED Plan and Recommended Plan were evaluated in detail under the EQ system of accounts in **Section 7**, but are briefly described here. The main effects of the NED Plan and Recommended Plan on significant natural resources would be impacts to oyster reef, unvegetated estuarine Bay and river bottom, and wetlands. The impacts to oyster reef and wetlands would be permanent in nature, while those to estuarine Bay and river bottom would be more of a temporary effect with concern to benthic infauna and use by fish species. These effects are detailed in **Section** 7. The impact to oyster reef would require mitigation as it is a significant impact to a significant ecological resource. The mitigation proposed is detailed in **Appendix P, Mitigation Plan for Oyster Reef Habitat**. The following bullets summarize the main EQ effects on significant natural resources most relevant to the project area:

- Oyster Reef – Approximately 88 acres would be impacted by the NED Plan and 410 acres would be impacted by the Recommended Plan, but either would be mitigated;
- Bay Bottom and EFH –Approximately 1,190 acres of estuarine river in the upper HSC and Galveston Bay bottom would be impacted by new work dredging for the NED Plan and 2,133 acres for the Recommended Plan. It is estimated that approximately 908 acres, and 1,596 acres have been previously dredged as part of existing main channel and side slopes. Impacts to benthic habitat would be temporary, and would be expected to recolonize and recover;
- Wetlands – Approximately 22.7 acres of forested wetland and 8.7 acres of mostly emergent wetland would be impacted by new work dredged material placement for either the NED

Plan or LPP. Future O&M for either the NED Plan or LPP would require use of a partially paved NFS property with 40.7 acres of mostly forested wetlands. All would be mitigated by purchase of mitigation bank credits.

- T&E Species – No significant adverse impacts expected. A BA determination to be coordinated with NMFS and USFWS for concurrence was made that the Recommended Plan may affect but is not likely to adversely affect West Indian manatee, as well as sea turtles and their critical habitat and the Giant manta ray in the existing ODMDS No. 1;
- Protected Lands – See bullet above for critical habitat. No other impacts to other critical habitat would occur. No impacts to WMAs or other refuges would occur;
- Marine Mammals – No significant adverse impacts expected. Temporary avoidance and disturbance during dredging to construct and maintain the NED Plan or the Recommended Plan would occur, similar to routine maintenance effects for the existing channels, and not be anticipated to result in incidental takes;
- Migratory Birds – No significant adverse impacts expected. Temporary avoidance and disturbance could occur during dredged material placement at existing PAs to construct and maintain the NED Plan or the Recommended Plan, similar to routine maintenance effects; and
- No specific cultural resource impacts have yet been identified as cultural resource investigations will be performed in the next planning phases. The USACE has determined that the NED Plan or the Recommended Plan has the potential to cause effects on historic properties and will address the identification and discovery of cultural resources that may occur during the construction and maintenance of the Recommended Plan in accordance with the Programmatic Agreement.

See **Section 7** for the full evaluation of NED Plan or the Recommended Plan (LPP) effects under the EQ system of accounts.

6.12.4 Regional Economic Development Benefits

The RED account measures changes in the distribution of regional economic activity that would result from each alternative plan. Evaluations of regional effects are measured using nationally consistent projections of income, employment, output, and population.

The USACE Online Regional Economic System (RECONS) is a system designed to provide estimates of regional, state, and national contributions of Federal spending associated with Civil Works and American Recovery and Reinvestment Act Projects. Results are summarized below. Additional information related to the development of the model and its inputs is provided in **Appendix B, Economic Appendix**.

The RED impact analysis was evaluated at three geographical levels: local, state, and national. The local-level analysis represents the Houston Sugar Land Baytown MSA impact area. The state-level analysis includes the State of Texas. The national-level includes the 48 contiguous U.S. States.

The total construction costs for the project is $876,848,000. Of this, up to $759 million would be captured within the regional impact area, and the rest would flow to the state or the nation. The expenditures for various services and products would be expected to generate additional economic activity measured in jobs, income, sales, and Gross Regional Product (GRP). Impacts at the national level include a tremendous expansion due to the multiple times money turns over and ripples throughout the national economy. According to the RECONS, the Civil Works expenditures $876.8 million support a total of 4,878 full-time equivalent jobs, $472 million in labor income, $685 million in the gross regional product, and $1.177 billion in economic output in the local impact area (Houston-Sugar Land-Baytown MSA). Nationally, these expenditures support 8,414 full-time equivalent jobs, $661.6 million in labor income, $1.014 billion in the gross regional product, and $1.880 billion in economic output in the nation.

6.12.5 Other Social Effects

As discussed in **Section 7.4.2**, the construction of the NED Plan or Recommended Plan would not have a disproportionally high and adverse impact to areas with high concentrations of low-income or minority populations. Though there are census blocks that have majority percentages of minority or low income populations, the amount of new work dredging to the construct either the NED Plan or Recommended Plan would not be disproportionately distributed in those census blocks compared to other blocks not predominantly minority or low income. Though PAs proposed for use in the upper HSC have minority-dominated populations, the impacts from their use for new work would be temporary, experienced over 3 months of site preparation at a given site, followed by 3 months of placement. The placement of material would not produce

significantly adverse long-term exposures from air, noise, water or other media impacts. Schools and hospitals are distributed throughout the study area and are not concentrated along the navigation channels, and no senior living facilities were identified in close proximity to the either the NED Plan or Recommended Plan footprint. No long-term adverse air or noise impacts would result from the either the NED Plan or Recommended Plan as explained in **Sections 7.1.7 and 7.1.8**. As discussed in **Section 7.1.7.2**, these effects would result in long-term reduction of air emissions, more so in the Recommended Plan than in the NED Plan. The closest school is approximately 0.5 miles away from the NED Plan or Recommended Plan footprint and would not be directly subject to temporary construction noise. Most of the directly adjacent land use along the channels are the industrialized portion of the HSC above Morgans Point.

As discussed in **Section 7.4.1**, the NED Plan or Recommended Plan is not expected to have adverse indirect effects on landside development or activities, as it will not induce development. The channel modifications would not induce new industrial growth, as it already has occurred, and occurs without the NED Plan or Recommended Plan, as evidenced by the permit activity discussed in the cumulative impact analysis in **Section 7.7**. Therefore, the NED Plan or Recommended Plan would have no long-term adverse effects on communities.

The following paragraphs summarize the impact on some of the suggested OSE categories of effects distilled from the ER 1105-2-100 and listed in the Institute for Water Resources (IWR) *Review of Guidance and Procedures for Regional Economic Development and Other Social Effects*, dated August 2006, and additional topics suggested by this guidance.

Urban and community impacts. The NED Plan or Recommended Plan will have no substantial adverse impact on the real income, employment distribution, or population distribution and composition of the surrounding community. These plan would help maintain the positive effect that port activity has on the metropolitan, State, and national economies by reducing transportation costs from inefficient delivery, delays, and congestion. It would not be expected to have a deleterious effect on the fiscal condition of the NFS. It would not be expected to significantly impact any educational, cultural, or recreational opportunities as discussed in **Section 7.4**, prevent enrollment or use, or reduce the diversity of engaging in these opportunities. The NED Plan or Recommended Plan would not have any impacts on community cohesion factors such as diversity, ties, integrity of neighborhoods etc. as they would not be impacted or displaced. Similarly, it would have no impact housing supply, community services etc. The nature of the NED Plan or Recommended Plan improvements is underwater modifications that will not affect any community aesthetics.

Life, health, and safety. The NED Plan or Recommended Plan channel modifications will not affect efforts to reduce risk of flood and other disaster risks, or efforts to reduce disease-carrying

vectors and insects. It will have no bearing on safety risks to community populations and property on land. It will have no impacts on emergency services or medical treatment facilities. As discussed in **Section 7**, the NED Plan or Recommended Plan will have no significant long-term adverse effects on water or air quality. Reductions in navigation congestion and constraints could contribute to reduction vessel accidents that could result in releases, but this has not been quantified.

Displacements or long-term productivity. The NED Plan or Recommended Plan would not displace any people, businesses, or farms as discussed in **Section 6.8.12** and **7.4**. The NED Plan or Recommended Plan would have no impacts to the productivity of landside resources such as agricultural land. However, the NED Plan or Recommended Plan would reduce transportation costs for shipping goods from this port, which would enhance the productivity of industry users of the channel. This in turn would have positive indirect effects on the cost of consumer goods that pass through this port.

Energy requirements and energy conservation. The NED Plan or Recommended Plan would have no adverse effect on broader energy consumption, conservation, or access to resources as discussed in **Section 7.1.5**. These plans would have the positive effect of reducing transportation delays and ship calls, which would save vessel fuel consumption that would have otherwise occurred. The Recommended Plan would have a greater positive effect than the NED Plan due to the approximate three times the reduction of in-port transit and delay hours.

Emergency preparedness. The NED Plan or Recommended Plan would have a positive effect on protecting a major component of the National water transportation system, which is Port Houston, the Nation's 2nd ranked port in the in 2015 for total tonnage, and for 2016, the 1st ranked in foreign tonnage, 3rd ranked in total foreign cargo value, and 6th in total container TEU. The Recommended Plan would also improve navigability in the HSC segment through the Bay, which is the main artery where vessel allisions, although few, occur. The NED Plan would also do this, but for a more limited length through the Bay, below Redfish Reef. Although the risk reduction is difficult to quantify, the improved navigability would be expected to reduce the risks where width constraints and turning geometries are contributing factors. The NED Plan or Recommended Plan has no effects on other emergency preparedness considerations such as water supplies, critical power supplies, reserve food production potential, conservation of scarce fuels, or dispersal of population and industry.

6.13 RISK AND UNCERTAINTY

This study incorporated consideration of risk in the development and evaluation of alternative by taking into account the likelihood and variability of physical performance, economic success, and residual risk.

6.13.1 Engineering Data and Models

Data Input for Models

The hydrologic and hydraulic information presented in this report relied heavily on available data gathered from many local, state, and national sources. Some of the information was preliminary, such as stream-flow model runs from the TWDB. The models had been through quality control and assessment by the entities they were acquired from, and additional Quality Assurance/Quality Control was performed by USACE. These models have relatively low risk and uncertainty; however, they should be reevaluated again during PED for the navigation study. Additionally, the streams and watersheds associated with Galveston Bay may change by the time PED begins; this would be addressed at that time.

The assemblage of input data is described in detail in the **Engineering Appendix, Attachment D, Engineering Data Used in Models**.

All of the data inputs to the models describe Existing Conditions. Future Conditions model predictions will necessarily have a much higher degree of uncertainty and risk.

Numerical Model

The HSC ECIP and CTR1 studies will use a joint model that includes the need to test a Recommended Plan for changes to hydrodynamics, salinity, and sediment transport in the lower HSC that may accrue from the flood-risk reduction measures contemplated for the system. The flood reduction measures for the CTR1 will only occur in the lower bay. Both the upper HSC and the CTR1 projects require an updated numerical model. The most efficient and cost-effective method to meet the needs of both projects is to perform the work concurrently. The District and ERDC have planned funding in such a way that the necessary comprehensive model can be developed and available to provide results for both studies. The ERDC model is being developed assuming the studies will be funded concurrently and thus will focus on building and validating a comprehensive three-dimensional (3D) numerical model of the entire HSC area, such that the plan conditions can be set up and tested for both projects. A fully validated 3D hydrodynamic, salinity, and sediment model will be available for both sets of analyses.

6.13.1.1 Relative Sea Level Rise

An essential element of developing a good understanding of the project area's exposure and vulnerability is assessing how quickly the individual scenarios might necessitate an action due to thresholds and tipping points. It is important to identify key milestones in the project timeline when impacts are expected. This involves inputs from all members of the PDT, since the threshold or tipping point could be a variety of different items or combinations of items.

Response strategies for the project planning horizon range from a conservative **anticipatory** approach, which constructs a resilient project at the beginning to last the entire life cycle (and possibly beyond), to a **reactive** approach, which would simply be to do nothing until impacts are experienced. Between these extremes is an **adaptive** management strategy, which incorporates new assessments and actions throughout the project life based on timeframes, thresholds, and triggers. A plan may include multiple measures adaptable over a range of SLC conditions and over the entire timeline, with different measures being executed as necessitated.

For a feasibility-level design, it is important to identify potential cost-risk items and **adaptation** costs to the stakeholders and decision makers. Further detailed design and analysis may be undertaken during the PED to optimize project features sensitive to relative sea level change. In this phase, the question of further adaptability beyond the 50-year economic analysis period may be addressed as part of the design optimization. The economic and cost formulation for the project should account for uncertainty in critical design items.

Hard structures (rock or concrete) are difficult to alter to accommodate changing conditions, unless they have been designed with that in mind from the beginning. Examples of the three types of approaches are listed below in **Table 6-19**. Since this navigation project does not include improvements to hard structures (in the Federal part of the project), then it will be relatively easy to design protections and solutions. In contrast, it is difficult to **accommodate** hard structures that have not been designed from the beginning with adaptation in mind. For example, a dock that has been designed from the beginning, with the intention that it will eventually need to be jacked up, is much cheaper in the long-run than a dock that has to be torn down and rebuilt. So again, this planning for an adaptive strategy will be much more important to the non-Federal part of the project.

Table 6-19 – Adaptive Approaches to Navigation Projects

Project Type	Protect	Accommodate	Retreat
Navigation	● Upgrade and strengthen existing primary structures ● Expand design footprint and cross section of existing structures, including raising for clearance and access ● Add secondary structures ● Add structures to protect backshore ● Improve resilience of backshore facilities	● Upgrade drainage systems ● Increase maintenance and dredging ● Adjust channel location and dimensions ● Modify operational windows ● Flood proof interior infrastructure ● Add sediment to shoreline or underwater morphology	● Relocate interior harbor infrastructure due to relative sea level rise or fall ● Abandon harbor/port ● Repurpose project area

Table from ETL 1100-2-1

In planning an adaptation strategy, **Table 6-20** provides a useful method of selecting the kind of adaptation to use (P = Protect, A = Accommodate, R = Retreat) and provides a list of specific solutions to pick from. Both the kind of adaptation and specific solutions are shown in the right-most column.

The two categories of sea-level effects in the left-most column that are more likely to affect this project are "wetland loss" (Federal) and "infrastructure damage" (non-Federal). Therefore, both the entire team and the non-Federal team should plan their adaptation strategies.

Table 6-20 –Relative Sea Level Rise Adaption Strategy

System Effects		Possible Interacting Factors		Possible Adaptation Approaches
		Climate	Non-Climate	
Increased Frequency / Severity of Storm Inundation	a. Coastal *(flooding directly from the sea)*	Waves, storm climate, erosion, rainfall, runoff, sediment supply, wetland loss and change	Sediment Supply, flood management, erosion, land reclamation, land management	● Revetments, seawalls, surge barriers **(P-hard)**; ● Dune,/beach construction, vegetation **(P-soft)** ● Building codes, flood-proof buildings **(A)** ● Land-use planning, hazard mapping, flood warnings **(A/R)** ● Abandonment, re-purpose **(R)**
	b. Inland *(flooding due to tail-water effects)*	Rainfall, runoff, wetland loss and change	Catchment management, land use, river and canal system, drainage system, geology	● Dikes, surge barriers, closure dams **(P-hard)**; ● Building codes, flood-proof buildings **(A)** ● Land-use planning, hazard mapping, flood warnings **(A/R)** ● Abandonment, re-purpose **(R)**
Accelerated Wetland loss and change		CO_2 fertilization, sediment supply, migration space, rainfall, runoff	Sediment supply, migration space, land reclamation (i.e. direct destruction) species population changes	● Nourishment, sediment management, hydraulic adjustments **(P-soft)** ● Land-use planning **(A/R)** ● Realignment, forbid hard defenses **(R)** ● Abandonment, re-purpose **(R)**
Accelerated Erosion (of "soft morphology)		Sediment supply, wave/storm climate, wetland loss and change	Sediment supply, structural measures	● Coastal defenses, seawalls, land claim **(P-hard)**; ● Nourishment, vegetation **(P-soft)** ● Building setbacks **(R)**
Infrastructure Damage		Sediment supply, wave/storm climate, wetland loss and change	Structure type, erosion, secondary structures	● Coast defenses, seawalls, adjust/improve structures **(P-hard)**; ● Nourishment **(P-soft)** ● Building setbacks **(R)**
Salt water Intrusion	a. Surface waters	Runoff, saltwater intrusion to ground water, temperature	Catchment management (over-extraction), land use	● Salt water intrusion barriers **(P-hard)**; ● Change water extraction **(A/R)**
	b. Groundwater	Rainfall, saltwater intrusion to surface waters, temperature	Land use, aquifer use (over-pumping)	● Freshwater injection **(A)** ● Change water extraction **(A/R)**
Impeded drainage, higher water tables		Rainfall, runoff	Land use, aquifer use, catchment management	● Drainage systems, polders **(P-hard)**; ● Change land use **(A)** ● Land-use planning, hazard delineation **(A/R)**

Example adaptation approaches are code: P = Protect (Hard, Soft), A = Accommodate, R = Retreat
This table was recreated from ETL 1100-2-1: Procedures to Evaluate Sea Level Change Impacts, Responses, and Adaptation (Table 7)

6.13.1.2 Hydrodynamics and Storm Surge

Typical Conditions.

The primary risk of this project's prediction of typical conditions is the obvious one: the numerical model may not accurately represent reality. This project has been clear from the beginning that a world-class model will be used, and will be performed by modelers who have done several previous studies of Houston Ship Channel. The best evidence that this **risk is low** is that current conditions in HSC are well reproduced by the "old" HSC numerical model.

Storm Conditions.

Waves in the entrance channel and the effects of ship wakes will be **solely** modeled with the physical Ship Simulation model.

The following general consensus in the coastal engineering community characterizes our ability to model different physical parameters:

- Wind: well measured and modeled (**Low Risk**);
- Waves & Ship Wake: well modeled, but will depend on Ship Simulations
- Water Levels: well measured and modeled (**Low Risk**);
- Current: well measured and modeled, but difficult in a stratified 3D environment, such as Galveston Bay (**Moderate Risk**);
- Salinity: easy to measure, but measurements are sparse. (Most of the Bay lacks measurements of salinity. Vertical profiles of salinity data are also sparse.) Difficult to model in a stratified 3D environment (**High Risk**);
- Sediment Transport: sparsely measured and difficult to model (**High Risk**); and
- Shoaling: well measured, but difficult to model (**High Risk**)

Recommendation for PED and for other future studies: Salinity is easy to measure and is the most critical parameter for the most critical and commercially important species in the Bay — oysters. A thorough set of salinity measurements (and coincidentally currents) in the Bay would be far less expensive than sediment transport and shoaling (bathymetric) measurements. A set of salinity/current measurements in the Bay would be the single most helpful addition to modeling Galveston Bay.

6.13.1.3 Feasibility-Level Ship Simulation

Feasibility-level ship simulations (**Appendix C, Attachment 5**) were conducted on November 17, 2017. In attendance were members of the USACE Galveston District, PHA, Houston Pilots and G&H Towing. The conclusions from the simulations are summarized in **Table 6-21**.

Table 6-21 – Feasiblity-Level Ship Simulation Conclusions

Segment	Area(s) Simulated	Description of Simulations	Conclusion
1	♦ Bolivar Roads to Redfish Reef ♦ Redfish Reef to BSC ♦BSC to BCC	♦Straight 650-foot wide channel sections were simulated for these three widening increments in the bay	♦Meetings between the design containerships and tankers were considered a risky maneuver ♦Meeting between the design containerships and tankers were considered a risky maneuver ♦Meetings in the 328-foot bends were not simulated as pilots considered such maneuvers unsafe
1	♦ Bolivar Roads to Redfish Reef ♦ Redfish Reef to BSC ♦BSC to BCC	♦Straight 700-foot wide channel sections were simulated for the three widening increments in the bay	♦Meetings between two design containerships acceptable ♦Meeting between the design containerships and tankers acceptable ♦Meetings in the 328-foot bends acceptable
2	♦BSC Widening	♦The design 455-foot channel in combination with the 4,000 foot BSC Flare, and 700-foot HSC widening was found to be acceptable. ♦The BSC was simulated with a 400-foot wide channel within the landcut	♦ The 455-foot was acceptable ♦The 400-foot was marginally acceptable, however, due to the drift angle required with cross-winds, a 455-foot design for the land cut is preferred.
2	♦Tuning Basin (TB2_RORO)	♦1,800 foot diameter simulated	♦Feasibility-level ship simulation determined BSC RoRo design was sufficient for the design vessel; however, the turning basin is not necessary for operations and is not economically justified. It is not included in the recommended plan.
3	♦BCC Widening	♦The design 455-foot channel in combination of BCC Flare widening (BETB3) BCCFlare_1800NS) and 700-foot HSC	♦Feasible for the navigation of the design containership, assist tugs and normal HSC vessel traffic
4	♦Boggy Bayou to Greens Bayou	♦Channel widening up to 530-feet from Boggy Bayou to Greens Bayou	♦This measure was found to provide for successful operations of Aframax and Suezmax vessels ♦ Increases size of ships allowed to operate in this reach above the existing LOA of 750 feet and beam of 106 feet. ♦This allows for the successful implementation of two-way traffic of loaded vessels with a maximum combined ship beam of 246 feet from Boggy Bayou to Greens Bayou ♦Meetings between a design Aframax and Panamax was found acceptable both above and below the BW-8 Bridge. ♦Meetings between a design Suezmax and Panamax was found acceptable both above and below the BW-8 Bridge.
6	TB6_Brady_900		Turning the design Panamax with ships and bunkering barges alongside at Wharfs 26-28 was considered acceptable with sufficient room with the assistance of available tugs.

6.13.2 Economic Data and Models Analysis

NED benefits include origin-to-destination benefits, meeting area benefits, moorage benefits, and tide delay reduction benefits. Origin-to-destination benefits are primarily derived "at-sea" based on the ability to utilize different vessels or to load more cargo onto them based on differing harbor condition scenarios. For deepening alternatives, most origin-to-destination benefits result from efficiencies related to the ability to use the additional draft to deploy larger, more efficient vessels and/or to transport more cargo on the same vessels and reducing the total number of trips needed to transport a given volume of cargo. Meeting area, moorage, and tide delay reduction benefits are derived near and within the harbor and result from a reduction in transit times needed to navigate the harbor. These benefits are normally smaller than the associated origin-to-destination benefits and are attributable to increased flexibility of harbor operations resulting from fewer tide delays, less concentrated traffic during high tides, and the ability of vessels to pass within the harbor (minimizing or eliminating the need for one-way traffic restrictions).

HarborSym modeling was completed on all measures and combination of measures considered in this study to determine the NED benefits of each alternative plan. These benefits were used in combination with other criteria for determining the TSP. Economic modeling used assumptions concerning changes in vessel operating practices resulting from the proposed project at HSC and these assumptions were tested using Feasibility-Level Ship Simulations.

6.13.3 Project Cost and Schedule Risk Analysis

In compliance with ER 1110-2-1302 – Civil Works Cost Engineering, dated June 30, 2016, a formal Cost and Schedule Risk Analysis (CSRA) was conducted by the PDT and Walla Walla Cost Engineering Mandatory Center of Expertise to develop contingencies for the Total Project Cost Summary. Details can be found **Appendix C, Section 11**.

6.13.4 Environmental Data and Analyses

The main risk and uncertainty in the environmental analysis relates to the lack oyster reef mapping above Morgans Point. Neither the Powell historical mapping nor the more recent TPWD mapping discussed in **Section 2**, cover the waters above Galveston Bay. There are no data sets publicly available. Private individual projects might have had limited local surveys, but these would not be in the public domain. The highly altered and frequently maintained nature of the HSC and the gradually decreasing average salinity would be expected to limit the potential for reef to be present. The potential for reef to be present based on the available salinity data and NOAA bathymetry discussed in **Section 7.2.2.4** indicate that the potential acreage is small compared to impacts of the NED Plan or Recommended Plan on Bay reef acreage. Reef is not expected in all of the NED Plan or Recommended Plan footprint area. As discussed in **Section 2.5.2.3**, salinity and

bathymetric data above Morgans Point was reviewed and coordinated with resource agencies and other private terminal project permit information reviewed upstream of Boggy Bayou, to prioritize surveys during feasibility-level design and analysis. Side-scan sonar surveys in 2018 focused on the remaining measures above Morgans Point that had greater potential to have adequate salinity and substantial areas of sufficiently shallow bathymetry. These were HSC widening above BCC, the combination turning basin/flare at the BCC, HSC widening along Hog Island, a proposed mooring near the San Jacinto Monument. All indicated some hard bottom signature, and all but the mooring were groundtruthed and confirmed reef presence. Of these, HSC widening above BCC, and the combination turning basin/flare at the BCC have remained in the NED Plan or Recommended Plan. The remaining measures above the extent of the survey have little potential to contain reef due to salinity and predominantly deepened bathymetry.

Other sources of uncertainty in the analysis are the use of aerials and TPWD land cover mapping to assess terrestrial habitat and potential for wetlands. Qualitatively, the uncertainty is small. This is because the recent aerials have sufficient resolution and indicator features of the nature of the shoreline, such as armoring and intertidal accretion, can be seen. There are not many areas in the NED Plan or Recommended Plan footprint where this situation is presented since most of the channel footprint is well within deep-water environments. For placement area impacts, field surveys performed for habitat modeling in newly proposed terrestrial PA or BU sites minimize the uncertainty of terrestrial and wetland information.

For the habitat modeling, there are not many overt sources or inclusions of uncertainty in the OHSIM model used. One uncertainty is the percent-cultch-coverage variable, which was conservatively assumed as 100-percent for the existing reef being impacted. To ascribe a true value would require effort intensive quadrat diving surveys that may have several issues for accomplishing including vessel traffic and visibility. One assumption used is that channel side reef would be comprised of a higher density of live oysters based on limited diving surveys performed for the NFS's BSC Improvements Project and subsequent AOM. Surveys to identify a lower percent coverage for impacted reef for use in the model may not yield large reductions in mitigation. The salinity inputs for the modeling came from TWDB **Sonde** data that was collected through many years and would not be expected to have any large uncertainty that would affect model outcomes given the monitoring methods, averaging, and model curve sensitivity to salinity.

A **Sonde** is an instrument package ideal for profiling and monitoring water conditions. They are torpedo-shaped and may have multiple sensors to record a range of water quality data from as deep as 656 feet. Upon retrieval from the water the information can be downloaded from the sonde to a computer with specialized software that can graph and interpret the data. http://oceanexplorer.noaa.gov/technology/tools/sondectd/sondectd.html (accessed 2 August 2017)

6.14 CONSISTENCY WITH OTHER STATE AND FEDERAL LAWS

The following sections summarize actions being taken in this study to comply with various statues applicable to Federal study or project.

6.14.1 Clean Air Act

The CAA contains provisions under the General Conformity (GC) Rule to ensure that actions taken by Federal agencies in air quality nonattainment and maintenance areas do not interfere with a state's plans to meet national standards for air quality. Under the General Conformity Rule (the Rule), Federal agencies must work with state, Tribal and local governments in a nonattainment or maintenance area to ensure Federal actions conform to the air quality plans established in the applicable state or tribal implementation plan. **Section 7.1.7.1** of this FIFR-EIS discusses the conformity demonstration requirements that will be necessary. An estimate of construction emissions was conducted to determine if the de minimis thresholds applicable to the HGB NAA for the ozone precursors NO_x and VOCs under this rule would be exceeded. The HGB NAA is currently in moderate nonattainment of the 8-hour ozone standard with an applicable de minimis threshold of 100 tons of any one pollutant in any construction year for NO_x or VOC.

The estimated emissions for either the NED Plan or the Recommended Plan are above de minimis requiring a Formal Determination of Conformity. A Draft General Conformity Determination (GCD) was prepared to help determine if emissions that would result from construction of the proposed action are in conformity with the Texas SIP for the HGB NAA and consultation and coordination with the TCEQ and the EPA was initiated. A public notice of availability (NOA) for the Draft GCD was published in the Houston Chronicle on November 22, 2019 in accordance with 40 CFR Part 93. No comments were received from the public regarding the Draft General Conformity Determination. The Final General Conformity Determination concurrence was received from TCEQ on December 10, 2019. A NOA for the Final GCD was published as required by 40 CFR Part 93 in the Houston Chronicle on January 8, 2020. **Appendix J** contains the Draft and Final GCD.

6.14.2 Clean Water Act

Section 404 of the CWA regulates dredge and/or fill activities in U.S waters. The proposed action would require dredging in U.S. waters. This program is responsible for ensuring the Administration's policy regarding "no net loss" of wetlands by requiring permit applicants to make every effort to avoid and minimize aquatic resource impacts, and provide compensatory mitigation to offset any permitted impacts. No wetlands would be impacted by the NED Plan or Recommended Plan channel modifications. Approximately 31 acres of wetlands would be impacted by construction of either the NED Plan or Recommended Plan, and another approximate

41 acres would be impacted by development of a future O&M PA. None of these are located within the 100-year floodplain, and most are the result of past land use practices such as material borrow, road grading ditching and levee construction. However, as discussed in **Section 6.9.14**, the Executive Order 11990 affords protection of wetlands outside of CWA jurisdictional boundaries for Federal projects. See that section for more detail.

The regulations implementing the CWA Section 404 also include the mandatory guidelines developed to implement Section 404(b)(1) which prescribes procedures for specifying dredged material disposal sites and determining the suitability of dredged material for disposal. An extensive review of existing past maintenance and new work sediment testing data covering the HSC, BSC, and BCC was performed. The data was then used to determine the next steps, in applying the procedures pursuant to USACE Regulatory Guidance Letter (RGL) 06-02, the Section 404(b)(1) guidelines, and related joint testing manuals developed for them. The review was used to identify data gaps, establish reasons to believe whether the material contained contaminants at levels to possibly present an unacceptable adverse impact and to ascertain what additional sampling and testing was required to ensure sediment quality is appropriate for the chosen disposal methods.

The resulting sampling and analysis was performed in September through December 2018, and is summarized in **Section 7.1.4.2**. The more detailed summary of these results can be found in **Appendix G Section 3.1.5.2.1** for south of Morgans Point and **Appendix G Section 3.1.5.2.2** for north of Morgans Point.

The results for new work sediments south of Morgans Point from Segments 1, 2 and 3 indicates the materials are suitable for open water disposal chemically; however, preliminary STFATE modeling showed load restrictions are needed to comply with the SMMP. During PED, further STFATE modeling is required for each of the Zones cited in the Galveston SMMP to more fully understand the placement options under operational conditions.

The results for new work sediments north of Morgans Point from Segments 4, 5 and 6 indicate exceedances of screening levels in sediment and elutriate for several constituents. Preliminary CDFATE modeling showed that dilutions sufficient to meet acute and chronic water criteria were not reached using the initial site parameters in the model. Further CDFATE modeling using more site-specific data is required during PED. A 404(b)(1) Evaluation Form for the NED and Recommended Plan impacts has been prepared and provided in **Appendix H** of this FIFR-EIS.

The TCEQ is responsible for conducting Section 401 certification reviews of USACE Federal Civil Works projects for the discharge of dredged or fill material into waters of the U.S., including wetlands, for the purpose of determining whether the proposed discharge would comply with State

water quality standards. A Section 401 certification has been coordinated with the provision of this FIFR-EIS and the Section 404(b)(1) evaluation. A Section 401 State Water Quality Certification for the Recommended Plan has been received from TCEQ (**Appendix H**).

6.14.3 Section 103 of the Marine Protection, Research, and Sanctuaries Act

Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) prescribes regulations, procedures, and evaluations applicable to Federal projects for the placement of dredged material in offshore waters. The currently permitted ODMDS No. 1 has been identified as one of the existing PAs in the HSC system that will be used for constructing and maintaining Recommended Plan features. Maintenance material from the existing HSC main channel from Bolivar Roads to the Main Turning Basin as well as the BSC and BCC is currently approved for placement at the ODMDS. It is expected that maintenance material from the Recommended Plan improvements directly adjacent to the existing HSC system would be similarly of suitable quality and would be approved for placement there, however, this would require approval from EPA Region 6. This coordination is ongoing and subject to the required testing being completed and meeting the standards necessary for placement in the ODMDS prior to dredging and placement. The current Site Management and Monitoring Plan (SMMP) for ODMDS No. 1, approves material that encompasses the whole HSC ECIP study limits, subject to the dredged material quality verification and testing required in the SMMP.

Currently, new work materials in Segment 1 from stations 78+000 to 100+000 (Bolivar Roads to Redfish) and from Stations 57+000 to 78+000 in (Redfish to BSC) are planned for placement in ODMDS No.1 during construction and have been tested in accordance with Section 103 guidelines(**Appendix G Section 3.1.5.2**). This material would be dredged mechanically and placed via scow at the ODMDS. Maintenance materials are currently dredged and placed via hopper dredge from Bolivar to Redfish, portions of Redfish to BSC, and the BSC Flare. This practice would continue and extend from Bolivar to Morgans Point including the BSC and BCC channels beginning as early as 2032 as described in **Appendix R, Section 7**. The current Site Management and Monitoring Plan (SMMP) for ODMDS No. 1, approves material that encompasses the whole HSC ECIP study limits, subject to the dredged material quality verification and testing required in the SMMP.

6.14.4 Section 7 of the Endangered Species Act

The ESA provides a program to conserve T&E plants and animals, and the habitats in which they are found. The Act requires Federal agencies to consult with the USFWS and NMFS, to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of designated critical habitat of

listed species. The Act also prohibits any action that causes an avoidable "taking" of any listed species of endangered fish or wildlife.

Compliance with the Endangered Species Act (7 U.S.C. 136; 16 U.S.C. 460 et seq.) has been coordinated with the USFWS and the NMFS for those species under their respective jurisdictions. A draft BA covering the proposed action of the TSP channel modifications and use of the existing PAs was included with the public release of the DIFR-EIS in the previous planning phase. The USACE provided a copy of the draft BA to the USFWS and NMFS and requested the initiation of informal consultation with NMFS on potential impacts to the endangered green, loggerhead, and Kemp's ridley sea turtles and the Giant manta ray a letter of concurrence from USFWS for potential impacts on West Indian manatee. The channel modifications of the TSP encompass the footprint of the NED Plan and Recommended Plan developed in the subsequent planning phase. The proposed DMMP for the NED Plan and Recommended Plan included several new BU sites and upland PAs for new work placement and future O&M, in addition to the existing PAs. These changes have been incorporated into an updated final BA (**Appendix K**) included in this FIFR-EIS.

The proposed dredge methods for constructing the NED Plan or Recommended Plan will predominantly be hydraulic cutterhead dredging and limited mechanical dredging in the lower Bay. No hopper dredging is proposed for construction. Maintenance hopper dredging currently conducted for the existing HSC would continue in the HSC modified by the NED Plan or Recommended Plan. The determination of may affect, but not likely to adversely affect, was made for sea turtles, Giant manta ray, and West Indian manatee and no effect for piping plover and rufa red knot. None of the new placement sites proposed in the specific DMMP for the NED Plan or Recommended Plan are located in designated critical habitat. The existing ODMDS No. 1 offshore placement site approved under MPRSA is located in the Sargassum critical habitat designated in 2014 for the Loggerhead turtle, essentially offshore Gulf waters from the 10-meter-contour. Use of this existing site for maintenance material from this project has been coordinated for Section 7 consultation compliance.

Though it is not likely West Indian manatee, and the other listed marine and shorebird species would be encountered within the NED Plan or Recommended Plan project area during construction, their presence in the area is possible. An advisory would be added to the USACE contract specifications for this project to make construction contractors aware of the possible presence of those species.

Best management practices (BMP) would be utilized, to the maximum extent practicable, to avoid project construction impacts to any T&E species or their critical habitat within the project area. The USACE will continue to closely coordinate and consult with the USFWS and the NMFS

regarding T&E species under their jurisdiction that may be potentially impacted by implementing the proposed action.

For Texas State Rare, T&E Species that are not otherwise listed federally, only three wading bird species that use brackish marsh, could be expected to use habitat near the project area in the vicinity of existing PAs. More specifically, the existing BU marshes contain this type of habitat, and maintenance of the NED Plan or Recommended Plan using BU marsh cells that are still being filled would continue the beneficial creation of habitat used by these species. All other State-listed species require terrestrial, freshwater, or other type of habitat not associated with the project area. This is discussed in more detail in **Section 2.4.5.1**.

6.14.5 Magnuson-Stevens Fishery Conservation and Management Act

The MSFCMA (P.L. 94-265), as amended, establishes procedures for identifying EFH and required interagency coordination to further the conservation of federally managed fisheries. Regulations codifying the Act in 50 CFR Sections 600.805–600.930 specify that any Federal agency that authorizes, funds, or undertakes, or proposes to do, an activity that could adversely affect EFH, is subject to the consultation provisions of the Act, and identifies consultation requirements. EFH consists of habitat necessary for spawning, breeding, feeding, or growth to maturity of species managed by Regional Fishery Management Councils (RFMC) in a series of FMP. EFH is designated for the project area in which the NED Plan and Recommended Plan are located. Consultation with NMFS was informally initiated with the release of the DIFR-EIS and receipt of any comments regarding EFH impacts. A separate EFH Assessment containing all the elements required in the EFH Final Rules for an assessment has been prepared for this project, and has been coordinated with NMFS. **Appendix L** provides the EFH Assessment.

6.14.6 Section 106 of the National Historic Preservation Act

Compliance with the National Historic Preservation Act of 1966, as amended (54 U.S.C. § 306108), requires the consideration of effects of the undertaking on all historic properties in the project area and development of mitigation measures for those adversely affected properties in coordination with the State Historic Preservation Officer (SHPO), the Advisory Council on Historic Preservation (ACHP), and Tribal Nations. It has been determined that there is a potential for new construction, improvements to existing facilities, and maintenance of existing facilities to cause effects to historic properties. Therefore, in accordance with 36 CFR 800.14, the USACE will address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities under the existing Programmatic Agreement between the USACE, the Texas SHPO, and the ACHP and in consultation with Tribal Nations. The existing Programmatic Agreement is provided in **Appendix N**. The USACE intends to execute a new Programmatic Agreement, in consultation with the ACHP, the Texas SHPO, and

Tribal Nations, that will include the HSC ECIP. The new Programmatic Agreement will be executed within the two years of the Record of Decision and replace the existing 1988 Programmatic Agreement.

6.14.7 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) of 1972, as amended, provides for the effective management, BU, protection, and development of the resources of the nation's coastal zone. The CZMA directs Federal agencies proposing activities within or outside of the coastal zone that could affect any land or water use or natural resource of the coastal zone, to assure that those activities or projects are consistent, to the maximum extent practicable, with the approved State programs. The Texas Coastal Management Program (TCMP) is the State entity that participates in the Federal Coastal Zone Management Program created by the CZMA. The TCMP designates the coastal zone and coastal natural resource areas (CNRA) requiring special management in that zone, including coastal waters, waters under tidal influence, coastal wetlands, submerged lands and aquatic vegetation, dunes, coastal historic areas, and other resources. The following CNRAs are found in the vicinity of the NED Plan, Recommended Plan and PAs and BU sites proposed in the DMMP for these plans:

- Water under tidal influence – Galveston Bay waters;
- Submerged land – Galveston Bay bottom in the project area;
- Hard substrate reefs and oyster reefs – Hard-bottom habitat and oyster reef discussed in **Section 2.5.2.3**;
- Special hazard areas – Floodplain areas mapped by FEMA as special hazard areas Zone AE and floodway, and Zone VE are located in the HSC as discussed in **Section 6.8.13**;
- Coastal shore areas – Areas 100-feet landward of the high water mark on submerged lands, which includes land surrounding the channel, land cuts, and existing placement areas, such as PAs 14 and 15;
- Coastal historic areas – Onshore historical markers and archaeological sites located adjacent to the channel. Cultural Resources surveys within the Recommended Plan's Area of Potential Effect (APE) will be conducted as needed to determine presence of submerged cultural resources;
- Coastal preserves – Atkinson Island WMA discussed in **Section 2.5.6.1**;
- Coastal wetlands – Estuarine wetlands (saltwater marsh etc.), and palustrine wetlands discussed in **Section 2.5.1.2**. None are expected in the channel footprint of the NED Plan or Recommended Plan; however, palustrine wetlands in the proposed terrestrial PAs within one mile of the mean high tide line of a designated tidal river would apply.
- Critical erosion areas – Galveston Bay shoreline in general is listed as eroding per latest Texas Bureau of Economic Geology data; and

- Tidal sand or mud flats – Tidal sand flats located between and around the fringes of existing PAs (PAs 14 and 15), Atkinson Island, or unarmored shoreline

Of these CNRAs, the first five are found in the NED Plan or Recommended Plan footprint; however, the fifth, coastal shore areas, is limited to small areas of armored, developed commercial tracts and not natural shoreline. All other CNRAs would be avoided by the channel modifications of the NED Plan or Recommended Plan. All oyster reef impacts would be mitigated as described in **Section 7.5**. New work placement at the Bay BU sites of 3-Bird Island Marsh, 8-Acre and 6-Acre Long Bird Islands, M-11, M-12, for the NED Plan or Recommended Plan would convert submerged land to BU marsh (another type of CNRA) or bird island habitat, a desirable habitat for coastal bird fauna. The proposed shoaling attenuation feature would convert a relatively small area of submerged land into a jetty-like structure of approximately 23 acres as currently conceived. For coastal wetlands, only the palustrine forested wetlands in the terrestrial construction BU site BW8 proposed for the NED Plan or Recommended Plan, would constitute wetlands within one mile of a designated tidal river (Buffalo Bayou/HSC). The forested wetlands on the Rosa Allen Expansion tract proposed for future maintenance of the NED Plan or Recommended Plan are just inside of one mile from the Sims Bayou Turning Basin connected to Buffalo Bayou/HSC but farther than a mile from the channel itself. The wetlands at both sites appear to have artificially developed from past land use alteration such as road ditching/grading or construction of a levee. For tidal sand or mud flats, only minor accretions on the northeast side of Atkinson Island would eventually be converted to tidal marsh (another type of CNRA) within the interior of the proposed M12 marsh cell BU site of the NED Plan and Recommended Plan. The impacts to these CNRAs have been coordinated with the local resource agencies during planning for this study, and most impacts are BU initiatives that would restore ecologically-beneficial coastal habitat types.

Changes in 2012 to the TCMP resulted in the Coastal Coordination Advisory Committee (CCAC) replacing the previous Coastal Coordination Council (CCC). The CCAC is composed of several State agencies and local officials, to advise the TXGLO Commissioned on administering the TCMP. The TCMP reviews all Federal actions that may affect natural resources in the coastal zone for consistency with the Federal goals and objectives. The Federal Agency proposing the action prepares a Consistency Determination for review by the TXGLO for consistency with the TCMP. A Statement of Compliance with the TCMP has been prepared (**Appendix I**) with specifics regarding the NED Plan and Recommended Plan and the proposed DMMP for these plans. A Consistency Determination has been obtained from TXGLO (**Appendix I**).

6.14.8 Fish and Wildlife Coordination Act

The USACE's proposed actions under the NED Plan and Recommended Plan have been coordinated with the USFWS, NMFS, TPWD and other State and Federal resource agencies

through periodic resource agency meetings held for this study, and additional coordination and consultation. Additionally, the USFWS, NMFS, and TPWD have been sent copies of the FIFR-EIS for review and comment during the State and Agency Review period. Pursuant to Fish and Wildlife Coordination Act (FWCA), the USFWS provided a draft 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. In addition, the USFWS has provided the FWCA Report with their recommendations related to fish and wildlife resource impacts. A copy of the PAL and FWCA Report are provided in **Appendix M**.

6.14.9 Marine Mammal Protection Act of 1972

The MMPA was passed in 1972 and amended through 2007. It establishes a moratorium on the taking and importation of marine mammals and marine mammal products by persons subject to the jurisdiction of the U.S, with certain exceptions. The Act is intended to conserve and protect marine mammals and it established the Marine Mammal Commission, the International Dolphin Conservation Program, and a Marine Mammal Health and Stranding Response Program. Consultation for the MMPA is conducted when proposed project effects would result in takes of protected marine mammal species. Review and consultation for the MMPA may also occur via the ESA when actions involve marine mammals listed under the ESA.

The only marine mammals covered under the MMPA expected to be regularly present in Galveston Bay are bottlenose dolphins (*Tursiops truncatus*). These are highly mobile species readily able to avoid dredging activities and vessels, and placement activity occurring in the water. As avoidance of the area would be only during construction of the NED Plan or Recommended Plan, and there is an abundance of similar habitat within the area, the proposed action would have minimal and temporary impacts, by way of disturbance, to the individuals present. Previous USACE project determinations coordinated with NMFS have not indicated dredging to result in incidental takes of cetaceans. Therefore, the dredging for construction and routine maintenance would not be expected to result in incidental takes of bottlenose dolphins that would require Incidental Take Authorizations under the MMPA (**Appendix G**).

6.14.10 Federal Water Project Recreation Act

This Act directs ". . . that . . . in investigating and planning any Federal navigation, flood control, reclamation, hydroelectric, or multipurpose water resource project, full consideration shall be given to the opportunities, if any, which the project affords for outdoor recreation." Any such features are subject to cost sharing with the beneficiaries of the recreational feature. Some public comments during the DIFR-EIS public comment period indicated interest and support for incorporating recreational features to the conceptual shoaling attenuation feature proposed under the Recommended Plan. However, currently, no local recreation entities have proposed

participating in cost sharing of recreational opportunities, or of features in connection with this navigation study or the dredged material placement that would result from a project.

6.14.11 Coastal Barrier Improvement Act of 1990

The Coastal Barrier Improvement Act (CBIA) of 1990 reauthorized the Coastal Barrier Resources Act (CBRA) of 1982. The CBRA designated relatively undeveloped coastal barriers along the Atlantic and Gulf coasts as part of a Coastal Barrier Resources System (CBRS), making these areas ineligible for most new Federal expenditures and financial assistance, to reverse previous Federal historical participation in subsidizing and encouraging development on coastal barriers. Neither the channel modifications nor existing or proposed PAs and BU sites for either the NED Plan or Recommended Plan, are located on coastal barrier islands. The closest CBRS designated units or protected areas are on Bolivar Peninsula near the southern limit of the study.

6.14.12 Farmland Protection Policy Act of 1981 and the Council on Environmental Quality Memorandum Prime and Unique Farmlands

The purpose of the Farmland Protection Policy Act is to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses. The act requires among other things, agencies to identify and take into account the adverse effects of Federal programs on the preservation of prime and unique farmlands, and consider alternative actions, as appropriate that could lessen such adverse effects. The Council on Environmental Quality (CEQ) issued a memorandum "Analysis of Prime and Unique Agricultural Lands in Implementing the National Environmental Policy Act" that supplemented NEPA procedures to include analysis of these impacts in NEPA documents. The regulation codifying the Act in 7 CFR Part 658 specified procedures and criteria for the analysis of these impacts. The definitions in this regulation specify that farmland does not include land already used as water storage, which would include open water. The channel modifications of the NED and Recommended Plan are almost entirely in open water, except for very small amounts of highly urbanized and industrial land.

No terrestrial resources other than very small amounts of urbanized, disturbed land at the channel margins are impacted by the NED or Recommended Plan channel modifications, and therefore, no prime or unique farmlands would be affected. For the proposed placement, only the proposed terrestrial upland PAs in the upper HSC in Segments 4 through 6 would impact terrestrial soils, as discussed in **Section 7.1.2**. As described in that section, two are existing upland PAs (Glendale and Filterbed), and two are NFS-owned undeveloped upland tracts (BW8 and E2 Clinton) with only a minor percentage (<6 percent) of soils classified as prime farmland soils. These are relatively small tracts surrounded by development that would not have significant agricultural use,

and had previous other non-farming uses. No significant impact or loss of prime or unique agricultural lands would occur.

6.14.13 Executive Order 11988, Floodplain Management

This EO directs Federal agencies to avoid possible impacts associated with the modification of floodplains and to avoid support of floodplain development wherever there is a practicable alternative. In carrying out the activities described above, each agency has a responsibility to evaluate the potential effects of any actions it may take in a floodplain associated with the one percent annual chance event.

The channel modifications of the NED Plan and the Recommended Plan are in sections of the Buffalo Bayou/HSC stream segment and Galveston Bay mapped by the Federal Emergency Management Agency as either subject to inundation by the one percent annual chance event (Zone AE) or floodways designated for Zone AE, or coastal flood zone with velocity hazard (Zone VE). As discussed in **Section 7.1.3.1**, the NED Plan or the Recommended Plan is not expected to have substantial hydrodynamic impacts including tidal variations or surge conditions, based on hydrodynamic modeling conducted by ERDC for project effects. Of the proposed new work PAs in the DMMP for the NED Plan and Recommended Plan, only the southern margin of BW8 has any area mapped as Zone AE or other regulated floodplain hazard zone. This is limited to 30 of 385 acres proposed for placement.

6.14.14 Executive Order 11990, Protection of Wetlands

This EO directs Federal agencies to avoid undertaking or assisting in new construction located in wetlands, unless no practical alternative is available, and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. As discussed in **Section 6.8.2**, the CWA Section 404 program is responsible for ensuring the Presidential policy to achieve "no net loss" of wetlands. This EO further strengthens the commitment for federally implemented and permitted projects to achieve no net loss of wetlands, primarily through avoidance of impacts. Therefore, impacts to wetlands and achieving no net loss of wetlands are important factors in complying with this EO. The channel modifications of either the NED Plan or Recommended Plan would not impact any wetlands. Proposed widening along the north shore of the BSC would be constructed using sheet piling to allow for steeper than 3:1 slopes to avoid small wetlands located there. As described in **Section 7.2.1.2**, two proposed new work PAs would impact 22.7 acres of mostly forested, and 8.7 acres of mostly scrub shrub wetlands, and future proposed O&M would impact 40.7 acres of mostly forested wetland. These would be mitigated through purchase of mitigation bank credits as discussed in **Section 7.5**.

6.14.15 Executive Order 12898, Environmental Justice

This EO directs Federal agencies to determine whether their programs, policies, and activities would have a disproportionately high or adverse effect on minority or low-income population groups within the Project Area to identify potential environmental justice (EJ) issues. Most of the project area is in the open waters of Galveston Bay and the industrial part of the HSC, with large, relatively sparsely populated census tracts (due to the land use and water). As documented in **Section 7.4.2**, though the 22-tract average of the census tracts containing the NED or Recommended Plan was 73.3 percent minority, analysis of the proposed dredged quantities per channel length, and demographics of the census blocks (a finer division) where populated land was closest to the modifications in Segments 2, 3, and 4 through 6, indicated construction dredging activity would not disproportionately impact blocks with predominantly EJ populations. These blocks would be closest to the NED or Recommended Plan footprint where direct effects experienced would be their greatest. The PAs proposed for use in the upper HSC of Segments 4 through 6 do have minority-dominated populations. However, the impacts from their use for new work would be temporary, experienced over 3 months of site preparation at a given site, followed by 3 months of placement. The placement of material would not produce significantly adverse long-term exposures to human receptors from air, noise, water or other media impacts. Therefore, the proposed action of either the NED Plan or Recommended Plan is not expected to have any disproportionately high or adverse effect on low-income or minority population groups.

6.14.16 Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds and the Migratory Bird Treaty Act

This EO directs Federal agencies to increase their efforts under the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Acts, Fish and Wildlife Coordination Act, the ESA of 1973, NEPA of 1969, and other pertinent statutes to avoid or minimize impacts on migratory bird resources. The EO directs Department of Defense (DoD) to encourage incorporation of comprehensive migratory bird management objectives in the preparation of DoD planning documents, including NEPA analyses. The EO also directs DoD to perform the following actions prior to starting any activity that is likely to affect migratory bird populations:

1. Identify species likely to occur in the area of the proposed action and determine if any species of concern could be affected by the activity;
2. Assess and document the effect of the proposed action on species of concern through the NEPA process when applicable; and
3. Engage in early planning and scoping with the USFWS to proactively address conservation, and initiate appropriate actions to avoid or minimize the take of migratory birds.

The NED Plan or Recommended Plan is not expected to permanently impact migratory bird populations. As discussed in **Section 2.5.5.2**, portions of several active PAs and islands adjacent to the HSC (including Atkinson Island, Alexander Island, and Goat Island), are mapped by the TXGLO in cooperation with TPWD and USFWS, as containing a colonial water bird rookery. None of these are proposed for use for new work or O&M of the project increment of maintenance material. Several migratory bird species listed by USFWS are documented in **Section 2.5.5.2** and **Appendix G, Section 1.4.5.2** as expected to use land areas or islands near the project area. While migratory birds commonly have been observed on active PAs foraging, nesting, and roosting, they are active PAs, and the timing of construction would be coordinated to avoid impacts to migratory and nesting birds. Options to avoid migratory and nesting bird impacts may include adjusting the construction timeline to accommodate the nesting season or re-sequencing construction activities to work in areas where no active nests are present. Maintenance dredged material placement cycles in these and other PAs have been conducted successfully with minimal disturbance to migratory species. Similar construction practices and timing would be implemented for the proposed action where existing PAs are proposed used for dredged material placement.

6.14.17 Executive Order 13045, Protection of Children from Environmental and Safety Risks

This EO mandates that Federal agencies identify and assess disproportionate environmental health and safety risks to children, and ensure that its policies, programs, activities, and standards address them. "Environmental health risks and safety risks" are defined as risks to health or safety that are attributable to products or substances that the child is likely to come in contact with or ingest, such as air, food, drinking or recreational use of water, soil children may live on, and products they use or are exposed to. The proposed action of building the NED Plan or Recommended Plan was evaluated for disproportionate effects towards children. The project area contains some schools in the vicinity of the NED Plan or Recommended Plan at the upper part of the HSC that have adjacent industrial land use, and the closest being approximately 0.5 miles away from the channel footprint. However, construction dredging of the NED Plan or Recommended Plan and the associated temporary ambient air and noise emissions will not have an impact that particularly targets or disproportionately affects children given the distance and general nature of the temporary impacts. Similarly, there are several schools within 0.5 miles of existing PAs in the upper part of the HSC currently used for maintenance, and proposed for project new work placement or O&M for the NED Plan or Recommended Plan. The temporary ambient air and noise emissions from the construction or maintenance placement actions are similarly not expected to have an impact that particularly targets or disproportionately affects children given the distance and general nature of the temporary impacts. Therefore, there would be no disproportionate effects on children due to environmental health or safety risks.

6.14.18 Resource Conservation and Recovery Act (RCRA) As Amended By The Hazardous and Solid Waste Amendments (HSWA) of 1984

This Federal law governs the management and disposal of solid waste. The Resource Conservation and Recovery Act (RCRA) may impose substantial requirements on Federal projects that manage even small amounts of hazardous waste. The HTRW investigation discussed in **Section 2.3.7** did not identify any RCRA sites within the project footprint for the proposed action under any of the proposed alternatives.

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7 ENVIRONMENTAL CONSEQUENCES*

This section describes the environmental consequences of both the NED Plan and the Recommended Plan, and contrasts them with those of the FWOP Conditions, which for the purposes of NEPA impact analysis is the same as the No Action Alternative. The FWOP/No Action Alternative is described in **Section 3**, and is not repeated here, but referenced. The environmental consequences are described for both the channel and dredged material placement impacts of the NED Plan and the Recommended Plan. Existing PAs identified for use for the HSC ECIP were shown previously in **Figure 2-2**, and discussed in **Section 2.4.1.1** have been identified for use for the HSC ECIP. The initial impacts for these existing or already planned and approved PAs have been accounted for under the HGNC Project discussed in **Section 1.7.1** and in the *Final Environmental Assessment, Expansion of Placement Areas 14 and 15, Houston Ship Channel, Chambers County, Texas, dated 2010*.

7.1 PHYSICAL RESOURSES CONSEQUENCES

7.1.1 Climate

The impacts of future climate changes on the NED Plan or Recommended Plan would not be significantly different than the impacts of these changes on the existing navigation channels in the No Action alternative. The increased temperature, the slight increase in heavy precipitation days, or the slight increase in drought conditions (consecutive dry days) predicted for the area would not particularly alter the efficacy of either the existing or proposed navigation channel improvements under either the NED Plan or Recommended Plan.

7.1.2 Topography, Soils, Geology, and Groundwater

The modifications to the navigation channels of either the NED Plan or Recommended Plan would not impact surface topography, but would have minor bathymetric changes in the vicinity of existing navigation channels.

Like the FWOP/No Action alternatives, the NED Plan or Recommended Plan would continue to result in periodic changes in topography from placement of maintenance of dredged material to the existing PAs located away from the mainland. The NED Plan or Recommended Plan would require terrestrial upland PAs in the upper HSC in Segments 4 through 6. Two PAs are existing with 10 to 20 foot high dikes that would be raised another 6 to 7 feet. Two other PAs are new one-time use sites that would be raised 5 feet. These are all relatively small isolated tracts and the change would be only to those sites. Mainland topography or drainage patterns would not be altered significantly. Neither the NED Plan nor Recommended Plan would be expected to have impacts on the regional physiography.

Dredging to deepen and widen the HSC for either the NED Plan or Recommended Plan would minimally impact the local soils and geology by redistributing existing bay bottom clays and sediments, causing potential increases of local shoaling rates within the HSC. New work placement for the NED or Recommended Plan would only involve use of two existing upland PAs (Filterbed and Glendale), and two NFS-owned undeveloped upland tracts, that have only a minor percentage (<6 percent) of soils classified as prime farmland soils. Placement for either plan would not deplete these soils and all are isolated, relatively small tracts surrounded by development that would not have significant agricultural use. Impacts to native soils would be minor. Net changes to the local or regional nature of the existing geology of the study area would be minimal. Additionally, there would be no impacts or changes to geologic hazards such as faults and subsidence.

Neither the NED Plan nor Recommended Plan would be expected to have indirect effects on groundwater, as there are no expected increases from associated human activity, including land excavation and water consumption.

7.1.3 Physical Oceanography

Channel modifications can have effects on salinity, circulation, tidal variation, and storm surge. Different improvements, deepening or widening, can impact each of these areas differently. Subsequent to release of the DIFR-EIS, a hydrodynamic model was developed by ERDC to evaluate those hydrodynamic effects as well as sediment transport. Recent studies involving hydrodynamic modeling of these effects for similar channel modification projects found minimal increases to surge levels, tidal variation, and small changes to salinity as a result of channel modifications.

7.1.3.1 Tides, Currents, and Water Level

Channel deepening has the potential to affect surge and tidal variations by lowering the bay bottom relative to existing conditions and reducing hydraulic resistance. Storm surge hydrodynamic modeling of modifications to existing channels in the U.S. in areas exposed to hurricanes shows more often than not that these effects are minimal, even during more adverse surge conditions. Further information on other studies is available in **Appendix G, Section 3.1.4.1**.

In the NED and Recommended Plan, the deepening would occur in the upper reaches (Segments 4, 5, and 6) of the HSC and not in the sections through Galveston Bay. However, the existing channel in the upper reaches is already scoured to proposed depths throughout the centerline as evidenced in USACE hydrographic surveys. For example, channel depths range from 41 to 43-feet deep and 48 to 50-feet deep in areas near the I-610 and BW 8 bridges, respectively. The NED or Recommended Plan would mostly be dredging the channel toes and slopes in these reaches. Therefore, effects to current tidal variations or surge conditions are not anticipated.

The NED or Recommended Plan would not be expected to have indirect effects on tides, currents, or water levels, as it is a modification to an existing navigation channel.

7.1.3.2 Salinity

Most salinity impacts from channel modifications are linked to deepening. With the proposed deepening, the saline water from the Gulf of Mexico has the potential to travel further upstream as a saltwater "wedge" along the bottom of the channel. The denser, saltier water is heavier than freshwater and, therefore, sinks to the bottom of the water column.

Modeling studies from the Texas City Channel Deepening and Miami Harbor Projects indicated that dredging would have little to no effect on salinity variations in areas upstream of proposed dredging activities.

The modeling for the 1995 LRR, proposed deepening the HSC by 5 feet to its current 46.5-foot depth. Results of the modeling mainly indicated a shifting of salinity contours further up channel and deeper into Trinity Bay mainly in the August-October seasonal period, and small increase in bottom salinities of less than 2.5 ppth.

As discussed in **Section 7.1.3.1** above, proposed HSC deepening for the NED Plan or Recommended Plan would be confined to the upper reach of the channel where part of the channel is already at proposed depths, and thus would not occur in the Bay. Considering the modeling results discussed from previous studies with deepening of channels extending from oceanic to estuarine conditions, and the limited deepening that does not extend into the Bay or Gulf, the NED Plan or Recommended Plan would not result in significant adverse impacts to salinity.

The NED Plan or Recommended Plan effects on salinity would be direct, and would not expect to have other indirect effects that would change the freshwater inflows from the mainland watershed, or induce other activity that would increase flows inward towards Galveston Bay of ocean salinity from the Gulf of Mexico.

7.1.3.3 Relative Sea Level Change

ER 1100-2-8162 requires formulating and evaluating alternatives for a range of possible future rates of SLC. These are represented by the "low," "intermediate," and "high" scenarios analyzed and discussed in **Section 3**, **Section 3.1.4.3**, including comparison to the without project conditions. The water level component of RSLC is a regional phenomenon at its smallest scale, with land subsidence adding a local scale component. As discussed in **Section 2.3.4.3**, the water level component has trended upward due to the general increase in the global sea level, while the local subsidence, although appearing to have curtailed, has moved local land surfaces downward.

Both of these would increase navigation water depths relatively uniformly across the project area. Therefore, the effects on water depth would be uniform throughout the study area for all alternatives, including the NED Plan and the Recommended Plan. The existing channel would experience the same RSLC. As a result, the change in depth affects the NED Plan, Recommended Plan and the No Action Alternative equally. The change ranging from 1.7 feet to 4.1 feet at 50 years between the low and high rate scenarios, would range from being a small to appreciable benefit for shipping towards the end of the period of analysis. However, the change would be gradual and not immediate.

Other possible ways RSLC impacts navigation (discussed in ETL 1100-2-1) are wave attack and erosion by changing the base elevation at which surface waves from weather or ships can propagate, since wave forces near the water surface are the strongest. None of the navigation features of the NED Plan or Recommended Plan would be subject to these effects as they are all essentially underwater dredging of existing channels and adjacent bay bottom to deeper bathymetry. All alternatives, including the NED Plan, Recommended Plan and the No Action Alternative, would be equally subject to the same changes in surface wave elevation. Therefore, any gradual adjustments in shore protection at dikes and channels necessary to raise the armored height would be required for any existing or planned dredged material PAs. Design of PA containment dike heights to maximize capacity take RSLC into account. For new placement locations, RSLC considerations will be determined and incorporated into final design during PED. Any impacts to any use of the existing PAs and marsh cells, including elevating outlet structures, or raising of dikes, for the NED Plan or Recommended Plan would be equally experienced for the existing project under the No Action Alternative. Therefore, impacts to placement would not be a differentiator among alternatives.

7.1.4 Water and Sediment Quality

7.1.4.1 Water Quality

Dredging under the NED Plan or Recommended Plan, would result in minimal impacts. It would not be expected to degrade the long-term water quality within the project area. These effects would be consistent with those that would occur during normal maintenance dredging operations occurring within the project area. In some cases, depending on the channel segment involved, the effects would last longer than the normal O&M dredging event, but effects would be spatially similar, and localized to the vicinity of the dredge. Minimal temporary impacts from increased turbidity and decreased DO could occur as a result of water column mixing during dredging and placement activities. These patterns would return to their previous condition following completion of dredging. Any impacts to the distribution patterns for these water quality parameters from dredging would be minimal. No significant long-term effects to DO or temperature from the proposed channel modifications are expected due to the relative shallow nature of the bay and the

high mixing rates which limit anoxic conditions in the open bay and resist the development of stratification and thermoclines. With the exception of a limited 5-foot deepening in the upper channel above Boggy Bayou, all proposed modifications are forms of widening, which does not impact DO or temperature. Most of the effect of deepening is localized within the channel, and most of that effect expected to have occurred with the initial excavation of the channel and significant deepening. **Appendix G, Section 3.1.5.1** contains a detailed discussion of the expected lack of substantial impact on long term DO due to the proposed modifications, using long term DO monitoring results at the two upper channel stations deepened from 2000-2005 with the last Federal project to illustrate that DO was not negatively impacted following project construction. It continued its historical increase mostly due to improved stormwater and wastewater treatment and standards. Also, the high rate of vessel traffic does not allow stratification to occur within the channel.

The proposed new work placement is not expected to produce impacts under ocean placement conditions other than in a transient manner (**Section 7.1.4.2.1**) and would involve only temporary impacts during use of existing upland PAs (**Section 7.1.4.2.2**), new one time use upland PAs (Section **7.1.4.2.2**), and new bay aquatic BU sites. These sites would be designed properly to dewater sediments and control discharges, or would be constructed using techniques that limit the temporary impacts of in-water placement. No significant adverse effect is expected from either the NED Plan or Recommended Plan

The NED Plan or Recommended Plan would not be expected to have indirect effects to water quality from inducing development, or changes in watershed runoff or discharge quality; either would be modification of an existing navigation channel. For information on Sampling, Chemical Analysis, and Bioassessment in Accordance with MPSRA Section 103 for south of Morgans Point and north of Morgans Point see **Appendix G Section 3.1.5.2.1** and **Section 3.1.5.2.2**, respectively.

7.1.4.2 Sediment Quality

7.1.4.2.1 ODMDS Placement

Chemical concentrations in shoaled sediment within the HSC will not change as a result of the NED Plan or Recommended Plan. The proposed actions will have no discernable effect on chemical concentrations in sediment. New work sediments from locations for the project situated south of Morgan's Point (SMP) were sampled representatively and in September through December of 2018 were analyzed for persistent chemical constituents and subjected to biological testing for direct toxicity and bioaccumulative effects. Based on the results of these tests, the SMP sediments are suitable chemically for open water placement chemically, however preliminary STFATE modeling showed load restrictions are needed to comply with the SMMP. During PED, further STFATE modeling is required for each of the Zones cited in the Galveston SMMP to more

fully understand the placement options under operational conditions. This can be completed during PED. For information on Sampling, Chemical Analysis, and Bioassessment in Accordance with MPSRA Section 103 for south of Morgans Point (**Appendix G Section 3.1.5.2.1**).

7.1.4.2.2 Upland PA

Chemical concentrations in shoaled sediment within the HSC will not change as a result of the NED Plan or Recommended Plan. The proposed actions will have no discernable effect on chemical concentrations in sediment. New work sediments from locations for the project situated north of Morgan's Point (NMP) were sampled representatively and in September through December of 2018 were both analyzed for a full spectrum of chemical constituents and subjected to effluent (biological and chemical) effects.

Although some environmental media from the 11 locations situated NMP screened above water quality and sediment screening values, the primary testing information for evaluating placement NMP are the elutriate testing and the CDFATE modeling. Elutriate testing showed some exceedances of Texas Water Quality Standards (TWQS) and preliminary CDFATE modeling showed that dilutions sufficient to meet acute and chronic water criteria were not reached using the initial site parameters in the model. Further CDFATE modeling using more site-specific data is required during PED. For information on Sampling, Chemical Analysis, and Bioassessment in Accordance with MPSRA Section 103 for south of Morgans Point (**Appendix G Section 3.1.5.2.1**).

7.1.5 Energy and Mineral Resources

Neither the NED Plan nor the Recommended Plan would have significant impacts on the availability or use of energy and mineral resources of the study area; access to these resources would not be impeded. To assess smaller potential impacts, geospatial data from the Texas Railroad Commission's public data viewer for oil and gas exploration activity was used to search for listed active wells in the project footprint. Except for one gas well in the lowest segment of proposed widening between Bolivar Roads and Redfish, all other oil and gas activity mapped within the channel footprint for the NED Plan or Recommended Plan were abandoned, plugged, or dry wells. The proposed use of the previously authorized but unconstructed M-11 for Recommended Plan new work would require continued coordination of access and relocation of active wells as provided in the previous PA 14-15 expansion project.

The NED Plan or Recommended Plan would not be expected to have adverse indirect effects on energy usage or exploration of energy and mineral resources. The NED Plan or Recommended Plan would only indirectly affect the cost of shipping those resources (positively), but not the availability or exploration of them.

7.1.6 Hazardous, Toxic, and Radioactive Waste Concerns

No known HTRW will be encountered for the NED Plan or Recommended Plan, as areas flagged as HTRW concerns (Patrick Bayou NPL site, San Jacinto Waste Pits AOC) were removed from subsequent plan consideration.

7.1.7 Air Quality

7.1.7.1 Construction Emissions and General Conformity

General Conformity is a Federal/state program designed to ensure that actions taken by Federal entities do not hinder states' efforts to meet the NAAQS. General conformity regulations in 40 CFR 93.152 define a Federal action to include any activity that the Federal agency funds in a NAA and is subject to General Conformity review, which would include implementation of the NED Plan or Recommended Plan. The NED Plan or Recommended Plan would require new work dredging in the HGB NAA, from 18.1 mcy for the NED Plan to 29.9 mcy for the Recommended Plan. New work dredging would produce construction emissions from main and auxiliary engines of the dredge and its support equipment (e.g. tugs and tenders). Dredged material placement emissions would be produced by earthmoving equipment. The emissions were estimated to determine the applicability of the GC rules. Both the NED Plan and Recommended Plan exceed the *de minimis* limit for NO_x with maximum annual emissions of 973 and 1,428 tons, respectively. Therefore, a formal General Conformity Determination (GCD) is required. A Draft GCD was coordinated with TCEQ. A Final GCD has been produced and provided to TCEQ (**Appendix J**).

7.1.7.2 Operational Air Emissions

Considering the effects on operational air emissions, compared to the No Action alternative, the NED Plan or Recommended Plan would reduce air emissions over the long-term (e.g. 50-year period of analysis) by reducing vessel calls and reducing port delays. The in-port emissions reductions were estimated using transit and delay hours produced from HarborSym output, and standard EPA ports emissions inventory methodology. The NED Plan would reduce annual NO_x emissions between 29 and 62 tons, and the Recommended Plan would reduce them between 118 and 245 tons, for 2029 and 2044 respectively. More information about these reductions can be found in **Appendix G, Section 3.1.8.2**.

The NED Plan or Recommended Plan would not be expected to have adverse indirect effects on air emissions, as it would only encourage the use of larger, economy-of-scale vessels that are more efficient, and would not induce landside changes of other port or industry source emitters, as it does not change any terminal capacity or throughput.

7.1.8 Noise

Impacts on noise from construction would be temporary, while those affecting operations in the channel would be long term. The following describes the expected impacts on noise from the NED Plan and Recommended Plan.

7.1.8.1 Airborne Noise

Short-term impacts of the NED Plan and Recommended Plan would primarily involve the construction sound during dredging. The effects of channel improvements on ship transit, terminal activity, and related rail and roadway sound would primarily account for the potential long-term noise impacts of the NED and Recommended Plan, which would be indirect effects. Dredged material placement areas do not involve permanent noise activity, and would therefore have no potential for long-term impacts.

The NED and Recommended Plan would result in temporary impacts due to the dredging activities required for construction of the channel improvements. The maximum sound levels expected would be similar to those produced during periodic maintenance dredging that occurs on the HSC, BCC, and BSC in sound level and duration. Because the construction noise impacts would be temporary and similar to noise already generated periodically by maintenance dredging, they are considered minor. Upland existing and one-time use PAs in the upper HSC are adjacent to neighborhoods and would require adherence to local noise ordinance during the three months of site preparation and dike raising and approximately three months of placement. Given the temporary nature, no significant adverse impact is expected. The long-term impacts on airborne noise of either the NED Plan or Recommended Plan would be related to their effects on vessel traffic. As discussed in **Section7.1.7.2**, the plans would reduce vessel calls and port delays, which would reduce vessel transit events and the associated sound generated compared to the No Action Plan. Similar to air quality, because the action plans would not induce landside changes of other port or industry source emitters, they would not induce adverse changes to noise sources from terminal activities. Considering this, no significant long-term adverse impact on airborne noise from operational effects is expected from the NED Plan or Recommended Plan.

7.1.8.2 Underwater Noise

The impact of underwater sound during construction of the NED Plan or Recommended Plan would be temporary and limited to the vicinity of the dredge. Current literature indicates that sound generated from conventional hydraulic cutterhead dredging is low frequency, and would not likely cause physical injury to fish species (Popper *et al.* 2006, Southall *et al.* 2007, Reine and Dickerson 2014). Temporary effects on hearing could occur if fishes remain in the immediate vicinity of the dredge for lengthy durations, although this is unlikely due to avoidance behavioral response of fish to the sound. For the predominant type of dredging involved (hydraulic),

attenuation to background levels would be expected to occur within relatively short distances of 500 meters. The underwater noise effect of construction would be a zone of disturbance around the dredge over the period of construction that ceases once dredging is complete. Pile driving required for sheet piling under either the NED Plan or Recommended Plan would produce impact noise with higher sound pressure levels, but would be limited to short lengths of shoreline near the BCC and BSC, where existing vessel traffic activity would tend to deter prolonged occupation or presence of marine mammals (dolphins) that regularly use Galveston Bay. No significant, adverse long-term effects are anticipated due to construction.

The long-term impacts on underwater noise of either the NED Plan or Recommended Plan would be related to their effects on vessel traffic. As discussed for airborne noise, the reduction in vessel calls and port delays would reduce transit events and the associated underwater sound generated compared to the No Action Plan. Similarly, since these plans would not be expected to induce increased terminal activity, and would therefore, not produce adverse changes to underwater noise from these activities. Considering this, no significant long-term adverse impact on underwater noise from operational effects is expected from the NED Plan or Recommended Plan.

The NED and Recommended Plan would not be expected to have adverse indirect effects on noise as it would not induce landside changes to other port, industry, or other landside sound sources, or change the behavior of such landside activity. It would not change the cargo demand or terminal throughput at the individual terminals, which are what dictate the road and rail movements necessary to transfer cargo.

7.2 BIOLOGICAL CONSEQUENCES

The following sections describe the anticipated impact to biological resources within the NED and Recommended Plan alternative area and the study area. Dredged material placement at the existing 27 PAs identified for continued use for the NED and Recommended Plan, and the associated wetland impacts within these PAs have already been accounted for and mitigated under previous USACE projects. Additional details and supporting tables and data are provided in **Appendix G, Section 3.2**. A series of figures showing the footprint of the channel deepening and proposed PAs for use is provided in **Appendix G, Figures G3.2-1** through **G3.2-3**.

7.2.1 Habitats

7.2.1.1 Terrestrial

NED and Recommended Plan channel improvements would impact approximately 2 acres of terrestrial habitat in two areas, the proposed expansion to the existing turning basin adjacent to Brady Island and the eastern end of Barbours Cut Terminal, near Morgans Point. The Brady Island impact is approximately 0.4 acre of mowed grass and tree landscaping and similar impacts to

vegetated, armored shoreline to the north. The alignment of the proposed basin expansion is preliminary and will be optimized in the next planning phase to reduce impacts to both properties as much as possible. The impacted area of Morgans Point is approximately 1.5 acres. This area is existing parking and boat launch on NFS property with maintained vegetation. Both are areas where the revised toe of proposed project features will have slight impacts to land. Sheet piling would be used to minimize land impact by allowing steeper slopes.

There are several areas along the HSC above Morgans Point (north shore approximately Station 1097+80) and areas along the northern shores of the BSC, and the BCC that were within the footprint of projected channel side sloping used for preliminary planning. However, geotechnical analysis for design during feasibility-level design and analysis indicated an adequate channel slope to avoid most shoreline impacts except for a few lengths that would use sheet piling. At the BSC, this was limited to 800 feet of sheet piling in front of San Jacinto maritime College along the northern shore to maintain the existing shoreline and adjacent wetlands.

No significant adverse impacts on terrestrial vegetation at the existing or proposed new PAs from anticipated construction or maintenance of either the NED Plan or Recommended Plan over the next 50 years is expected. Approximately 76 acres of mostly open pasture at E2 Clinton, and 385 acres of an abandoned munitions storage facility that now is currently over grown forest would be impacted from proposed new work placement of the NED Plan or Recommended Plan. Future maintenance could impact approximately 138 acres of previously disturbed land that includes approximately 20 acres of pavement and 65 acres of overgrown forest. Apart from the wetlands to be mitigated on these new work and O&M sites, the terrestrial vegetation do constitute ecologically unique or rare vegetation communities. The approximately two acres of terrestrial area that would be impacted by channel modifications are upland vegetation and located in industrialized or urban locations. No mitigation is anticipated for these impacts.

Neither the NED Plan nor the Recommended Plan channel improvements would be expected to have adverse indirect effects to terrestrial habitat by inducing landside population growth or changes in land use.

7.2.1.2 Wetlands

Three wetlands that are adjacent to BSC northern shore would be avoided by sheet piling of the shore at the existing water line. The approximately 5.7 acres of potential tidal marsh north and west of Morgans Point and within 500 feet of the centerline of the existing HSC would be avoided by the NED Plan or the Recommended Plan.

The NED Plan and the Recommended Plan would have identical wetland impacts. Two proposed new work PAs at BW8 and E2 Clinton would impact 22.7 acres of mostly forested, and 8.7 acres

of mostly scrub shrub wetlands. The future proposed use of the Rosa Allen Expansion for O&M would impact 40.7 acres of mostly forested wetland. These are relatively low quality wetlands dominated by Chinese tallow.

NED Plan or Recommended Plan channel improvements would not be expected to have adverse indirect effects to wetlands by inducing landside population growth or changes in land use. The NED Plan and Recommended Plan would also not be expected to indirectly change the surface hydrology or reduce tidal inundation of wetlands.

7.2.1.3 Bays and Deepwater Habitats

Aquatic habitat within the NED Plan and Recommended Plan project footprint includes open-bay water, open-bay bottom, and oyster habitat. There are no special aquatic sites regulated under 40 CFR 230 such as sanctuaries and refuges, coral reefs, mudflats, vegetated shallows, or riffle and pool complexes present within the project footprint. Portions of the aquatic habitat in the NED Plan and Recommended Plan would be directly impacted by the proposed modifications to the channel, including impacts to oyster habitat, presented below. Temporary and minimal impacts to aquatic life in the project area and immediate project vicinity similar to what occurs during existing channel maintenance dredging could occur as a result of increased turbidity, sedimentation, noise, light, and vessel activity during the construction period. Dredging activities would be intermittent and localized. These impacts are considered temporary. The proposed new BU sites for the NED Plan and Recommended Plan would convert this habitat to approximately 600 acres of tidal marsh, 14 acres of rookery and shorebird island habitat, and to an upland groin in the case of the proposed sediment attenuation feature in the Recommended Plan. The marsh and bird island is ecological beneficial, while the shoaling attenuation feature conversion would be offset by only a small portion of the tidal marsh created.

Benthic Habitat

The benthic habitat in the NED Plan and Recommended Plan footprint and adjacent areas is comprised primarily of featureless soft-bottom substrates likely dominated by benthic infauna, such as polychaetes and amphipods. **Table G4-2** of **Appendix G** details the nature of the footprint with respect to shallow or previously deepened estuarine channel or bay bottom. Approximately 372 acres of estuarine channel in the HSC above Morgans Point would be dredged, of which 205 acres would be estimated to be previously dredged and deepened channel and side slope. In Galveston Bay, approximately between 1,700 and 2,400 acres would be dredged with approximately 1,145 to 1,545 acres already previously dredged and deepened as part of the existing main channel. This would mean between approximately 620 and 890 acres are previously undredged shallow bay bottom. These represent a relatively small proportion (<1 percent) of Galveston Bay's 600 square miles. As discussed in **Section 7.1.4.1**, these effects would be

temporary and minor given the nature of hydraulic dredging, as suspended sediments would return to background levels within a short time frame, and would be similar to what occurs during existing channel maintenance dredging. This would also apply to the periodic maintenance dredging over 50 years.

Mitigation of oyster habitat may replace some soft-bottom benthic habitat with new oyster reef construction. Placement of cultch over previous soft-bottom habitat would create a new bottom habitat beneficial to pelagic species. This would be a permanent impact, but would be minor, as it would only affect a relatively small portion (less than 0.2 percent at most) of the Bay bottom.

The NED Plan and Recommended Plan channel improvements would not be expected to have adverse indirect effects to bay/deepwater habitat by inducing other marine projects. Other projects impacting bay bottom on the HSC already occur in the No Action alternative.

7.2.2 Wildlife

7.2.2.1 Terrestrial

Upland urban and industrial habitat, which is described in **Section 7.2.1.1,** has limited wildlife habitat value. At existing PAs, wildlife that are tolerant to the urban and industrial areas (e.g., foraging or nesting avian species, raccoons) may be temporarily displaced during dike modification and PA use. Noise and light associated with the construction and maintenance activities would be expected to temporarily affect wildlife behavior, as would the general increase in human activity. Construction impacts would be considered minimal in these areas, which are subjected to routine maintenance activity disturbances; these impacts also occur in the No Action Alternative. No significant adverse impacts to terrestrial wildlife would occur.

7.2.2.2 Aquatic

Fish and Nekton

During NED Plan and Recommended Plan construction, only temporary disturbances and minor, temporary impacts associated with dredging would occur. Disturbances to finfish such as from noise and light during construction dredging would be temporary. Given their high mobility, finfish juveniles and adults would be able to readily avoid impacts of the dredging activity. These temporary impacts are the same that occur during maintenance dredging under the No Action Alternative. Impacts on fish and nekton resulting from the implementation of the NED Plan and Recommended Plan would be temporary and minor.

Plankton

Impacts to other free-floating or limited-mobility pelagic fauna, such as phytoplankton, macroalgae, and zooplankton would be temporary during construction of the NED Plan and Recommended Plan, and minor. These impacts, such as entrainment into cutterheads or vessel cooling water intakes and discharges are the same that occur during maintenance dredging under the No Action Alternative. The amount of water exchange involved is volumetrically insignificant compared to the Bay, and the ubiquity and high turnover in populations of these types of fauna would quickly replace any impacted organisms. Impacts on plankton resulting from the implementation of the NED Plan and Recommended Plan would be temporary and minor.

7.2.2.3 Benthos

The benthos in the NED Plan and Recommended Plan footprint and adjacent areas is dominated by benthic infauna, such as polychaetes and amphipods. It can be assumed that dredging would result in high mortality to benthic infauna present in the dredged material footprint, but the community would be expected to recover sometime after dredging ceases. The resultant turbidity and settling from dredging has the potential for smothering sessile benthic organisms and/or inhibiting filtration functions required by some organisms for respiration and nutrition. The temporary lower DO concentrations that could result from temporary suspension of organic material during dredging could cause a temporary displacement of mobile organisms and may stress or cause mortality to sessile organisms. As discussed in **Section 7.1.4.1**, these effects would be temporary and minor given the nature of hydraulic dredging, as suspended sediments would return to background levels within a short time frame, and would be similar to what occurs during existing channel maintenance dredging. This would also apply to the periodic maintenance dredging over 50 years.

7.2.2.4 Oyster Reef

The dredging to implement modifications to the channel for the NED Plan and Recommended Plan would result in removal of oyster reef and shell hash habitat that have been mapped within the project footprint. If not mitigated for, this would be a permanent impact to the local oyster reef habitat; however, mitigation of these impacts will include restoration of healthy oyster reefs damaged by Hurricane Ike through construction of reef pads in Galveston Bay. Further detail regarding oyster mitigation is described in **Section 7.5**.

Impacts to Mapped Reef

The area of impact to reef was assessed using the TPWD and 2018 sidescan and groundtruthing survey discussed in **Section 2.4.2.3**, the NED Plan and Recommended Plan geospatial extent data and a geographic information system (GIS) to determine acreages of direct impact within the footprint of the NED Plan and Recommended Plan to the extent of proposed channel top-of-banks.

Estimates of directly impacted oyster reef within NED Plan footprint total 88 acres and 409.5 acres with the Recommended Plan. This constitutes a significant adverse impact to a significant resource. These impacts would be fully mitigated if the project were constructed. The impacts of the TSP on reef are detailed in **Appendix G, Section 3.2.2.3**.

Potential Oyster Reefs in Previously Unmapped Areas

Reef mapping is not available above Morgans Point. A limited segment up to Hog Island was survey in 2018. Therefore, to determine potential reef impacts of measures upstream of Galveston Bay, various information and data for salinity, depth, and disturbance were used to indicate conditions conducive (or not) to reef development. This dataset was reviewed to identify areas in the NED Plan and Recommended Plan footprint that would have the potential to support growth. This was done to prioritize areas for reef surveillance in the next planning phase rather than to ascribe reef presence in those areas, or to completely rule out the presence of reef. The details of this review are discussed in **Appendix P, Mitigation Plan for Oyster Reef Habitat**.

As discussed in **Section 2.4.2.3**, oyster reef needs average salinities greater than 5 ppth to survive, and in the range of 10 to 30 ppth to thrive. Data from the TCEQ Surface Water Quality Monitoring Program, and from the TWDB's Bays and Estuaries monitoring program were examined. TCEQ salinity data with long periods of record and from key stations between Morgans Point and the upstream study limit at the Main Turning Basin were selected along the HSC to observe the expected downward average salinity trend moving upstream. Stations above Alexander Island were focused on, given the sufficient salinity apparent in oyster reef found in the shallow bay south of the island.

The HSC salinity condition for reef growth above Morgans Point can be summarized as follows:

- Morgans Point to the Battleship – higher probability for growth;
- Battleship to Greens Bayou – medium probability for growth;
- Greens Bayou to Vince Bayou – low probability for growth; and
- Vince Bayou to Main Turning Basin – too fresh; growth not expected

Most of the measures are in portions of the existing HSC, turning basins, or adjacent to berths where waters are deepened and periodically maintained by dredging, which would not support growth.

Areas within the NED Plan and Recommended Plan measure footprints with less than 20 feet of depth and no sign of active vessel berthing were identified as having more potential to support growth in order to prioritize mapping during the feasibility-level phase. Most of these areas were

eliminated when measures such as the proposed mooring were eliminated. The anticipated reef acreage that could possibly exist is small compared to the potential impacts in the Bay.

Reef Accretion and Regrowth in the HSC

It has been well observed in studies for the historical Powell reef mapping that regrowth of oyster reef will occur into the HSC after the channel has been dredged for modification. Because the NED Plan and Recommended Plan will again widen right alongside the current HSC where regrowth has clearly occurred, re-accretion of reef inside of the main channel and relocated barge lanes would be expected. However, because the responsible factors are complex and not yet well studied, the specific amount of regrowth expected cannot be predicted.

Indirect Effects

Indirect impacts from turbidity and sedimentation could occur to the oyster habitat down-current from the directly impacted areas, but are expected to be minimal due to the extensive presence of reef directly adjacent to the HSC system. Turbidity can inhibit successful filter-feeding and spawning activity while excess sedimentation can prevent efficient settlement and recruitment over existing consolidated reef and shell hash substrates. However, these effects from hydraulic dredge induced turbidity are expected to be minimal, as discussed in **Section 7.1.4.1**. It is unlikely that turbidity concentrations will be high enough for a length of time to significantly affect oysters adjacent to the area of dredging.

7.2.3 Essential Fish Habitat

The majority of impacts to managed species and their associated EFH would be limited to the estuarine benthic environment where the actual dredging would take place, as well as temporary impacts to the water column as a result of increased turbidity. The life stages of fish anticipated to be most impacted are the eggs and larval stages, with those utilizing benthic habitats within the dredged footprint expected to have high mortality. The majority of the juvenile and adult life stages present in the project footprint are primarily forage and pelagic species capable of detection and avoidance behavior when exposed to unfavorable conditions. It is expected that construction of the NED Plan and Recommended Plan would have only temporary direct impacts to juvenile and adult fish by way of displacement, and individuals would re-inhabit affected areas upon dredging completion. No aquatic vegetation has been identified in the project area for the TSP, and so no impacts to seagrass or the nursery habitat it provides to juvenile fish would occur. Therefore, only impacts to benthic EFH are expected.

The dredging would occur in the estuary of Galveston Bay, which is a nursery area for some species known to inhabit the Gulf of Mexico. The degradation of coastal and estuarine EFH habitats is associated with the following:

- Temporary disturbance and displacement of fish species;
- Temporary increases in sediment loads and turbidity in the water column;
- Temporary loss of benthic food items to fisheries;
- Loss of oyster habitats; and
- Limited sediment transport and re-deposition

For the purposes of this project, most of the above effects are temporary and likely either offset by environmental protection guidelines, or are negligible considering the localized effect of the actions compared to the proportional area of the Gulf that would be unaffected. In this sense, the coastal and marine environmental degradation from the proposed action would have minor effects on designated EFH or commercial fisheries.

Turbidity generated by the project could affect the foraging behavior of visual predators and the efficiency of filter feeders. The turbidity plume would be expected to migrate only a short distance and cover a small area relative to the total pelagic habitat area available to managed species, and dissipate quickly due to prevailing water circulation and the nature of hydraulic dredging proposed to be used for the NED Plan and Recommended Plan. Numerous studies indicate that dredge-induced turbidity plumes are mostly localized, spreading less than a thousand meters from their sources and dissipating to ambient water quality within several hours after dredging is completed, with the vast majority of re-suspended sediments resettling close to the dredge within an hour. The main dredging method, hydraulic cutter suction, generally produces small plumes that rapidly decay, and when properly operated limits elevated suspended bottom sediments to several hundred meters from the cutterhead with little turbidity actually reaching surface waters. The impact to the water column EFH would be considered minor and short-term. This is described in more detail in **Appendix G, Section 3.1.5.1**.

The proposed project is not in or near any of the areas identified as HAPC. These areas are all located offshore. Therefore, no impacts to HAPC are anticipated through the completion or maintenance of the proposed project. A full EFH Assessment will be coordinated with NMFS and no further coordination is required.

7.2.4 State Managed, Commercial, and Recreational Fisheries

No commercial or recreational fishing would be allowed to occur within or near the dredging or placement operations. The commercial fishing most widely conducted in Galveston Bay is shrimp trawling. Other shellfish species frequently landed include blue crab and eastern oyster. The footprint of the NED Plan and Recommended Plan spans areas that are prohibited, restricted, conditionally approved, as well as those approved for shellfishing. Therefore, the actual dredge

operation would have temporary and minor impacts on commercial fishing in the project area, but could resume upon completion of dredge operations within approved areas.

The entire HSC and upper Galveston Bay is within a consumption advisory area for blue crabs, and the entire Galveston Bay is within a consumption advisory area for all catfish species as well as spotted seatrout. While the recreational landings associated with Galveston Bay account for 35 percent of the State total, it is unclear how much of this fishing is actually done within or near the active channels. The HSC above the Battleship Texas, the BSC south of its centerline within the land cut, and the BCC are USCG security zones are restricted from recreational use. The remaining unrestricted areas in the NED Plan and Recommended Plan footprint are right near the active channels. Any recreational fishing could resume upon completion of dredge operations. Therefore, no significant disruption to recreational fishing is expected to occur during the initial construction or periodic maintenance dredging events over the 20-year maintenance period. The construction over 600 acres of tidal marsh with BU would positively impact recreational fishing as they serve as nurseries for many native game fish and shrimp.

The NED Plan and Recommended Plan is not expected to have indirect effects on the commercial and recreational fisheries by inducing or changing long-term activity, as this is a modification of an existing deep draft navigation channel.

7.2.5 Protected Species

7.2.5.1 Threatened and Endangered Species

Federally listed T&E species that may be present within the project area in the vicinity of the NED Plan and Recommended Plan area include the Kemp's ridley sea turtle, loggerhead sea turtle, green sea turtle, Piping plover, and Rufa Red knot. Other species listed are not likely to occur in the vicinity of the project due to lack of suitable habitat or the area is beyond their known range limits. There is no designated critical habitat for any of the listed species within the NED Plan and Recommended Plan footprint. The project area does not involve habitat required for oceanic species (e.g. Blue whale, coral). For species using estuarine habitats, the specific habitat required for regular use by most of those species is not present within the NED Plan and Recommended Plan footprint, including those for the Piping plover, Red knot, and West Indian manatee. The effects of the project on federally listed species are considered in detail in the BA provided in **Appendix K**. Though it is not likely that the listed marine and shorebird species would be encountered within the project area, their presence in the area is possible.

Hydraulic cutterhead dredges (non-hopper) would be anticipated to be primarily used for the NED Plan and Recommended Plan for both construction and maintenance. Non-hopper dredges are not known to take sea turtles (NMFS 2003). As such, construction of the NED Plan and

Recommended Plan would have no direct effects on any listed sea turtle species within the area when dredged by hydraulic cutterhead. Avoidance of use of transient forage habitat in the Bay by sea turtles due to dredging noise and light would be the same as currently occurs during periodic maintenance dredging. This may affect but is not likely to adversely affect sea turtle species using the Bay for transient foraging habitat, as plenty of directly adjacent habitat would be available during the temporary construction. Hopper dredging would only be used for maintenance of the NED Plan and Recommended Plan, as is currently done for the existing HSC, and not for new work. Offshore placement of new work would be performed using hydraulically loaded scows. The impact was determined in the BA to be one that may affect but is not likely to adversely affect Loggerhead species that use critical habitat there when Sargassum is present. This determination follows the recent clarification to the 2007 Gulf of Mexico Regional Biological Opinion (GRBO) on hopper dredging, discussed in **Appendix K**. The BMP recommended in the GRBO would be employed when hopper dredging.

The NED Plan and Recommended Plan channel improvements are not expected to have indirect effects on the transient and forage habitat for the several turtle species that may use the area through inducing or increasing other vessel or dredging activity that would result in takes of these mobile species.

Migratory Birds

The channel modifications of the NED Plan and Recommended Plan would not have direct or indirect impacts on migratory bird habitat and would therefore, not be expected to cause significant adverse effects to migratory birds.

Some of the PAs in the area have been mapped by TXGLO geospatial data to host colonial waterbird rookeries, and several of migratory species on the USFWS's 2008 Birds of Conservation Concern for the Gulf Coast Bird Conservation Region 37 have been recorded at PAs 14 and 15. While migratory birds commonly have been observed on these PAs foraging, nesting, and roosting, they are active placement areas, and the timing of construction and placement of maintenance dredged material would be coordinated to avoid impacts to migratory and nesting birds. The new work BU sites proposed under the NED Plan and Recommended Plan would provide bird island habitat and tidal marsh beneficial to various colonial waterbird and shorebird species.

7.2.5.2 Marine Mammals

The only marine mammals expected to regularly be present in Galveston Bay are bottlenose dolphins (*Tursiops truncatus*). These are highly mobile species that would be able to readily avoid dredging activities and vessels. The NED Plan and Recommended Plan would not have significant impacts on the fish food source or remove open water column habitat used by bottlenose dolphins.

Considering this, the NED Plan and Recommended Plan would not be expected to cause significant adverse effects to marine mammals.

Temporary effects from noise, light, and turbidity could cause avoidance of the area by the bottlenose dolphins. No long-term adverse effects are expected from the NED Plan and Recommended Plan on marine mammals.

7.2.6 Protected/Managed Lands

7.2.6.1 Wildlife Management Areas

The Atkinson Island WMA is approximately 1,400 feet north of Marsh Cell M3, one of the existing dredged material placement features proposed for continued maintenance of the HSC, and for the NED Plan and Recommended Plan. Marsh Cell M3 and other adjacent ones have been used for periodic maintenance for many years with no impacts to the WMA, and would be continued to be used under the No Action Alternative, and for the NED Plan and Recommended Plan. No USFWS wildlife refuge is in the vicinity of the NED Plan and Recommended Plan. No significant impacts to WMAs or wildlife refuges would occur.

WMAs and refuges are set aside lands that would not be subject to development, and the NED Plan and Recommended Plan channel changes would not induce landside development. Therefore, indirect effects are not expected to WMAs and refuges from the NED Plan and Recommended Plan channel modifications.

7.2.7 Critical Habitat Areas

The only critical habitat for piping plover is more than a mile away from the NED Plan and Recommended Plan as described in **Section 2.4.5.1**. Direct impacts would therefore not occur, and it would be too far to have any disturbance effects on nesting Piping plover. Therefore, no impacts would occur to Piping plover critical habitat. The existing offshore placement site ODMDS No. 1 that would be used for any hopper dredging used for construction or maintenance of the NED Plan and Recommended Plan is located in Gulf waters designated as Loggerhead turtle critical habitat. The effect determination on the critical habitat resulting from the BA provided in **Appendix K** is that the TSP may effect, but is not likely to adversely affect, the critical habitat. No significant adverse effects are expected on critical habitat.

Similar to WMAs, critical habitat are set aside areas that would not be subject to development, and the NED Plan and Recommended Plan channel changes would not induce landside development or offshore placement. The TSP channel modifications would not change the character of the beach habitat of Piping Plover nor the offshore nature of sea turtle Gulf of Mexico habitat. Therefore, no significant indirect effects are expected to critical habitat from the NED Plan and

Recommended Plan channel modifications. None of the proposed PAs or BU sites for the NED Plan or Recommended Plan would impact critical habitat.

7.3 CULTURAL RESOURCES

The NED Plan and Recommended Plan would both include deepening and widening selected portions of the HSC as well as improvements to the BCC and the BSC. The NED Plan and Recommended Plan would also include the BCC Turning Basin, the Hunting Turning Basin, and the Brady Island Turning Basin. The primary difference between the NED Plan and the Recommended Plan is that the NED Plan proposes to widen the HSC by 170 feet between Bolivar Roads and Redfish Reef and expand the flare at the entrance to the BSC, whereas the Recommended Plan proposes widening the HSC by 170 feet from Bolivar Roads to the BCC and no expansion of the BSC flare. All of the areas of potential impact within the NED Plan and the Recommended Plan are located in a marine setting and therefore there is a potential for impacts to submerged cultural resources and sites located on the shoreline adjacent to the ship channel. This project would also include existing and new dredged material PAs for new construction and maintenance material, as well as potential mitigation sites that could potentially impact terrestrial and aquatic cultural resources, these areas are discussed below and in the DMMP.

There are 18 previously recorded archeological sites, one National Register property (Washburn Tunnel), and two National Historic Landmarks (*USS Texas* and the San Jacinto Battlefield) that occur within 1,000 feet of the project centerline. Seven of these sites (41HR33, 405, 577, 680, 832, 1168, and 1169) have been previously investigated and determined to be not eligible for inclusion in the National Register of Historic Places (NRHP). Another site, 41GV151, the wreck of *USS Westfield*, was determined eligible for inclusion in the NRHP, but the site was investigated and mitigated for impacts as part of the Texas City Channel Improvement project. The remaining ten sites are all terrestrial sites located on the shoreline and include six prehistoric open campsites (41HR29, 30, 31, 41, 121, 140 and 808), a historic site (41HR32), a possible historic age town site (41HR526), and the potential site of the Harrisburg Depot (41HR623). None of these ten sites have been evaluated for NRHP eligibility. However, sites 41HR30, 31, 41, and 121 appear to have completely eroded away or been destroyed by development according to site records.

The San Jacinto Battlefield is located just to the south of the project area and there are no direct impacts proposed within the boundaries of the battlefield. Additionally, the shoreline of the battlefield has been reinforced with bulkheads or armoring to control shoreline erosion. USS *Texas* is permanently moored within a sheltered berth at the San Jacinto Battlefield. There will be no direct or indirect impacts to these NHLs due to project activities. The Washburn Tunnel is the only NRHP property within the footprint of the existing project located within the reach between Boggy Bayou and Sims Bayou. The tunnel was constructed in 1950 and listed on the NRHP in

April 2008. Neither the NED Plan nor the Recommended Plan have proposed activities between Hunting Turning Basin and Sims Bayou. Therefore, no impacts are anticipated for the Washburn Tunnel. Finally, there are over 30 anomalies, representing shipwrecks or obstructions, identified by the NOAA within or adjacent to the proposed project area.

Dredged material disposal will occur in both upland and aquatic PAs. Three new upland PAs will be constructed and include the East-east Clinton PA, the Beltway 8 one-time use PA, and an expansion of the existing Rosa Allen PA. There are no cultural resources recorded within the East-east Clinton PA or the Rosa Allen PA expansion, however these areas have not surveyed and portions of these tracts should be surveyed to determine the presence or absence of historic properties. The proposed Beltway 8 one-time use PA area overlaps with the boundaries of Site 41HR424, the San Jacinto Ordnance Depot. This site was investigated by PBS&J in 2007 and USACE determined that the site was not eligible for inclusion in the NRHP. However, a small unnamed cemetery was identified in the southern portion of the site and recommended for avoidance. The USACE recommends continued avoidance of this cemetery. The remaining placement areas are located in Galveston Bay and include the expansion of the mid-bay placement areas between BSC and BCC, construction of four bay beneficial use sites (BABUS), construction of three bird islands, and 18 linear oyster mitigation sites in western Galveston Bay. There are no cultural resources recorded within these placement areas, however they have not been intensively surveyed. The USACE recommends a marine survey for these proposed placement areas within Galveston Bay.

Based on the current information for the proposed construction and improvements, there is a potential to affect historic properties. Direct effects would consist of impacts from dredging activities related to channel deepening and widening that would occur if resources were not surveyed and recovered. If eligible terrestrial cultural resources are identified at sites near the channel shoreline where NED Plan or Recommended Plan improvements are planned, indirect effects such as the potential for erosion of shorelines from ship wakes to impact the resources would have to be evaluated, especially where widening or other improvements moves the shoreline closer to identified resources. The USACE recommends intensive cultural resources investigations to identify and evaluate any historic properties within proposed construction areas that have not been previously investigated. The scope of these investigations will be determined in concert with the Texas SHPO and Tribal Nations and in accordance with the existing Programmatic Agreement for this project (**Appendix N**). The USACE intends to execute a new Programmatic Agreement, in consultation with the Advisory Council on Historic Preservation (ACHP), the Texas SHPO, and Tribal Nations, that will include the HSC ECIP. The new Programmatic Agreement will be executed within the two years of the Record of Decision and replace the existing 1988 Programmatic Agreement.

7.4 SOCIOECONOMIC CONSIDERATIONS

The NED Plan and Recommended Plan would have minimal direct impacts to human environment resources because work will primarily be located in the open water (Galveston Bay) and uninhabited manmade dredged material placement islands in Galveston Bay. The only impacts to land, described in **Section 2.4.1.1**, are minimal, and do not involve any displacement of occupied structure, residences, facilities, or businesses. The information is summarized below; additional details are provided in **Appendix G**.

7.4.1 Population, Employment, and Income

The NED Plan and Recommended Plan channel improvements would have a negligible direct effect on population growth or employment trends within surrounding communities, cities, and counties located in the project area since it does not directly affect landside resources that encourage or discourage development. It would have a negligible effect on direct employment in the region during construction of the project because most of the project involves large scale dredging which involves a relatively limited industry and population of workers. There will be direct economic benefits to the nation in terms of reduced transportation costs, as detailed in the economic analysis for this study. Shipping and shipping-related industry has far-reaching direct and indirect economic benefits to the Houston region and the State, and the NED Plan and Recommended Plan channel improvements would help preserve the efficiency and competitiveness of the Port of Houston, which has been the first and second-ranked port in the nation in terms of total, import, and foreign import/export tonnage in recent years. In that regard, the indirect effect of the NED Plan and Recommended Plan would be a positive one. No human environment impacts would be expected as a result of maintenance dredging events over the 50-year maintenance period.

The NED Plan and Recommended Plan channel modifications would not have significant indirect effects on population, employment, or income for several reasons. Navigation channel modifications to existing channels are not expected to induce landside population growth or development as other social and economic factors (e.g. economy, jobs) influence this, and the study area is already highly developed. Therefore, associated significant indirect impacts to population, employment, and income would not occur.

7.4.2 Demographics

EO 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* requires each Federal Agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse

human health or environmental effects of its programs, policies, and activities on minority and low income populations."

As provided in the April 1998 EPA guidance, a minority population is defined as a group of people and/or a community experiencing common conditions of exposure or impact that consists of persons classified by the U.S. Census Bureau as Black, Asian, American Indian or Alaska Native, Hispanic, or other non-white persons, including those persons of two or more races. Due to the size of the project area, and due to the fact that the NED Plan and Recommended Plan footprint is primarily located within open water, Census Tract level data was used for initial screening, but in areas where the NED Plan and Recommended Plan impacts near or on the shoreline closest to populated areas, Census block group data was examined.

For the evaluation of the potential for environmental justice (EJ) issues, the low-income population was defined as a group of people and/or a community that, as a whole, lives below the national poverty level. The average poverty level threshold for a family of four people in 2017, as defined by the U.S. Department of Health and Human Services (HHS) thresholds, was a total annual household income of $24,600. For purposes of determining low-income populations, median household was examined, using the U.S. Census poverty estimates for 2013 to 2017 (a 5-year average), as reported in the 2017 American Community Survey (ACS). Geographies with a majority percentage of minority population were also considered in the screening for potential issues.

The 22-Tract Census area that encompasses the project area is 73.3 percent minority and the average median household income is $48,358, which is almost double the 2017 HHS poverty level ($24,600) for a family of four. However, with respect to percent minority populations in the areas closest to the NED Plan or Recommended Plan where direct effects would be expected to be greatest, the Census block group data with land nearest to the NED Plan and Recommended Plan indicate the population varies from 100 percent minority in the upper HSC to 2 percent minority by the BSC, and the average median household income in $48,358. Demographic data and new work dredging quantities were spatially analyzed in GIS to estimate an intensity of activity exposure to the Census block group populations expressed as cubic yards of dredging per yard of channel. For the census blocks meeting an EJ demographic threshold, the CY/Y ranged from minimum of 112 to a maximum of 372 and averaging 196, while the non-EJ blocks ranged from minimum of 133 to a maximum of 603 and averaged 356. There would not appear to be a disproportionate impact from the dredging itself. The PAs proposed for use in the upper HSC do have minority-dominated populations. However, the impacts from their use for new work would be temporary, experienced over 3 months of site preparation at a given site, followed by 3 months of placement. The placement of material would not produce significantly adverse long-term exposures from air, noise, water or other media impacts. Therefore, EJ issues are not anticipated from implementing the NED Plan or Recommended Plan.

Minimal impacts to the human environment are expected, because a majority of the project construction will be located in the open water (Galveston Bay) and an uninhabited manmade dredged material placement island in Galveston Bay. Therefore, impacts to minority and low-income individuals and communities living within the project area would experience no adverse changes to the economic, or community cohesion characteristics. No residential displacements would occur; adverse impacts due to increased traffic noise and air quality degradation are not anticipated; and areas with shoreline impacts are not located in areas with high minority or low-income populations; therefore, disproportionately high and adverse impacts on minority and low-income populations are not anticipated.

For the same reasons as for population, employment, and income, the NED Plan or Recommended Plan channel modifications would not be expected to have significant indirect effects to the demographics of the project area or broader study area.

7.4.3 Community Resources and Facilities

The NED Plan or Recommended Plan is not expected to have any direct physical impact to land-based community resources and facilities as the alternative would primarily be located in open water and manmade dredged material PAs. Potential impacts to parks and recreational areas, which are also considered community resources, are discussed in **Sections 2.6.3 and 2.6.4**. None of these facilities would be directly impacted by the NED Plan or Recommended Plan; therefore, not impacts to community resources and facilities are anticipated.

Channel improvements would impact approximately 2 acres of land in two areas, the proposed turning basin expansion adjacent to Brady Island and the eastern end of Barbours Cut Terminal at Morgans Point. On Brady Island, 0.4 acre of land would potentially be impacted which includes undeveloped land and shoreline at a scrap yard, part of a pavilion with a ship channel viewing area and a boat landing at the Brady's Landing restaurant. The alignment of the proposed basin expansion is preliminary and will be optimized in the next planning phase to further reduce impacts to both properties, as much as possible. The impacted area of Morgans Point is approximately 1.5 acres located on Port of Houston land, which has a parking area and boat dock not currently in use. Other areas impacted near land would be avoided by placing sheet piling along the existing water line to maintain the existing shoreline. The Shore Acres community and the San Jacinto Maritime campus are located north of the BSC, where sheet piling is proposed to avoid impacts to land.

For the same reasons as for population, employment, and income, the NED Plan or Recommended Plan channel modifications would not be expected to have significant indirect effects to community resources in the project area.

7.4.4 Recreational Resources

As discussed in **Section 2.6.4**, boat ramps, marinas, parks, colonial waterbird rookery areas are located within the recreational study area, which includes the NED Plan or Recommended Plan footprint (**Appendix G**, **Figure G3-7 through G3-9**). As part of the project improvements, the outer extent of a proposed mooring basin is located less than 75 feet from the armored shoreline of the San Jacinto Battleground State Historic Site park but does not impact the upland portion. Three colonial waterbird rookies are directly adjacent to the NED Plan or Recommended Plan footprint including areas where the rookeries are also PAs used for maintaining the existing HSC. These areas may be used by birdwatchers, and currently experience large vessel traffic daily. Many of the rookeries are PAS and BU sites that created habitat for waterbirds in Galveston Bay. The NED Plan or Recommended Plan is expected to have minimal impact to the current activities that occur in close proximity to these recreational resources.

The NED Plan or Recommended Plan channel improvements will not have significant impacts on recreational use of waters. The proposed improvements are directly adjacent to the existing navigation channels. They will not obstruct passage in recreational waters in the Bay. Passage through the three boaters cut in the Bay will not be obstructed. The maximum width of the Bay widening (widening by 290 feet to achieve an 820-foot channel) would add less than 1.5 minutes to cross the revised HSC under a slow sailing speed of 2 knots and for crossing the revised BSC would add less than 20 seconds. Other measures of the NED Plan or Recommended Plan are either in waters with limited recreational boating traffic or in areas where use is restricted to commercial navigation. The proposed BU sites would not have significant adverse impacts on recreational use, and would afford more opportunities for bird watching (proposed bird island) or be beneficial to recreational fisheries (tidal marsh). The shoaling attenuation feature proposed under the Recommended Plan would not significantly hinder sailing access, and was a feature positively received in verbal comments received from recreational boating representatives during the DIFR-EIS public meetings. The proposed upper HSC PAs would not impact any recreational resources.

For the same reasons as for population, employment, and income, the NED Plan or Recommended Plan channel modifications would not be expected to have significant indirect effects to recreational resources. Indirect effects to water recreation from changing commercial vessel activity would actually be positive due to reduction of vessel calls, although any positive effect would be minor.

7.5 MITIGATION

In accordance with SMART planning guidance to minimize the length of the integrated study documents, a summary level of information is included below with additional details provided in **Appendix P, Mitigation Plan for Oyster Reef Habitat**. The ER 1105-2-100 requires mitigation

of significant unavoidable losses to significant ecological resources. ER 1105-2-100 and the P&G describe the procedures for determining the significance of resources that will be impacted by a project alternative. Under these criteria, oyster reef is a significant ecological resource since it has institutional significance from national and regional perspectives due to the various Federal and State laws and statutes that protect oyster reef. In the State of Texas, all natural oyster reefs are considered public resources and are managed by the TPWD. TPWD has broad authority under the Restitution and Restoration Rule, Chapter 69 of Title 31 of the Texas Administrative Code (TAC) to seek restoration of fish, wildlife, and habitat loss occurring as a result of human activities, pursuant to enforcement powers in the Parks and Wildlife Code and Water Code. Oyster reefs are also designated as CNRA and "critical areas" under the TCMP managed by the TXGLO pursuant to the CZMA, requiring compensatory mitigation for adverse impacts. Oyster reefs also have technical significance due to the number of research papers that document their importance to water quality, biodiversity, and ecological productivity.

As discussed in **Section 7.2.1.3**, benthic fauna in the portion of the project comprised of soft, featureless bay bottom would be temporarily impacted following dredging, expected to recover and recolonize fairly quickly, becoming deeper water benthic habitat, as previous projects' studies have shown. Considering the ubiquity of the habitat and the temporary nature of the impact, the effects of the NED Plan or Recommended Plan would not be considered to constitute a significant impact to a significant ecological resource.

Mitigation is proposed by restoring oyster reef in Galveston Bay to compensate for the loss of like habitat from the channel modifications of the NED Plan or Recommended Plan. Two desirable sites were selected in coordination with the resource agencies from among reef sites impacted by Hurricane Ike that have been the focus of TPWD efforts to restore reef in the Bay. These sites in the San Leon and Dollar Reef areas were shown in the oyster reef habitat modeling to provide better restoration quality per acre restored than the other sites.

Modeling using a USACE-certified habitat model for the American oyster was used to calculate functional losses. The resultant average annual habitat units (AAHUs) impacted, and range of calculated mitigation amounts is summarized in **Table 7-1** below. A summary of the modeling procedure, results, and mitigation is provided in the Mitigation Plan provided in **Appendix P**.

Table 7-1 – Calculated Mitigation for NED Plan and Recommended Plan Impacts

Plan	Acres Impacted	AAHUs Impacted
Total NED Plan mitigation needed	**88.2**	**-73.2**
Mitigation Provided	**Acres**	**AAHUs Provided**
6 ac Long bird island oyster mitigation acreage	4.0	3.6
3-Bird Island oyster mitigation acreage	14.1	9.9
Dollar Mitigation Site	67.0	59.8
Total Replacement Oyster Reef Provided for NED Plan	**85.1**	**73.2**
Recommended Plan incremental mitigation needed	**321.3**	**-259.9**
Total Recommended Plan mitigation needed (NED Plan + LPP increment)	**409.5**	**-333.1**
Mitigation Chosen – San Leon and Dollar Mitigation Sites	**Acres**	**AAHUs Provided**
Amount needed for LPP Increment	**291.3**	**259.9**
Total mitigation (including bird island reefs) for Total Recommended Plan	**376.4**	**333.1**

The mitigation method proposed would be the BU of dredged new work material to build bottom relief berms capped with a thin veneer of suitable cultch such as crushed limestone or clean crushed concrete, and rely on natural recruitment to propagate growth. The type of cultch material has been successfully used in local mitigation projects, including the mitigation at Fisher's Reef for the NFS's BSC Improvements Project. The full details and required content for the Mitigation Plan are provided in **Appendix P**.

A total of 72 acres of wetlands would be impacted from construction and operation of either the NED Plan or Recommended Plan due to proposed new upland PA or construction of BU sites. New work placement at BW8 would impact approximately 22.7 acres of forested wetland, and at E2 Clinton, 8.7 acres of mostly emergent wetland. Future O&M placement at the Rosa Allen Expansion would impact 40.7 acres of mostly forested wetlands when it is built. Habitat modeling was conducted using certified habitat suitability index (HSI) models for palustrine forested and palustrine emergent wetlands based on fieldwork conducted in March and April 2019. Following review of candidate models and their applicability, constraints, and limitations, the potential models were coordinated with the resource agencies during the February 21, 2019 and March 21, 2019 BUG meetings. This resulted in selection of Gray squirrel for forested wetlands, and Marsh wren for palustrine emergent wetlands. Also, because the anticipated mitigation method selected was going to mitigation bank use, the models used in all mitigation banks in the Galveston District were also selected to be applied to ultimately determine necessary credits. These are the interim Hydrogeomorphic (iHGM) riverine forested, and the riverine herbaceous/shrub models. The resultant scores for HSI Average Annual Habitat Units (AAHU) and iHGM Functional Capacity Units (FCU) are summarized in **Table 7-2**.

Due to exceedances above the *de minimus* for NO_x and VOCs, alternatives needed to be considered to bring the project into conformity with the State Implementation Plan (SIP) under the Clean Air Act. These options included: 1) extending the construction schedule to reduce the number of tons

per year of emissions; 2) working with the regulatory agencies to get the project included in the SIP for future years; and 3) purchasing discrete emission reduction credits (DERCs) to fully offset the projects emissions. Extending the construction schedule is not a viable option. Under the current schedule the project is expected to be completed in five years and emit 3,652 tons of NO_x. In order to accommodate the SIP budget and get the project under the *de minimus* level the schedule would need to be extended to more than 36 years (at the current allowances). This schedule would not allow for the accrual of benefits in a timely manner. Including the project in future year SIPs was excluded, because the emissions would be too great to be accommodated within applicable SIP budgets. The purchase of DERCs is the option selected and agreed to with TCEQ to fully offset the project's emissions. The purchase of DERCs is the least-cost, most efficient option. With a 10 percent Environmental Contribution and 5 percent Compliance Margin included as part of the purchase process, the necessary number of credits needed, assuming use of only Tier 1 equipment, would be 4,199.8 tons of NO_x and 107 tons of VOCs. These credits are priced at market rates and the price may fluctuate. On December 3, 2019, the market rate price for the credits in total was $14,532,933.40 (costs provided by TCEQ) and no DERC trades had been made in the previous 12 months.

Table 7-2 – Modeling Results for Mitigation Requirements

Placement Area		HSI AAHU		IHGM FCU		
	Habitat Type	Marsh Wren	Grey Squirrel	Temporary Storage & Detention of Storage Water	Maintain Plant and Animal Community	Removal & Sequestration of Elements & Compounds
C2 Clinton	Emergent	3.0	-	0	5.52	3.88
Beltway 8	Forest	-	3.3	0	12.59	10.8
Rosa Allen Extension	Emergent		7.9	0	19.6	14.3
	Forest	1.4		0	15.2	11.1
	subtotal	4.4	11.2			
	Total	**15.6**		**0**	**52.91**	**40.08**

The CECW-P Memorandum, *Implementation Guidance for the Water Resources Development Act of 2007 – Section 2036(c) Wetlands Mitigation*, dated November 6, 2008 required Civil Works projects to first consider the use of available mitigation banks in the Primary Service area for mitigating wetland impacts. Mitigation banks that have their primary service within the location of three proposed PAs would be used to purchase credits for all mitigation for the wetland impacts. The FCUs listed above represent the credits that would be purchased to offset the impact to wetland acreage identified.

7.6 CUMULATIVE IMPACTS

7.6.1 Cumulative Projects Considered

The analysis focused on projects with a more substantial impact to Galveston Bay and bay bottom through dredging or dredged material placement, such as channel dredging projects. The largest past changes to natural bay bottom appear to occur in Galveston Bay. Therefore, the past and present projects focus on that part of the study area. Projects such as HGNC, Cedar Bayou Federal Navigation Channel, BSC, and BCC were considered among other recently completed channel and berth modifications. The full list of past and present actions considered is discussed in **Appendix G, Section 4.3.2**.

Where information was available to quantify the size of project impacts, this information was extracted and summarized in **Appendix G, Table G4-1**.

7.6.2 Cumulative Effects Analysis

The evaluation of cumulative effects brings together the past, present and reasonably foreseeable future projects. Information from permit application material was tabulated and used to estimate quantities, such as dredge quantities, acreage of dredged areas in water/bay bottom, and impacts to oyster reef that portray the size of the relevant impacts. Where not directly given, areas of dredging in existing water and bay bottom were estimated from the given information. The impacts for each project are summarized in **Appendix G, Table G4-1**.

7.6.2.1 Water Quality

For water quality, temporary effects of increased turbidity, decrease in DO, and short-term changes in contaminant levels would occur from the disturbance of sediments during dredging. The past actions would not continue to have these effects from construction dredging, but would during periodic maintenance dredging. The present projects that still have berths to construct would have effects from construction dredging, and all would have effects from maintenance dredging. The reasonably foreseeable projects would have effects from construction of dredging berths and access channels.

The temporary effects lasting only a few hours and spreading less than a thousand meters would require timing, and spacing of the projects, for effects to spatially, or temporally overlap. Except for three projects, all of the foreseeable future projects are located at two ends of the HSC system, sufficiently far from the Bay portion of the NED Plan or Recommended Plan. Therefore, effects from the construction of the HSC through Galveston Bay would not overlap with these projects. For the three projects in the Bay portion of the study, several factors would preclude overlapping: the timeline and urgency differences between projects for implementation, and vessel pilot and

USCG safety spacing. These factors, and the need to safely navigate the upper HSC, make overlap of dredging projects unlikely for projects above State Highway (SH) 146. The limited population and availability of suitable dredges also makes it unlikely these projects would be dredged simultaneously.

For the effects of maintenance dredging of the existing channels of the past and present actions, the same factors of safety spacing restrictions and dredge availability would make simultaneously dredging in sufficiently close proximity unlikely. The last deepening and widening of the HSC under the HGNC Federal project was constructed primarily between 1998 and 2005. Given that other private berth construction projects and ongoing existing channel maintenance would have also been performed during that period, the similar situation for cumulative effects would have been present. No long-term water quality concerns have arisen and no adverse impacts from these temporary effects cumulatively resulted either. Considering the information discussed, the temporary localized effects from turbidity from either the NED Plan or Recommended Plan would likely not have cumulative effects with the past, present, or reasonably foreseeable actions since their effects would not overlap due to either timing or distance.

7.6.2.2 Bays and Deepwater Habitats and EFH

The NED Plan or Recommended Plan would involve impacts to estuarine bottom in two main areas: Galveston Bay, and the Buffalo Bayou/San Jacinto River tidal channel, in which the HSC above Galveston Bay is located. **Table G4-2 in Appendix G** summarizes the impact acreage and location with respect to these two areas of the estuary system. Bay bottom impacts of the NED Plan or Recommended Plan would involve between 1,711 and 2,396 acres with 469 and 538 acres of oyster reef, which would be directly mitigated. Cumulative projects in the Bay would impact approximately 59 acres contributing little cumulatively to NED Plan or Recommended Plan impacts of unvegetated bay bottom of between 1,242 and 1,858 acres without reef. Cumulatively, this would represent 0.5 percent of the approximately 600 square miles of Galveston Bay, a relatively small amount. If the full acreage with oyster reef is considered, a total maximum of 2,455 acres or 0.6 percent would be impacted, still less than 1 percent. Fairly quick recovery of benthic infauna would be expected.

In the Buffalo Bayou/San Jacinto River, the 372 acres of the NED Plan or Recommended Plan dredging would have 205 acres that would become new deepened channel within the toe of the channel, with the remaining 167-acre side slope, that would be typically located in shallow bayou bottom. The cumulative projects total approximately 479 acres of estuarine bottom dredged. However, 351 acres are within an existing deepened berth or channel footprint, leaving approximately 128 acres in shallower areas. Cumulatively, this would represent about 295 acres of shallow area or about 3 percent of the approximate 17 square miles of open water along the HSC above Galveston Bay up to the Main Turning Basin. Similar to the Bay, benthic infauna

would also be expected to recover some time after disturbance from dredging. Recolonization by benthic fauna has been shown to occur as soon as 6 months post-disturbance with recovery to pre-disturbance conditions occurring within 2.5 years and as soon as 18 months. This is described in more detail in **Appendix G, Section 3.2.1.3**.

Considering the temporary effect with eventual recovery, and the relatively small percentages involved of existing Bay and estuarine channel bottom involved, a cumulatively significant effect would not be anticipated. However, the impact is part of the EFH defined for the area and was evaluated in detail as part of the EFH assessment coordinated with NMFS.

7.6.2.3 Oyster Reef

Only a few of the cumulative projects listed oyster reef impacts. Most reef impacts were associated with past actions, and only one of the reasonably foreseeable projects had reef impacts identified. This is likely due to the vast majority of future permits occurring in areas of the highly modified segment of the upper HSC. The NED Plan or Recommended Plan would impact between 88 acres and 410 acres of mapped reef, respectively. The past and present cumulative projects have impacted approximately 177 acres of which virtually all were known to have been mitigated by replacement reef in the Bay. The foreseeable project impact of 29.9 acres is a USACE project that will also have mitigation in the Bay. Therefore, these losses would be replaced in the Bay.

Of the 28,000 acres of reef historically mapped throughout Galveston Bay, between 50 and 60 percent was impacted by Hurricane Ike sedimentation. Though a minor portion has been restored, it was conservatively assumed that 40 percent remained unaffected (11,200 acres) for comparison. For the NED Plan or Recommended Plan and cumulative projects that have not yet been mitigated, up to approximately 587 acres of reef would be impacted or 5-percent of the reef assumed unaffected. If not mitigated for, this impact would be significant because it would be permanent. Mitigation for the NED Plan or Recommended Plan reef impact is already proposed for its direct significant adverse impact to a significant ecological resource per USACE planning guidance.

7.6.2.4 Coastal Texas Protection and Restoration Feasibility Study

The Coastal TX study has proposed a comprehensive plan to reduce storm surge risks and restore ecosystems coast wide. In the Houston/Galveston area, the plan focuses on keeping storm surge from entering the Galveston Bay by deploying a multiple lines of defense. The Coastal TX Barrier system includes an estimated 45 miles of Gulf-side beach and dune complexes in conjunction with two sets of navigation sector gates, 15 vertical lift gates and 16 shallow water environmental gates (SWEGs) at the Bolivar Roads Inlet. Improvements to the existing Galveston Seawall and 18 miles of ring barrier around the bay-side of the City of Galveston and four large pumping stations are included in the plan as a second line of defense. The third line of defense includes a series of

flood gates (and accompanying pumping stations) at Dickinson Bayou and Clear Creek in combination with on-structural measures (buildings being raised and flood-proofed) on the upper west side of Galveston Bay. The plan also includes 6,000 acres of habitat restoration in the form of marsh creation, bird island development, oyster reef recovery and dune/beach improvements using thin layer placement of BU dredge materials and over 50 MCY of sand sourced from near-shore or offshore locations. The study is scheduled to submit a Chief's Report to Congress in the spring of 2021, and construction is estimated to begin as early as 2025 if authority and appropriations are received from Congress. The cost-share sponsor for the current study is the Texas General Land Office. A cost-share sponsor will need to be identified in advance of the next phase of the project (PED). The Texas Legislature will take this cost-sharing proposition under consideration in their next session (i.e., 2021).

The Recommended Plan would not alter tidal exchange or amplitude significantly as it is maintaining the natural channel conveyance unaltered to the extent it is feasible. As a result, the impact on salinity and circulation in the bay and channel due to the Recommended Plan are estimated to be negligible.

7.6.3 Mitigation and Monitoring of Significant Cumulative Effects

The last steps in the cumulative impact analysis are to modify or add alternatives to mitigate significant cumulative effects, and to monitor the cumulative effects of the selected alternative and adapt management. The cumulative effects evaluation in the previous section resulted in identifying impacts to oyster reef as a significant adverse cumulative impact if not mitigated for, mostly due to the direct impact of the NED Plan or Recommended Plan. Mitigation is proposed for the NED Plan or Recommended Plan as discussed in **Section 7.5**, and detailed in **Appendix P, Mitigation Plan for Oyster Reef Habitat**. The mitigation is part of the NED Plan or Recommended Plan and would consist of beneficially using dredged materials to build elevated relief above the bay bottom, capped with a veneer of suitable cultch. This method has been previously used successfully to restore reef as discussed in the Mitigation Plan. The Mitigation Plan also contains a monitoring and adaptive management plan to ensure success criteria will be met, and that the mitigation effort can respond to changes that prevent achieving success.

7.6.4 Conclusions

The cumulative impact analysis resulted in identifying a significant cumulative adverse impact due to oyster reef impacts of the NED Plan and Recommended Plan, for which mitigation has been proposed. The impact to bay bottom, although expected to be temporary as benthic infauna would recover to inhabit modified portions of the channel, is regulated as an impact to EFH. A full EFH Assessment was evaluated by NFMS. The cumulative impact analysis for this FIFR-EIS has been

updated with consideration of the effects from the specific dredged material placement plan developed for the NED Plan or Recommended Plan.

7.7 ANY ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED SHOULD THE NED PLAN OR RECOMMENDED PLAN BE IMPLEMENTED

The NED Plan or Recommended Plan would result in adverse impacts to oyster reef and unvegetated bay bottom that cannot be avoided should the NED Plan or Recommended Plan be implemented. There would be between 88 acres and 409.5 acres of permanent impact to oyster reef for the NED Plan or Recommended Plan. However, mitigation for this loss is proposed by restoring reef in Galveston Bay. The impact to unvegetated bay bottom and the associated benthos from channel construction of both plans would be temporary, as benthic species, ubiquitous in the bay, would recolonize the deepened channel after dredging is complete and the habitat expected to recover. For new work placement, both plans would convert approximately 416 acres of unvegetated bay bottom to either upland bird island habitat or tidal marsh. However, this would be an ecologically beneficial conversion to habitat types much less ubiquitous in the region than unvegetated bay bottom, and 402 of those acres would be tidal marsh beneficial to aquatic fauna and fishery resources. The LPP would convert approximately 23 acres of bay bottom to a shoaling attenuation feature as currently conceived. This would be a jetty-like structure of which part would be the emergent upland crest, but approximately 17 acres would be inter- or subtidal rock-armored surface that would provide a hard substrate for oyster recruitment. According to the habitat modeling performed, only a minor portion of the proposed 3-bird island marsh BU site would be needed to offset upland conversion impacts of the shoaling attenuation feature. No other long-term adverse environmental impacts would be expected to occur as a result of implementing the NED Plan or Recommended Plan.

7.8 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE NED PLAN OR RECOMMENDED PLAN

The labor, capital, and material resources expended in the planning and construction of the NED Plan or Recommended Plan would be irreversible and irretrievable commitments of human, economic, and natural resources. Material resources would chiefly be the fuel spent in dredging, and the minor portion would be steel and concrete for the few structural components of the NED Plan or Recommended Plan, such as sheet piling or slope armoring. These commitments would be a relatively minor portion of the available material resources. The commitment of economic resources would be for a plan analyzed to reasonably maximize NED benefits to the Nation, producing more in net annual benefits than cost, as demonstrated in the economic analysis for this

study. The oyster reef, an impacted fisheries resource, would be mitigated, and would therefore be replaceable.

7.9 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The construction of the NED Plan or Recommended Plan would result in the loss of between 88 acres and 410 acres, respectively, of oyster reef that will be mitigated in the same vicinity of Galveston Bay. The mitigation was determined using a habitat model that determines the function provided by the reef that would be impacted, and the mitigation reef that would replace that lost function. Replacement of the function would be achieved by ensuring all AAHUs measured by the model, are replaced. The modeling accounted for the temporal lag between the time the mitigation is constructed and the time that a living reef would develop on to the constructed mitigation. The modeling and mitigation would ensure the long-term productivity of impacted reef is maintained. Reef is also expected to recover and regrow in part of the areas dredged for the NED Plan or Recommended Plan. The long-term productivity of the channel margins to support reef regrowth following dredging should not be compromised.

As previously discussed, the function of the bay bottom in the areas dredged for the NED Plan or Recommended Plan would recover some time after dredging ceases and benthic infauna recolonizes the new sea floor. This is consistent with the research on benthic recovery performed during the HGNC project and observed in other benthic recovery studies. Though periodic disturbance would occur during maintenance dredging, long-term use of the water column and benthic habitat in the areas dredged for the NED Plan or Recommended Plan would continue, and the areas disturbed would constitute a relatively small percentage of the estuarine bottom. The construction of new BU marsh features for the NED Plan or LPP would increase contribution to the long term productivity of the Galveston Bay by constructing habitat that provides nursery and juvenile habitat for several key finfish and shellfish species, such as Black drum and shrimp. The BU of new work and maintenance material from the NED Plan or Recommended Plan at existing BU sites would continue to contribute to the completion of existing marsh cells. This would enhance the long-term productivity of Galveston Bay's aquatic habitat by providing the aforementioned nursery and juvenile habitat for several key finfish and shellfish species. There would be no other impacts expected on the long-term productivity of other natural resources.

7.10 ENERGY AND NATURAL OR DEPLETABLE RESOURCE REQUIREMENTS AND CONSERVATION POTENTIAL OF VARIOUS ALTERNATIVES AND MITIGATION MEASURES

NEPA regulations in 40 CFR 1502.16 (e) and (f) require a discussion of project energy requirements and natural or depletable resource requirements, along with the conservation potential of alternatives and mitigation measures in an EIS. The NED Plan or Recommended Plan will not have any permanent or continuous energy consumption requirements. Fuel would be required to dredge the channel modifications of the either plan; however, this would be a short-term requirement over several years, and would not result in significant depletion of nonrenewable energy or natural resources. Periodic maintenance of the new NED Plan or Recommended Plan improvements would require fuel to conduct maintenance dredging every one to two years. This would just be an incremental increase over the current maintenance performed on the existing HSC, BSC, and BCC, and not be expected to significantly deplete nonrenewable resources. The NED Plan or Recommended Plan would help reduce fuel consumption by reducing vessel calls, vessel delays, and allowing use of more efficiently loaded ships over the long-term. The LPP would have approximately three times as much reduction in transit and delay hours experienced in-port, as the NED Plan, as discussed in **Section 7.1.7.2**. The NED Plan or Recommended Plan would increase the efficiency and safety of navigation for the Nation's primary port serving the refining industry that produces significant portions of refined products and plastics. Due to the greater reduction of transit and delay hours of the LPP, it would be expected to increase efficiency of navigation to a greater degree than the NED Plan.

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8 IMPLEMENTATION REQUIREMENTS

This section provides a summary of the implementation requirements for the project.

8.1 Division of Plan Responsibilities and Cost-Sharing Requirements

As shown in **Table 8-1**, the Water Infrastructure Improvements for the Nation Act (WIIN) of 2016 modified the new work cost share percentages originally stated in WRDA 1986. Cost shares for GNFs vary according to the channel depth as follows: 20 feet or less, greater than 20 feet but not more than 50 feet, and greater than 50 feet. The percentage applies as well to mitigation and other work cost shared the same as GNFs. 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 GNFs. This may be paid over a period not to exceed thirty years, and LERRs may be credited against it.

Table 8-1 - General Cost Allocation

Feature	Federal Cost %[1]	Non-Federal Cost %[1]
NED General Navigation Features (GNF) [2]	●90% from 0 feet to 20 feet ●75% from > 20 feet to 50 feet ●50% for > 50 feet	●10% from 0 feet to 20 feet ●25% from > 20 feet to 50 feet ●50% for > 50 feet
LPP GNF	●0%	●100%
GNF costs for this project include mobilization, all dredging costs, and all PA construction costs.		
NED O&M	●100% except cost share 50% costs for maintenance > 50 feet.	●0% except cost share 50% costs for maintenance > 50 feet.
LPP O&M	●0%	100% of the O&M cost over the NED Plan
NED Mitigation	●75%	●25%
LPP Mitigation	●0%	●100% of the mitigation cost associated with the LPP
Navigation Aids	●100% USCG	●0%

[1] The NFS shall pay an additional 10 percent of the costs of GNF over a period of 30 years, at an interest rate determined pursuant to Section 106 of WRDA 86. The value of LERRD acquired for this project shall be credited toward the additional 10 percent payment.

[2] WIIN Act (2016) modified new work cost share percentages originally stated in WRDA 1986 and ER 1105-2-100.

8.2 Cost for the Recommended Plan

The Total Project Cost Summary (TPCS) for the design and construction of the Recommended Plan was certified on December 6, 2019, at October 1, 2019 price levels (see **Engineering Appendix, Attachment 1**). The Project First Cost (Constant Dollar Cost at current price level) of the Recommended Plan is $876,848,000. The Total Project Cost or Fully Funded Cost (Constant Dollar Cost full funded with escalation to the estimated midpoint of construction) is $996,912,000. The Project First Cost and Fully Funded Cost break outs by Cost Account were provided previously in **Table 6-9 in Section 6.2.1**.

8.3 Cost Sharing of the Recommended Plan

The Recommended Plan is the LPP. The NFS is responsible for 100 percent of the costs over the NED Plan. Therefore, the Federal cost share for the Recommended Plan is the same as the Federal cost share for the NED Plan. Then, by subtracting the NED costs from the LPP costs we can determine the non-Federal cost share (**Table 8-2**).

Table 8-2 – Comparison of Cost for GNF (NED vs LPP)($000s)

Cost Account and Item Descriptions		Project First Cost – NED Plan			Total Cost	Federal Share	Non-Fed Share
		Federal Cost	Non-Federal Cost	Total	Allocated (LPP Total)	GNF (NED Cost Total)	GNF Difference (LPP-NED)
		October 2019 Price Level					
Construction Item							
01	Lands & Damages (100% non-Federal)	$0	$14,624	$14,624	$14,658	$0	$14,658
02	Relocations	$0	$34,571	$34,571	$37,350	$0	$37,350
06	Fish & Wildlife Mitigation	$40,655	$13,552	$54,207	$81,758	$40,655	$41,103
12	Navigation	$363,071	$121,024	$484,094	$638,862	$363,071	$275,792
	SUBTOTAL	**$403,726**	**$183,771**	**$587,496**	**$772,628**	**$403,726**	**$368,902**
30	Planning, Engineering & Design	$37,595	$12,532	$50,126	$66,322	$37,595	$28,728
31	Construction Management	$21,483	$7,161	$28,644	$37,898	$21,483	$16,415
	SUBTOTAL	**$59,078**	**$19,693**	**$78,770**	**$104,220**	**$59,078**	**$45,143**
	TOTAL PROJECT COSTS	**$462,804**	**$203,464**	**$666,266**	**$876,848**	**$462,804**	**$414,045**

Note: There may be slight differences due to rounding

Table 8-3 provides the cost share breakout for the Recommended Plan. The PHA has provided a Sponsor Letter of Intent to affirm their support of the project (**Appendix S**).

Table 8-3 – Recommended Plan Cost Share Apportionment ($000s)

Cost Account and Item Descriptions		Federal	Non-Federal	Total Project First Cost
		October 2019 Price Level		
General Navigation Features (GNF)				
06	Fish & Wildlife Mitigation	$40,655	$41,103	$81,758
12	Navigation	$363,071	$275,792	$638,862
30	Planning, Engineering & Design	$37,595	$28,728	$66,322
31	Construction Management	$21,483	$16,415	$37,898
GNF Total		**$462,803**	**$362,037**	**$824,840**
LERR (100% Non-Federal Cost)				
01	Lands & Damages (100% non-Federal)	$0	$14,658	$14,658
02	Relocations	$0	$37,350	$37,350
LERR Total		**$0**	**$52,008**	**$52,008**
Project First Cost		**$462,803**	**$414,045**	**$876,848**
Associated Costs (Other Federal Cost) [1]				
12	Navigation Aids (100% Federal – USCG) [1]	$4,609	$0	$4,609
Associated Cost Subtotal (Other Federal Costs) [1]		**$4,609**	**$0**	**$4,609**
Associated Costs (Non Federal Cost) [2]				
12	Local Service Facilities (100% non-Federal) [2]	$0	$78,204	$78,204
Associated Cost Subtotal (Other Federal Costs) [1]		**$0**	**$78,204**	**$78,204**
Total Associated Costs (Other Federal and Non-Federal) [1,2]		**$4,609**	**$78,204**	**$82,813**
Project Cost plus Associated Costs		**$467,412**	**$492,249**	**$959,661**

[1] Other non-Federal costs that are not part of the recommended Federal project but are another Federal agency responsibility.
[2] Associated financial costs that are not part of the recommended Federal project but are a necessary non-Federal responsibility.
Note: There may be slight differences due to rounding

8.4 Additional non-Federal Sponsor Cash Contribution

Section 101 of Public Law 99-662 requires for all navigation channel depths that the NFS must provide an additional cash contribution equal to 10 percent of fully funded GNF costs (minus costs for LERRs). This total is detailed in **Table 8-4** below. These costs may be paid over a period not to exceed 30 years.

Table 8-4 - Total GNF Costs & Credits(October 2019 Price Level)

Cost-Shared GNF[1]	$824,840,000
10% of GNF	$82,484,000
Creditable Land Costs[2]	$11,584,000
Cash Contribution	$70,900,000

[1]PED and CM costs included

[2]Includes Brady Island Shaving ($23,600), Rosa Expansion ($8,980,000); these cost include land cost and all admin cost associate to acquiring land and/or pipeline relocations. Clinton PA and BW8 were evaluated as one-time use; therefore, land value is not creditable and is not included in real estate cost estimate.

8.5 Cost Sharing Allocation for Operations and Maintenance for Recommended Plan

As shown previously in **Table 8-1**, O&M for channels shallower than 50 feet are generally 100 percent Federal Cost. However, the Sponsor requests a LPP and is therefore required to pay 100 percent of the additional O&M costs above that required for the NED Plan. **Table 8-5** provides the costs for the NED O&M increment, the LPP O&M increment, and the Difference between the NED-LPP O&M Costs. The "Incremental" O&M refers to the maintenance above normal / existing practices.

Table 8-5 – Cost Sharing Allocation for Incremental O&M of Recommended Plan ($000s)

Segment	Incremental O&M - NED Plan (GNF)[1, 2]			Incremental O&M - LPP (GNF)[1,2]		
	Total O&M	Fed	Non-Fed[1]	Total O&M	Fed	Non-Fed [3]
	(October 2019 Price Levels)			*(October 2019 Price Levels)*		
1	$69,984	$69,984	$-	$401,198	$249,018[5]	$152,180
2	$259,262	$259,262	$-	$80,228	$80,228[5]	$0
3	$119,025	$119,025	$-	$119,025	$119,025	$0
4	$143,596	$143,596	$-	$143,596	$143,596	$0
5&6	$34,903	$34,903	$-	$34,903	$34,903	$0
Total	**$626,770**	**$626,770**	$-	**$778,950**	**$626,770**	**$152,180**

Note: Non-Federal sponsor responsible for Berthing Costs (associated cost) totaling $37,035,000) ($37,015,000 in Segment 4 and $20,000 in Segment 5&6) are identical for the NED and O&M Plan; these costs are not included in the GNF totals.

[1] Costs above normal / existing practices; uninflated (constant dollar @ October 2019 price levels.

[2 3] Non-Federal costs (Fed NED costs minus LPP Total)

[5] No BSC Flare in LPP, just maintenance of current footprint. This savings to Segment 2 ($179,034,000) transfers to Segment 1.

As shown in **Table 8-5**, the NED incremental O&M over the 50-year period of analysis is estimated at $626,770,000 of which the government would be responsible for 100 percent. However, because the Recommended Plan is a LPP, the NFS is responsible for the costs over the $626,770,000. The LPP shows a savings in Segment 2 (BSC) of $179,034,000. That savings is transferred to Segment 1 for the LPP features. As such, the government is still responsible for the $626,770,000 cost of the NED and the NFS is responsible for the remaining $152,180,000.

See **Appendix R, Table 7-2**, for a comparison between the existing and proposed shoaling rates over the 50-year period of analysis. The total 50-year shoaling rate for the existing project is estimated to be about 344 MCY. The total 50-year shoaling rate with the Recommended Plan is estimated to be about 412 MCY. The Recommended Plan is estimated to increase shoaling by approximately 68 MCY.

8.6 Project Activities to be Completed During PED

This section provides the activities that would be completed during PED and the assumptions or risks associated with the activity.

Cultural Resource Activities. Section 106 investigations, including any identification, NRHP evaluation, and NRHP mitigation necessary to address Section 106 compliance would be deferred to PED. Surveys may include sidescan and magnetometer surveys of the proposed channel modifications, proposed mitigation sites, and proposed placement area and BU site. While the potential for these investigations to affect the design and costs of the project is low, the investigations should be initiated and completed as early as possible in the PED phase to design of project features to avoid and/or mitigate adverse effects to historic properties.

Environmental Activities. Environmental activities deferred to PED include detailed surveys of the modified channel, proposed mitigation sites, and proposed placement area and BU sites. Surveys would include sidescan sonar surveys to inform the presence and extent of oyster reef habitat at these locations. Clay ball degradation studies would be performed to determine the suitability and behavior of new work dredged material planned for placement at the BIM BU site.

NEPA Coordination on BABUS. The BABUS are features of the FWP DMMP for the HSC and still require completion of an environmental assessment. Analysis has been conducted during this feasibility study and the BABUS have been coordinate with the BUG. Expectations are that the first BABUS would be a test of this feature. District Operation will need to complete and environmental assessment during PED.

Ship Simulation. The ship simulation will be performed by ERDC to determine navigation and safety impacts due to anticipated changes in vessel sizes as a result of the proposed channel widening. This is necessary to confirm the necessary dimensions needed to ensure proposed modifications are adequately sized to provide the stated economic benefits and whether the "design" vessels can safely operate within the width and depth of the proposed channel dimensions.

Sediment Study and Velocity Analysis. The study will conducted by ERDC to determine anticipated shoaling rates (sediment build-up) along the waterway and estimate any increase in channel erosion. Erosion concerns are also addressed by the analysis by determining whether the channel velocities in the areas would result in increased channel erosion.

Vessel Effects Study. A vessel effects study will be conducted by ERDC to determine the potential erosional effects to adjacent shorelines and bay bottom from vessel traffic, specifically in the Bay.

Advance Maintenance Study. Advance maintenance consists of dredging deeper than the authorized channel dimensions to provide for the accumulation of and storage of sediment. The study is conducted, using the Sediment Study conclusions, to validate proposed advance maintenance depths, determine if additional depth is needed, and where within the waterway. Recommendations are based on best value.

Pipeline Evaluation. 14 pipelines (**Engineer Appendix, Attachment 2**) will require additional evaluation during PED, but have been slated for removal and relocation in this documentation for budgeting purposes. The risk with this activity is the potential for increase in costs, delay in construction and possible environmental cleanup.

Sedimentation Attenuation Feature. The purpose of this feature would be to alter the existing sediment pathways currently leading to the BSC Flare and redirect them to a location that would decrease the amount of flare shoaling occurring now, while also not worsening channel shoaling elsewhere. Modeling analysis would be conducted to provide a feature that would accomplish the cited purpose. This is a LPP feature; the potential for an attenuation feature which redirects sediment, without negative impacts, would reduce dredging costs, reduce the burden on placement areas, reduce navigation constraints and allow for an extended duration between dredging frequencies.

Dredging Template Analysis. New work template analysis following the guidance from ER 1130-2-520 and EP 1130-2-520 would be conducted to define the channel limits based on the hard and not hard material found in the channel widening and deepening. Cost should not increase based on being captured in the cost risk analysis which should have captured it; but realistically, costs can increase due to increased new work dredge quantities.

Geotechnical Data. Additional geotechnical data will be gathered as required during PED within the channel reaches where deepening and/or widening is planned, at upland confined PA and bay BU sites, and at mitigation sites. Geotechnical analyses will be performed to check channel side slope stability and to better characterize the new work material. Foundation conditions and design

parameters will be developed for design of project features, including placement areas and mitigation. Using the new data, refinements will be made to the study-level analyses performed to design and size the upland confined PAs and bay BUs, and for mitigation sites, and determine available volume of acceptable dike building materials from the channel improvements. The additional data will also be used to perform sheet pile wall design analyses for the planned BSC and BCC sheet pile wall features. The capture of additional geotechnical data and the analysis of that data performed during PED will provide refined design parameters for the various project features, thus will facilitate lower constructability and cost risks compared to the assumptions made for this study.

Hydrographic Surveys. Surveys will be conducted to better define the quantity of new work material to be dredged. Additionally, hydrographic surveys shall extend approximately 1000 feet beyond the channel and barge lane toes on 1000 foot intervals to track changes in channel side slopes and adjacent bay bottom over time for monitoring of channel conditions that relate to shoaling analysis. These surveys will help to reduce cost uncertainties.

8.7 Views of Non-Federal Sponsor and Others

PHA, the NFS for the HSC ECIP Feasibility Study, has been actively engaged in the formulation of the Recommended Plan, fully supports the implementation of the Recommended Plan in accordance with the items of local cooperation set forth in this report (**Section 10.1**). The PHA believes this plan represents the most effective implementation of features to economic growth and safe, efficient navigation, while protecting environmental resources.

8.8 Financial Self-Certification by Non-Federal Sponsor

The NFS has indicated financial capability to satisfy its obligations for construction of the Recommended Plan. This includes responsibility for 100 percent of the Project First Cost over the NED Plan and 100 percent of the O&M over the NED O&M Plan. The PHA has provided a Sponsor Statement of Self-Certification of Financial Capability (**Appendix S**).

8.9 Recommended Plan and Recent USACE Initiatives

These initiatives were developed to ensure USACE success in the future by improving the current practices and decision making processes of the USACE organization. The goals and objectives outlined in the latest (as of June 1, 2017) USACE Campaign Plan (FY 18-22) include 1) Support National Security; 2) Deliver Integrated Water Resource Solutions; 3) Reduce Disaster Risk; and 4) Prepare for Tomorrow. This project specifically supports Goals 2 and 4 of the Campaign Plan available at the following address: *http://www.usace.army.mil/about/campaignplan.aspx*.

8.9.1 USACE Actions for Change as Reflected in the Campaign Plan

This project supports the USACE Campaign Goal 2 (Deliver Integrated Water Resource Solutions and Goal 4 (Prepare for Tomorrow) in the following actions.

- The study analyzed potential effects over the study area.
- Direct and indirect effects of the project on the environment were avoided to the maximum extent possible.
- Risk analysis is being conducted throughout the study.
- Project risks will be communicated during the public review of the study findings.

8.9.2 Environmental Operating Principles

The USACE Environmental Operating Principles (EOPs) were developed to ensure our missions include totally integrated sustainable environmental practices. Throughout the study process, these EOPs are considered at the same level as economic issues. Environmental consequences of construction and operation have been considered in developing the Recommended Plan, which avoids and minimizes all significant environmental impacts. Sustainability and risk management were integral considerations in developing a plan that will minimize impacts to the project area.

The Recommended Plan has been developed in consultation with stakeholders and resource agencies. Resource agency knowledge and evaluation methods developed for similar projects were applied in the impact analysis. A thorough NEPA and engineering analysis has ensured that we will meet our corporate responsibility and accountability for actions that may impact human and natural environments in the Harris and Chambers County areas. This analysis will be transparent and communicated to all individuals and groups interested in USACE activities. The seven re-energized EOP principles (July 2012) are available at the following webpage: http://www.usace.army.mil/Missions/Environmental/Environmental-Operating-Principles/. More detail on how the EOPs are being addressed in the study can be found in **Plan Formulation Appendix**, **Section 4.3**.

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9 PUBLIC INVOLVEMENT

NEPA was enacted by Congress in 1969 to ensure that Federal agencies consider the potential environmental impacts of their proposed actions and alternatives prior to making decisions. NEPA requires the preparation of an EIS for major Federal actions that may significantly affect the quality of the environment.

NEPA established the Council on Environmental Quality (CEQ), which issues guidance and interprets regulations that implement NEPA's procedural requirements. Pursuant to CEQ Regulations for Implementing the NEPA (40 CFR §1501.7 and §1508.22), public involvement is an essential part of the Federal Feasibility study processes and requires an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action. It is integral to assessing the environmental consequences of the proposed action, and improving the quality of the environmental and feasibility study decision making. The USACE planning regulations in ER 1105-2-100 also requires a public involvement, collaboration, and coordination process with the goal of opening and maintaining channels of communication with the public in order to give full consideration to public views and information in the planning process. The objectives of public involvement are 1) to provide information about proposed Corps activities to the public; 2) to make the public's desires, needs, and concerns known to decision-makers; 3) to provide for consultation with the public before decisions are reached; and, 4) to consider the public's views in reaching decisions.

9.1 SCOPING PROCESS

The best time to identify issues, determine points of contact, establish project schedules, and provide recommendations to the agency is during the scoping period. This period provides the most opportunity to alter existing alternatives, propose new alternatives, and refines the proposed action and is usually the best time to initiate collaborative processes. Collaborative processes can improve communication, reduce conflict, and provide generally more acceptable and practical alternatives and solutions.

The scoping process presents citizens the opportunity to provide input on the range of issues to be addressed in the EIS. USACE planning regulations also require to use a scoping process to gain input on the initial planning steps required of a feasibility study, namely Step 1 of the six-step planning process, which is to identify problems and opportunities that a Federal project could address under the purpose of the feasibility study (deep draft navigation in this case). This is to gain agency and public stakeholder input on the specific problems and opportunities that planning could address, and it is recommended to combine efforts to conduct scoping for both NEPA and USACE planning purposes. USACE used this process to receive citizens' ideas on the significant

issues and impacts to be addressed in the analysis of environmental impacts, to help define the scope of the study and the context of the issues that will be analyzed in depth in the EIS. The USACE also specifically sought the public's input on the problems, opportunities, and potential alternatives that navigation improvements can address.

The project sponsors are required to identify and invite the participation of interested persons or resource agencies and, therefore, should use communication methods best suited for the effective involvement of local, regional, and/or national communities, which are interested in the proposed action. The intent of the scoping process was to engage each affected interest as soon as the EIS process began to afford them the opportunity to provide input on the impacts and alternative solutions to potential issues, problems, and actions. **Appendix E**, **Public Coordination**, provides a summary of the public coordination conducted during the scoping process. The following subsections summarize the coordination conducted.

9.1.1 Notice of Intent

A Federal agency first issues a NOI in the Federal Register to inform the public that an EIS (or supplemental EIS) will be prepared and to formally announce the beginning of the scoping process. The process began with publication of the NOI stating the intent to prepare an EIS for the HSC ECIP.

The NOI to *Prepare a Draft EIS for the Houston Ship Channel 45-Foot Expansion Channel Improvement Project (HSC ECIP), Harris and Chambers Counties, Texas* was prepared by the USACE and published in the Federal Register, Volume 81, No. 60, on Tuesday, March 29, 2016. A brief description of the proposed action and possible alternatives was provided along with the proposed scoping process, including any meetings and how the public can become involved. The NOI also provided an agency point of contact to answer questions about the proposed action and the NEPA process.

The **NOI** published March 29, 2016 for the HSC ECIP study included "45-Foot" in the title. The 45-Foot reference was to the mean low tide (MLT) datum. Because the HSC has been converted to the mean lower low water (MLLW) datum this portion of the name was dropped to prevent future confusion.

Legal notices were published in English in the *Houston Chronicle*, and Spanish notices were published in *La Voz* announcing the date, time, location, purpose of the public scoping meeting, and the opportunity for hearing impaired or language translation services if requested.

The USACE created and maintains a HSC ECIP website located at the following link: www.swg.usace.army.mil/Missions/Projects/Houston-Ship-Channel-Expansion/

This website contains project information, public notices, an informational video, and study status. The website provides members of the public the opportunity submit comments during comment periods.

The USACE issued a news release on April 19, 2016. This was made available on the USACE Galveston District website and it was distributed by the Galveston District Public Affairs Office. The news release included a description of the project, as well as information about the public scoping meetings including date, time, location, and the opportunity for hearing impaired or language translation services if requested.

9.1.2 Notice of Intent and Cooperating Agencies

Agencies were invited to participate in the study as cooperating agencies under NEPA by letter dated April 19, 2016. The EPA accepted by letter dated May 23, 2016. The Texas Water Development Board accepted by letter dated June 1, 2016.

9.1.3 Public Scoping Meeting

On May 17 and 19, 2016, public scoping meetings were held to provide the public with information about the preparation of a DEIS and concurrent USACE Feasibility Study, the proposed Project, how the public can participate in the process, and gather information regarding public questions, concerns, and issues regarding the proposed Project. Further information regarding the public scoping meetings is detailed below.

The public scoping meetings took place on Tuesday, May 17, 2016, at Houston Community College Northeast Campus, 555 Community College Drive, Houston, Texas 77013, from 5:30 p.m. to 8:00 p.m., and Thursday, May 19, 2016, at Sylvan Beach Pavilion, 1 Sylvan Beach Dr., La Porte, Texas 77571, from 5:30 p.m. to 8:00 p.m.

Following an open house style format, attendees were asked to complete an attendee card and were provided with the first edition of the project newsletter and a written comment form upon arrival. The newsletter included a description of the proposed project, project background information, the purpose and need for the proposed project, information about the NEPA and concurrent Feasibility Study process, directions on how to submit written comments, and encouraged the recipients to offer their comments. Eleven people completed attendee cards.

Attendees were invited to view a narrated informational presentation and informational display stations around the room and discuss the proposed project with project representatives from USACE, the Port of Houston Authority, and PDT. Display stations provided project background information and information about the NEPA and concurrent Feasibility Study process. The

project information video presentation was approximately nine minutes in length and was played on a loop during the open house.

During the open house, project team members were available to engage the public in discussion about problems and opportunities, to ask questions, and to have one-on-one dialogue. Attendees were invited to submit their comments in writing at the scoping meeting or at any time during the comment period via mail, e-mail, or the project website.

Two written comments were received at the scoping meetings. Several verbal comments were received in verbal discussions by members of the project team. Written comments received at the scoping meeting and throughout the commenting period were considered for the DIFR-EIS. The scoping commenting period ended May 26, 2016.

9.1.4 Agency Coordination

Pursuant to CEQ Regulations for Implementing the NEPA (40 CFR §1501.6 and §1508.5), the Water Resources Council principles and guidelines (42 U.S.C. §1962–3), and USACE ER 1105-2-100 (Paragraph 2-5.a.), several resources agencies were invited to participate as a Cooperating Agency relating to the continuing coordination and participation in the study for the HSC ECIP. As such, an agency coordination meeting was conducted to gain early key agency stakeholder input as recommended by ER 1105-2-100 on the problems and opportunities related to improving deep draft navigation in the planned reaches of the HSC.

The initial interagency workshop took place on May 3, 2016, from 1:00 to 4:00 p.m., at the USACE Galveston District Headquarters, 2000 Fort Point Road, Galveston, Texas. The purpose of the workshop was to gain early agency stakeholder input as recommended by ER 1105-2-100 on the problems and opportunities related to improving deep draft navigation in the planned reaches of the HSC. Letters inviting stakeholder agencies to participate as cooperating agencies were distributed on April 19, 2016.

Follow up meetings were held on February 16, 2017 and May 17, 2017 in conjunction with regularly scheduled the BUG Meetings at Bayport Administration Building, 12619 Port Drive, Seabrook, Texas.

Topics covered include an introduction to the study, measures, and alternatives being considered, options for the BU of dredged material, potential oyster impacts and proposed mitigation, updates to the study schedule, and the TSP.

9.1.4.1 Subcommittee Meetings

In order to focus on specific issues identified by the resource agencies, subcommittees were created for Oyster/Habitat Modeling, Hydrodynamic Modeling, HTRW and Sediment, and the BU of PAs.

The intent of a subcommittee was to hold meetings on specific issues identified by the resource agencies to allow PDT technical staff to discuss with interested agencies how impacts for those issues are planned to be analyzed, and to obtain input from those agencies to help inform the analysis of those issues. Meetings for each subcommittee would be held as needed throughout the conduct of the four-year study process for the HSC-ECIP, as specific analyses and planning activities involved occur. For this study phase, the Oyster/Habitat Modeling subcommittee has met on January 19, 2017, March 24, 2017, and June 29, 2017 to discuss impact assessment, habitat modeling, and mitigation for oyster reef that would be impacted by the proposed TSP.

9.1.5 Coordination

The next major step in the EIS process that provides an opportunity for public input is when the agencies submit a draft EIS for public comment. This provides the opportunity for the USACE to gain public input on the alternatives analyzed and TSP proposed. Two public meetings were held: one on October 19, 2017 at La Porte Junior High and one October 25, 2017 at Galena Park High School. A public notice notifying the public of the DIFR-EIS and announcing the date, time, and location of the originally scheduled public meetings in September 2017 was published in English in the Houston Chronicle and the Galveston Daily News on September 1, 2017, and in Spanish in La Voz on August 30, 2017. A second public notice notifying the public of the DIFR-EIS and announcing the rescheduled public meetings in October 2017 was published in English in the Houston Chronicle and Galveston Daily News on September 15, 2017, and in Spanish in La Voz on Houston Ship Channel Expansion Channel Improvement Project: Public Meeting Summary Report 5 September 24, 2017. The public notice also included information about where to access the DIFR-EIS for review and solicited written comments throughout the public review period via mail or email.

A total of 282 postcards to interested parties and local, state, and Federal elected officials were sent via mail on August 25, 2017, announcing the originally scheduled public meetings in September 2017, and again on September 15, 2017, announcing the rescheduled public meetings in October 2017. The postcards also solicited written comments throughout the public review period via mail or email. A webpage for the HSC ECIP was developed and maintained by the USACE throughout the study process (www.swg.usace.army.mil/Missions/Projects/Houston-Ship- Channel-Expansion/). The webpage announces public meetings for the study, provides information about the study focus and study progress, and provides links to study notices, study

documents, public meeting documents and both versions of the informational study video. Additionally, the webpage lists the study email and mailing addresses.

The comment deadline for the study was Monday, November 13, 2017. Comments were received via the following channels:

- Verbal comments were received during the verbal comment period at the public meetings.
- Comment forms were submitted at the public meetings or mailed to U.S. Army Corps of Engineers, Galveston District, Coastal Section, Regional Planning & Environmental Center, P.O. Box 1229, Galveston, Texas 77553-1229.
- Comments were received via the study email at HSC-ECIP@usace.army.mil or study team representatives.

A total of 32 comments were submitted. The comments and meeting summary are provided in **Appendix E, Public Coordination**.

10 RECOMMENDATIONS

10.1 Overview

I have given consideration to all significant aspects in the overall public interest and concur with the findings presented in this report. The Recommended Plan developed is technically sound, economically justified, and socially and environmentally acceptable.

I recommend that the Houston Ship Channel be modified to in accordance to the Locally Preferred Plan selected herein, with such further modifications thereto as in the discretion of the Chief of Engineers, may be advisable. Mitigation is principally required for approximately 409.5 acres of direct impacts to oyster reef due to the widening in the bay reach. Aids to navigation would be provided at 100 percent Federal cost. For the purpose of calculating the Section 902 limit, the estimated first cost of the project at 01 October 2019 price levels is $876,848,000 including an estimated Federal share of $462,803,000 and an estimated non-Federal share of $414,045,000. The average annual costs are $53,251,000. Average annual benefits are $133,551,000 with a benefit to cost ratio of 2.51.

The Recommended Plan conforms to the essential elements of the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies and complies with other Administration and legislative policies and guidelines on project development. If the project were to receive funds for Federal implementation, it would be implemented subject to the cost sharing, financing, and other applicable requirements of Federal law and policy for navigation projects including WRDA 1986, as amended; and would be implemented with such modifications, as the Chief of Engineers deems advisable within his discretionary authority. Aids to navigation are to be funded by the USCG. Federal implementation is contingent upon the non-Federal sponsor agreeing to comply with applicable Federal laws and policies. The non-Federal sponsor shall, prior to implementation, agree to perform the required items of cooperation:

a. Provide, during the periods of design and construction, funds necessary to make its total contribution for commercial navigation equal to 25 percent of the cost of design and construction of the general navigation features attributable to dredging to a depth in excess of -20 feet MLLW but not in excess of -50 feet MLLW, plus 100 percent of the costs of the LPP which the Government determines would exceed such dredging for the NED plan.

b. Provide all lands, easements, rights-of-way, and relocations, including those necessary for the borrowing of material and placement of dredged or excavated material, and perform or assure performance of all relocations, including utility relocations, as determined by the federal

government to be necessary for the construction or operation and maintenance of the general navigation features, all in compliance with applicable provisions of the Uniform Relocation and Assistance and Real Property Acquisition Policies Act of 1970, as amended (42 U.S.C. 4601-4655) and the regulations contained in 49 C.F.R. Part 24;

c. Pay with interest, over a period not to exceed 30 years following completion of the period of construction of the general navigation features, an additional amount equal to 10 percent of the total cost of construction of the NED Plan general navigation features less the amount of credit afforded by the federal government for the value of the lands, easements, rights-of-way, and relocations, including utility relocations, provided by the non-federal sponsor for the general navigation features. If the amount of credit afforded by the federal government for the value of lands, easements, rights-of-way, and relocations, including utility relocations, provided by the non-Federal sponsor equals or exceeds 10 percent of the total cost of construction of the general navigation features, the non-federal sponsor shall not be required to make any contribution under this paragraph, nor shall it be entitled to any refund for the value of lands, easements, rights-of-way, and relocations, including utility relocations, in excess of 10 percent of the total costs of construction of the general navigation features;

d. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

e. Provide, operate, and maintain, at no cost to the federal government, the local service facilities in a manner compatible with the project's authorized purposes and in accordance with applicable federal laws and regulations and any specific directions prescribed by the federal government;

f. Provide 100 percent of the excess cost of operation and maintenance of the project over that cost which the Government determines would be incurred for operation and maintenance of the NED plan.

g. Hold and save the United States free from all damages arising from the design, construction or operation and maintenance of the project, any betterments, and the local service facilities, except for damages due to the fault or negligence of the United States or its contractors;

h. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements, rights-of-way, relocations, and disposal areas that the Federal government determines to be necessary for the construction or operation and maintenance of the general navigation features. However, for lands, easements, or rights-of-way that the federal government determines to be subject to the navigation servitude, only the federal government shall perform such investigation unless the federal government provides the non-federal sponsor with prior specific written direction, in which case the non-federal sponsor shall perform such investigations in accordance with such written direction;

i. Assume complete financial responsibility, as between the federal government and the non-federal sponsor, for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, rights-of-way, relocations, and disposal areas required for the construction or operation and maintenance of the project;

j. Agree, as between the federal government and the non-federal sponsor, that the non-federal sponsor shall be considered the operator of the local service facilities for the purpose of CERCLA liability, and, to the maximum extent practicable, perform its obligations related to the project in a manner that will not cause liability to arise under CERCLA.

10.2 **Recommendation**

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 NFS, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

10 DEC 2019
Date

Timothy R. Vail
Colonel, U.S. Army
Commanding

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11 REFERENCES

Armstrong DA, Chippendale D, Knight AW, Colt JE (1978) Interaction of ionized and un-ionized ammonia on short-term survival and growth of prawn larvae Macrobrachium rosenbergii. Biol Bull 154: 15–31. doi: 10.2307/1540771

Armstrong, N. T. 1987. The ecology of open-bay bottoms of Texas: a community profile. U.S. Fish and Wildlife Service. Biological Report 85 (7.12), pp 104.

Butler, P.A. 1954. Summary of Our Knowledge of the Oyster in the Gulf of Mexico. U.S. Fish and Wildlife Service, U.S. Department of the Interior.

Buzan, D., W. Lee, J. Culbertson, N. Kuhn, and L. Robinson. 2009. Positive Relationship between Freshwater Inflow and Oyster Abundance in Galveston Bay, Texas. Estuaries and Coasts, Vol. 32, Issue 1, pp 206-212.

Cake, E.W. 1983. Habitat Suitability Index Models: Gulf of Mexico American Oyster. U.S. Fish and Wildlife Service (USFWS) Publication FWS/OBS-82/10.57. 37 pp. USFWS, Department of the Interior, Washington, D.C.

Culbertson, J., L. Robinson, P. Campbell, L. Butler. 2004 Trends in Texas Commercial Fisheries Landings, 1981-2001. Texas Parks and Wildlife Coastal Fisheries Division. Management Data Series No. 224.

Department of Commerce, National Oceanic and Atmospheric Administration. 2012. Takes of Marine Mammals During Specified Activities; Confined Blasting Operations by the U.S. Army Corps of Engineers During the Port of Miami Construction Project in Miami, FL. *Federal Register* 77, No. 158 (August 15, 2012) : 49278.

Drake, C. 2012. Oyster Restoration in Galveston Bay Following Hurricane Ike. *Texas Saltwater Fishing Magazine*. July 1, 2012. Retrieved from: http://www.texassaltwaterfishingmagazine.com/fishing/oyster-restoration-galveston-bay-hurricane-ike/subpage26.html (Accessed November 29, 2016)

Energy Information Agency (EIA). 2015. "Table 5. Electric power industry generation by primary energy source, 1990 through 2013" Texas Electricity Profile. Retrieved from: https://www.eia.gov/electricity/state/Texas/ (Accessed January 25, 2016)

GBEP. 2002. The State of the Bay - A Characterization of the Galveston Bay Ecosystem, Second Edition. https://repositories.tdl.org/tamug-ir/handle/1969.3/26314

GBEP. 2011. The State of the Bay - A Characterization of the Galveston Bay Ecosystem, Third Edition.

Greater Houston Partnership (GHP), 2014. The *Social, Economic and Demographic Characteristics of Metro Houston Report with Projections to 2040 and 2050.*

Hons, C. and L. Robinson. 2010. Recovering from the Storm: Oyster Reef Restoration in Galveston Bay, Texas. Presentation given at *Restore America's Estuaries 5th National Conference on Coastal and Estuarine Habitat Restoration Preparing for Climate Change: Science, Practice, and Policy*, Monday 15, 2010, Galveston, Texas.

*Required by CEQ Regulations 40 CFR 1502.10

Houston Galveston Area Council (HGAC), 2010a. *2010 Air Quality Reference Guide for the Houston-Galveston-Brazoria Area* [Online] www.cleanairaction.org (Accessed March 2011)

Kilgen, R.H., and R.J. Dugas. 1989. The ecology of oyster reefs of the northern Gulf of Mexico: an open file report. National Wetlands Research Center (NWRC) Open File Report 89-03. U .S. Fish and Wildlife Service (USFWS) NWRC, Slidell, Louisiana

Lester, J., L. Gonzales. 2002. The State of the Bay: A Characterization of the Galveston Bay Ecosystem.

Minnesota Pollution Control Agency (MPCA). 2008. *A Guide to Noise Control in Minnesota: Acoustical Properties, Measurement, Analysis and Regulation.* MPCA. October 2008. Saint Paul, MN.

National Oceanic and Atmospheric Administration (NOAA) Fisheries Eastern Oyster Biological Review Team. 2007. Status review of the eastern oyster (*Crassostrea virginica*). Report to the National Marine Fisheries Service, Northeast Regional Office. February 16, 2007. NOAA Technical Memorandum NMFS F/SPO-88, 105 p.

NOAA. 2017. C-CAP Land Cover Atlas. 2010 Land Cover Data for Chambers, Galveston, and Harris Counties. Retrieved from: https://coast.noaa.gov/ccapatlas/?redirect=301ocm (Accessed February 2017)

NOAA. 2016. National Weather Service (NWS). Houston IAH Extremes, Normals, and Annual Summaries. Retrieved from: http://www.weather.gov/hgx/climate_iah_normals_summary (Accessed February 2017)

Natural Resource Conservation Service (NRCS). 2016. Soil Survey Data for Chambers, Galveston, and Harris County. Retrieved from: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm (Accessed August 2016)

National Marine Fisheries Services (NMFS). 2006. Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Sustainable Fisheries, Highly Migratory Species Management Division, Silver Spring, MD. Public Document. pp. 1600.

NMFS. 2011. National Oceanographic and Atmospheric Administration Fisheries: Office of Science and Technology. http://www.st.nmfs.noaa.gov/st1/commercial/index.html (Accessed March 2011)

NMFS. 2016. Roy E. Crabtree/NMFS, March 4, 2016 Memorandum to Alvin B. Lee, SES/USACE, South Atlantic Division, Subject: Continued Operations of Maintenance Dredging and Beach Sand Placement Actions under the 2007 Gulf of Mexico Regional Biological Opinion (GRBO)(I/SER/2015/17543)

NRCS. 2011. Restoration and Management of Rare or Declining Habitats, Oyster Bed Restoration. NRCS - Maryland

Ornolfsdottir, E. B., S. E. Lumsden, J. L. Pickney. 2003. Phytoplankton community growth-rate response to nutrient pulses in a shallow turbid estuary, Galveston Bay, Texas. *Journal of Plankton Research* 26(3), pp 325.

Parker, Jack C. 1965. An annotated checklist of the fishes of the Galveston Bay system, Texas. *Publications of the Texas Institute of Marine Science* 10:201-220.

Poole, J.M., W.R. Carr, D.M.Price, and J.R. Singhurst.2007. Rare Plants of Texas. Texas A&M University Press. College Station, Texas. 640p.

Port of Houston Authority. 2013. Bayport Ship Channel Improvement and Barbours Cut Channel Improvement Projects, Section 204(f) Assumption of Maintenance Assessment Report for Harris and Chambers Counties, Texas.

Powell, E.N., J. Song, M. Ellis, and K. Choi. 1997. Galveston Bay Oyster reef Survey: Technical Reports Volume I. Galveston Bay National Estuary Program Publication GBNEP-50. Department of Oceanography, Texas A&M University.

Robinson, L., P. Campbell, and L. Butler. 1998. Trends in Texas Commercial Fishery Landings 1972 – 1997. Management Data Series Number 158. Texas Parks and Wildlife Department, Fisheries Division. Coastal Fisheries Branch. Austin, Texas.

Rohrer, J., J. Bauer, W. Rodney, D. Westbrook, L. Robinson, J. Carlin, A. Baker, T.M. Dellapenna. 2010. The Impact of Hurricane Ike on Oyster Reefs in Galveston Bay and Ongoing Recovery Efforts. Presentation given at *Restore America's Estuaries 5th National Conference on Coastal and Estuarine Habitat Restoration Preparing for Climate Change: Science, Practice, and Policy*, November 16, 2010, Galveston, Texas.

Scott, W. 2011. Modern Efficient Ships Engines and Engine Rooms. Bright Hub. http://www.brighthub.com/engineering/marine/articles/123371.aspx (Accessed September 29, 2011)

South Carolina Department of Natural Resources (SCDNR). 2015. American Oyster. Ashepoo-Combahee-Edisto (ACE) Basin Species Gallery. Online resource of the SCDNR Marine Resources Research Institute (MRRI). Retrieved from: http://www.dnr.sc.gov/marine/mrri/acechar/speciesgallery/Invertebrates/AmericanOyster/index.html (Accessed November 30, 2016)

Texas Commission on Environmental Quality (TCEQ). 2007. *Galveston Bay Estuary Program* Retrieved from: www.gbep.state.tx.us (Accessed July 2017)

Texas Department of State Health Services. Shellfish harvest maps. Accessed online October 20, 2016. https://www.dshs.texas.gov/seafood/shellfish-harvest-maps.aspx

Texas Department of Water Resources. 1981. Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows. LP-113. Austin, pp 491

Texas Parks and Wildlife Department (TPWD) 2016a. Fish catch rates, website accessed 10/19/2016. http://tpwd.texas.gov/gis/ris/catchrate

TPWD. 2011. News Release, website accessed 10/20/2016. http://tpwd.texas.gov/newsmedia/releases/?req=20110815a

TPWD. 2000. FY1998-1999 Recreational hunting and fishing license sales by county. Unpublished data.

Texas Water Development Board. 1987. Regional and statewide economic impacts of sportfishing, other recreational activities, and commercial fishing associated with major bays and estuaries of the Texas gulf coast: Executive Summary.

Tunnel, John W., and Judd, Frank. 2002. *The Laguna Madre of Texas and Tamaulipas*. Corpus Christi, Texas A&M University Press, 372 pgs.

U.S. Department of Transportation. 2010. *Highway Traffic Noise: Analysis and Abatement Guidance.* Federal Highway Administration. June 2010. Washington, D.C.

U.S. Environmental Protection Agency (EPA). 2015. "Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements," *Federal Register* 80, no. 44 (March 6, 2015): 12264

U.S. Army Corps of Engineers (USACE) Galveston District. 1995. Houston-Galveston Navigation Channels, Texas, Limited Reevaluation Report and Final Supplemental Environmental Impact Statement. USACE Galveston District, Galveston, Texas.

USACE Galveston District. 2015. Jacintoport Ship Channel, Houston, Texas, Assumption of Maintenance Decision Document.

USACE Galveston District. 2003a. Final Environmental Impact Statement for Port of Houston Authority's Proposed Bayport Ship Channel Container/Cruise Terminal, pp 3.18-1 to 3.18-29.

Volety, A.K., M. Savarese, S.G. Tolley, W.S. Arnold, P. Sime, P. Goodman, R.H. Chamberlain, P.H. Doering. 2009. Eastern Oysters (Crassostrea virginica) as an Indicator for Restoration of Everglades Ecosystems. Ecological Indicators 9 (2009) 120 – 136.

12 INDEX*