Appendix C-9

Mitigation Plan

U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Appendix C-9

Draft Mitigation Plan

for the

Coastal Texas Protection and Restoration Study
Integrated Feasibility Report and
Environmental Impact Statement

October 2018

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Acronyms and Abbreviations

AAHUs	Average Annual Habitat Units
ADM	Agency Decision Milestone
C-CAP	Coastal Change Analysis Program
CE/ICA	Cost-Effectiveness and Incremental Cost Analysis
Coastal Texas Study	Coastal Texas Protection and Restoration Feasibility Study
CSRM	Coastal Storm Risk Management
DEM	Digital Elevation Model
ECO-PCX	Ecosystem Planning Center of Expertise
ER	Ecosystem Restoration
FWOP	Future Without-Project
FWP	Future With-Project
HEP	Habitat Evaluation Procedures
HSI	Habitat Suitability Index
LiDAR	Light Detection and Ranging data
MAMP	Monitoring and Adaptive Management Plan
NOAA	National Oceanic and Atmospheric Administration
RSLR	relative sea level rise
SAV	submerged aquatic vegetation
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
TSP	Tentatively Selected Plan
TY	target year
USACE	U.S. Army Corps of Engineers
WRDA 07	Water Resources Development Act of 2007

1.0 INTRODUCTION

Implementation of the Coastal Texas Protection and Restoration Feasibility Study's (Coastal Texas Study) Tentatively Selected Plan (TSP) for Coastal Storm Risk Management (CSRM) will have permanent impacts to multiple different habitat types. The TSP will consist of a barrier system of levees or floodwalls along Bolivar Peninsula, a closure with both navigation and environmental gates along Bolivar Roads, improvements to the Galveston Seawall, and a barrier system of levees or floodwalls along the west end of Galveston Island. In addition, a ring levee around the city of Galveston and potential nonstructural improvements along the bay rim on the west side of Galveston Bay are proposed. Currently, the Coastal Texas Study has completed the TSP milestone phase of the U.S. Army Corps of Engineers' (USACE) Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process, where a plan has been tentatively selected for agency, technical, and public review, and vertical chain of command approval. At this stage of the planning, the major components of the plan have been identified and evaluated at a higher level of analysis, and will be analyzed in greater detail and refined in the next planning phase, following approval during the Agency Decision Milestone (ADM) meeting. Consistent with USACE policy in Planning Bulletin PB 2017-01, there is a certain level of uncertainty expected in the size and make-up of the TSP, and other plans identified from the suite of alternatives analyzed in this initial phase, including the National Economic Development Plan, or a variant preferred by the non-Federal sponsor (the Locally Preferred Plan). As such, the final size of the measures (width, length, etc.), and inclusion or exclusion of some of them in the TSP presented in this Draft Mitigation Plan may change in the next planning phase. These changes can affect the habitat impacted. Because of the conservative nature of economic and engineering assumptions used during the initial planning of the TSP, it is anticipated that the design of proposed structures will result in equal or lesser environmental impacts.

The USACE Civil Works CECW-PC Memorandum for Implementation Guidance for Section 2036(a) of the Water Resources Development Act of 2007 (WRDA 07) – Mitigation for Fish and Wildlife and Wetlands Losses, dated August 31, 2009, reiterates mitigation requirements for any report being submitted to Congress for approval, but also adds the requirement for mitigation plans to comply with the mitigation standards and policies of the USACE Regulatory Program including specific mitigation plan components. The memo is applicable to Civil Works water resources projects that require specific authorization.

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2.0 CALCULATING DIRECT IMPACTS OF CSRM FEATURES

In accordance with USACE planning policy, credit for mitigation was determined by using USACE-certified species models to determine functional losses from impacts and functional gains (or "lift") from mitigation. USACE Civil Works policy contained in the CECW-CP policy memo *Policy Guidance on Certification on Ecosystem Output Models*, dated August 13, 2008, requires that only standard models already certified by the USACE Ecosystem Planning Center of Expertise (ECO-PCX) be used to determine mitigation, or that models proposed for use undergo the model certification process outlined by the USACE. Direct impacts of all the alternatives for consideration for CSRM were calculated based on National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) data and similar data sets for the region. The number of acres of each type of habitat that may be impacted by the actions being considered for CSRM were measured using GIS analysis (Table 1). The environmental team and interagency team determined which Habitat Suitability Index (HSI) models would be used to evaluate these impacts (Table 2). The models selected were all approved models and were coordinated with the USACEs ECO-PCX and vertical team. The models determine an HSI based on specific variables for each species. The species models are used to represent the habitat, not necessarily that specific species. Habitat evaluation for directly impacted areas was measured as the quality of each habitat category (the HSI value) multiplied by the quantity of each habitat category (acres) resulting in habitat unit measurements. Adding target years (TYs), or changes in habitat over time, allowed calculation of Average Annual Habitat Units (AAHUs). Habitat Evaluation Procedures (HEP) allowed determination of mitigation requirements for loss of or degraded habitat due to construction of CSRM features.

The environmental team used the same HSI models for the mitigation assessment and the HEP analysis of the Ecosystem Restoration (ER) measures (see Appendix C-8 for additional details on the ER). To maintain consistency, model variable inputs and assumptions were kept the same for the HEP for mitigation and the ER measure analysis, due to the potential impacts occurring in the Galveston Bay area. The AAHUs were calculated based on the HEP tool.

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Table 1
CSRM Alternatives Baseline Direct Cover Type Acreages Based on NOAA C-CAP Data

NOAA C-CAP Land Cover Classifications	Total CSRM Footprint Acres	Islands/Bird Rookeries		Developed/Upland[2]			Palustrine Emergent Wetland Freshwater Wetland and Marsh				Estuarine Emergent Wetland[3] Wetland and Marsh (Saline and Brackish)				SAV[4]	Oyster Reef[5]	Open Water				Minimum Total Acres Required Mitigation
Land Ownership		Protected State	Protected Federal	Protected State	Protected Federal	Other[1]	Protected State	Protected Federal	Other[1]	Subtotal	Protected State	Protected Federal	Other[1]	Subtotal	Protected State	Protected State	Protected State	Protected Federal	Other[1]	Subtotal	
Alternative A - Coastal Barrier	4,525.3	--	--	43.3	218.3	1,259.3	19.3	15.6	477.6	512.5	5.7	52.5	279.7	338.0	--	--	4.3	7.0	2,142.7	2,154.0	850.5
Alternative B - Coastal Barrier (Texas City Dike)	3,145.8	--	--	--	78.4	629.3	--	36.9	300.0	337.0	--	140.9	486.0	626.9	--	--	--	2.4	1,471.8	1,474.2	963.9
Alternative C - Mid-Bay Barrier	3,814.6	--	--	29.0	44.2	844.8	0.1	24.4	205.1	229.6	6.2	0.02	96.7	102.9	--	471.8	4.0	--	2,088.2	2,092.3	804.2
Alternative D1 - Upper Bay Barrier–Hwy 146	2,038.3	--	--	28.8	--	1,121.7	2.6	--	231.7	234.2	14.5	--	140.3	154.8	--	0.0001	2.4	--	496.3	498.7	389.1
Alternative D2 - Upper Bay Barrier–Bay Rim	2,334.3	--	--	28.8	--	1,342.4	2.6	--	224.6	227.1	14.5	--	157.5	172.0	--	0.0347	2.4	--	561.5	564.0	399.2

[1] The "Other" category under Land Ownership consists of privately owned tracts (including preserves owned and managed by non-government organizations) and Texas General Land Office-state submerged lands. The "Other" category under Developed/Uplands also includes USACE placement areas.
[2] The "Developed/Upland" category consists of bare land, cultivated crops, deciduous forest, developed (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub.
[3] Estuarine Emergent Wetland includes Estuarine Scrub/Shrub Wetland from the NOAA C-CAP 2010 landcover data.
[4] Submerged Aquatic Vegetation (SAV) data were obtained from Texas A&M University Status and Trends Atlas (2016).
[5] Oyster Reef data were obtained from Texas General Land Office.

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Table 2
Habitats Impacted Based on NOAA C-CAP Classification and HSI Models
Used to Calculate Mitigation Requirements for Each Habitat

Habitat Impacted	Model Used
Palustrine Emergent Wetland	American Alligator (Newsom et al., 1987)
Estuarine Emergent Wetland	Brown Shrimp (Turner and Brody, 1983)
American Oysters	Oyster Model (Swannack et al., 2014)

For the mitigation evaluation, the input values for the variables were estimated using best professional judgment. It was assumed that an area with low-quality habitat would be used for a mitigation site. The values were then entered into the HEP tool to determine AAHUs for the new habitat that would be created. A comparison of AAHUs for the impacted habitat and mitigation areas were used to calculate the number of acres that would need to be created for the mitigation areas. The HEP tool requires the number of acres to determine AAHUs; therefore, a starting acreage was added into the mitigation HEP model to get a value of AAHUs. This was then recalculated adjusting the number of acres of mitigation to calculate AAHUs until the value of AAHUs was at least equivalent to the number of AAHUs that was calculated in the impact HEP model. This process was followed for each habitat type to calculate an estimation of the number of acres that would be necessary for mitigation. Tables 3–10 show the HEP calculations to determine direct mitigation requirements.

The habitat type that would require the most mitigation based on the preliminary findings is estuarine emergent wetland. Potential locations for the mitigation have been developed and will be refined further during ongoing phases of project development. Additionally, Cost-Effectiveness and Incremental Cost Analysis (CE/ICA) will be used to determine the most cost-effective mitigation plan.

Open water impacts were not addressed in the mitigation calculations due to the majority of these being caused by dredging impacts. The dredged material will be used beneficially in the ER measures closest to the impact areas. Any other open water impacts will be calculated during future planning and design phases as the actual impacts are more refined. Additional impacts in open water may be mitigated for using Habitat Equivalency Analysis or other appropriate methodology approved by the USACE, non-Federal sponsor, and interagency team.

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Table 3
Direct Impacts: Alternative A American Alligator HSI Model (Impacts)

Acres	512.5						
Condition: Future Without Project		**TY**	0	**TY**	1	**TY**	10
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	5	0.05
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.1846	**HSI=**	0.1846	**HSI=**	0.1846

Acres	512.5						
Condition: Future With Project		**TY**	0	**TY**	1	**TY**	10
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	0	0.00	0	0.00
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	0	0	0	0
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0		0
		HSI=	0.1846	**HSI=**	0	**HSI=**	0

Condition: Future Without Project		**TY**	11	**TY**	51	**TY**	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50		
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		
		HSI=	0.1846	**HSI=**	0.1846	**HSI=**	

Condition: Future With Project		**TY**	11	**TY**	51	**TY**	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	0	0.00	0	0.00		
V2	% open water in bayous, canals or > 1.2 m deep	0	0.00	0	0.00		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	0	0	0	0		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0		0		
		HSI=	0	**HSI=**	0	**HSI=**	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	513	0.18	94.59	
1	513	0.18	94.59	94.59
10	513	0.18	94.59	851.31
11	513	0.18	94.59	94.59
51	513	0.18	94.59	4,729.50
Max TY=	**51**	**AAHUs=**		**94.6**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	513	0.18	94.59	
1	513	0.00	0.00	47.30
10	513	0.00	0.00	0.00
11	513	0.00	0.00	0.00
51	513	0.00	0.00	0.00
Max TY=	**51**	**AAHUs=**		**0.8**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.8
Future Without Project AAHUs	94.6
Net Change	-93.8

Table 4
Direct Impacts: Alternative A American Alligator HSI Model (Mitigation)

Acres 138

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	5	0.05
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.1846	HSI=	0.1846	HSI=	0.1846

Acres 138

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	15	0.75
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	10	1.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	50	0.5
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.4217
		HSI=	0.1846	HSI=	0.1846	HSI=	0.6043

6

Condition: Future Without Project

Variable		TY 11	SI	TY 51	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50		
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		
		HSI=	0.1846	HSI=	0.1846	HSI=	

Condition: Future With Project

Variable		TY 11	SI	TY 51	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	20	1.00	20	1.00		
V2	% open water in bayous, canals or > 1.2 m deep	10	1.00	10	1.00		
V3	Interspersion Class	High	1.00	High	1.00		
V4	% ponded area ≥15 cm deep (May–September)	80	0.8	80	0.8		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.9283		0.9283		
		HSI=	0.9635	HSI=	0.9635	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	138	0.18	25.47	
1	138	0.18	25.47	25.47
10	138	0.18	25.47	229.23
11	138	0.18	25.47	25.47
51	138	0.18	25.47	1,273.51
Max TY=	**51**		**AAHUs=**	**25.5**

Net Change in AAHUs due to Project

Future With Project AAHUs	119.2
Future Without Project AAHUs	25.5
Net Change	93.7

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	138	0.18	25.47	
1	138	0.18	25.47	25.47
10	138	0.60	83.40	489.91
11	138	0.96	132.96	108.18
51	138	0.96	132.96	6,648.10
Max TY=	**51**		**AAHUs=**	**119.2**

Table 5
Direct Impacts: Alternative A Brown Shrimp HSI Model (Impacts)

Acres 338

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90	92	0.92
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00	soft bottom	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.93	HSI=	0.95

Acres 338

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	0	0.00	0	0.00
V2	Substrate Composition	soft bottom	1.00	hard bottom	0.20	hard bottom	0.20
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.00	HSI=	0.00

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	92	0.92	0	0.00		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.95	HSI=	0.00	HSI=	

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	0	0.00	0	0.00		
V2	Substrate Composition	hard bottom	0.20	hard bottom	0.20		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.00	HSI=	0.00	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	338	0.93	315.07	
1	338	0.93	315.07	315.07
10	338	0.95	319.72	2,856.59
11	338	0.95	319.72	319.72
51	338	0.00	0.00	7,993.10
Max TY=	51		AAHUs=	188.3

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	338	0.93	315.07	
1	338	0.00	0.00	157.54
10	338	0.00	0.00	0.00
11	338	0.00	0.00	0.00
51	338	0.00	0.00	0.00
Max TY=	51		AAHUs=	2.6

Net Change in AAHUs due to Project

Future With Project AAHUs	2.6
Future Without Project AAHUs	188.3
Net Change	-185.7

Original acres 330.4

Table 6
Direct Impacts: Alternative A Brown Shrimp HSI Model (Mitigation)

Acres 270

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Acres 270

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	0	0.00		
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.00	HSI=	

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	270	0.20	54.00	
1	270	0.20	54.00	54.00
10	270	0.20	54.00	486.00
11	270	0.20	54.00	54.00
51	270	0.00	0.00	1,350.00
Max TY=	51		AAHUs=	31.9

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	270	0.20	54.00	
1	270	0.20	54.00	54.00
10	270	0.20	54.00	486.00
11	270	0.93	251.69	152.84
51	270	0.93	251.69	12,584.29
Max TY=	51		AAHUs=	217.7

Net Change in AAHUs due to Project

Future With Project AAHUs	217.7
Future Without Project AAHUs	31.9
Net Change	185.8

Table 7
Direct Impacts: Alternative D2 American Alligator HSI Model (Impacts)

Acres	227.1						
Condition: Future Without Project		**TY**	0	**TY**	1	**TY**	10
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	5	0.05
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.1846	**HSI=**	0.1846	**HSI=**	0.1846

Acres	227.1						
Condition: Future With Project		**TY**	0	**TY**	1	**TY**	10
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	0	0.00	0	0.00
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	0	0.00	0	0.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	0	0	0	0
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0		0
		HSI=	0.1846	**HSI=**	0	**HSI=**	0

6

Condition: Future Without Project		**TY**	11	**TY**	51	**TY**	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50		
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		
		HSI=	0.1846	**HSI=**	0.1846	**HSI=**	

Condition: Future With Project		**TY**	11	**TY**	51	**TY**	
Variable			**SI**		**SI**		**SI**
V1	% wetland that is open water (ponds, bayous, canals).	0	0.00	0	0.00		
V2	% open water in bayous, canals or > 1.2 m deep	0	0.00	0	0.00		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	0	0	0	0		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0		0		
		HSI=	0	**HSI=**	0	**HSI=**	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	227	0.18	41.91	
1	227	0.18	41.91	41.91
10	227	0.18	41.91	377.23
11	227	0.18	41.91	41.91
51	227	0.18	41.91	2,095.75
Max TY=	**51**		**AAHUs=**	**41.9**

Net Change in AAHUs due to Project

Future With Project AAHUs	0.3
Future Without Project AAHUs	41.9
Net Change	-41.6

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	227	0.18	41.91	
1	227	0.00	0.00	20.96
10	227	0.00	0.00	0.00
11	227	0.00	0.00	0.00
51	227	0.00	0.00	0.00
Max TY=	**51**		**AAHUs=**	**0.3**

Table 8
Direct Impacts: Alternative D2 American Alligator HSI Model (Mitigation)

Acres 62

Condition: Future Without Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	10	0.50
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	5	0.05
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	10	0.1
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.2154
		HSI=	0.1846	HSI=	0.1846	HSI=	0.1846

Acres 62

Condition: Future With Project

Variable		TY 0	SI	TY 1	SI	TY 10	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50	15	0.75
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05	10	1.00
V3	Interspersion Class	Low	0.20	Low	0.20	Low	0.20
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1	50	0.5
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		0.4217
		HSI=	0.1846	HSI=	0.1846	HSI=	0.6043

6

Condition: Future Without Project

Variable		TY 11	SI	TY 51	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	10	0.50	10	0.50		
V2	% open water in bayous, canals or > 1.2 m deep	5	0.05	5	0.05		
V3	Interspersion Class	Low	0.20	Low	0.20		
V4	% ponded area ≥15 cm deep (May–September)	10	0.1	10	0.1		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.2154		0.2154		
		HSI=	0.1846	HSI=	0.1846	HSI=	

Condition: Future With Project

Variable		TY 11	SI	TY 51	SI	TY	SI
V1	% wetland that is open water (ponds, bayous, canals).	20	1.00	20	1.00		
V2	% open water in bayous, canals or > 1.2 m deep	10	1.00	10	1.00		
V3	Interspersion Class	High	1.00	High	1.00		
V4	% ponded area ≥15 cm deep (May–September)	80	0.8	80	0.8		
V5	% substrate exposed at MLT (May–Sept) - Tidal only						
	CI (tidal) | CI (non-tidal)		0.9283		0.9283		
		HSI=	0.9635	HSI=	0.9635	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	62	0.18	11.44	
1	62	0.18	11.44	11.44
10	62	0.18	11.44	102.99
11	62	0.18	11.44	11.44
51	62	0.18	11.44	572.15
Max TY=	**51**	**AAHUs=**		**11.4**

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	62	0.18	11.44	
1	62	0.18	11.44	11.44
10	62	0.60	37.47	220.10
11	62	0.96	59.74	48.60
51	62	0.96	59.74	2,986.83
Max TY=	**51**	**AAHUs=**		**53.6**

Net Change in AAHUs due to Project

Future With Project AAHUs	53.6
Future Without Project AAHUs	11.4
Net Change	42.1

Table 9
Direct Impacts: Alternative D2 Brown Shrimp Model HSI (Impacts)

Acres 172

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90	92	0.92
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00	soft bottom	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.93	HSI=	0.95

Acres 172

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	0	0.00	0	0.00
V2	Substrate Composition	soft bottom	1.00	hard bottom	0.20	hard bottom	0.20
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.00	HSI=	0.00

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	92	0.92	0	0.00		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.95	HSI=	0.00	HSI=	

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	0	0.00	0	0.00		
V2	Substrate Composition	hard bottom	0.20	hard bottom	0.20		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.00	HSI=	0.00	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	172	0.93	160.33	
1	172	0.93	160.33	160.33
10	172	0.95	162.70	1,453.65
11	172	0.95	162.70	162.70
51	172	0.00	0.00	4,067.49
Max TY=	51	AAHUs=		95.8

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	172	0.93	160.33	
1	172	0.00	0.00	80.17
10	172	0.00	0.00	0.00
11	172	0.00	0.00	0.00
51	172	0.00	0.00	0.00
Max TY=	51	AAHUs=		1.3

Net Change in AAHUs due to Project

Future With Project AAHUs	1.3
Future Without Project AAHUs	95.8
Net Change	-94.5

Table 10
Direct Impacts: Alternative D2 Brown Shrimp Model HSI (Mitigation)

Acres 138

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Acres 138

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	0	0.00		
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.00	HSI=	

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	138	0.20	27.60	
1	138	0.20	27.60	27.60
10	138	0.20	27.60	248.40
11	138	0.20	27.60	27.60
51	138	0.00	0.00	690.00
Max TY=	51	AAHUs=		16.3

Net Change in AAHUs due to Project

Future With Project AAHUs	111.2
Future Without Project AAHUs	16.3
Net Change	95.0

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	138	0.20	27.60	
1	138	0.20	27.60	27.60
10	138	0.20	27.60	248.40
11	138	0.93	128.64	78.12
51	138	0.93	128.64	6,431.97
Max TY=	51	AAHUs=		111.2

3.0 CALCULATING INDIRECT IMPACTS OF CSRM FEATURES

Due to a partial closure at Bolivar Roads from the CSRM navigation and environmental gate structures, reduced tidal flow and a change in the tidal amplitude may occur (McAlpin et al., 2018). The navigation gate is currently proposed as a floating sector gate that requires islands to be built to store the gates when not open for storms. These islands, along with the structural base of the environmental lift gates, reduces the opening across Bolivar Roads. At the time of the TSP, the reduction of the opening at the pass was optimized to 27.5 percent closure. This closure amount may be further optimized in future planning and design phases of the study process to reduce impacts to the hydrology of the Galveston Bay system.

The environmental team developed a methodology for determining the potential impacts to estuarine marshes within the tidal influence areas of Bolivar Roads. ADH modeling was used to predict hydrological impacts, changes in tidal prism, and tidal amplitude that may occur from the proposed CSRM gates (McAlpin et al., 2018). A change in tidal amplitude was assumed to create a situation where the high tides are lower and the low tides are high than in a without-project condition. It was assumed that a change in tidal amplitude would affect tidal marsh since the potential would exist for marsh at the upper bounds of the cover type to experience less inundation while marsh at the lower bounds of the area would experience potentially constant inundation.

To generate an estimate of indirect tidal marsh impacts due to the presence of CSRM structures across Bolivar Roads, a spatial analysis was developed using the NOAA Marsh Migration viewer outputs associated with a projected 1 foot of relative sea level rise (RSLR). It was assumed that 2035 would represent the condition to apply potential effects from the CSRM structure on tidal marsh, which corresponds to approximately 1 foot of sea level rise (SLR) based on USACE RSLR curves. For the analysis, only tidally-influenced cover types, which included estuarine and brackish wetlands were included.

3.1 FUTURE WITHOUT-PROJECT CONDITION

As aforementioned, the NOAA Marsh Migration viewer for 1 foot SLR was used to represent marsh extents in 2035. A polygon that only consisted of the tidal marsh cover types was created and overlaid on a NOAA Digital Elevation Model (DEM) developed from Light Detection and Ranging (LiDAR) data. By clipping the DEM by the tidal marsh polygon, a range of elevations was determined that presumably are associated with Future Without Project (FWOP) tidal amplitude. The lower bound of the tidal range was determined to be –0.25 foot, representing low tide. A tidal range of 1.5 feet (identified by referencing tide data at 3 stations in Galveston Bay) was determined. By adding 1.5 feet to the lower bound value of –0.25 foot, a FWOP tidal range of –0.25 to +1.75 feet was calculated.

3.2 FUTURE WITH PROJECT CONDITION

Preliminary ADH modeling of Galveston Bay determined that 0.5 foot would be eliminated from the tidal amplitude if a CSRM structure were placed across Bolivar Roads (McAlpin et al., 2018). The reduction was assumed to be symmetric about the high and low tide. The reduction of 0.5 foot resulted in a Future With Project (FWP) tidal range of 0.0 to +1.5 feet.

Using GIS, marsh acres were calculated. FWOP Tidal Marsh Acres were estimated to be 38,696 acres. FWP Tidal Marsh Acres were estimated at 35,321 acres. Subtracting the FWP acre estimate from the FWOP acre estimate resulted in a total of 3,375 acres of tidal marsh indirectly impacted by a CSRM structure or storm surge barrier across Bolivar Roads.

The above described HEP tool was then used to calculate the AAHUs of impacted estuarine emergent marsh and the AAHUs and associated number of acres of mitigation that would be needed to address these impacts (tables 11 and 12). The starting acreage of 38,696 was used for both the FWOP and FWP in the HEP tool. However, the “percent of estuary covered by vegetation” variable was decreased in the FWP scenario to show the indirect impacts to tidal marsh, and the subsequent reduction in acres of tidal marsh.

Table 11
Indirect Impacts: Alternative A Brown Shrimp HSI Model (Impacts)

Acres 38,696

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90	92	0.92
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00	soft bottom	1.00
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.93	HSI=	0.95

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	92	0.92	20	0.20		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.95	HSI=	0.34	HSI=	

Acres 38,696

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90	81	0.81
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.93	HSI=	0.93	HSI=	0.81

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	81	0.81	11	0.11		
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.81	HSI=	0.21	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	38,696	0.93	36,071.24	
1	38,696	0.93	36,071.24	36,071.24
10	38,696	0.95	36,603.67	327,037.10
11	38,696	0.95	36,603.67	36,603.67
51	38,696	0.34	13,233.85	1,245,937.88
Max TY=	51	AAHUs=		26,977.9

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	38,696	0.93	36,071.24	
1	38,696	0.93	36,071.24	36,071.24
10	38,696	0.81	31,214.24	302,784.66
11	38,696	0.81	31,214.24	31,214.24
51	38,696	0.21	8,246.91	986,528.69
Max TY=	51	AAHUs=		22,239.3

Net Change in AAHUs due to Project

Future With Project AAHUs	22,239.3
Future Without Project AAHUs	26,977.9
Net Change	-4,738.5

Table 12
Indirect Impacts: Alternative A Brown Shrimp HSI Model (Mitigation)

Acres 6,887

Condition: Future Without Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future Without Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	0	0.00		
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.20	HSI=	0.00	HSI=	

Acres 6,887

Condition: Future With Project		TY	0	TY	1	TY	10
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	10	0.10	10	0.10	10	0.10
V2	Substrate Composition	muddy bottom	0.80	muddy bottom	0.80	muddy bottom	0.80
V3	Mean salinity - spring	18	1.00	18	1.00	19	1.00
V4	Mean water temperature - spring	24	1	24	1	24	1
		HSI=	0.20	HSI=	0.20	HSI=	0.20

Condition: Future With Project		TY	11	TY	51	TY	
Variable			SI		SI		SI
V1	% of estuary covered by vegetation (marsh and seagrass)	90	0.90	90	0.90		
V2	Substrate Composition	soft bottom	1.00	soft bottom	1.00		
V3	Mean salinity - spring	19	1.00	23	0.94		
V4	Mean water temperature - spring	24	1	24	1		
		HSI=	0.93	HSI=	0.93	HSI=	

Condition: Future Without Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	6,887	0.20	1,377.40	
1	6,887	0.20	1,377.40	1,377.40
10	6,887	0.20	1,377.40	12,396.60
11	6,887	0.20	1,377.40	1,377.40
51	6,887	0.00	0.00	34,435.00
Max TY=	51	AAHUs=		812.9

Condition: Future With Project

TY	Acres	HSI	Total HUs	Cumulative HUs
0	6,887	0.20	1,377.40	
1	6,887	0.20	1,377.40	1,377.40
10	6,887	0.20	1,377.40	12,396.60
11	6,887	0.93	6,419.85	3,898.63
51	6,887	0.93	6,419.85	320,992.65
Max TY=	51	AAHUs=		5,551.9

Net Change in AAHUs due to Project

Future With Project AAHUs	5,551.9
Future Without Project AAHUs	812.9
Net Change	4,739.0

4.0 MITIGATION PLAN

Because of the preliminary nature of the planning to identify the TSP at this initial phase and the planning policy requiring detailed analysis post-ADM, the specific mitigation sites have not been fully evaluated. Due to the combination of direct and indirect estuarine emergent marsh impacts a conceptual plan of potential mitigation sites has been developed. Direct impacts (512.5 acres) to palustrine emergent marsh were also found using the NOAA C-CAP tool, but no sites have been selected at this time. Due to uncertainty of the C-CAP tool to distinguish between freshwater and saltwater marsh, it may be necessary to ground-truth the actual direct impacts. Therefore, at this planning stage only mitigation banks (Greens Bayou Wetlands Mitigation Bank, Lower Brazos River Mitigation Bank, Gulf Coastal Plains Mitigation Bank) have been considered for mitigation for freshwater marsh, but will be examined for cost effectiveness using CE/ICA. As the project is refined and impacts are more closely examined, the need for palustrine marsh mitigation and other potential mitigation options will be explored. Table 13 provides a preliminary estimation of the direct and indirect habitat acreage impacts that could result from construction and implementation of Alternative A.

Table 13
Total Mitigation Requirements for Each CSRM Alternative

	Alternative A		Alternative D2 (Bay Rim)	
Impact/Mitigation	Acres	AAHUs	Acres	AAHUs
IMPACTS:				
Direct				
Palustrine Wetlands	512.5	–93.8	227.1	–41.6
Estuarine Wetlands	338.0	–185.7	172.0	–94.5
Oyster	0	0	0	0
Total Direct Impacts	850.5	–279.5	399.1	-136.1
Indirect				
Tidal Prism Change	38,696.0	–4,738.5		
MITIGATION:				
Direct Impacts				
Palustrine Wetlands	138.0	93.7	62.0	42.1
Estuarine Wetlands	270.0	185.8	138.0	95.0
Oyster	0		0	0
Mitigation Direct Subtotal	408.0	279.5	200.0	137.1
Mitigation Indirect Subtotal	6,887.0	4,739.0		
Total Mitigation	7,295.0	5,018.5	200.0	137.1

4.1 SITE SELECTION CRITERIA

At this preliminary phase of planning, potential mitigation sites in Galveston Bay have been identified in consultation with the interagency team including Texas Parks and Wildlife Department (TWPD), National Marine Fisheries Service, U.S. Fish and Wildlife Service (USFWS), Texas General Land Office, Natural Resource Conservation Service, U.S. Environmental Protection Agency, Texas Water Development Board and others. In addition, coordination with the Houston Ship Channel's proposed expansion project, potential Beneficial Use of Dredge Material (BU) locations for the ship channel dredged material were used as a guiding point for locations for mitigation sites. At this planning stage, site selection is preliminary, and CE/ICA will be used to determine the exact mitigation plan. The potential mitigation sites do not overlap the Houston Ship Channel sites, but many are located in close proximity to some of their potential BU sites. This will allow continued coordination if both this study and the Houston Ship Channel's proposed expansion project are authorized and funded. Figure 1 displays the potential mitigation sites. The proposed mitigation areas depict conceptual boundaries that could serve as mitigation for project-induced estuarine marsh impacts. The areas do not necessarily reflect boundaries of mitigation measures that may ultimately be included in the completed wetland mitigation plan, which will be included in Appendix C-9 to the Coastal Texas Study's Final Integrated Feasibility Report and Environmental Impact Statement.

The USACE-constructed mitigation features shown on Figure 1 would be located and constructed in a manner that avoids adverse impact to existing wetland habitats to the greatest degree practicable. Any unavoidable adverse impacts to existing wetland habitats or to other habitats would be fully compensated as part of the mitigation plan, as necessary. The selected sites are distributed across the Galveston Bay watershed to capture the diversity of wetlands within each portion of Galveston Bay with unique characteristics; i.e., West Bay, East Bay, Trinity Bay, and lower Galveston Bay.

The following four sites have been identified as potential mitigation areas:

1. Trinity River Delta: 1,106 acres of river delta. Restoration of estuarine emergent marsh in this area would complement potential mitigation sites proposed by the Houston Ship Channel's proposed expansion project. Reduction in sediment supply due to impoundment of the Trinity River has altered geomorphic processes that sustain wetlands in this area. The delta, currently reduced in size, would benefit from marsh restoration.

2. Dollar Bay: 487 acres of shallow bay on the west side of Galveston Bay. Restoration of estuarine emergent marsh in this area would complement existing TPWD marsh restoration. A marsh complex historically existed in this area, but has since degraded due to erosion and subsidence.

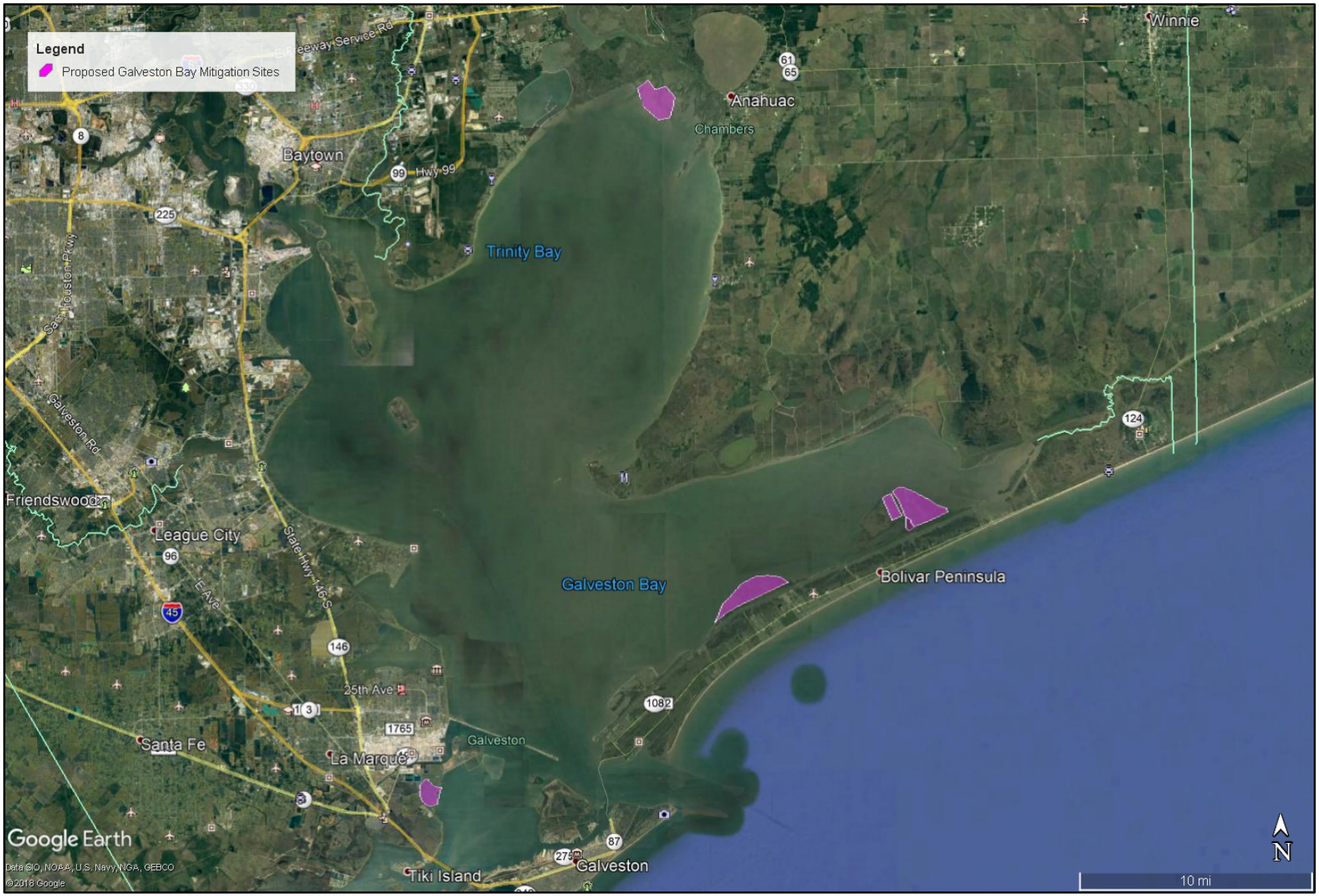

Figure 1. Proposed Mitigation Sites within Galveston Bay

3. West alluvial fan on Bolivar Peninsula: 1,272 acres of back-bay marsh complex. Restoration of estuarine emergent marsh in this area would complement the Houston Ship Channel's proposed expansion project as well as the Galveston Bay ER measures of the Coastal Texas Study. Marsh restoration would maintain the depositional environment of the alluvial fan.

4. East alluvial fan on Bolivar Peninsula: 1,682 acres of back-bay marsh complex. Restoration of estuarine emergent marsh in this area would complement the Houston Ship Channel's proposed expansion project as well as the Galveston Bay ER measures of the Coastal Texas Study. Marsh restoration would maintain the depositional environment of the alluvial fan.

As discussed above, mitigation site planning and selection is at a preliminary stage for the reasons discussed therein. This mitigation plan will be updated at the end of the post-ADM planning phase to revise the impact and mitigation amounts with changes driven by the project refinement and more-detailed mitigation site planning.

5.0 MONITORING AND ADAPTIVE MANAGEMENT PLAN

The USACE, in consultation with the interagency team, will develop a full Monitoring and Adaptive Management Plan (MAMP). The monitoring plan will include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring. Additionally, monitoring will be performed until mitigation success is achieved. Discussions on meeting the success criteria would be included in each monitoring report. Corrective actions would depend on the assessed or probable cause of the failure and could include things like replanting vegetation if substrate has subsided or is otherwise not exposed, or seeding if all other factors are not an issue. At any time during the monitoring period, if the success of the mitigation plan appears not to be meeting the success criteria, USACE would notify the interagency team, so that the mitigation can be evaluated and measures pursued to address deficiencies.

The MAMP will establish a framework for decision making that utilizes monitoring results and other information, as it becomes available, to update project knowledge and adjust management actions through adaptive management. Having a MAMP ensures success under a wide range of conditions and enables implementing corrective actions in cases where monitoring demonstrates that the measures are not achieving ecological success. Monitoring and adaptive management provides an iterative approach to achieve restoration project goals and objectives by promoting flexible decision making where uncertainties are present. Future planning and design phases of this study will incorporate a more detailed monitoring and adaptive management plan and cost breakdowns.

As implementation planning occurs, Adaptive Management Teams consisting of the USACE, local non-Federal sponsor, and resource agencies will be formed to develop MAMPs specific to each mitigation site to fully use the technical knowledge of local experts to guide the adaptive management decision-making process. The Adaptive Management Teams will review monitoring results, advise on, and recommend actions that reflect the needs of the habitats and the species they support. Uncertainties include RSLC, climate change, sediment dynamics, and natural variability in ecological and physical processes. Individual teams will develop a monitoring plan to identify performance standards, desired outcomes, and monitoring design, as well as designate the monitoring period to achieve ecological success.

Monitoring results will be documented in reports to be used to evaluate adaptive management needs and inform decision making. Decision criteria, or adaptive management triggers, are used to determine any implementation of adaptive management opportunities.

Potential adaptive management actions that may be considered for marsh restoration mitigation include renourishment with additional material to correct elevation or topography to target; erosion control measures; berm construction, removal or modification to affect tidal exchange; replanting to increase vegetative cover; and changes in invasive species control and management.

Initial Monitoring and Adaptive Management Cost estimates were estimated as a percent of the total construction cost and based on the complexity of the proposed ER activity and the estimated level of effort and frequency of

need. Section 2039 of the WRDA 07 allows monitoring to be cost-shared for up to 10 years postconstruction; however, monitoring may continue beyond that point, funded by the local non-Federal sponsor, if success criteria are not yet met. Monitoring and adaptive management costs will be refined as project design evolves.

6.0 REFERENCES

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