Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Management and Ecosystem Restoration
Final Integrated Feasibility Report and Environmental Impact Study

Appendix O

WETLAND VALUE ASSESSMENT MODELING

May 2017

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1 MODEL APPROVAL FOR USE

In the Review Plan for the Sabine Pass to Galveston Bay, Texas (S2G), Coastal Storm Risk Management (CSRM) and Ecosystem Restoration (ER) Study, Galveston District proposed to use the Wetland Value Assessment (WVA) coastal marsh, swamp and bottomland hardwood community models to evaluate ecosystem impacts. The U.S Army Corps of Engineers (USACE) National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) agreed, noting that while the swamp and bottomland hardwood models are certified, use of the coastal marsh models would require approval by USACE Headquarters (HQUSACE) (Attachment 1). By memo dated May 6, 2014 (Attachment 2), the HQUSACE Model Certification Panel reported that it had reviewed the WVA marsh model in accordance with EC 1105-2-412 and determined that the model and its accompanying documentation are sufficient to approve the Coastal Marsh Community Model Version 1.0 for use on the S2G Feasibility Study. Since several unresolved issues exist with the form of suitability graphs for Variables 1, 2, and 3 and the aggregation methods used to combine marsh and open water habitat units, Galveston District was directed to conduct sensitivity analyses for application of the marsh models using a sensitivity spreadsheet prepared by the Engineering Research and Development Center's (ERDC) Environmental Lab. These analyses have been coordinated with the ECO-PCX and reported in a separate appendix to the Final Integrated Feasibility Report and EIS (FIFR-EIS).

2 STUDY OVERVIEW

The Sabine Pass to Galveston Bay study area encompasses six coastal counties of the upper Texas coast (Orange, Jefferson, Chambers, Galveston, Harris and Brazoria) (Figure 2-1). The study area consists of three watershed-based regions: the Sabine, Galveston, and Brazoria Regions. Although the S2G study addresses coastal storm risk management and ecosystem restoration problems and opportunities within the six-county region, the detailed evaluation of alternatives focused on two regions outlined in Figure 2-1, the Sabine and Brazoria regions. The FIFR-EIS presents a programmatic overview of coastal storm risk problems and opportunities in the Galveston region and a programmatic overview of ER opportunities for the entire six-county study area. This overview provides recommendations for future studies in the Galveston Region; no in-depth alternative analyses were conducted and no recommendations for project construction are made for this region. None of the ER proposals were fully developed or recommended for construction and thus no environmental modeling was conducted.

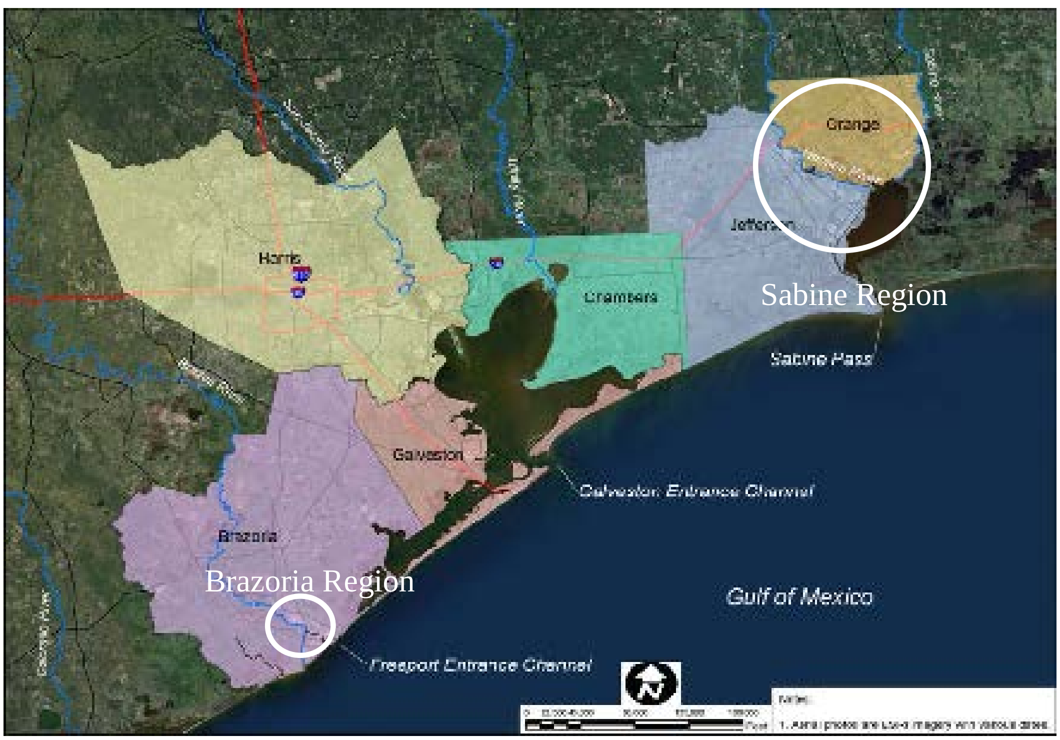

Figure 2-1. Six-County Study Area – Sabine and Brazoria Regions

The S2G Draft Integrated Feasibility Report and EIS (DIFR-EIS) study conducted a detailed evaluation of the following structural plans: 1) the Freeport and Vicinity CSRM Plan (Figure 2-2); 2) the Port Arthur and Vicinity CSRM Plan (Figure 2-3); and 3) the Orange-Jefferson CSRM Plan (Figure 2-4). The Port Arthur and Orange-Jefferson project areas are located in the Sabine region in the vicinity of Port Arthur, Beaumont, and Orange, Texas, and the Freeport project area is located in the Brazoria region in the vicinity of Freeport, Clute, and Oyster Creek.

The Tentatively Selected Plan (TSP) presented in the DIFR-EIS retained the following elements: Orange 3, Beaumont A, and the Jefferson Main (Figure 2-5). Orange 1 and 2 reaches were eliminated from consideration, as well as Beaumont A and B.

As a result of the final feasibility analyses, additional reaches of the Orange-Jefferson CSRM plan were eliminated from further consideration. Beaumont A and most of the Jefferson Main reach were eliminated and the final Recommended Plan, which is shown in Figure 2-6, is comprised of the Orange 3 reach presented in the TSP, and a 1,900 feet-long new levee in Jefferson County, called the Port Arthur Addition. The Addition will be incorporated into the Port Arthur and Vicinity CSRM Plan.

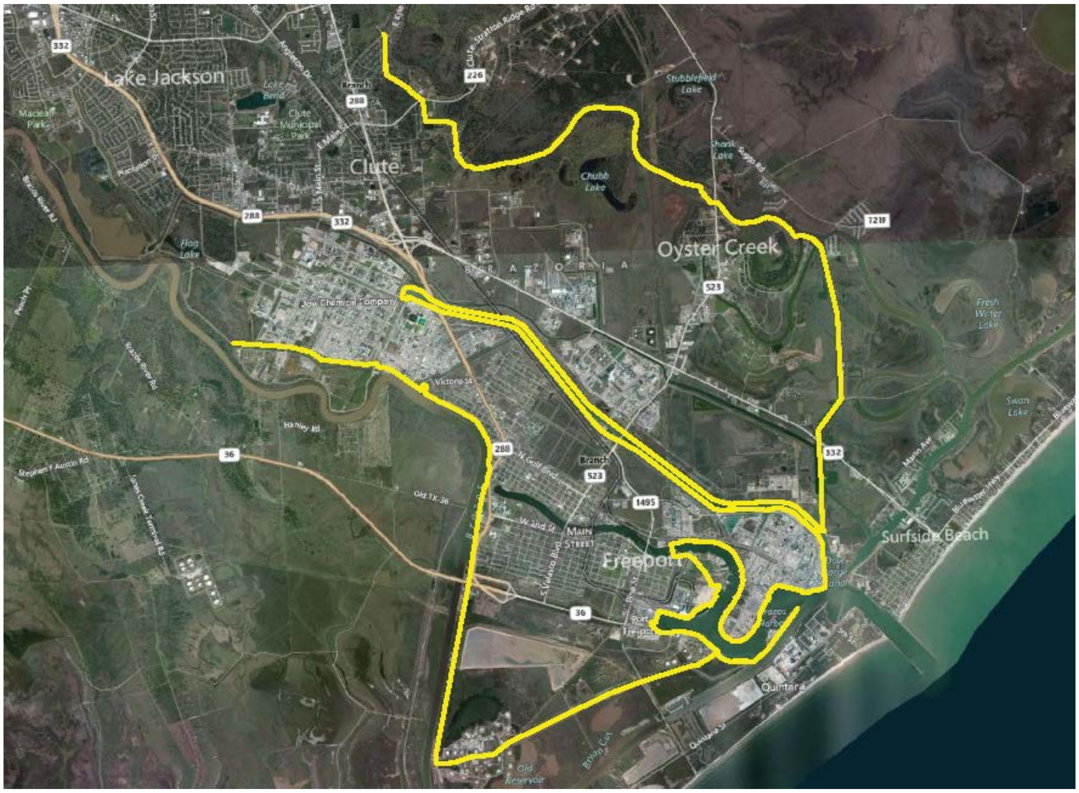

Figure 2-2. Existing Freeport HFP System

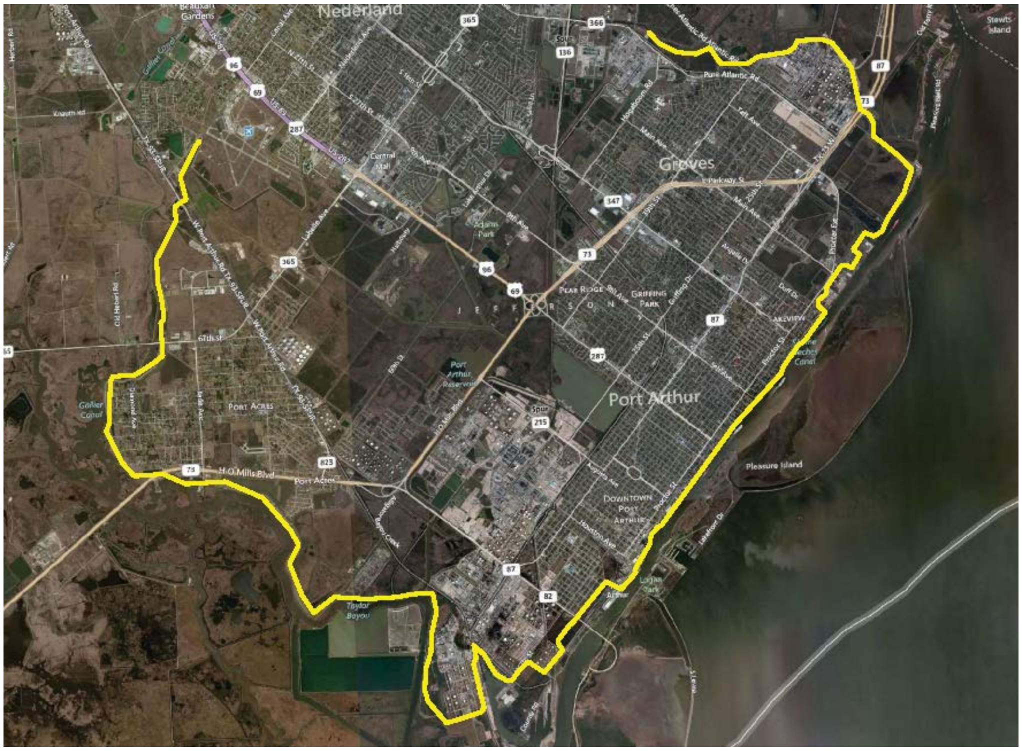

Figure 2-3. Existing Port Arthur HFP System

Figure 2-4. All Evaluated Reaches for the Orange-Jefferson CSRM Analysis

Figure 2-5. Orange-Jefferson CSRM TSP Plan

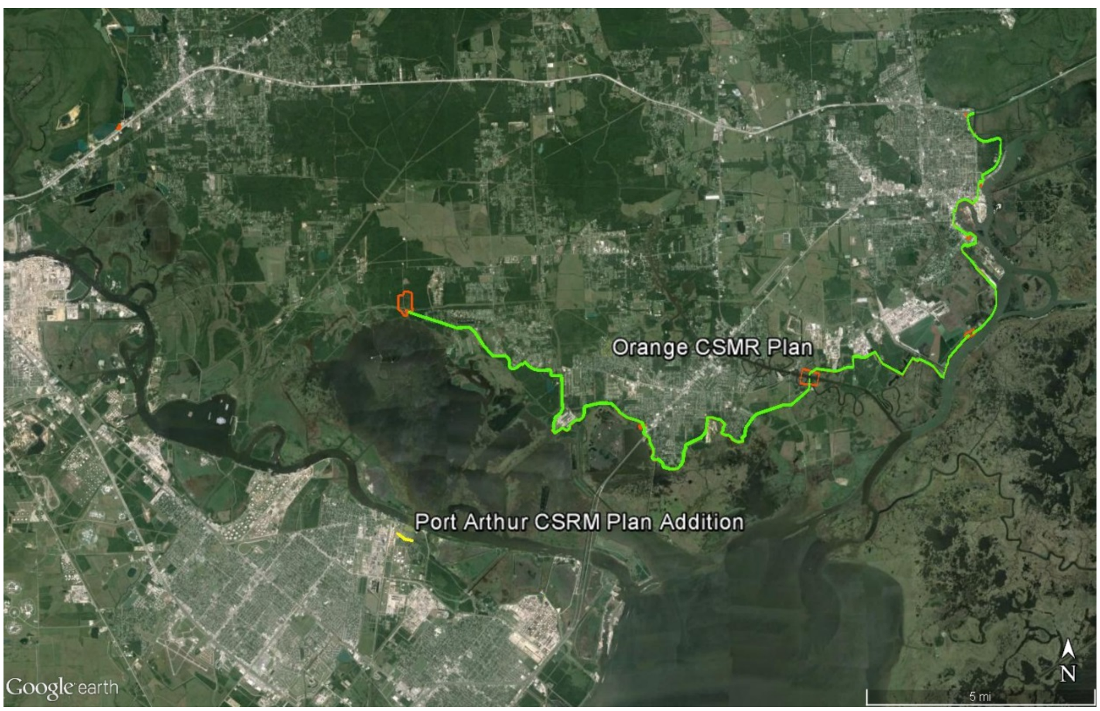

Figure 2-6. Recommended Plan for Orange and Port Arthur Addition CSRM

This WVA modeling appendix focuses on an evaluation of the final Recommended Plan and its two remaining elements, the Orange CSRM Plan. The Freeport and Port Arthur and Vicinity CSRM plans involve improvements to existing Hurricane Flood Protection (HFP) projects. WVA evaluation of the Freeport and Port Arthur CSRM Plans was not needed because these projects would have no wetland impacts. Construction would be confined primarily to the existing project rights-of-way, and no wetland or other significant habitats would be affected.

3 EXISTING CONDITIONS IN THE STUDY AREA

3.1 WETLAND VEGETATION COMMUNITIES

In the study area, coastal marshes occur in four types that are differentiated by salinity, elevation, and soil regimes. Information on indicator species, salinity regime, and lists of vegetation community species provided by marsh type below was completed from references cited here (The Nature Conservancy, 2006; USFWS, 1998; White et al., 1987).

Salt marsh is located primarily along the Gulf shoreline and the shores of Sabine Pass. Small areas of salt marsh can also be found north of Sabine Lake, primarily in areas regularly exposed to higher salinities in the deep draft navigation channels. Subjected to regular tidal inundation, low saline marsh is dominated by smooth cordgrass/oystergrass (*Spartina alterniflora*) and often accompanied by seashore saltgrass (*Distichlis spicata*), blackrush (*Juncus romerianus*), saline marsh aster (*Aster tenuifolius*), and marshhay cordgrass/wiregrass (*S. patens*). The dominant species in high salt marsh, which is subject to less-frequent tidal inundation, is glasswort (*Salicornia* spp.). Relative to other marsh types, salt marsh typically supports fewer terrestrial vertebrates although some shorebird species are common.

Brackish marshes in the study area are located primarily along the lower reaches of the Neches and Sabine Rivers, and the north shore of Sabine Lake. The dominant species in low brackish marsh is saltmarsh bulrush (*Scirpus robustus*); seashore saltgrass and marshhay cordgrass are co-dominant species in high brackish marsh. These species are often accompanied by marsh pea (*Vigna luteola*), waterhemp (*Amaranthus tamariscinus*), and dwarf spikerush (*Eleocharis parvula*). Brackish marshes are extremely important as nurseries for fish and shellfish. Other characteristic species include fur-bearers and shorebirds.

Intermediate marshes are subjected to periodic pulses of salt water and maintain a year-round salinity in the range of 3 to 4 parts per thousand (ppt). In the study area, they are the major marsh type along the Neches and Sabine Rivers. The diversity and density of plant species are relatively high with marshhay cordgrass the most dominant species in high marsh. Co-dominant species in low marsh are seashore paspalum (*Paspalum vaginatum*), Olney bulrush (*S. americanus*), California bulrush/giant bulrush (*S. californicus*), and common reedgrass/roseau cane (*Phragmites australis*); bulltongue (*Sagittari lancifolia*) and sand spikerush (*E. montevidensis*) are also frequent. Intermediate marshes are considered extremely important for many wildlife species, such as alligators and wading birds, and serve as important nursery areas for larval marine organisms.

Freshwater marshes are heterogeneous, with local species composition governed by frequency and duration of flooding, topography, substrate, hydrology, and salinity. Tidal fresh marsh is located in the riparian zone of the Neches and Sabine rivers. Co-dominant species in low marsh are maidencane (*P. hemitomen*), giant cutgrass (*Zizaniopsis milacea*), and bulltongue. Co-dominant species in high marsh are squarestem spikerush (*E. quadrangulata*) and marshhay cordgrass. Other characteristic species include American lotus (*Nelumbo lutea*), watershield (*Brasenia screben*), duckweed *(Lemna* spp.), and fanwort (*Cabomba caroliniana*). Salinity rarely increases above 2 ppt, with a year-round average of approximately 0.5 to 1 ppt. Tidal fresh marshes support extremely high densities of wildlife, such as migratory waterfowl.

Upstream of the coastal marshes in Sabine Lake estuary, the area north of Interstate 10 is dominated by dense bottomland hardwood forests and cypress-tupelo swamps. These wetland forests cover an intricate network of sloughs and sandy ridges formed within the rivers' relict meander belts. Bald cypress (*Taxodium distichum*) – tupelo-gum (*Nyssa aquatica*) swamps grow in the inundated areas between the ridges, and floodplain hardwood forest of oaks (*Quercus nigra, Q. phellos, Q. alba, Q. lyrata*), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), American elm (*Ulmus americanus*), maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), American holly (*Ilex opaca*), and loblolly pine (*Pinus taeda*) grow atop the sandier ridges. In general, these are healthy, stable habitats. The hardwoods, and especially the cypress trees, have been logged repeatedly since the turn of the century and as recently, perhaps, as the 1950s (USACE, 1998). Pockets of bottomland hardwood forest remain in the uplands south of Interstate 10, and cypress swamp can still be found in low lying drainages such as Cow and Adams Bayous. Though much of the forest is secondary growth, the swamp and bottomland hardwood habitats have medium to high value for food and cover to resident and migratory fish and wildlife.

3.2 LOSS OF EMERGENT MARSH

Marshes in the study area are severely threatened, with the conversion of numerous large marshes to open water documented by various mapping studies (Barras et al., 2004; Texas Parks and Wildlife Department (TPWD), 2003). Immediately east of the study area in the Chenier Plain subregion of coastal Louisiana, a net land loss of 21 percent between 1978 and 2000 has been reported (USACE, 2004: MR 2-24; Appendix B). In Texas, the most-extensive losses of interior coastal wetlands in the state (12,632 acres between 1930 and 1978) have occurred in the Neches River delta. In total, over 90 percent of the emergent marshes in the Lower Neches River delta have been converted to open water (White et al., 1987; Morton and Paine, 1990), which is more than half of the total wetland loss in the State of Texas (Sutherlin, 1997). The breakup of previously intact emergent marsh is apparent, and shoreline erosion is occurring around larger lakes. In the conversion of marsh to open water, topsoils and nutrients have eroded, leaving dense clay substrates that do not support marsh vegetation. More recently, however, the rate of land loss in the Chenier Plain region appears to have ameliorated and interior marshes appear to have stabilized. Over the last 20-30 years, rates of loss have declined and marshes do not appear to be undergoing rapid conversion of large areas to open-water like areas to the east in Louisiana (LCWCR/WCRA, 1998; TPWD, 2003; USACE, 2004; USGS 2014). For example, 61 percent of the total land loss in the Chenier Plain region occurred between 1978 and 1990 as compared to 39 percent between 1990 and 2000 (Barras et al., 2004). A recent analysis of satellite images covering the period from 1984 and 2014 in Orange County documented much lower marsh loss rates, as well as documenting increases in areas with active marsh restoration projects (USGS 2014).

3.3 EFFECTS OF RECENT HURRICANES

Three large hurricanes have occurred in and near the study area within the last ten years. In 2005, Hurricane Katrina devastated areas to the east but did not affect this area. The same year, Hurricane Rita's storm surge at Louisiana Point was 10.6 feet as recorded by USGS sensors (Farris et al., 2007). The surged deposited 3.3 feet of new sediment on the Hackberry Beach chenier ridge and inundated thousands of acres of coastal marsh. Bar welding of nearshore sediments to the lower shore face was also evident (Guidroz et al., 2006). Immediately after the storm, hundreds of acres of marshhay cordgrass marsh in Cameron Parish appeared to have been severely impacted by extensive flooding of high-salinity waters. When the water finally subsided, the vegetation in some areas appeared dead, and the marsh had areas that were 30 to 50 percent devegetated. Over time, porewater salinity levels should decline as rainwater flushes salinity from the system (Farris et al., 2007).

In 2008, Hurricane Ike struck the north Texas Gulf Coast, with the eye passing over the city of Galveston, approximately 60 miles southwest of the study area. Ike's hurricane-force winds, record-breaking levels of storm surge, and extensive coastal and inland flooding had a direct impact on the coastal wetlands, including significant marsh loss, scouring, and compression (Federal Emergency Management Agency [FEMA], 2008). The secondary effects of saltwater intrusion, in which freshwater habitats and species are stressed by elevated soil salinities from the surge overwash and sediments, may not be fully realized for years to come.

Chenier plain marshes in the Sabine and Neches River floodplains are concave in shape, and under normal conditions, do not drain as rapidly as tidal fringe marshes. The normal drainage of these marshes is also impaired by numerous human-caused hydrologic modifications within and adjacent to these marshes, such as the GIWW, the Sabine-Neches Waterway, numerous roads and other infrastructure (FEMA, 2009). In addition to inundating salt marshes near the coast, tidal surges resulted in significantly increased salinities in large areas of swamp and freshwater marsh in the Sabine system for months after the storms (FEMA, 2009). The marshes of Sabine Lake are comprised of generally brackish and intermediate vegetation communities which were not tolerant of the higher salinity of Ike's storm surge. Therefore, the high salinity water was either lethal to these plants or had sub-lethal effects ranging from reduced seed production, vegetative stress and increased vulnerability to disease (Linthurst and Seneca, 1981; Howard and Mendelssohn, 1999). Further compounding the problem is the organic soils that are typical of these marshes, and when exposed to saline waters, can produce high amounts of hydrogen sulfide, which can lead to sulfide toxicity and death in marsh plants. Organic soils are also dependent on plant roots for cohesion; therefore, upon plant death, these soils are subject to rapid erosion and dissolution in normal marsh conditions (FEMA 2009).

4 FUTURE WITHOUT-PROJECT CONDITIONS

4.1 EXPECTED NAVIGATION CHANNEL IMPROVEMENTS

Deepening of the existing Sabine-Neches Waterway (SNWW) 40-foot deep-draft navigation channel to 48 feet was authorized by the Water Resources Reform and Development Act (WRDDA) 2014. Deepening of the channel will allow the saltwater wedge in the deep draft navigation channel to reach further inland and increase salinity in the lower Neches and Sabine River channels, as well as Sabine Lake (USACE 2011). Since project implementation is likely, projected future with-project (FWP) salinities from the SNWW feasibility study have been utilized as the future without-project (FWOP) salinities for this study.

4.2 PROJECTIONS OF FUTURE RELATIVE SEA-LEVEL CHANGE

Future rates of freshwater inflow and relative sea-level change (RSLC) are likely to result in significant changes in the FWOP condition for the study area (National Research Council [NRC], 1987; Intergovernmental Panel on Climate Change [IPCC], 2013; Milliken et al., 2008a). FWOP forecasts of salinity, marsh loss, and related impacts on plant and animal communities in the study area are important in establishing the baseline condition against which FWP impacts are measured. For the purpose of predicting FWOP salinities in the Orange-Jefferson study area, this modeling effort utilized the results of 3-dimensional TABS-MDS hydrodynamic salinity (HS) modeling conducted for the SNWW deepening feasibility study (USACE 2009). The HS model incorporated the effects of relative sea-level change (RSLC) and forecasts of future freshwater inflows into the FWOP and FWP conditions through 2069. Salinities and tidal circulation through the environmental period of analysis for this study (2019-2080) are expected to be similar to those projected by the SNWW HS model.

The projected rate of RSLC at the Sabine-Neches estuary is very uncertain. The uncertainty inherent in the rates of eustatic sea level rise is evident in the wide range of various estimates from the NRC (1987) and the IPCC (2013). The confidence that any estimate will match actual future sea levels decreases over time, and significant deviations are possible. In order to incorporate a risk-based assessment given this uncertainty, Galveston District used current USACE guidance to assess the effects of changes in RSL over the period of analysis on economic benefits and engineering design considerations. USACE guidance (ER 1100-2-8162, December 2013 and ETL 1100-2-1, June 2014) specifies the procedures for incorporating climate change and relative sea level change into planning studies and engineering design projects. Projects must consider alternatives that are formulated and evaluated for a wide range of possible future rates of relative sea level change for both existing and proposed projects. The USACE guidance requires that projects be evaluated using “low”, “intermediate”, and “high” rates of future sea level change, as defined below.

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

Project impacts and costs of the Orange-Jefferson CSRM Plan have been assessed against 50-year projections of the three potential rates of RSLC calculated for Sabine Pass, Texas (Table 4-1). The computed future rates of RSLC given here give the predicted change by 2080 for the Sabine Lake system. The SNWW HS modeling (2009) included an estimate of +1.1 feet of RSLC over a period of analysis ending in 2069. The estimated amount of historic RSLC applied for this study is 1.63 feet for the period of analysis ending in 2080. Use of the SNWW HS modeling for salinity estimates provides reasonable salinity values for this study.

Table 4-1. Projected RSLC at Sabine Pass, Texas by 2080

Tidal Gage	Low RSLC (feet)	Intermediate RSLC (feet)	High RLSC (feet)
Sabine Pass, Texas	1.63	2.32	4.51

Recent wetland loss rates (1984-2014) have been calculated by USGS for 12 subunits of the study area by analyzing multiple dates of cloud free Landsat imagery from 1984-2014 (USGS 2014). The conversion of wetland acres to open water is assumed to have occurred under the low (or historic) rate of RSLC. For the low RSLC scenario, the historic marsh loss rates were held constant and projected forward to provide yearly wetland acres through the period of analysis. This was considered to be the baseline loss rate.

4.3 CLIMATE CHANGE AND CHANGES IN FRESHWATER INFLOWS

Future projections of freshwater inflows for the study area are also highly uncertain. These flows would be influenced by changes in the timing and amount of precipitation, temperature, water demand, and water supply strategies. The Texas State Climatologist concluded that it is impossible to predict with confidence what precipitation trends will be in Texas over the next half century

(Nielsen-Gammon, 2009). Unlike precipitation, there is more consensus for a predicted temperature increase in Texas of close to 4 degrees Fahrenheit (°F) by 2060. Patterns of precipitation change are affecting coastal areas in complex ways. The Texas coast saw a 10 to 15 percent increase in annual precipitation for 1991-2012 compared to the 1901-1960 average. Texas coastal areas will see heavier runoff from inland areas, with the already observed trend toward more intense rainfall events continuing to increase the risk of extreme runoff and flooding.

Projections of future water demand and supply strategies are also very difficult to make and often involve controversial subjects such as interbasin transfer and new reservoirs. Freshwater inflows applied in the 2009 SNWW HS modeling were based upon the 2007 Texas State Water Plan and the associated regional plan for the study area (TWDB, 2007), and Run 8 of the Texas Commission on Environmental Quality (TCEQ) Water Availability Models (WAMs) for the lower Sabine and Neches Rivers.

The 2007 State Water Plan took into consideration existing flows in the Sabine River that are dedicated to the State of Louisiana as prescribed by the Sabine River Compact. The states of Texas and Louisiana are apportioned equal shares of the total Sabine River flow, and therefore freshwater inflows for Louisiana in the HS modeling were equivalent to Texas inflows. The plans were based upon evaluations of population projections, water demand projections, and existing water supplies available during drought. By 2060, population in the region encompassing the study area was projected to grow 36 percent. In the 2007 plan, water demands were projected to increase 41 percent but the region was assessed as having surplus water available beyond projected demands.

Texas updated its State Water Plan in 2012 (TWDB 2012). Projections still apply to a planning horizon ending in 2060, with the same projection of 36 percent growth in population. However, water demands are now projected to more than double, with the existing water supply projected to meet demands through 2040. Conservation, new water-supply reservoirs, and new diversion from existing reservoirs are recommended water management strategies.

The Texas Water Code requires that flow quantities adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats be maintained. Work on setting target inflows for the Sabine-Neches area was undertaken as part of the Texas Senate Bill (SB) 3 Environmental Flows Allocation Process (TCEQ 2014). The Texas Commission on Environmental Quality (TCEQ) adopted environmental flow standards for the Sabine-Neches region in 2011; however, there are some questions that the standards are adequate to support a sound ecological environment in the coastal estuarine system. To address this concern, the Stakeholder Committee developed a work plan for adaptive management which was approved. It requires additional monitoring and studies, with a review of the Sabine-Neches environmental flow standards on a 5-year cycle. The first review of the current standards may be completed by 2016.

4.4 FREQUENCY OF HURRICANES

Texas' entire Gulf Coast historically averages three tropical storms or hurricanes every four years, generating coastal storm surges and sometimes bringing heavy rainfall and damaging winds hundreds of miles inland. The expected rise in sea level will result in the potential for greater damage from storm surge along the Gulf Coast of Texas. Tropical storms have increased in intensity in the last few decades. Future projections suggest increases in hurricane rainfall and intensity (with a greater number of the strongest – Category 4 and 5 – hurricanes) (Melillo 2014).

Storm surge modeling conducted by ERDC for this study (USACE 2014) provided a predicted return interval of 10-15 years for storm surges high enough to threaten the areas targeted for protection in the Sabine Region. Upland areas in Orange and Jefferson Counties are generally 7-10 feet higher than the structure locations.

4.5 EMERGENT MARSH LOSS

For the WVA wetland change analysis for the Sabine region, trend line projections were made for three scenarios – low (historic), intermediate and high RSLC. These scenarios were based on the 50-year projections of RSLC calculated by SWG for Sabine Pass, Texas (see Table 4-1).

Recent wetland loss rates (1984-2014) were calculated by USGS for 12 subunits of the Sabine study area by analyzing multiple dates of cloud free Landsat imagery from 1984-2014. The historic rate of conversion of wetland acres to open water is assumed to have occurred under the low (or historic) rate of RSLC. For the low RSLC scenario, the historic marsh loss rates was held constant and projected forward to provide yearly wetland acres through the period of analysis. This was considered the baseline loss rate.

For the intermediate and high RSLC scenarios, the annual FWOP wetland loss rates for each subunit of the study area were gradually increased (beginning at Target Year 1 or 2020) by adding an additional annual increment of loss in the landloss spreadsheet that is based on the projected annual RSLC increase for the intermediate and high scenarios. The annual wetland loss rate increases were based on the negative relationship that has been observed between wetland loss rates and RSLC from coastwide non-fresh marshes outside of active deltaic influences in Louisiana (USACE 2013). The percentage change per year from the Low to Intermediate RSLC rate and from the Low to High RSLC rate were computed as shown in Table 4-2. The annual percentage change from Low to Intermediate RSLC was .01 feet/year; and from Low to High RSLC was 0.04

feet/year. This additional RSLC related wetland loss was added to the baseline or historic wetland loss rate to obtain total annual loss rates for each year to project wetland loss over the period of analysis for the intermediate and high RSLC scenarios.

Table 4-2. RSLC Scenarios for Sabine Pass, Texas

Tidal Gage	Low RSLC (feet)	Intermediate RSLC (feet)	High RLSC (feet)
Sabine Pass, TX	1.633	2.32	4.51
Percent Total Change by Year 2080			
Low to Intermediate	0.4233		
Low to High	1.77		
Percent Change Per Year			
Low to Intermediate	0.01		
Low to High	0.04		

4.6 SALINITY

In the FWOP condition, RSLC would also increase salinity in the floodplain portions of the study area due open hydrologic connections to the tidally-influenced reaches of the Sabine and Neches Rivers. The RSLC estimates for the intermediate and high scenarios would be expected to increase tidal flows over historic rates, and this higher tidal energy would likely increase water surface elevation and salinity. WVA impacts modeling for the intermediate RSLC scenario utilized outputs from the SNWW hydrodynamic salinity modeling as inputs for the salinity variables in the WVA marsh and swamp models. Because the rates of RSLC utilized for the SNWW hydrodynamic-salinity modeling are lower than the rates predicted for this study (i.e. 1.1 feet by 2069 as compared to 2.3 feet by 2080), an independent check on the salinity values used for the WVA modeling was conducted using modeled output from a similar study in the northwest Gulf of Mexico region..

ERDC hydrodynamic salinity modeling conducted for the Morganza to the Gulf of Mexico Project (USACE 2013) provided salinity projections for the three RSLC scenarios in accordance with the same guidance utilized for this study. Modeled outputs of salinities within ranges associated with fresh, intermediate and brackish marshes were averaged over the Morganza study area and used to calculate a percentage change in salinity between the baseline (or historic) rate and the intermediate and high rates of RSLC occurring over 75 years. Since the Morganza area has significantly higher rates of subsidence than this study area, the percentage changes calculated for the Morganza area were adjusted by reducing them by the percentage difference of the RSLC rates between Morganza and the Sabine region. The adjusted percentage change for the intermediate and high scenarios was applied to the baseline salinities to provide estimates of FWOP salinities in year 2080. The calculations described here are presented in Table 4-3.

Table 4-3. Method for Estimating FWOP Intermediate and High Salinities for Sabine Region

Morganza Average Modeled Salinities from RSLC Scenarios			
	Average Salinity (parts per thousand)		
RSLC Scenario	Brackish	Intermediate	Fresh
Historic (Low)	9.1	4.4	0.5
Intermediate	10.7	4.9	0.5
High	12.1	5.0	0.7
Percentage Morganza Salinity Change for RSLC Scenarios			
Difference between	Brackish	Intermediate	Fresh
Historic – Intermediate RSLC	18.2%	10.4%	2.6%
Historic – High RSLC	33.5%	11.8%	32.1%
Percentage Change Adjusted for Difference in Subsidence Rates			
	RSLC (feet over 75 years)		
RSLC Scenario	Morganza	Sabine	% Difference
Historic (Low)	1.7	0.93	-45.3%
Intermediate	2.4	1.49	-37.9%
High	4.8	3.26	-32.1%
Percentage Change in Salinity Adjusted for Difference in RSLC for Sabine Region			
Difference between	Brackish	Intermediate	Fresh
Historic – Intermediate RSLC	11.3%	6.5%	1.6%
Historic – High RSLC	22.7%	8.0%	21.8%

This comparison indicates that salinities associated with Intermediate RSLC would increase by 11.3% in brackish marsh areas, 6.5% in intermediate marsh areas, and 1.6% in fresh marsh areas. WVA modeling for this study assumed that salinities for all marsh types would increase by an average of 50% over the period of analysis, well over the increase indicated by the Morganza comparison. Thus, using the SNWW modeling for salinity inputs provides a conservative estimate of salinity changes for the WVA modeling.

5 WVA MODELING METHODOLOGY

This study applies WVA Coastal Marsh (Version [V] 1.0), Swamp (V 1.0) and Bottomland Hardwood (V 1.0) models to calculate impacts and develop mitigation for the Recommended Plan (USFWS 2002; 2010). Sensitivity analyses of WVA Coastal Marsh Versions 2.0 and 2.0B will be conducted after the plan has been finalized; the sensitivity analysis will be presented in an appendix to the Final IFP-EIS. Plan selection and mitigation utilized WVA Model V 1.0 outputs.

The WVA methodology is similar to the USFWS Habitat Evaluation Procedures (HEP), in that habitat quality and quantity are measured for baseline conditions and predicted for FWOP and FWP conditions. Instead of the species-based approach of HEP, the WVA models use an assemblage of variables considered important to the suitability of a given habitat type for supporting a diversity of fish and wildlife species. As with HEP, the WVA allows a numeric comparison of each future condition and provides a combined quantitative and qualitative estimate of project-related impacts on fish and wildlife resources.

WVA models operate under the assumption that optimal conditions for fish and wildlife habitat within a given coastal wetland type can be characterized, and that existing or predicted conditions can be compared to that optimum to provide an index of habitat quality. Habitat quality is estimated and expressed through the use of a mathematical model developed specifically for each habitat type. Each model consists of 1) a list of variables that are considered important in characterizing fish and wildlife habitat; 2) a Suitability Index graph for each variable, which defines the assumed relationship between habitat quality (Suitability Indices) and different variable values; and 3) a mathematical formula that combines the Suitability Indices for each variable into a single value for wetland habitat quality, termed the Habitat Suitability Index (HSI).

The habitat variable-habitat suitability relationships within these WVA models have not been verified by field experiments or validated through a rigorous scientific process. However, the variables were originally derived from HEP suitability indices taken from species models for species found in that habitat type. An independent external peer review of the WVA Models has been conducted by the USACE Eco-PCX (Battelle 2010). The reviewers agreed that the concept and application of the models are sound for planning efforts. The models seem to sufficiently capture the habitats being modeled and do not have any irreparable deficiencies. However, some aspects of the WVA Coastal Marsh Model concerning variables 1, 2, and 3 were found to have been defined primarily by policy and/or functional considerations of Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). These concerns are being evaluated with a sensitivity analysis presented in DIFR-EIS Appendix Q. Plan formulation for this study will be based on V 1.0 of these models.

A new WVA spreadsheet has been developed by ERDC that allows for all three versions of the Marsh Model (V1.0, V2.0 and V2.0B) to be run simultaneously. The Swamp and Bottomland Hardwood models (V 1.0) are also included in the spreadsheet, as well as other WVA models not used for this study. The capability to handle risk and uncertainty was incorporated by the use of a Monte Carlo simulation and the ability of the user to either input High/Low or Standard Deviations for inputs. One hundred iterations were run each time the model was applied and results are reported for the 95 percent confidence level with standard deviations.

5.1 PERIOD OF ANALYSIS/TARGET YEARS

The environmental period of analysis for the Orange-Jefferson CSRM Plan is a total of 61 years based on the following assumptions. The construction period is assumed to begin in 2020 and end in 2030. All direct impacts are assumed to occur in the first year of construction (2020). This is conservative assumption since construction would not impact the entire project area in the first year of construction, and construction is not currently projected to be complete until 2030. Indirect impacts may begin later but all are assumed to begin by 2031. Mitigation area construction is assumed to be concurrent with levee system construction, beginning in 2020 and ending in 2030. The period for which mitigation benefits are analyzed is 2031-2080, which is the same as the 50-year economic period of analysis. A target year summary is provided in Table 5-1.

Table 5-1. Target Year Summary

TY0	2019 (the year before impacts begin)
TY1	2020 (all impacts occur)
TY11	2030 (levee and mitigation construction complete)
TY12	2031 (mitigation and economic benefits begin)
TY61	2080 (end of mitigation and economic period of analysis)

5.2 LAND AREA CHANGE ANALYSIS

Recent historic land area change rates (1984-2014) were calculated by USGS (2014b) for 12 subunits of the study area, and separately for Jefferson and Orange Counties, by analyzing multiple dates of cloud free Landsat imagery from 1984-2014. These change rates are shown in Table 5-2. Those shown in red are loss rates; those in black are accretion rates. They are uniformly very low and reflect lower subsidence rates that have resulted from decreased water and oil/gas withdrawals in the region in recent decades. The areas showing accretion are largely degraded swamp or marsh areas with significant ongoing beneficial use projects where marsh has been restored. Since none of the construction ROW is located in areas directly affected by these beneficial use projects, the applicable overall county change rate (which both show losses) was applied when evaluating marsh impacts in hydro-units which exhibited overall accretion (TX 3, 11 and 12 specifically).

Land loss change rates were not applied to the Swamp or Bottomland Hardwoods models because land loss is either not a factor in these areas or too small to warrant tracking

Table 5-2. USGS Aerial Photography Analysis of Marsh Change Rates

Hydrologic Unit	Name	Rate perc/yr	r^2
TX 1	North Neches River	0.0085%	0.15
TX 2	Neches River	-0.0567%	0.289
TX 3	Rose City	0.0543%	0.0201
TX 4	Beaumont South	0.0703%	0.165
TX 5	Bessie Heights	-0.0052%	0.000113
TX 6	Old River Cove	-0.0892%	0.0345
TX 10	Cow Bayou	-0.0203%	0.0424
TX 11	Adam Bayou	0.0032%	0.00106
TX 12	Blue Elbow South	0.0110%	0.0994
TX 13	Lower Neches	-0.0456%	0.0809
Texas/LA 1	Sabine Island	0.0036%	0.0115
Texas/LA 2	Blue Elbow North	0.0087%	0.0513
Jefferson County	Marshes county-wide	-0.0196%	0.00138
Orange County	Marshes county-wide	-0.0183%	0.217

The wetland loss rates were calculated separately for subdivisions of the Sabine Region study area called hydrounits. The hydrounits are subdivisions of the Sabine and Neches River floodplains that are distinguishable by topography and hydrology from surrounding areas. They were developed for WVA modeling of impacts of the proposed deepening of the Sabine-Neches Waterway (SNWW) (USACE 2011). Inasmuch as they cover the same geographic area affected by this study, the same units were adopted for this WVA modeling effort. The hydrologic areas included in the wetland change mapping for this study are shown in Figure 5-1.

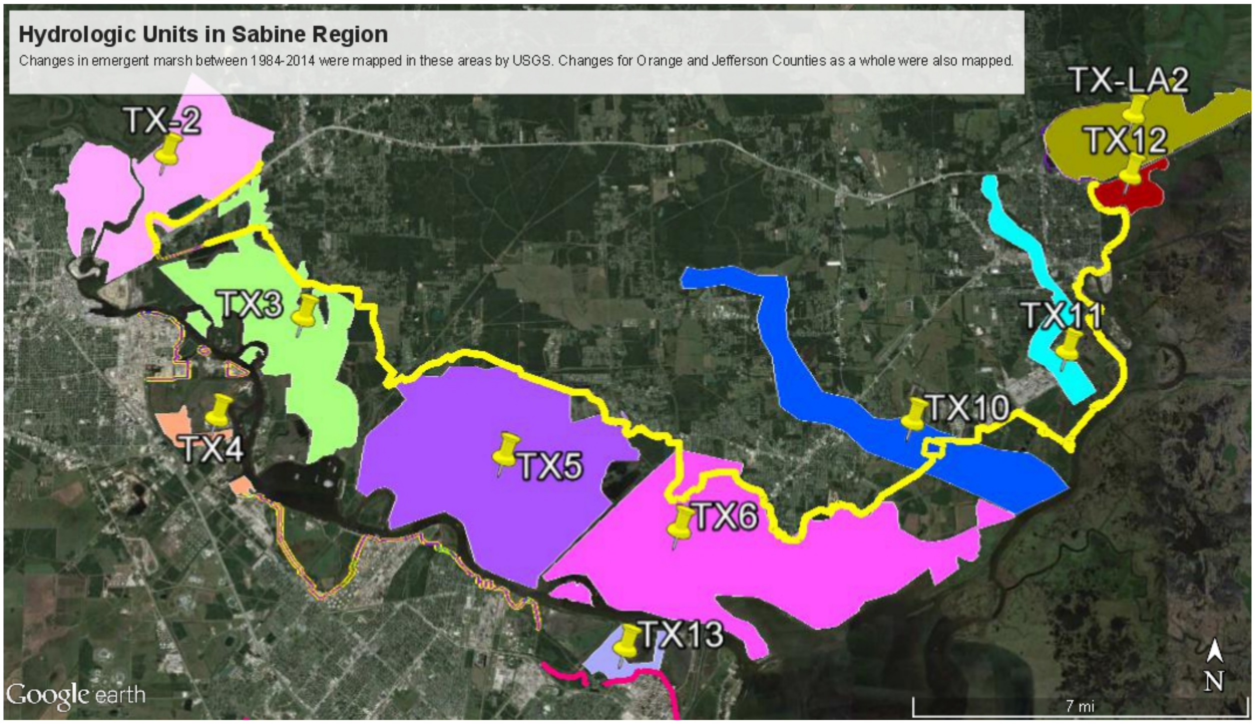

Figure 5-1. Hydrologic Units in Sabine Region

5.3 WETLAND VEGETATION MAPPING

Marsh vegetation and water acreages are based on a USGS classification using 2010 imagery (USGS 2014a). Forested wetland acreages are based on the 1992 National Wetland Inventory classification that were updated within impact areas by referencing 2015 Google Earth imagery. As impacts are not projected to start until the year 2020, the relative percentage of emergent marsh and water acreage in each subunit were updated to reflect changes in emergent marsh acreage occurring between 2010 and 2020 due to the baseline emergent marsh loss rate. Wetland vegetation maps of the Recommended Plan alignment are shown in Figures 5-2 through 5-13. Color numbers in the maps legends indicate 1) fresh marsh, 2) intermediate marsh, 3) brackish marsh; 4) saline marsh, 5) water, 6) other (non-wetland), 7) bottomland hardwood and 8) cypress tupelo swamp. Marsh and forested wetland acreages within the Recommended Plan alignment right-of-ways were aggregated by wetland type within each hydrounit. Water acreages within the ROW were tracked separately associated with adjacent marsh areas or forested wetland areas.

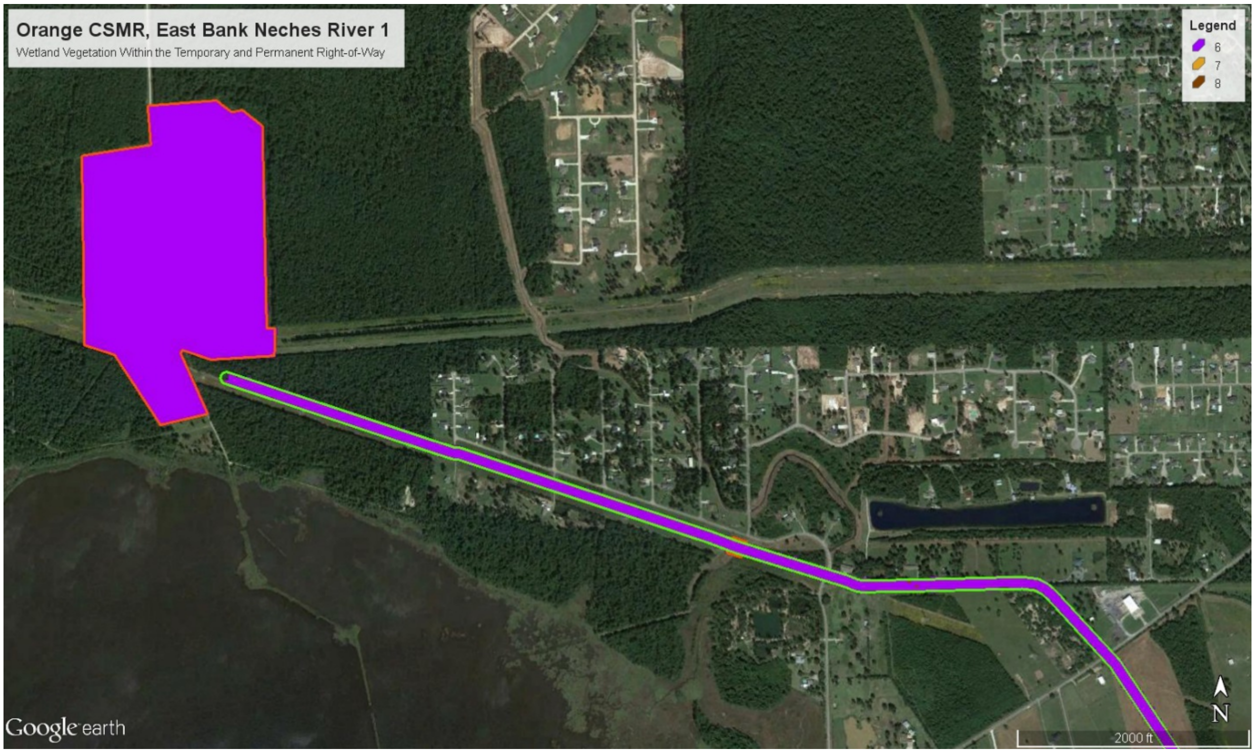

Figure 5-2. East Bank Neches River 1

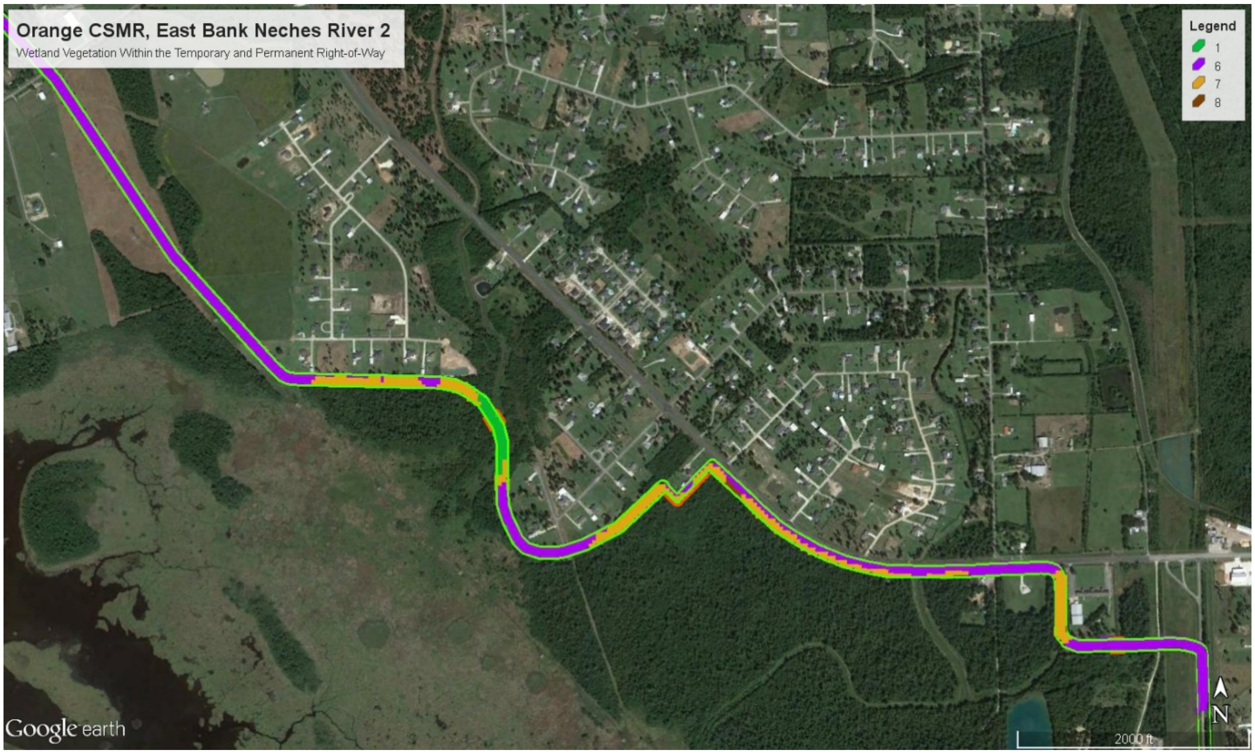

Figure 5-3. East Bank Neches River 2

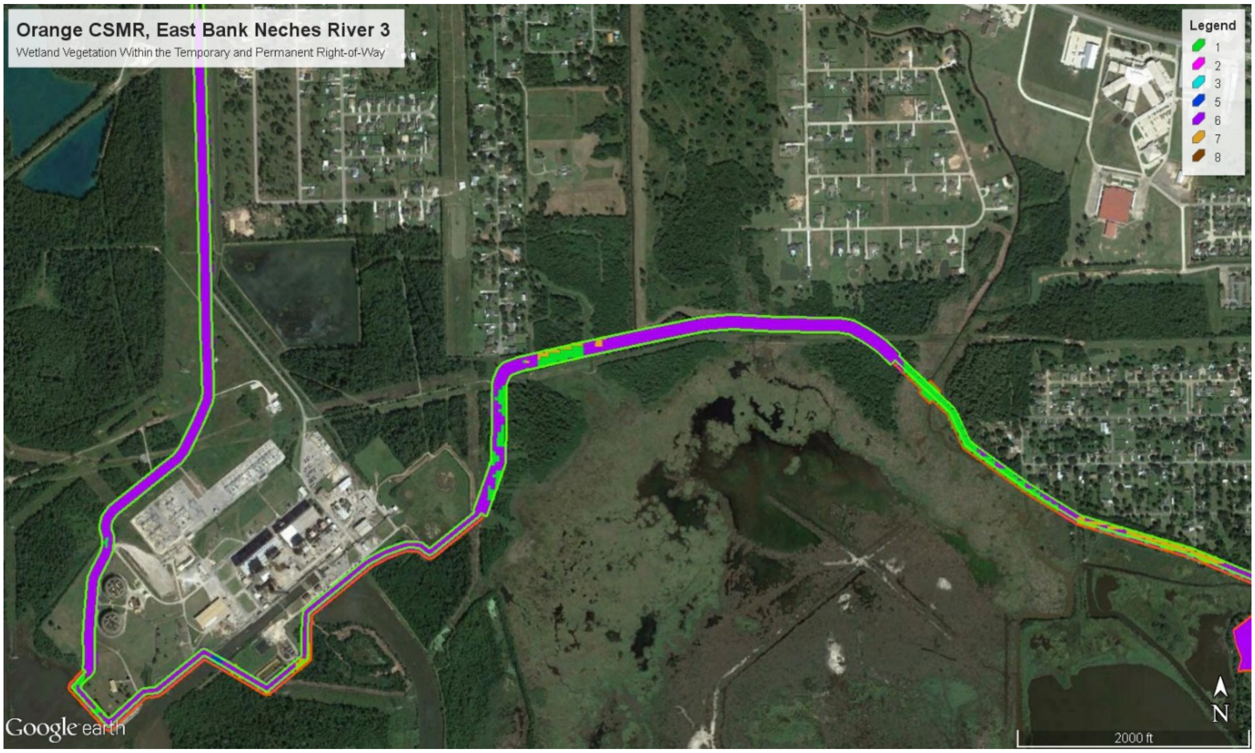

Figure 5-4. East Bank Neches River 3

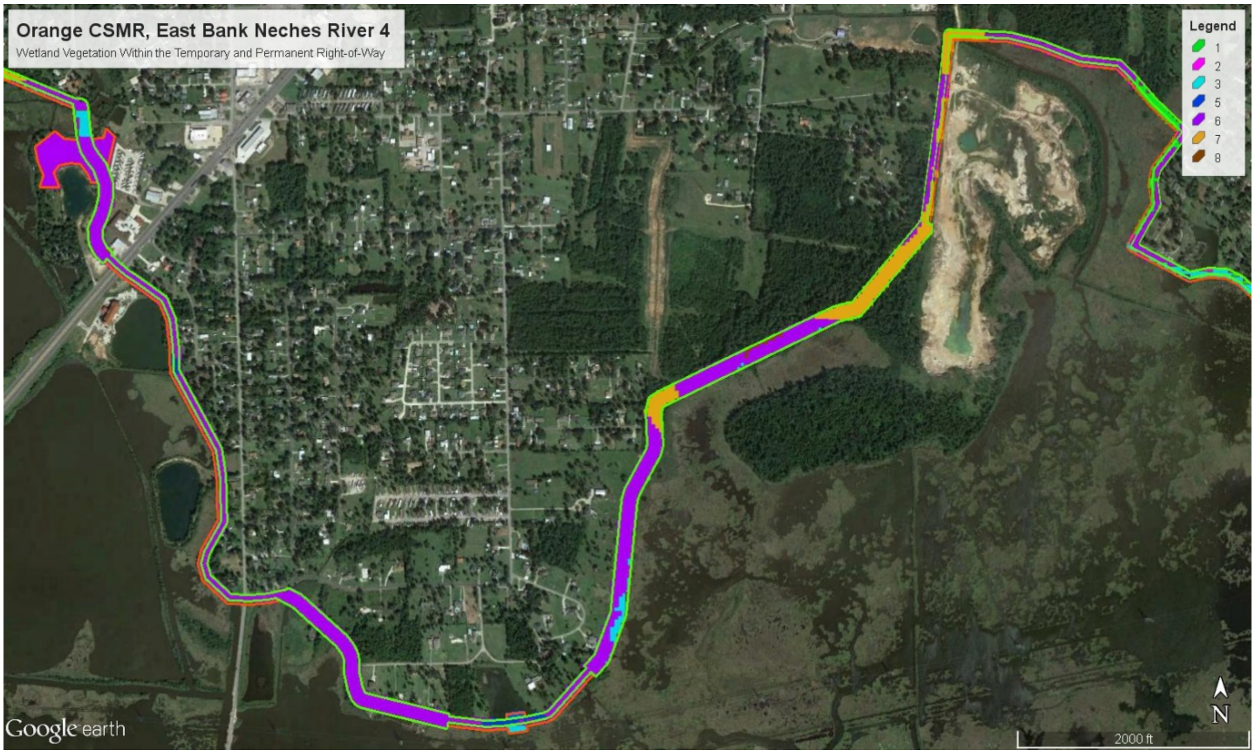

Figure 5-5. East Bank Neches River 4

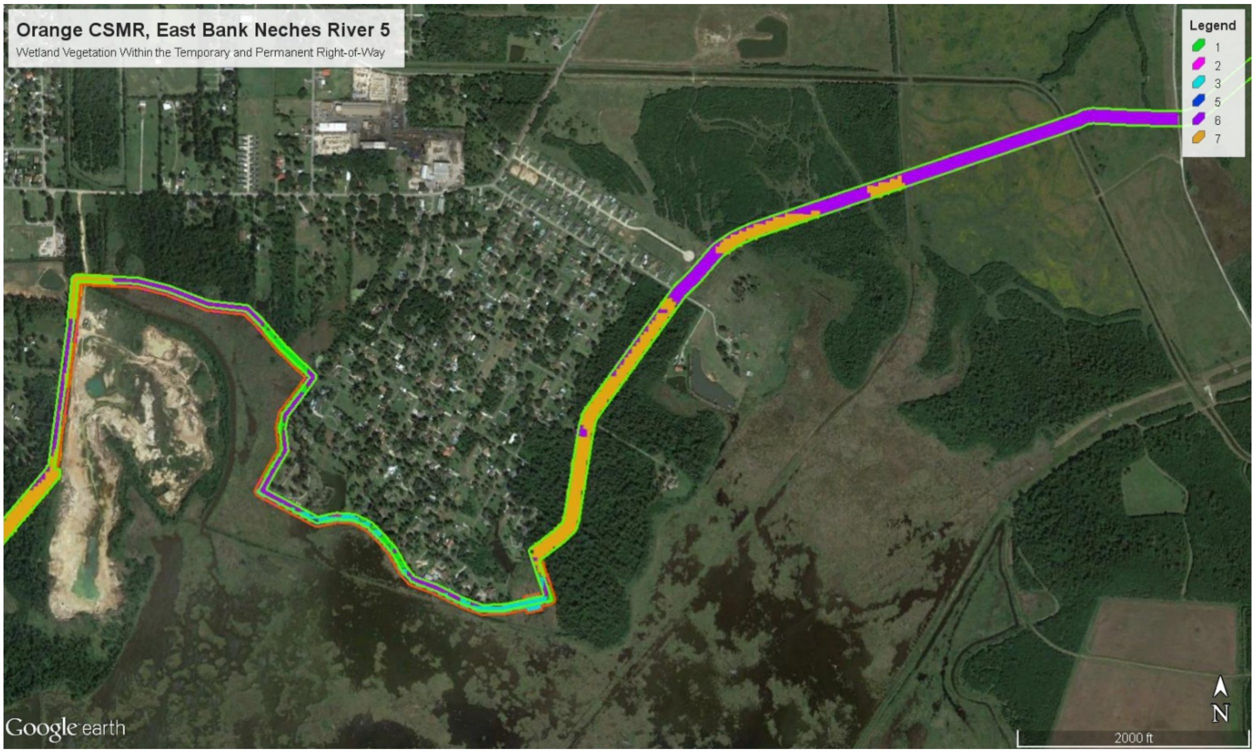

Figure 5-6. East Bank Neches River 5

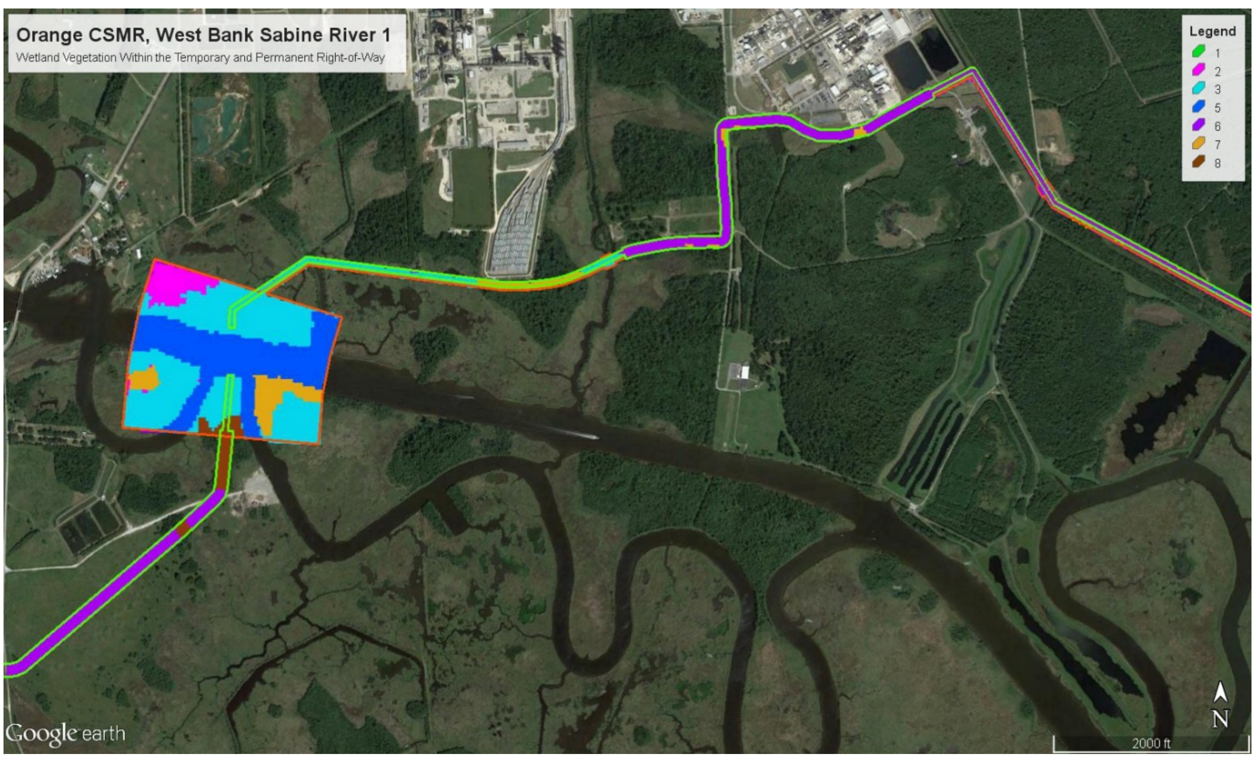

Figure 5-7. East Bank Neches River 1

Figure 5-8. East Bank Neches River 2

Figure 5-9. East Bank Neches River 3

Figure 5-10. East Bank Neches River 4

Figure 5-11. East Bank Neches River 5

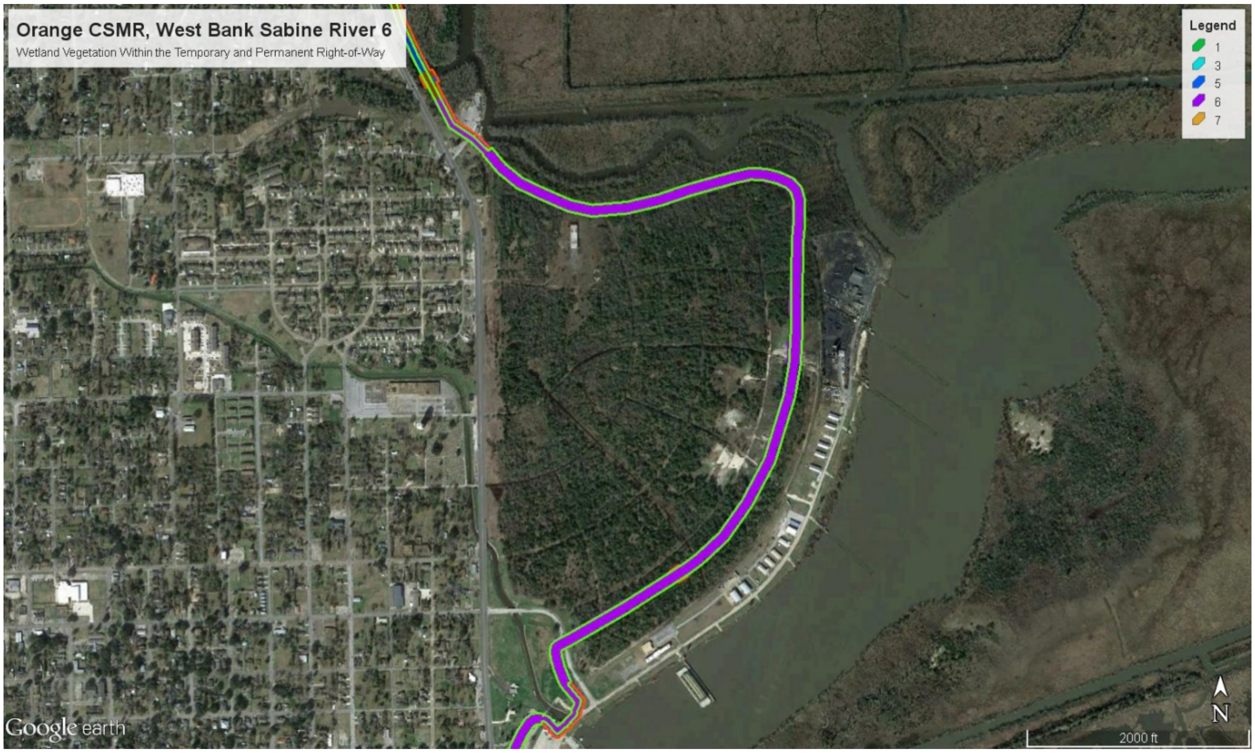

Figure 5-12. East Bank Neches River 6

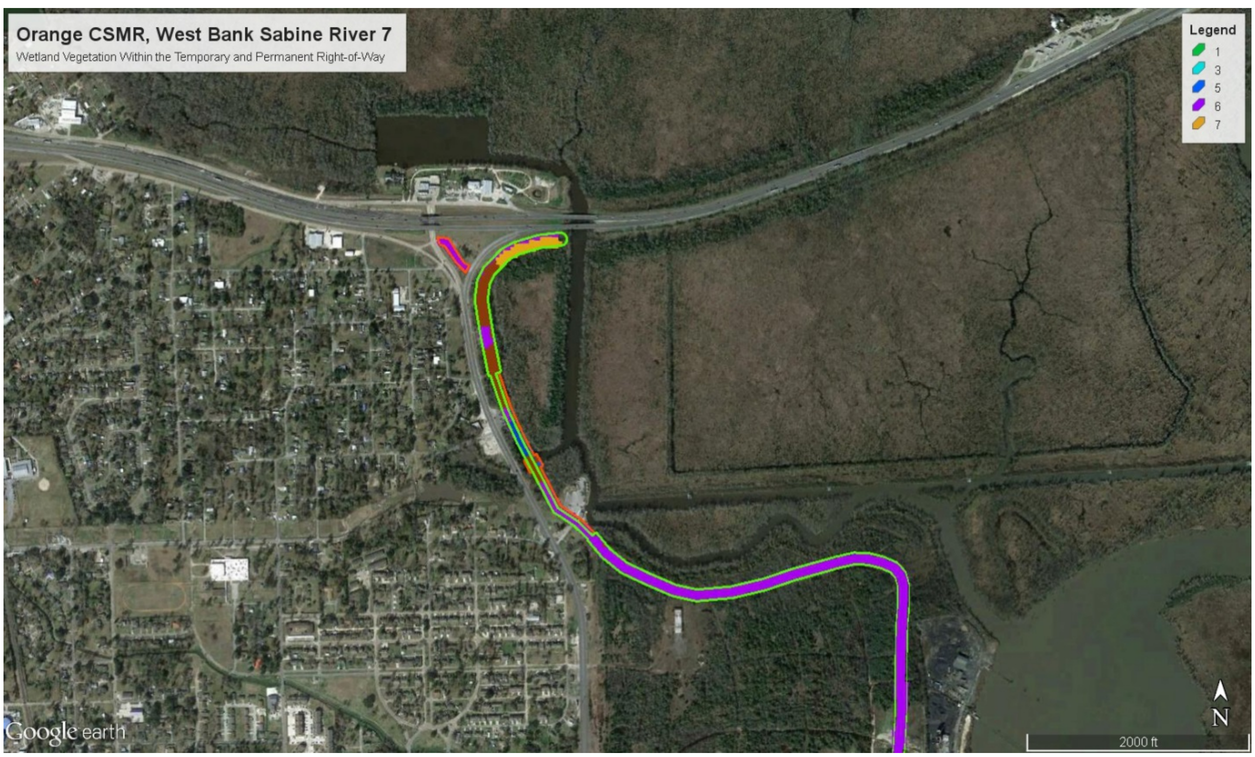

Figure 5-13. East Bank Neches River 7

5.4 DATA COLLECTION/GROUNDTRUTHING

Groundtruthing of wetland types and collection of data from WVA variable inputs were based upon field investigations and previous observations of the S2G study area by the Habitat Workgroup of the Interagency Coordination Team for the Sabine-Neches Waterway (SNWW) Channel Improvement Project (USACE, 2011). In addition, these observations were updated with current observations of the resource agency review team for this study, and field trips conducted in 2015 and 2016 specifically for this study. Data were collected from a total of 17 bottomland hardwood and swamp reference sites on the Neches and Sabine Rivers in August and October, 2014, January, 2015, and February, 2016. The forested wetland reference sites are in areas affected by this study, and conditions have not changed sufficiently to make comparison to these areas invalid.

6 FWP ANALYSIS OF DIRECT IMPACTS

Direct impacts are those that would result from construction of the Recommended Plan's new levee system alignments in Orange and Jefferson counties. All WVA impacts modeling was redone for the Recommended Plan, using the same procedures and assumptions that were applied for the TSP. For alignment segments that were the same as the TSP alignment, the same variable inputs developed by the resource agency team for the DIFR-EIS analysis were applied to the Recommend Plan alignment. In areas where the alignment diverged from that presented in the DIFR-EIS, variable input was developed following the same basic premises. The RSLC procedures and assumptions for the WVA modeling of direct impacts to emergent marsh, cypress-tupelo swamp, and bottomland hardwoods are presented below, followed at the end of this section with a summary of the direct impacts of the Recommended Plan. The specific areas of divergence between the TSP and Recommended Plan alignments are also mapped and described in this last section.

6.1 RSLC MARSH MODELING – PROCEDURES AND ASSUMPTIONS

Since the marsh vegetation and water acreages are based on a classification conducted using 2010 imagery (USGS 2014), and impacts are not projected to start until the year 2020, the relative percentages of emergent marsh and water acreage in each subunit were updated to reflect changes projected to occur between 2010 and 2020 due to the baseline land loss rate. A Microsoft Excel spreadsheet was used to calculate this change, and to track changes in wetland/water acres associated with the USGS wetland change rates over the period of analysis. Impacts were developed utilizing the intermediate RSLC rate for the FWOP and FWP conditions.

6.1.1 V1 Emergent Marsh

Persistent emergent vegetation provides foraging, resting, and breeding habitat for a variety of coastal fish and wildlife species. Detritus from coastal marshes also provides a source of mineral and organic nourishment for organisms at the base of the food chain. In this model, an area that is 100 percent shallow water is assumed to have minimal habitat suitability (SI = 0.1). For all marsh types, optimal vegetative coverage is assumed to be 100 percent (SI = 1.0) because the loss of emergent coastal marsh is a serious existing condition in the study area, and it is assumed that this loss will continue due to RSLC. This assumption diverges from the general biological understanding that optimum cover falls in the 60 to 80 percent range. The HQUSACE single-use approval of the WVA marsh model for this study requires the use of Version 1.0 for plan formulation, and the preparation of a sensitivity analysis that is described in Section 1.0 and presented in Appendix P. The results of the sensitivity analysis will be used by the ECO-PCX in decisions regarding assumptions related to variables 1, 2 and 3 of the WVA Coastal Marsh Model only and its application to future studies.

Existing Condition. Baseline total marsh and water acres of each affected wetland area are based on the acreages provided in Attachment 3, adjusted using the baseline emergent marsh loss rate to reflect marsh and water acres in 2019 (TY0). As uncertainty associated with the baseline marsh/water acres is very low, a narrow range for the baseline percent emergent marsh was assumed; typically one percent higher and lower than the mapped acreage.

FWOP. The baseline acreage at TY0 will be reduced each year of the period of analysis by the USGS (2014b) percent loss per year for the specific hydrounit, using the landloss spreadsheet. It is assumed that the emergent marsh that is lost is converted to water, and therefore, the acres lost from the marsh are added to the water acres. The baseline rate of emergent marsh loss includes chronic, regional effects of subsidence, altered sediment delivery, historical rates of sea level rise, and tropical storms or hurricanes that occurred during the period of observation. The effects of the intermediate rate of RSLC on marsh loss were included in the FWOP condition by adding the additional RSLC-related wetland loss to the baseline loss rate (see Table 4-2). The uncertainty of the estimation of the percent of emergent marsh coverage at the beginning of the period of analysis is low because it is based on a recent GIS classification. Therefore, a narrow range (one percent higher and lower than the mapped acreage) was assumed. The uncertainty of projections of emergent marsh percentage for TY61 are higher given greater uncertainties associated with average temperatures, precipitation, freshwater inflows and RSLC. Therefore, for TY 61, a total range of 20 percent was assumed.

FWP. It is assumed that construction impacts will begin in TY1, and that all wetlands within the construction right-of-way will be removed and replaced by levees, floodwalls, pump stations, staging areas or other project features. Wetland and water acres would fall to zero at TY1 and remain unchanged through TY61. There is no uncertainty associated with the projection of zero percent wetland coverage in TY61, and therefore a range of zero to 0.1 percent was assumed.

6.1.2 V2 Percent Submerged Aquatic Vegetation

For the purpose of this model, SAV is defined as any of the diverse array of floating-leaved and submerged aquatic plants that are typically found in the study area. Seagrasses, included in the SAV designation, are flowering plants that grow entirely underwater. SAV coverage is included as an important marsh variable because it provides important food and cover to a wide variety of fish and wildlife (Virnstein, 1987; Thomas et al., 1990; Castellanos and Rozas, 2001; Raz-Guzman and Huidobro, 2002; Wyda et al., 2002; Lazzari and Stone, 2006). SAV provides a refuge from predation, and because of this protection, densities of many invertebrates (infaunal and epifaunal) and small fishes are greater in SAV than in nearby unvegetated areas. SAV (including seagrasses) provide additional benefits by stabilizing sediments and filtering water. SAV (including seagrasses) tolerate or require a wide range of salinities.

The species composition and primary productivity of SAV communities corresponds to the salinity regime (Haller et al., 1974; Longstreth et al., 1984; Dunton, 1990; Bonis et al., 1993; Bortone, 2002; La Peyre and Rowe, 2003; Singh and Arora, 2003; Paresh and Freedman, 2006). Fresh and intermediate marshes, in particular, often support diverse communities of submerged and floating-leaved vegetation. Open water with no aquatics within a fresh or intermediate marsh is assumed to have low suitability (SI = 0.1). Optimal conditions are assumed when 100 percent of the open water is dominated by aquatic vegetation (SI = 1.0). Brackish marshes can also support aquatic plants that provide food and cover for several species of fish and wildlife. Although amounts are generally less than that which occurs in fresh or intermediate marshes, certain species such as widgeon-grass, coontail, and milfoil, can be abundant under some conditions, and widgeon grass, in particular, is an important food source for waterfowl. The SI graph for brackish marsh is identical to the fresh/intermediate model.

Existing Condition. Baseline values for this variable were based largely upon previous observations in the area by SNWW Habitat Workgroup members, the current review team's knowledge of SAV types and prevalence in the general area and examination of Google Earth's 2015 and earlier historic images. Since SAV cover and species can change rapidly in response to a complex interaction of environmental conditions, even TY0 values are fairly uncertain. Therefore, a total range of 10 percent was assumed for TY0.

FWOP. No change in percentage SAV cover was assumed through TY61. While the intermediate rate of RSLC would result in slightly higher salinities and a slightly larger tidal prism, it was assumed that salinity and water depth changes would not be great enough to result in a change in SAV coverage in TY1 through TY61. However, greater uncertainty associated with climate change and RSLC exists for the later years of the period of analysis, and therefore, a larger total range of 20 percent was assumed for TY61.

FWP. All water areas would be converted to levees, floodwalls or other project features in TY1 and remain unchanged through TY61. There is no uncertainty associated with the projection of zero percent wetland coverage in TY61, and therefore a range of zero to 0.1 percent was assumed.

6.1.3 V3 Interspersion

This variable takes into account the relative amount of marsh to open water, and the degree to which open water is dispersed throughout the marsh. Interspersion is an important characteristic for freshwater and estuarine fish and shellfish nursery and foraging habitat in all marsh types (Rakocinski et al., 1992; Baltz et al., 1993, 1998; Rozas and Reed, 1993; Minello et al., 1994; Peterson and Turner, 1994; Rozas and Zimmerman, 2000; Minello and Rozas, 2002; Whaley and Minello, 2002; Rozas and Minello, 2007). The marsh/open-water edge provides cover for postlarval and juvenile organisms. Smaller, isolated ponds are less turbid and contain more aquatic vegetation, thereby providing more suitable waterfowl habitat. Conversely, a large degree of interspersion is assumed indicative of marsh degradation, as solid marsh converts to ever-larger areas of open water. Areas with a high degree on interspersion in the form of tidal channels and small ponds, Class 1 interspersion was assigned (SI = 1.0). Large ponds (Class 3) and open water areas with little surrounding marsh (Class 4) offer lower interspersion values and indicate advanced stages of marsh loss. Class 3 was also assigned to areas of "carpet" marsh which contain no or relatively insignificant tidal channels, creeks, or ponds but still provide aquatic organism habitat during tidal flooding. If the entire area is open water or contains a few small marsh islands, Class 5 interspersion was assigned (SI = 0.1).

Existing Condition. The degree of marsh/waterbody interspersion was assessed for each wetland group within the construction right-of-way using Google Earth 2015 imagery at the same scale as the photographs of class examples shown in the WVA marsh model (V1.1). Each wetland group was carefully examined and assigned interspersion classes by comparing them to the photographic examples. In some cases, the wetland groups contain wetlands of more than one interspersion class. The percentage of acreage exhibiting each class was entered in the spreadsheet, such that all added up to 100 percent.

FWOP. No change in interspersion was assumed for TY1. The greater the percentage loss of emergent wetland tracked with V1 was assumed to relate to changes in interspersion by TY61. Changes greater or equal to 1 percent were reflected in similar changes in interspersion classes.

FWP. All marsh and water areas within the construction right-of-way would be converted to levees, floodwalls or other project features in TY1 and remain unchanged through TY61. Therefore, all were assumed to convert to the class associated with conversion to a non-marsh area (Class 5). There are no uncertainty ranges required for this variable in the sensitivity spreadsheet.

V4 Percent Open Water ≤ 1.5 Feet

Deeper water is assumed to be less biologically productive than shallow water because sunlight, oxygen, and temperature are reduced as depth increases. Shallow water also provides better bottom access for waterfowl, better foraging habitat for wading birds, and more-favorable conditions for the growth of aquatic vegetation. Certain species typically use shallow water for spawning, feeding, and/or shelter during various life stages (e.g., white/brown shrimp, Gulf flounder, red drum, roseate spoonbill, and mottled duck). SIs for shallow water are calculated differently for fresh/intermediate, brackish and saline marshes. Optimal shallow-water conditions in fresh/intermediate marsh are assumed when 80 to 90 percent of the open water is equal to or less than 1.5 feet deep. It is assumed that brackish marshes generally contain deeper open-water areas because of tidal scouring, and therefore lower percentages of shallow water receive a higher SI than in fresh/intermediate marsh.

Existing Condition. Baseline values for this variable were based largely upon previous observations in the area by SNWW Habitat Workgroup members, the current review team's knowledge of the area and examination of Google Earth imagery (2015 and earlier historic images). As uncertainty associated with the baseline V4 acres is low, a fairly narrow range for the baseline percent emergent marsh was assumed; typically a 10 percent range.

FWOP. No change in V4 was assumed for TY1. RSLC of about 2.3 feet by TY61 is assumed to increase the depth of current shallow water, and to inundate new areas, resulting in no net change from existing conditions. The uncertainty range for TY61 would be higher, associated primarily with uncertainties in the intermediate RSLC rate. Uncertainties related to three evaluated rates of RSLC were evaluated under separate WVA model runs for those scenarios. The total range of the percentage of open water at the beginning of the period of analysis was assumed to be 10 percent.

FWP. All shallow water areas would be converted to levees, floodwalls or other project features at TY1 and remain unchanged through TY61. There is no uncertainty associated with the projection of zero percent wetland and wetland coverage in TY61, and therefore a range of zero to 0.1 percent was assumed.

V5 Salinity

This variable may appear to duplicate or overlap with V1 (emergent marsh cover) because the functionality and potential land loss of the marsh vegetation are related to salinity. However, this variable was included as a separate variable in order to account for salinity impacts on fish and wildlife as well as on vegetation.

Salinity is one of the most important factors affecting coastal marsh loss. Salinity projections affect all of the other WVA variables with the exception of aquatic organism access. Small increases in mean salinity can adversely affect aquatic systems by reducing overall biological productivity. An extensive literature review (Visser et al., 2004) compiled information on the effect of salinity on the productivity of emergent tidal marsh. Productivity algorithms, based upon measurements of total biomass, stem/leaf elongation, and photosynthesis, were developed that predict changes in primary productivity for every part per thousand (ppt) change in salinity. Salinity and primary productivity were found to be inversely related, as salinity increases, primary productivity decreases by different amounts dependent upon the salinity tolerance of the vegetation community.

For fresh/intermediate marshes, the mean high salinity (calculated as a roaming mean of the highest 33 percent consecutive salinity readings) during the growing season is used to assess impacts. For brackish and saline marshes, average annual salinity is recommended. Optimum salinity ranges assumed by the WVA model for the various habitat types are as follows: swamp and bottomland hardwood (≤1 ppt), fresh marsh (≤2 ppt), intermediate marsh (≤4 ppt), brackish marsh (≤10 ppt), and saline marsh (≥9 and ≤ 1 ppt). For V5, salinity changes within the optimal salinity ranges of each marsh type are not considered an impact, and are assigned a maximum suitability index score of "1." But even a small salinity change outside of these optimal ranges, as shown in the formulas for the salinity variable, reduces the suitability index scores below "1."

Existing Condition. Baseline salinities for the wetland areas in the construction right-of-way were taken from baseline salinities reported by the 3-D hydrodynamic-salinity model for the SNWW navigation project (USACE 2009) and from Texas Parks and Wildlife data. Mean salinities associated with median flows during the growing season were used for all marsh types, and were taken from the SNWW 48-foot deepening FWP runs. Model values were obtained from the nearest model output node, and in some cases, salinity values were adjusted for the salinity gradient observed on isohaline maps for swamps located upstream of the nearest node. The uncertainty range of the salinity projection was based on the standard deviation of the average of the surface and mid-depth salinity values at the nearest station at which salinity data was collected for validation of the HS model.

FWOP. It was assumed that salinity will also change with RSLC, based on the SNWW modeling which estimated 1.1 feet of RSLC by year 2069, which is very close to the 0.93 foot of RSLC now projected for S2G by year 2080. In general, the model predicted an increase of between 1.0 and 1.5 ppt in the Neches River near Bessie Heights and Old River, and on the lower Sabine River in the vicinity of Cow and Adams Bayous.

FWP. All water areas would be converted to levees, floodwalls or other project features at TY1 and remain unchanged through TY61. Using a value of zero for the salinity variable is not appropriate, since it would be interpreted by the model as an optimal condition for all marsh types, and inappropriately increase the quality of the FWP habitat units. Therefore, the salinity value utilized for TY1 through TY61 was the same as FWOP. There are no uncertainty ranges required for this variable in the sensitivity spreadsheet.

6.1.4 V6 Aquatic Organism Access

Access by estuarine-dependent fishes and shellfishes, as well as other aquatic organisms, is important in assessing the quality of marsh systems. It is assumed that a high degree of surface hydrologic connectivity with adjacent systems provides high organism access, as well as providing greater nutrient exchange. The SI is calculated by determining an Access Value that is based on an interaction between the wetland area accessible to aquatic organisms during normal tidal fluctuations and the type of man-made structures (if any) blocking access channels (USFWS, 2002c: Appendix B). Access ratings for specific structures, developed by the Louisiana EnvWG, were adopted for the SNWW application. The installation and operation of water control structures has been shown to significantly impact marine fishery access to, use of, and production on wetlands behind those structures (Rogers and Herke, 1985; Herke et al., 1992; Rogers et al., 1992; Sanzone and McElroy, 1998); therefore, optimal conditions are assumed when the entire wetland area is accessible and access points are unobstructed. Brackish and saline marshes are assumed to be more important than fresh/intermediate marshes as habitat for estuarine-dependent fish and shellfish.

Existing Condition. Baseline values for this variable were based largely upon previous observations in the area by SNWW Habitat Workgroup members, the current review team's knowledge of the area and examination of Google Earth imagery (2015 and earlier historic images). Fisheries access is not blocked to any of the marshes in the construction right-of-way and therefore all were assigned a value of "1".

FWOP. The review group has no knowledge of planned water control structures, impoundments, or other impediments to fisheries access through the period of analysis. No changes to the fisheries access value is projected TY1 though TY61; all were assigned a value of "1".

FWP. All water areas would be converted to levees, floodwalls or other project features at TY1 and remain unchanged through TY61. This would result in the complete blockage of access to the area within the construction right-of-way. Therefore, a value of "0" was applied for TY1 through TY61. There are no uncertainty ranges required for this variable in the sensitivity spreadsheet.

6.2 SWAMP MODELING – PROCEDURES AND ASSUMPTIONS

6.2.1 V1 Stand Structure

Wildlife foods in swamp habitats consist predominantly of soft mast, other edible seeds, invertebrates, and vegetation. Since most swamp tree species produce soft mast or edible seeds, the actual tree species composition is not considered a limiting factor. However, a variety of stand structure should be present to provide appropriate habitat for resting, foraging, breeding, nesting, and nursery activities. Three structures are evaluated: (1) overstory closure, (2) scrub-shrub midstory cover, and (3) herbaceous cover. The variable assigns the lowest suitability to sites with a limited amount of all three stand structures, and the highest suitability to sites with significant amounts of all three stand structures.

Existing Condition. WVA input data for percentage overstory, midstory, and understory cover in swamp areas that would be directly impacted by construction were estimated using data from the most similar reference sites. These sites were selected based upon knowledge of the study area and close examination of Google Earth imagery. As reference sites were used as the basis for input data, uncertainty in the accuracy of the input is reflected in a 10 percent range for overstory, midstory and understory coverage estimates.

FWOP. Predicted changes in percentage overstory, midstory, and understory cover were based on the existing overstory closure; higher overstory growth rates were assumed for moderately open areas and slower growth rates for moderately dense swamp areas. With steady maturation, an increase in percentage overstory coverage was generally associated with a decrease in percentage of understory coverage. Generally, no changes in midstory coverage were predicted, as it was assumed that trees growing into the overstory would be replaced by trees growing from the understory. Steady maturation was projected for all hydro-units, as changes related to historic rates of sea-level rise and changes in salinity would not be large enough to affect growth rates substantially. Greater uncertainty exists for TY61 projections, primarily related to changes in rainfall and RSLC; therefore, a 30 percent range was applied around overstory and midstory coverages, and a 20 percent range around understory.

FWP. A 10-year construction period is assumed, beginning TY1. No specifics are available at this time regarding construction contracts or timing. Therefore, all impacts are assumed to occur in TY1. It is assumed that all swamps within the construction right-of-way will be removed and replaced by levees, floodwalls or other project features through the period of analysis. There is little uncertainty associated with this projection, so a conservatively small range of zero to 0.1 was used for all percentage cover input.

6.2.2 V 2 Stand Maturity

Swamps with mature sizable trees are considered to be rare and ecologically important because of the historical loss of swamp habitat from timber harvesting, saltwater intrusion, and a reduced growth rate in the subsiding coastal zone. Two components, stand age and stand density, are combined in the SI for this variable. Stand age is included because older trees provide important wildlife requisites such as snags, nesting cavities, and the medium for invertebrate production. Additionally, as the older, stronger trees establish themselves in the canopy, weaker trees die and form additional snags that would not be present in younger stands. Stand age is determined by average trunk diameter measured at breast height (DBH). The optimal size for canopy-dominant and canopy co-dominant bald cypress is greater than 16 inches, and greater than 12 inches for tupelo-gum and other species. Stand density allows evaluation of mature swamp ecosystems that contain an overstory of a few widely scattered, mature bald cypresses but in which other stand characteristics important for nesting, foraging, and other habitat functions are absent. Basal area is used as a measure of stand density; it measures how much of the forest floor is covered by the area of standing tree trunks. Stand age and density are evaluated separately for cypress and tupelo-gum.

Existing Condition. Baseline values for the relative percentage of the canopy provided by baldcypress and tupelo, the average DBH of each of these species, and estimates of abundance of each species based on average basal area per acre were estimated using data from the most similar reference sites. These sites were selected based upon knowledge of the study area and close examination of Google Earth imagery. As reference sites were used as the basis for input data, uncertainty in the accuracy of the input is reflected in a 10 percent range around canopy coverage estimates and a 2-3 inches^2 range was used around the DHB estimates. Since basal area inputs were estimated based upon an association with percentage overstory cover (i.e., a moderate DBH range would be associated with a moderate overstory coverage), the full range of DBH for each density class as defined in the model was used as the low and high range for DBH values. For example, a swamp site with a moderately open overstory coverage was estimated to have a DBH range from 40 feet^2 to 80 feet^2.

FWOP. Rates of tree growth were based on data for relevant species from the USDA Silvics of North America (USDA, 2004), and other forest research literature (Brown and Montz, 1986) that generally reflect optimum growth conditions on managed lands. This is appropriate because swamps in the study area are generally not impounded and in relatively good condition. Steady growth throughout the period of analysis was assumed. For TY1, a 10 percent range around canopy coverage estimates and a 2-3 inches^2 range was used to bracket the DHB estimates. For TY61, a larger range was used to capture the uncertainties associated with climate change and

RSLC. For the percentage of cypress and tupelo canopy coverage, a 20 percent range was assumed. For DBH growth projections, a range of 10 $inch^2$ was utilized. Annual basal area growth rates were estimated for cypress and tupelo using information from the US Forest Service Silvics Manual (USDA, 2004).

FWP. It is assumed that all swamps within the construction right-of-way will be removed and replaced by levees, floodwalls or other project features through the period of analysis. There is little uncertainty associated with this projection, so a conservatively small range of zero to 0.1 was used for all percentage canopy cover by species and for DBH. For basal area, the range for TY1 through TY61 was entered as 5.0 to 5.1, based on ERDC instructions that the sensitivity spreadsheet being used for this modeling will not accept a value less than 5.

6.2.3 Water Regime

Seasonal flooding with periodic drying cycles increases nutrient cycling, vertical structure complexity, and recruitment of dominant overstory trees. The optimal water regime is assumed to be seasonal flooding with abundant and consistent riverine/tidal input and water flow-through. Optimal flow-through is assumed to be an abundant and consistent input, allowing maximum use as fish and wildlife habitat. Temporary or seasonal flooding is optimal because permanent flooding produces poor water quality during warm weather and reduces fish and invertebrate production.

Existing Condition. Baseline values for flooding duration and exchange were based on the review group's knowledge of the swamp impact areas and on careful review of Google Earth imagery.

FWOP. The FWOP values consider the effects of gradual RSLC on water surface elevation and tidal circulation. The increase in water surface elevation was forecast by the HS model, which in addition to RSLC, also incorporated forecasted changes in freshwater inflow. The effects of higher FWOP water surface elevations on hydrologic conditions were estimated by comparing FWOP water surface elevations over the period of analysis to existing land elevations within the swamp areas. The 2.3- feet increase in water surface elevation projected with intermediate RSLC was added to existing average and extreme water surface elevations, and compared to the land surface elevations taken from recent LIDAR survey data (CADGIS, 2009; NOAA Coastal Service Center, 2009). While some of the lower-lying areas could see a marginal increase in the depth and duration of tidal flooding by the end of the period of analysis, the gradual change in water surface elevation due to RSLC would not permanently inundate swamp substrate throughout the year, and therefore no change in flooding duration and exchange classes were forecast through TY61.

FWP. At TY1, it is assumed that all swamps within the construction right-of-way would be removed and replaced by levees, floodwalls or other project features through the period of analysis. Existing water regimes would be permanently disrupted. In order to capture the effect on water regime, the FWP assumed a change to classes with the lowest SI values for TY1 through TY61 (permanently flooded with no flows/exchange).

6.2.4 Mean High Salinity

Many swamp species, especially tupelo-gum and many herbaceous species, are salinity sensitive (Conner et al., 1997; Pezeshki et al., 1989). Swamp systems may be acutely affected by the sudden addition of only a few parts per thousand of salt during an intrusion event (Reid and Wood, 1976). Primary biological productivity is lowered 8.4 percent for each 1 ppt increase in salinity, slowing growth rates for dominant overstory species such as tupelo-gum (and, to a lesser degree, bald cypress since it is more salt tolerant), reducing the overstory coverage, and reducing the percentage cover and variety of fresh, herbaceous understory vegetation. These changes would result in lower wildlife values for forage, cover, and reproduction (Palmisano, 1972).

Bald cypress is able to tolerate higher salinities than the other species. Optimal conditions are assumed to occur at salinities less than 1 ppt, and habitat suitability is assumed to decrease rapidly as mean high salinities exceed that mark. Mean high salinity during the growing season (March 1 through October 31) is defined as the average of the highest 33 percent consecutive salinity readings.

Existing Condition. Baseline salinity values were based upon SNWW HS model (USACE 2009) output or empirical data provided by resource agencies, if available. The HS model salinities are the mean of the highest consecutive 33 percent of values, median flow scenario during the growing season, with the SNWW 48-foot deepening in place. Model values were obtained from the nearest model output node, and in some cases, salinity values were adjusted for the salinity gradient observed on isohaline maps for swamps located upstream of the nearest node. The uncertainty range of the salinity projection was based on the standard deviation of the average of the surface and mid-depth salinity values at the nearest station at which salinity data was collected for validation of the HS model. Inasmuch as prevailing salinities in the swamp areas are generally fresh, the uncertainty range for the existing condition was zero to zero.

FWOP. FWP salinities values were obtained from the authorized SNWW 48-foot channel deepening model runs. FWP TY1 salinities were expected to be the same as TY0 salinities because the deepening of the inland portions of the SNWW channels would not be expected to occur by 2020 (TY1). The HS model incorporates the most likely effects of RSLC and future freshwater inflows for the period of analysis. On average, the uncertainty range for was very small, with the low being zero and the high range less than or equal to 1.2 ppt for most areas. However, swamps on the Sabine River near Interstate 10 are an exception. The high range for salinity at TY61 was 2.3 ppt in these areas because of salinities introduced by the 30-foot-deep Channel to Orange in the lower Sabine River, and higher salinity waters entering through the GIWW from the Calcasieu Ship Channel in Louisiana.

FWP. Destruction of swamps within the construction right-of-way would not affect salinities in the area generally. To avoid the model interpreting any change as a move toward optimal conditions, the FWP salinity range was equal to the FWOP salinity range for TY61.

6.3 BOTTOMLAND HARDWOOD MODELING – PROCEDURES AND ASSUMPTIONS

6.3.1 V1 Tree Species Association

Bottomland hardwood wildlife depends heavily on mast, other edible seeds, and tree buds as primary sources of food. The model assumes that more production of mast and other edible seeds is better than less, and that hard mast is more critical than soft mast because it is available during late fall and winter and has high energy content. Typical hard mast producers in the SNWW study area are oaks, pecan, and other hickories. Soft mast and other edible seeds are produced by red maple, sugarberry, green ash, boxelder, common persimmon, sweetgum, honeylocust, red mulberry, bald cypress, tupelo-gum, American elm, and cedar elm. Nonmast/inedible seed producers are eastern cottonwood, black willow, and American sycamore. The model defines five classes based upon the percentage of the overstory that contains mast-producing trees, and the percentage of hard mast producers in the canopy.

Existing Condition. WVA input data for the percentages of mast-producing trees and hard mast producers in the overstory were estimated using data from the most similar reference sites. The reference sites were selected based upon knowledge of the study area and close examination of Google Earth imagery.

FWOP. It was assumed that the bottomland hardwood sites would remain intact and mature at a steady rate. All bottomland hardwoods in the study area appear to have some hard mast producers in them and, therefore, there were no Class 1 sites. For Classes 2-4, it was assumed that the percentage of hard mast producers would steadily increase over the period of analysis, such that Class 2 sites become Class 3, and Class 4 sites become Class 5 by TY61. Class 5 sites were assumed to remain Class 5 through TY61, as changes in climate and RSLC are not expected to significantly affect the health and growth of these forested wetlands.

FWP. It was assumed that all bottomland hardwoods within the construction right-of-way would be removed and replaced by levees, floodwalls, or other project features through TY61. To best capture this effect, the classification was changed to Class 1 from TY1 through TY61, as it has the lowest SI value for this variable.

6.3.2 V2 Stand Maturity

Mature stands of bottomland hardwood are rare in the study area and ecologically important. Historical and ongoing timber harvesting has reduced the number of mature stands and increased the ecological importance of those that remain. These stands provide more hard and soft mast, other edible seeds, and buds than younger stands. They provide important wildlife requisites such as snags, nesting cavities, and medium for invertebrate production. Older, stronger trees in the canopy outcompete understory trees and stimulate the production of additional snags and downed treetops as younger trees die. The model allows for either the average age of stands, or the average DBH to be entered for this variable. As we do not have reliable data on age, DBH was utilized.

Existing Condition. WVA input data for the stand maturity, as reflected in DBH, were estimated using data from the most similar reference sites. The reference sites were selected based upon knowledge of the study area and close examination of Google Earth imagery. As reference sites were used as the basis for input data, uncertainty in the accuracy of the input is reflected in a 2-$inch^2$ range for smaller average sizes, and a 3-$inch^2$ range for larger average sizes.

FWOP. An average rate of growth was developed based on data for species prevalent in the study area from the USDA Silvics of North America (USDA, 2004). These growth rates generally reflect optimum growth conditions on managed lands. This is appropriate because bottomland hardwood stands in the study area are generally not impounded and in relatively good condition. Steady growth throughout the period of analysis was assumed. For TY61, a larger range was used to capture the uncertainties associated with climate change and RSLC. For DBH growth projections, a range of 10 $inch^2$ was utilized.

FWP. At TY1, it is assumed that all bottomland hardwoods within the construction right-of-way will be removed and replaced by levees, floodwalls or other project features through the period of analysis. Since there is little uncertainty in this projection, a range of zero to 0.1 was entered for TY1 through TY61.

6.3.3 V3 Understory/Midstory

Midstory and understory plants also provide important food sources for bottomland hardwood wildlife, and also are preferable habitat for breeding, nesting, and feeding activities. The percentage coverage of understory and midstory is the variable input. Highest SIs apply to a mid-range coverage. The optimal range for understory is between 30 and 60 percent, while for midstory, it is between 20 and 50 percent.

Existing Condition. WVA input data for understory/midstory percentage coverage were estimated using data from the most similar reference sites. The reference sites were selected based upon knowledge of the study area and close examination of Google Earth imagery. As reference sites were used as the basis for input data, uncertainty in the accuracy of the input is typically reflected in a 20 percent range for understory and midstory.

FWOP. Changes over the period of analysis are assumed to be associated with canopy growth. It was assumed that the steady growth of BH stands will result in greater closure of the canopy. As the canopy closes, it is assumed that the percentage midstory coverage would decrease by 27 percent and understory coverage would decrease by 33 percent by TY61.

FWP. At TY1, it is assumed that all bottomland hardwoods within the construction right-of-way will be removed and replaced by levees, floodwalls or other project features through the period of analysis. Since there is little uncertainty in this projection, a range of zero to 0.1 was entered for TY1 through TY61.

6.3.4 V4 Hydrology

The model assumes that the optimum hydrology for stands of bottomland hardwood is one that is essentially unaltered from natural conditions, allowing natural wetting and drying cycles that are beneficial to vegetation and associated fish and wildlife species. The variable utilizes two sets of classes to evaluate and compare flooding duration and flow/exchange. The highest SI value is applied to temporary flooding with high flow/exchange, and the lowest is permanent flooding or dewatering and no flow/exchange.

Existing Condition. WVA input data for flooding duration and flow/exchange were estimated using the review team's knowledge of the study area and elevation data for specific areas.

FWOP. The bottomland hardwoods are generally located in elevations high enough that they would not be affected by changes in water surface elevation associated with RSLC. Changes in precipitation and freshwater inflows could affect them, but the uncertainty associated with current predictions is very large. Therefore no change in flooding duration and exchange classes were forecast through TY61.

FWP. At TY1, it is assumed that all bottomland hardwoods within the construction right-of-way will be removed and replaced by levees, floodwalls or other project features through the period of analysis. In order to capture the effect on water regime, the FWP assumed a change to classes with the lowest SI values for TY1 through TY61 (permanently flooded with no flows/exchange).

6.3.5 V5 Size of Contiguous Forest Area

The model assumes that larger forested tracts are less common and offer higher-quality habitat than smaller tracts, and that species in greatest need of conservation are specialists in habitat use requiring large forested tracts. It is recognized that forest edge and diversity are important, but the model assumes that species that thrive in edge habitat are highly mobile and occur in substantial numbers because of the increase in forest fragmentation. Species found in “edge” habitat are generalists in habitat use but are capable of existing in larger tracts. For this model, tracts greater than 500 acres in size are considered optimal.

Existing Condition. For the direct impacts of the construction corridor, small parcels of bottomland hardwood have been aggregated into groups within hydrounits. For this reason, it was not appropriate to consider the total acreage of each group as the forest size. Since the construction right-of-way is a linear corridor that crosses forest areas, the size of the encompassing contiguous forest area was used to identify the class size for each bottomland hardwood group. The measurement was made using Google Earth.

FWOP. It was assumed that the size of the encompassing forested area would not change by TY61.

FWP. In order to capture the effect on contiguous forest size, the FWP assumed a change from TY 1 through TY61 to the class representing the size of smallest forest area left after bisection by the levee alignment.

6.3.6 V6 Surrounding Land Use

The model assumes that surrounding land uses affect the wildlife value of specific bottomland hardwood tracts. Many wildlife species commonly use adjacent areas as temporary escape or resting cover, as seasonal or diurnal food sources, or as connecting corridors to other desirable habitats. Surrounding areas that meet these needs can make a specific bottomland hardwood area more valuable. Furthermore, some types of surrounding land use are more valuable than others in providing food sources or encouraging wildlife movement. The model defines five types of surrounding land use that are typically found in the study area, and assigns weighting factors that reflect their estimated potential in meeting specific needs. The effect of surrounding land use is measured within a 0.5-mile perimeter of the bottomland hardwood tract. The percent of this area occupied by each of the land use types is calculated and summed.

Existing Condition. Since bottomland hardwood parcels that would be impacted by the construction right-of-way have been aggregated within each hydrounit, the 0.5-mile perimeter was drawn around the aggregated individual stands. The existing condition was assessed using Google Earth imagery dated May 2016. Uncertainty associated with the assessment for TY1 in 2020 was assumed to be a range of 10 percent.

FWOP. The review group had no specific information regarding future land use or development changes in the areas surrounding the construction right-of-way. Land use types identified in the study area were predominantly nonhabitat (linear, residential, commercial, and industrial development) and natural habitats such as forested wetlands and marsh. In areas with existing industrial development, professional judgment was used to estimate the likely percentage increase in developed areas. Between 5 and 10 percent of forested or marsh areas in some of the bottomland hardwood groups were assumed to convert to developed areas by TY61. It was assumed that no changes would occur in state lands managed for fish and wildlife conservation purposes, and that navigation project placement areas would not change in use over the period of analysis. Significant uncertainty is associated with any prediction of land use change over 60 years from now. For those areas where no change was projected, a range of 20 percent was assumed. For those areas where a change was projected, a larger range of uncertainty (30 percent) was assumed. Land changes were predicted based upon recent development and general socioeconomic trends in the area.

FWP. Development is occurring now in the absence of storm surge protection, and the majority of the alignment would protect areas that are already developed. For those areas that are currently undeveloped, it was assumed that changes in surrounding land use would occur with or without the project, and therefore, the projected change was the same as the FWOP. However, significant uncertainty is associated with any prediction of land use change over 60 years from now. Therefore, a 20 percent uncertainty range at TY61 was assumed for those areas where no change was predicted and a 30 percent range was assumed for those areas where change was predicted.

6.3.7 V7 Disturbance

The model assumes that human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. The model measures the effect of disturbance using two components: (1) type of disturbance, and (2) distance from disturbance. The magnitude of the effect of each type of disturbance is a factor of the distance to that disturbance.

Existing Condition. Since bottomland hardwood parcels that would be impacted by the construction right-of-way have been aggregated within each hydrounit, the distance to disturbance was measured in Google Earth from the edge of the right-of-way to the nearest disturbance type. Disturbance classes are predominantly frequent/moderate due to roads and industry or seasonal/intermittent due to distance from disturbances. Since the construction right-of-way follows the transition between the floodplain and the upland terrace margin to the greatest extent possible, distance to disturbance was often quite close, primarily in the 50- to 500-foot range.

FWOP. The review group had no specific information regarding future land use or development changes in the areas surrounding the construction right-of-way. Therefore, TY-1 through TY61 projections on type and distance to disturbance were the same as TY 0.

FWP. Since the source of the disturbance would be within the bottomland hardwood stands in the construction right-of-way, the FWP assumed a change from TY 1 through TY61 to the class representing constant/major disturbance, and distance was changed to the closest range (zero to 50 feet).

6.4 SUMMARY OF DIRECT IMPACTS FOR THE RECOMMENDED PLAN

For the FIFR-EIS, temporary and permanent construction rights-of-way containing all areas needed to construct and operate the new levee system were developed in GIS and applied to the USGS wetland vegetation files to identify all wetland vegetation and water areas that would be affected by levee construction. All of the wetlands located within temporary and permanent rights-of-way would be destroyed by construction. It is assumed that all material needed to construct the levee system will be obtained from commercial borrow sources. If other sources of fill material are proposed during PED, additional environmental evaluation will be required as requested by USFWS and NMFS Conservation Recommendation 6. It is assumed that the majority of excavated material resulting from construction will be utilized for other construction features. If there is excavated material in excess of construction needs, placement areas will need to be identified. During the construction phase, proposed placement areas will be identified and reviewed for environmental and wetland impacts. The plan for the disposal of this material will avoid or minimize additional adverse impacts to the maximum extent practicable. If significant impacts are identified for a proposed placement area, environmental review and coordination will be conducted in compliance with the National Environmental Policy Act and other applicable regulations.

As explained in Section 2.0, the Orange 3 Recommended Plan is very similar to the plan referenced as Orange 3 in the DIFR-EIS. The DIFR-EIS evaluated the impacts of a range of levee system elevations (11-14 feet), and disclosed that an additional 3 feet would likely be necessary to account for the effects of wave run-up and RSLC. The highest final elevation of Recommended Plan is about 17 feet, but the height in any specific location is dependent upon the existing ground elevation at that location and the needed levee/floodwall height established by storm surge modeling and wave run-up analysis. The length of the system remains approximately 27 miles in total, the same length as the TSP. The overall percentage of floodwalls has increased from about 20 percent of the overall system to about 40 percent. This was necessary to avoid impacts to residences and pipelines, and to minimize impacts to wetlands. The alignment has been relocated in several short segments, but overall remains similar to that presented in the DIFR-EIS. Differences in the two alignments are shown by overlying the Recommended Plan alignment on the TSP alignment (Figures: 6-1 through 6-4).

The Port Arthur Addition is significantly smaller than the TSP Plan in Jefferson County (Figure 6-5). The Beaumont A and most of the Jefferson Main elements are not included in the Recommended Plan. A reevaluation of the existing protection system at Beaumont A found that it provides a similar level of protection to that proposed by the TSP. It was determined that, for the most part, the Jefferson Main element was not needed when elevation data was revised in some sections and local preferences for no levee system were taken into account. One short levee reach (approximately 1,900 feet long) in the Jefferson Main area is still recommended, but it can now be combined with the Port Arthur CSRM Plan since it is located within the jurisdiction of the non-Federal sponsor for the existing Port Arthur Hurricane Flood Protection (HFP) project. This short levee segment connects high ground to high ground, and completes the risk reduction measure for Jefferson County. The TSP and Recommended Plans, therefore, reduce the risks of storm surge impacts to the same general areas. The Port Arthur Addition impacts are negligible and no mitigation is required.

Since conservative assumptions were applied in estimating TSP wetland impacts, direct impacts of the Recommended Plan are approximately 50 percent lower than those presented in the DIFR-EIS. Total direct impacts for the TSP (-161.8 AAHUs) have been reduced to -86.5 AAHUs for the Recommended Plan. Details of the Recommended Plan direct impacts are presented in Table 6-1. Revisions in the alignment have also resulted in a significant reduction of impacts to existing structures, from about 64 structures under the TSP to about 30 structures in the Recommended

Plan. Indirect impacts, which increase the total wetland impacts of the Recommended Plan, are described in Section 7.

The direct impacts reflect the assumed loss of all forested and marsh wetlands within the construction right-of-way of the Recommended Plan due to construction impacts in the first year of construction. Detailed tables of WVA model output of direct impacts for the intermediate RSLC scenario are presented in Attachment 3. Direct impacts that would occur under the low RSLC scenario was not modeled, as they are expected to be similar by slightly less than the intermediate scenario, and the differences in mitigation costs would not be large enough to affect plan selection. The width of the right-of-way might be slightly narrower under the low RSLC scenario; the right-of-way width for the high scenario would be similar to that modeled for the TSP.

Figure 6-1. Comparison of TSP and Recommended Plan Alignments – Neches 1

Figure 6-2. Comparison of TSP and Recommended Plan Alignments – Neches 2

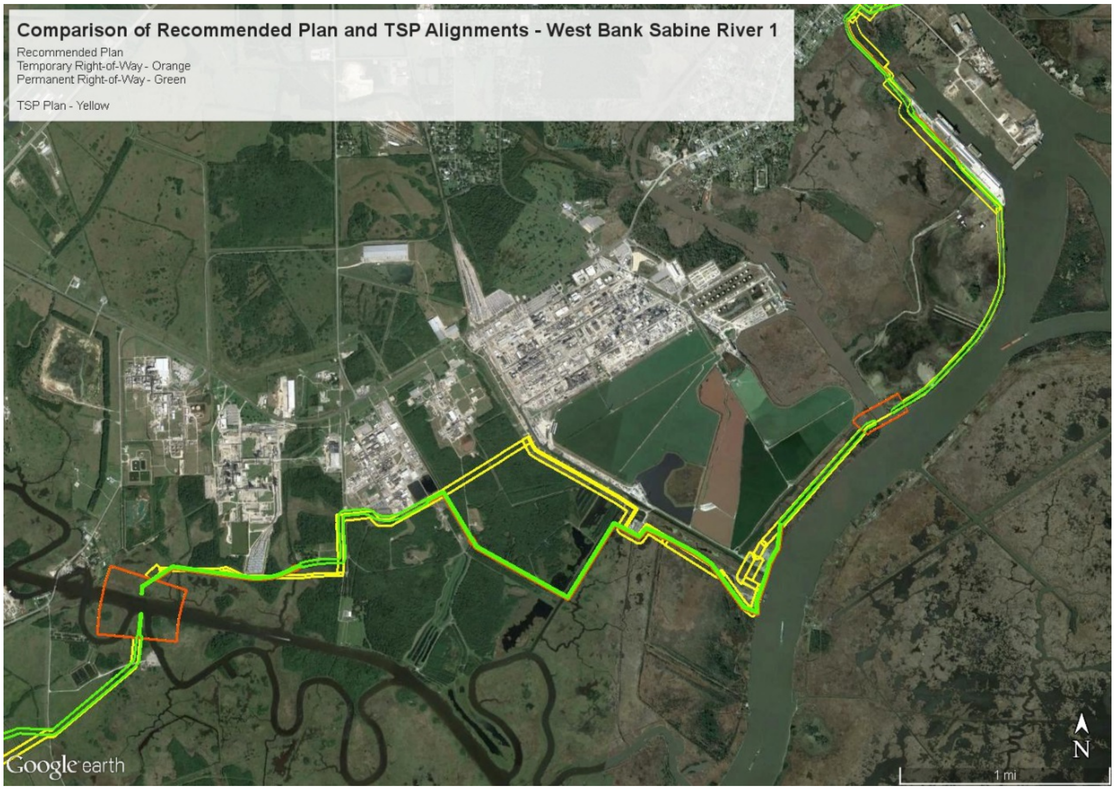

Figure 6-3. Comparison of TSP and Recommended Plan Alignments – Sabine 1

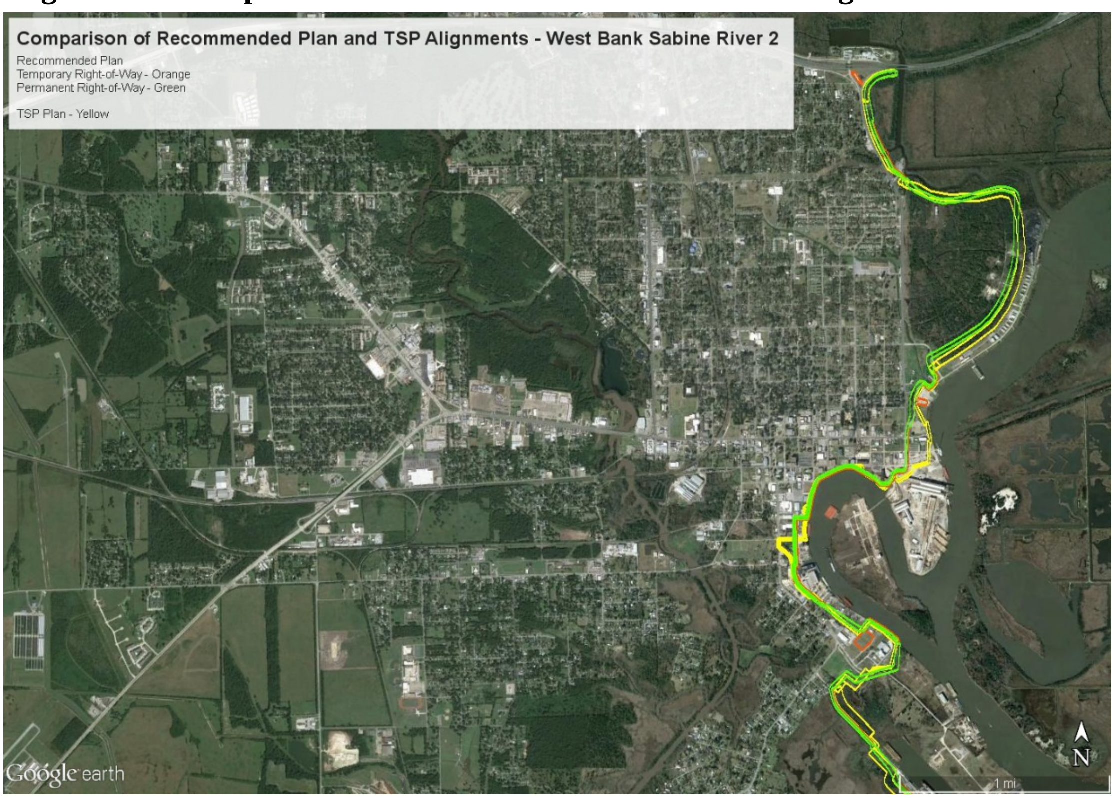

Figure 6-4. Comparison of TSP and Recommended Plan Alignments – Sabine 2

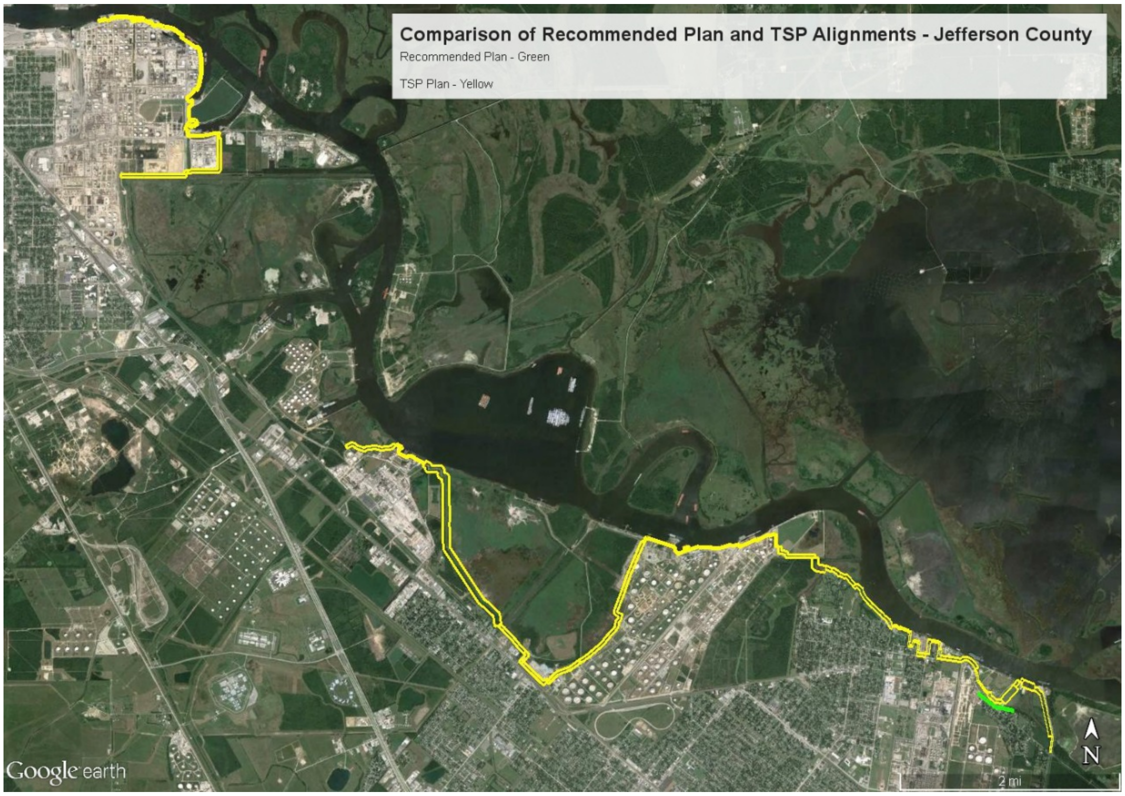

Figure 6-5. Comparison of TSP and Recommended Plan Alignments – Jefferson County

Table 6-1. Recommended Plan Direct Impacts (Intermediate RSLC)

Direct Impacts		
	Orange 3 CSRM Plan	
Wetland Type	**Acres**	**AAHUs**
Forested Wetlands		
Swamp	10.5	-7.2
Bottomland Hardwood	43.9	-30.3
Subtotal	54.4	-37.5
Coastal Marsh		
Fresh Marsh	24.3	-11.4
Intermediate Marsh	6.8	-4.0
Brackish Marsh	74.2	-33.7
Subtotal	105.3	-49.0
Total Direct Impacts*	**159.7**	**-86.5**
* Totals may not add exactly due to rounding.		

7 FWP ANALYSIS OF INDIRECT IMPACTS

Indirect impacts of the Recommended Plan are related to two primary project effects – those associated with fisheries access impacts on the extensive marshes in the lower Cow and Adams Bayous floodplains and indirect impacts related to changes in hydrologic connectivity caused by the new levee system and the Cow Bayou structure. The Port Arthur Addition has no indirect impacts.

The potential for hydrologic impacts of the Adams and Cow Bayou surge gate structures on the Adams and Cow Bayou watersheds was evaluated using desktop hydrologic modeling as presented below. It is assumed that normal flows would be constricted by the presence of surge gates in the bayous in their normal open condition, and that this constriction would result in fisheries access impacts. An analysis of the location of the levee system alignment identified small, localized areas that would experience changes in hydrologic connectivity by being impounded between the new levee system and terrace bluff. Construction of the Cow Bayou gate structure and levee system would indirectly affect a few areas both inside and outside the levee system by permanently disrupting tidal connections. Tidal access to one bottomland hardwood area outside of the levee would also be permanently disrupted by levee construction.

WVA models were used to quantify the indirect impacts of these effects; methods and assumptions used in this modeling are presented below. Wetland areas affected by the indirect impacts of the levee system would change in type and extent due to different levels of tidal flooding under the three RSLC scenarios, and therefore impacts were modeled for each scenario. For example, it was assumed that some swamp would convert to brackish marsh under the Intermediate and High RSLC, because of changes to the salinity regime and higher water elevations. Likewise, some marsh areas switched from intermediate to brackish or brackish to saline due to the changing salinity regime. At other locations, former uplands were assumed to convert to marsh as tides push into new areas due to intermediate and high RSLC. These wetland switches were assumed to occur at the midpoint of the period of analysis (TY 31) which simulates a gradual change over the period of analysis. Indirect fisheries impacts on marsh function associated with the surge gates in Adams and Cow Bayous were modeled for the low RSLC scenario, and these impacts were applied to the intermediate and high scenarios. Higher tidal inundation would improve fisheries access even with the structures in place; the low RSLC condition thus provides a conservatively high impact assessment. Table 7-1 displays all of the indirect impacts described in this section.

Table 7-1. Recommended Plan Indirect Impacts (Intermediate RSLC)

Orange CSRM Plan Indirect Impacts					
Wetland Type	**Indirect Wetland**	**AAHUs**	**Functional**	**AAHUs**	**Total AAHU**
Forested Wetlands					
Forested Wetlands					
Swamp	1.9	-0.1	0.0	0.0	-0.1
Bottomland Hardwood	12.7	-5.1	0.0	0.0	-5.1
Subtotal	14.6	-5.2	0.0	0.0	-5.2
Coastal Marsh					
Fresh Marsh	0.0	0.0	785.2	-18.8	-18.8
Intermediate Marsh	19.2	-8.5	322.5	-4.1	-12.6
Brackish Marsh	78.5	-35.2	1029.5	-27.6	-62.8
Subtotal	97.7	-43.7	2137.2	-50.5	-94.2
Total Indirect Impacts*	**112.3**	**-48.9**	**2137.2**	**-50.5**	**-99.4**
* Totals may not add exactly due to rounding.					

Indirect fisheries impacts associated with the surge gates in Adams and Cow Bayous would affect about 2,137 marsh acres in those watersheds under all RSLC scenarios, resulting in the loss of 50.5 AAHUs. These are functional losses only; the wetlands would not be physically impacted by construction of the levee system. All other indirect impacts would affect about 112 acres with the loss of 48.9 AAHUs. These reflect hydrologic impacts that are predicted to lead to actual wetland loss. Modeling assumptions for all of these impact evaluations are described in more detail below. Tables of WVA model output of indirect impacts are presented in Attachment 4.

7.1 ANALYSIS OF SURGE GATE IMPACTS ON ADAMS AND COW BAYOUS

7.1.1 Hydrologic Modeling of the Surge Gates

ERDC's DOWSMM modeling (USACE 2015) indicates negligible impacts on the water surface elevation and salinity within Adams and Cow Bayous from potential constrictions to the channel cross-section with the proposed surge gates in their normal open condition. This was determined by a sensitivity analysis conducted on the inlet size for each bayou, based on the assumption that construction of the gates would result in some reduction of the cross-section in their normal, open condition. In the analysis, bayou cross-sections were reduced by a wide range of estimated parameters, up to a maximum 75 percent constriction. It was determined that the limited tidal prism associated with the bayous results in minimal energy loss across the connection between the bayous and the Sabine River, and therefore constriction of this access point results in little change in the tidal energy passing into the bayou. The insensitivity of the water surface elevation and the salinity impacts gives high confidence that the general conclusion associated with this study is robust; constriction of the inlet, even significant constriction, results in minimal impacts on water surface elevation and salinity within the bayous.

The extent to which these constrictions would impound storm water within the bayous was also examined by evaluating the effects of a significant rainfall event (Tropical Storm Allison) that had been captured in the median flow simulation. Once again, this analysis applies to the normal, open condition of the gate and evaluated the impacts of rainfall not associated with a significant storm surge event. Given the type of structures currently being evaluated (sector gates on the navigation channels with one or more flanking vertical lift gates to maintain flows on one or both sides of the navigation gates), it is estimated that existing flows may be reduced by a maximum of 50 percent. An aerial view of this type of structure is shown in Figure 7-1. The DOWSMM analysis showed that, even for a 50 percent constriction, the volume of water resulting from such a storm could still pass through the constriction with little impact on upstream stage. There was no attempt made to determine if this storm event represented a project flood, and hence a larger storm could have a more significant impact.

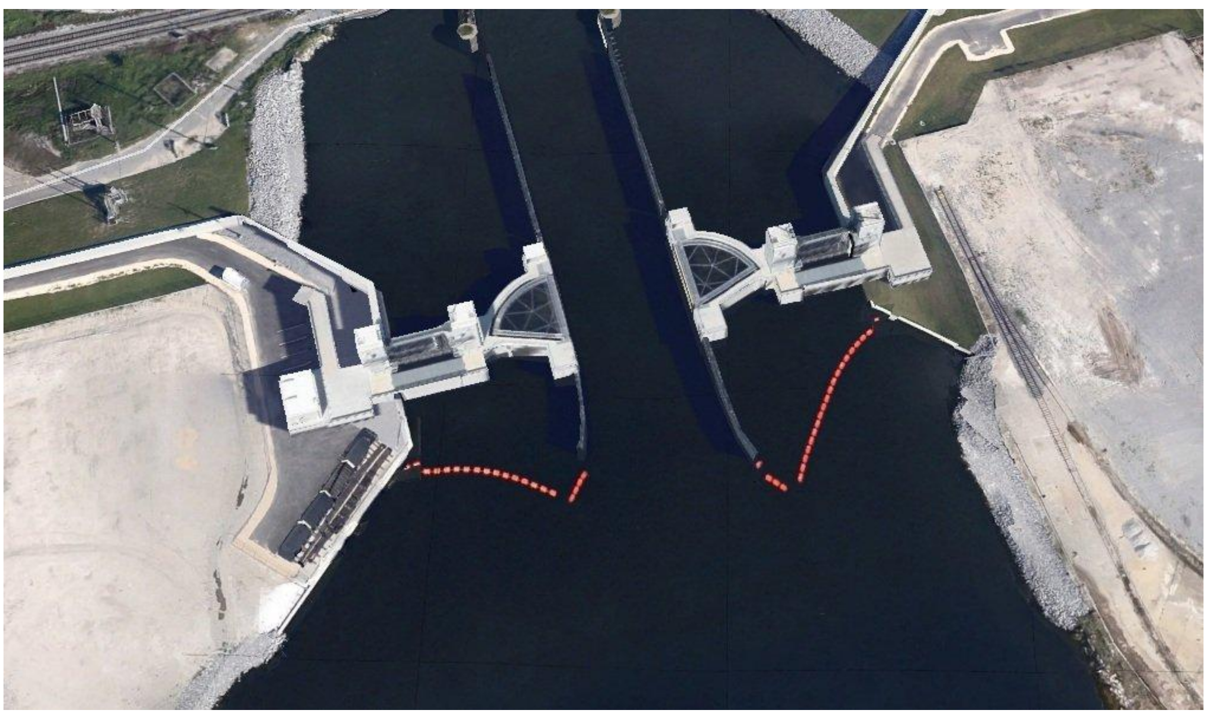

Figure 7-1. Conceptual Plan View of Adams and Cow Bayou Structures

7.1.2 Indirect Impacts on Coastal Marsh and Aquatic Organisms

Impacts related to the temporary closure of the gates were also considered to determine whether fisheries migration would be impacted with placement of the gates in the bayous and temporary surge-related gate closures. Potential impacts to the transport of sediments, nutrients and organic matter between wetlands upstream of the gates and the wetlands and estuary downstream of the gates are addressed in Section 7.2.

The degree of impact would be influenced by the timing and duration of a structure closure relative to peak migration seasons. However, given the predicted return interval of 10 to15 years for storm surges high enough to threaten the areas targeted for protection by this study (which are generally 7 to 10 feet higher than the structure locations), interruption of fishery migrations would be rare. In addition, it is not anticipated that the gates, once closed, would remain closed for an extended period. The project design includes a pump system that would significantly reduce the flood duration upstream of the structures after the gates have been closed to protect against storm surge impacts. Gates or water control structures would need to be closed for large storm events, even if the storms occur more frequently than the predicted return period. The operating plan for the gates has not yet been developed, but an estimated closure time of one week for surge events would result in only minor and temporary impacts to fisheries access. In addition to storm event closures, the gates would need to be closed periodically for maintenance. These closures would also generally be of short duration with only minor and temporary impacts. It must be noted, however, that should the final structure design reduce the cross section by more than 50 percent, additional modeling and environmental analysis would be needed to more thoroughly characterize potential hydrologic impacts of the gate structures.

Based on all of the above analyses and assumptions, it appears that the only significant impact of the Cow and Adam Bayous structures would be fisheries access impacts associated with the day-to-day operation in the open condition. For the historic RSLC scenario, indirect impacts on swamps and bottomland forests upstream of the gated structures are expected to be negligible because changes in water surface elevation and salinity are expected to be negligible (USACE 2015). Therefore, no WVA impact modeling was needed for the Adams and Cow Bayou forested wetlands. However, indirect impacts associated with fisheries access through the gated structures would be expected for extensive marshes in the bayou floodplains upstream of the gated structures (Figures 7-2 and 7-3). These impacts could be expected to affect approximately 1,237 and 900 acres of coastal marsh in the Cow and Adams Bayou floodplains, respectively. The upstream limit of the affected areas, defined to include all upstream marshes in the bayou floodplains, is approximately 7.7 stream miles upstream of the Cow Bayou structure and 4.4 stream miles upstream of the Adams Bayou structure. Despite the limited hydrologic effect demonstrated by the modeling, functional impacts to the marshes may result from potential interference with aquatic organism movement into and out of the bayou caused by the physical presence of the tide gate structures in the bayous.

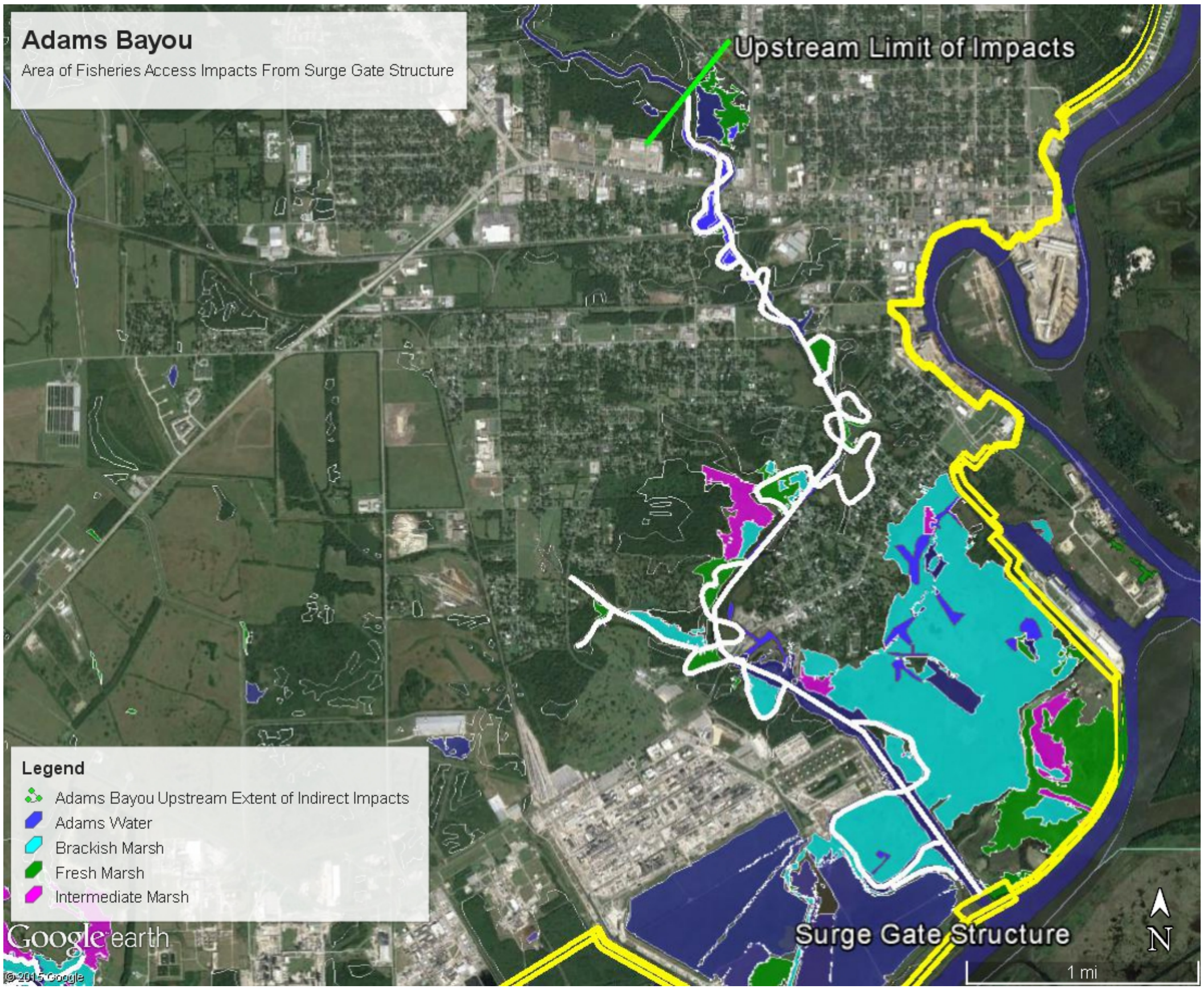

Figure 7-2. Adams Bayou Indirect Impact Area of Surge Gate Structure

According to the NMFS (2008), the ability of estuarine dependent marine fishery organisms to migrate to and from coastal habitats decreases as structural restrictions increase, thereby reducing fishery production (Hartman et al. 1987; Rogers et al. 1992; Rozas and Minello 1999). The physical ability (i.e., swimming speed) to navigate through a structure is not the only factor influencing fish passage. Both behavioral and physical responses govern migration and affect passage of fishery organisms through structures. These responses may vary by species and life stage. In addition, most marine fishery species are relatively planktonic in early life stages and are dependent on tidal movement to access coastal marsh nursery areas. For this reason, in general, the greater the flow through a structure into a hydrologically affected wetland area, the greater the marine fishery production functions provided by that area. It should not be assumed that structures that have been determined to provide sufficient drainage capacity also optimize or provide adequate fishery passage. More investigation is warranted to refine and adaptively manage water control structure design and operations to minimize adverse impacts to fishery passage. Structures constructed along the sides of Cow and Adams Bayou would interfere with organism movement into and out of the bayou, but this impact would be minimized by following specific NMFS design recommendations (NOAA 2008).

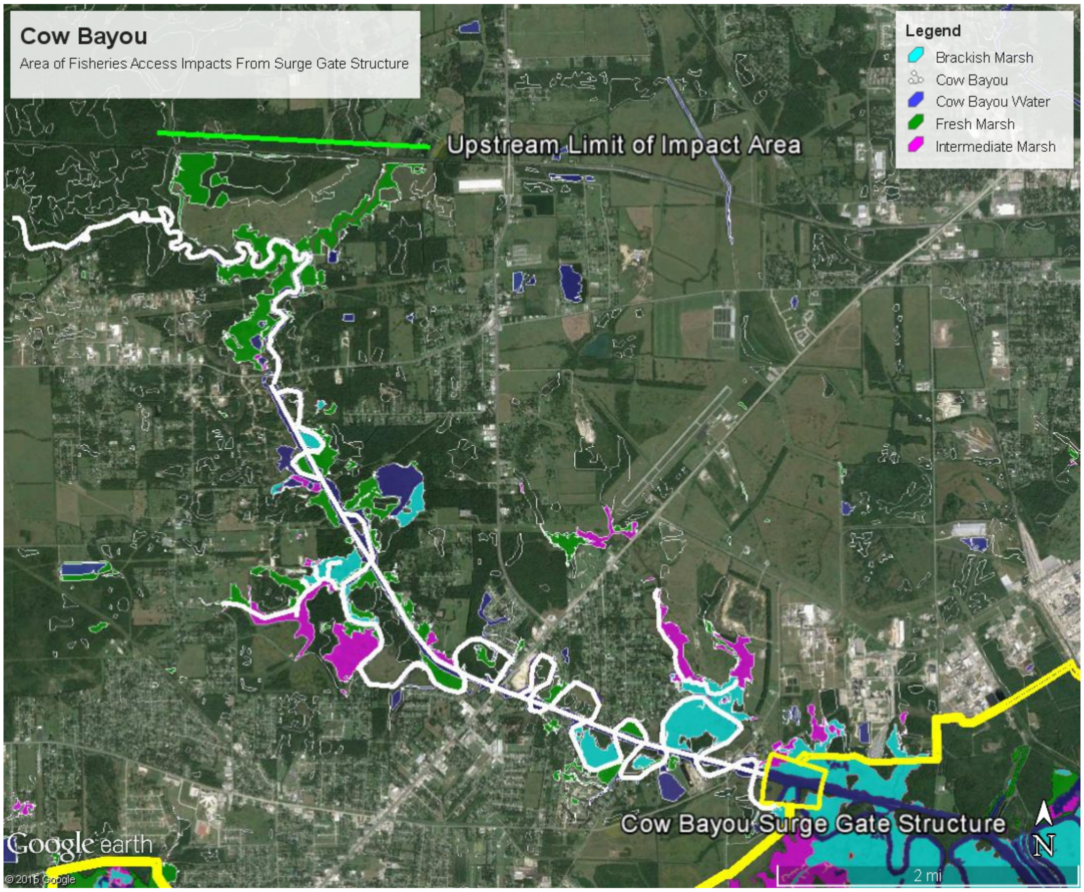

Figure 7-3. Cow Bayou Indirect Impact Area of Surge Gate Structure

Since only preliminary information on the Cow and Adams gate structures is available at this time, the WVA indirect impacts analysis assumed that the structures would reduce the cross-sectional area of the inlets by 50 percent. Final structural designs will incorporate fisheries-friendly considerations recommended by NMFS (2008) to the greatest extent possible (Attachment 4). Final feasibility design will be completed during PED. If it is determined at that time that the design will reduce the cross-sectional area of the bayou inlets by more than 50 percent, additional modeling and environmental analysis will be initiated in consultation with the resource agencies, and as requested by NMFS Conservation Recommendation 3.

7.1.3 WVA Coastal Marsh Modeling of Indirect Impacts

The following method was used to develop input for the WVA Coastal Marsh variables 1 through 6 to capture the indirect effects described above, particularly the fisheries access affects. The WVA marsh models include a variable (V6) that can evaluate impacts on fisheries access. Persistent emergent marsh vegetation and associated open water play an important role in coastal wetlands by providing foraging, resting, and breeding habitat for a variety of fish and wildlife species; and by providing a source of detritus and energy for lower trophic organisms that form the basis of the food chain. Access to these marsh and water systems by aquatic organisms, particularly estuarine-dependent fishes and shellfishes, is considered to be a critical component in assessing the quality of a given marsh system. Additionally, a marsh with a relatively high degree of access by default also exhibits a relatively high degree of hydrologic connectivity with adjacent systems, and therefore may be considered to contribute more to nutrient exchange than would a marsh exhibiting a lesser degree of access.

For V1 input (Percent Emergent Marsh and Water), emergent marsh and water acres within the Cow and Adams floodplains upstream of the gates was taken from the USGS wetland vegetation classification of the Cow and Adam water basins (USACE 2014). These are the only basins for which surge gate structures are proposed; large marsh areas are located upstream of the levee right-of-way on both bayous. Marsh polygons were lumped within each basin for each marsh type - brackish, intermediate, and fresh (no saline marsh is present in these areas). Lumping all polygons of one marsh type for the WVA modeling of each basin is appropriate because of the general uniformity of the marshes in these basins.

Two areas on Adams Bayou were investigated to determine if they should be modeled separately. An area of impounded fresh and intermediate marsh within a former dredged material placement area at the mouth of Adams Bayou (the TPWD Adams Bayou Unit) was found to be hydrologically isolated from the adjacent Sabine River and Adams Bayou. Dredged material placement has raised the elevation of the area to between 7 and 10 feet, and there is no tidal access from the Sabine River or Adams Bayou. Since the proposed surge gate would have no additional impact on fisheries access to this area, the Adams Bayou Unit was excluded from the impact analysis. Separate WVA modeling of the 475-acre marsh west of the Adams Bayou Unit was considered but it was ultimately lumped together with the other Adams Bayou marshes. Primary access is provided by Adams Bayou on its southwestern side, although up to an estimated 40 percent of the flows enter the area near its northernmost point through a bridge-culvert under the road leading into the Port of Orange. An old levee, which bisects the area from northwest to southeast, is degraded in many areas, allowing flows to pass unencumbered to both sides of the levee. Since the Adams Bayou hydrologic openings are capable by themselves of providing full access to the entire area, the separate marsh types in this area were lumped with the rest of the marshes in the impact area, and all were assigned a structure rating of 1.0 since no impediments to access are known.

The total amount of the classified water in each basin, including the channelized bayou reaches and the natural oxbows within the tidal segment, is included in the V1 water acres since all are important avenues for fisheries access, and all would be affected in some way by the structures. Water acres were subdivided and associated with each of the three marsh types in accordance with the total relative percentages of the marsh types themselves. All of the polygons for each marsh type within each basin were added together, and the relative percentages of fresh, intermediate, and brackish marsh were calculated. If, for example, 30 percent of the marsh in the basin was brackish, then 30 percent of the water in the affected reach of the bayou was associated with brackish marsh.

The percent of aquatic vegetation cover (V2) was estimated based upon observations documented for these areas for the SNWW Channel Improvement Project Feasibility Study and Environmental Impact Statement (USACE 2011), review of Google Earth 2015 imagery and best professional judgment.

The degree of marsh/waterbody interspersion (V3) was assessed for each marsh type over each drainage using Google Earth 2015 imagery at the same scale as the examples shown in the WVA marsh model V 1.0

The percent shallow water (V4) of total water in each drainage was calculated by apportioning the shallow water percentage across the marsh types in accordance with their relative percentages. The percent shallow water was estimated using a weighted average based on length of the dredged channel, natural oxbow channels, and small shallow streams with the assumptions that the dredged channel has 10 percent shallow water along its edges, the natural oxbows have 30 percent shallow water along their edges, and the shallow tributaries have 40 percent shallow water along their edges. The breakdown of the three water body types is shown in Table 7-1 for each bayou. Calculations to estimate the percentage of shallow water in the affected areas of for Adams and Cow Bayous are shown in Tables 7-2 and 7-3 below.

Table 7-2. Affected Bayou and Stream Miles in Cow and Adams Bayous

	Adams Bayou		Cow Bayou	
Water Body Types	Total Length (miles)	Water Body Type (%)	Total Length (miles)	Water Body Type (%)
Channelized Bayou	4.1	33.0%	4.4	19%
Natural Bayou	7.12	57.3%	14.8	65%
Shallow Streams	1.2	9.7%	3.6	16%
Total	12.42	100.0%	22.8	100%

Table 7-3. Estimation of Percentage Shallow Water for Adams Bayou

Adams Bayou Calculations to Estimate Percent Shallow Water (V4)	Marsh Type Percentage	Emergent Marsh by Type (acres)	Water Acres Proportioned by Relative Percentage of Water Body Type	Assumed Percentage Shallow Water*	Calculated Shallow Water (Acres)	Total Marsh & Water (Acres)
Fresh Marsh (F Indirect-3)	21.2%	63.1	47.5			110.6
Channelized Water (19%)			9.0	10%	0.9	
Natural Channels (65%)			30.9	30%	9.3	
Shallow Streams (16%)			7.6	40%	3.0	
Subtotal					13.2	
Intermediate Marsh (I Indirect-4)	7.3%	35.8	16.4			52.2
Channelized Water (19%)			3.1	10%	0.3	
Natural Channels (65%)			10.6	30%	3.2	
Shallow Streams (16%)			2.6	40%	1.0	
Subtotal					4.6	
Brackish Marsh (B Indirect-5)	71.5%	578.7	160.3			739.0
Channelized Water (19%)			30.5	10%	3.0	
Natural Channels (65%)			104.2	30%	31.3	
Shallow Streams (16%)			25.7	40%	10.3	
Subtotal					44.6	
Totals		677.6	224.3		62.3	901.9
Percentage Shallow Water Associated with All Marsh Types					**35.7%**	

*Weighting based on following assumptions:
Channelized bayou has 10 percent shallow water along edges.
Natural bayou and oxbows have 30 percent shallow water along edges.
Small shallow streams have 40 percent shallow water along edges.

Table 7-4. Estimation of Percentage Shallow Water for Cow Bayou

Cow Bayou Calculations to Estimate Percent Shallow Water (V4)						
	Marsh Type Percentage	Emergent Marsh by Type (acres)	Water Acres Proportioned by Relative Percentage of Water Body Type	Assumed Percentage Shallow Water*	Calculated Shallow Water (Acres)	Total Marsh & Water (Acres)
Fresh Marsh (F Indirect-2)	54.6%	421.0	253.6			674.6
Channelized Water (19%)			48.2	10%	4.8	
Natural Channels (65%)			164.8	30%	49.4	
Shallow Streams (16%)			40.6	40%	16.2	
Subtotal					70.5	
Intermediate Marsh (I Indirect-3)	21.9%	168.7	101.6			270.3
Channelized Water (19%)			19.3	10%	1.9	
Natural Channels (65%)			66.0	30%	19.8	
Shallow Streams (16%)			16.3	40%	6.5	
Subtotal					28.2	
Brackish Marsh (B-Indirect-4)	23.5%	181.3	109.2			290.5
Channelized Water (19%)			20.7	10%	2.1	
Natural Channels (65%)			71.0	30%	21.3	
Shallow Streams (16%)			17.5	40%	7.0	
Subtotal					30.4	
Totals		771.0	464.4		129.1	1,235.4
Percentage Shallow Water Associated with All Marsh Types					**27.8%**	

*Weighting based on following assumptions:
Channelized bayou has 10 percent shallow water along edges.
Natural bayou and oxbows have 30 percent shallow water along edges.
Small shallow streams have 40 percent shallow water along edges.

Salinity (V5) for the existing condition (historic RSLC) was based on salinity projections developed for the SNWW 48-foot channel improvement project as described for WVA modeling of S2G direct impacts.

Impacts to fisheries access (V6) were assessed based on limited, preliminary information on the type of surge prevention structure planned for Cow and Adams Bayous. Fisheries access impacts for the affected tidal areas are associated solely with the proposed surge gate structures. The final design will attempt to minimize impacts on the existing flow and cross-sectional area of the bayous, and will utilize fisheries-friendly design concepts recommended by NOAA (2008). However, to provide a conservatively high estimate of potential impacts, the WVA modeling assumed a 50 percent reduction in the cross-section of the channel. Based on a curve developed with data from Rogers et al. (1992) for the "Percent Open Channel Method" for calculating fisheries access impacts, this equates to a structure rating of 0.7 for the type of open structure planned (Figure 7-4). This method has been used by NOAA-NMFS and USACE on recent projects in Louisiana (NMFS 2012).

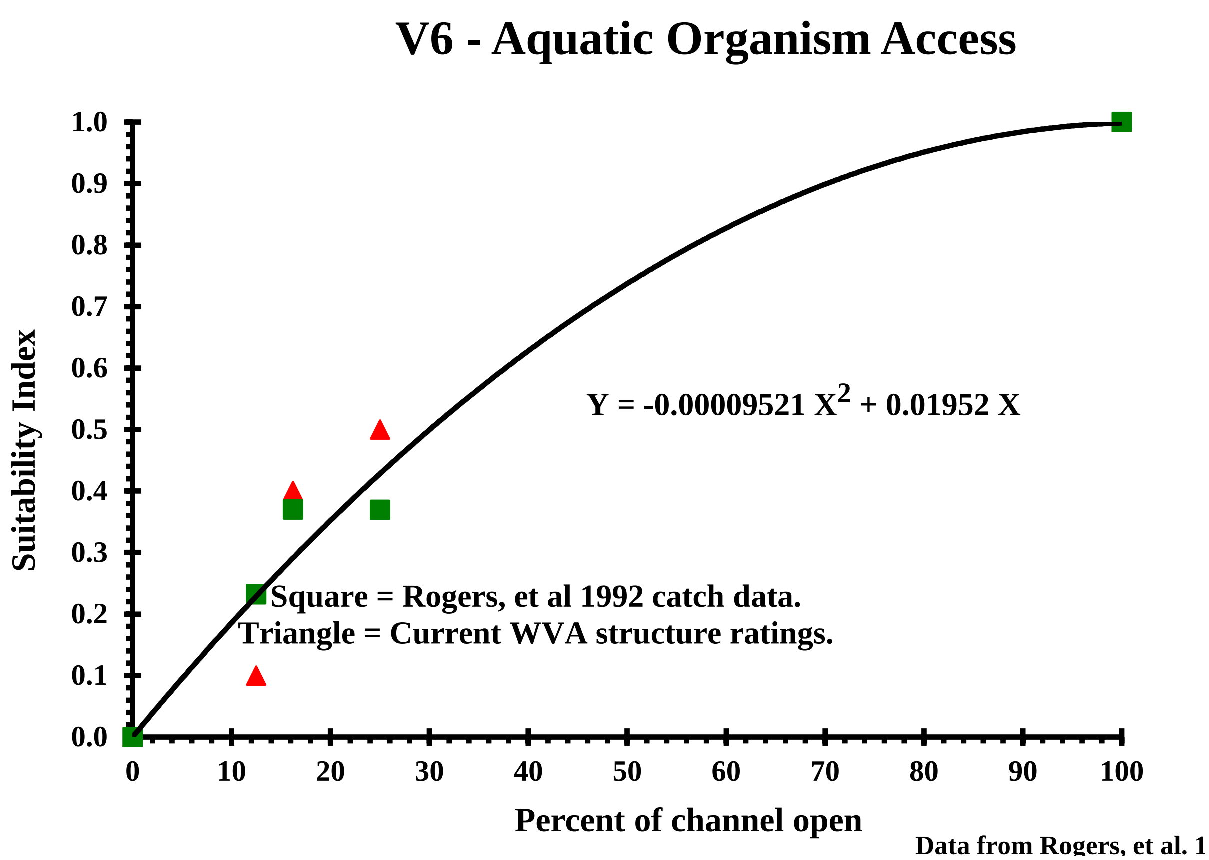

Figure 7-4. Percent Open Channel Curve

7.1.4 Intermediate and High RSLC Scenarios

Indirect impacts related to the Cow and Adams gated structures were modeled for the historic RSLC scenario. Surge gate structures on Cow and Adams Bayou would be open the vast majority of the time, allowing sea levels to rise upstream of the structure as they would in the FWOP condition. In Cow and Adams Bayous, water levels under intermediate RSLC should remain largely within the existing channels; with high RSLC, water elevations would encroach into some developed areas of Bridge City which are adjacent to the bayou and tidal inundation of all wetland areas would be deeper. Large areas of brackish marsh in the floodplains downstream of the Cow Bayou gate and around the mouth of Adams Bayou on the Sabine River would experience much deeper daily tidal inundation with high RSLC, with some areas possibly converting to open water. Higher tidal inundation would improve fisheries access even with the structures in place. However, the degree of improvement is difficult to estimate, and therefore indirect fisheries impacts were not modeled for the intermediate and high RSLC scenarios; impacts quantified for the historic scenario were applied, providing a conservatively-high impact assessment.

Indirect fisheries impacts of the Adams and Cow Bayous structures would affect about 2,137 acres, resulting in the loss of 50.5 AAHUs. Inasmuch as impacts of the three RSLC scenarios are assumed to similar, differences in mitigation costs would not affect plan selection.

7.2 ANALYSIS OF INDIRECT IMPACTS OF THE LEVEE SYSTEM

7.2.1 Historic RSLC Scenario

7.2.1.1 FWOP Condition

A desktop analysis of interior drainage requirements has been performed by Galveston District as required using current USACE guidance contained in ER 1100-2-8162 and ETL 1100-2-1. This analysis identified all of the sub-drainage basins behind the proposed new levee alignment and the primary small drainage in each sub-basin for which existing flow will need to be maintained. Figure 7-5 shows the sub-basins outlined in white, the primary drainage in each sub-basin in red, and the major rivers in blue. The longest evaluated levee alignment is shown in yellow. The analysis calculated the amount of both overland and channelized flow from each basin. The Recommended Plan alignment does not affect large segments on both the western and eastern ends of the illustrated alignment.

7.2.1.2 FWP Condition

An analysis of potential impacts to the Sabine and Neches River floodplains is presented in Appendix D (Engineering) of the FIFR-EIS. The Sabine and Neches River floodplains are largely untouched by the Recommended Plan, as the levee system has been located along the upland/floodplain interface, or situated to follow existing levee systems or upland placement areas which impound some floodplain areas in the existing condition. The levee system will have negligible impacts on flow, stage, velocity and other factors as determined by HEC-RAS analysis. Because there is little effect on flow, there is expected to be a negligible impact on the exchange of sediment, nutrients and organic matter between wetlands upstream of the levee system and the wetlands and Sabine estuarine downstream of the system. The Cow and Adams Bayou surge gates will result in higher water velocities in the immediate vicinity of the structures, and this may cause a minor increase in shoaling downstream of the gates. Minor scouring of the stream bed adjacent to the structures may also result.

Sluice gate culverts are planned for use everywhere there is tidal influence (Figure 7-6); flap gate culverts may be utilized in upstream areas above tidal influence (Figure 7-7). It is likely that all of the culverts would be sluice gates because the entire proposed Orange levee system is located in areas that are tidally influenced. Gated culverts would be placed everywhere the red drainage lines intersect the yellow levee alignment, and they would be placed in additional areas where they are needed to ensure adequate flows to adjacent wetlands. The sluice gates would remain open except when surge protection or maintenance is needed; they would be closed temporarily for a short period before and after a storm occurs. Flap gate culverts would provide for one-way flow downstream from the levee system.

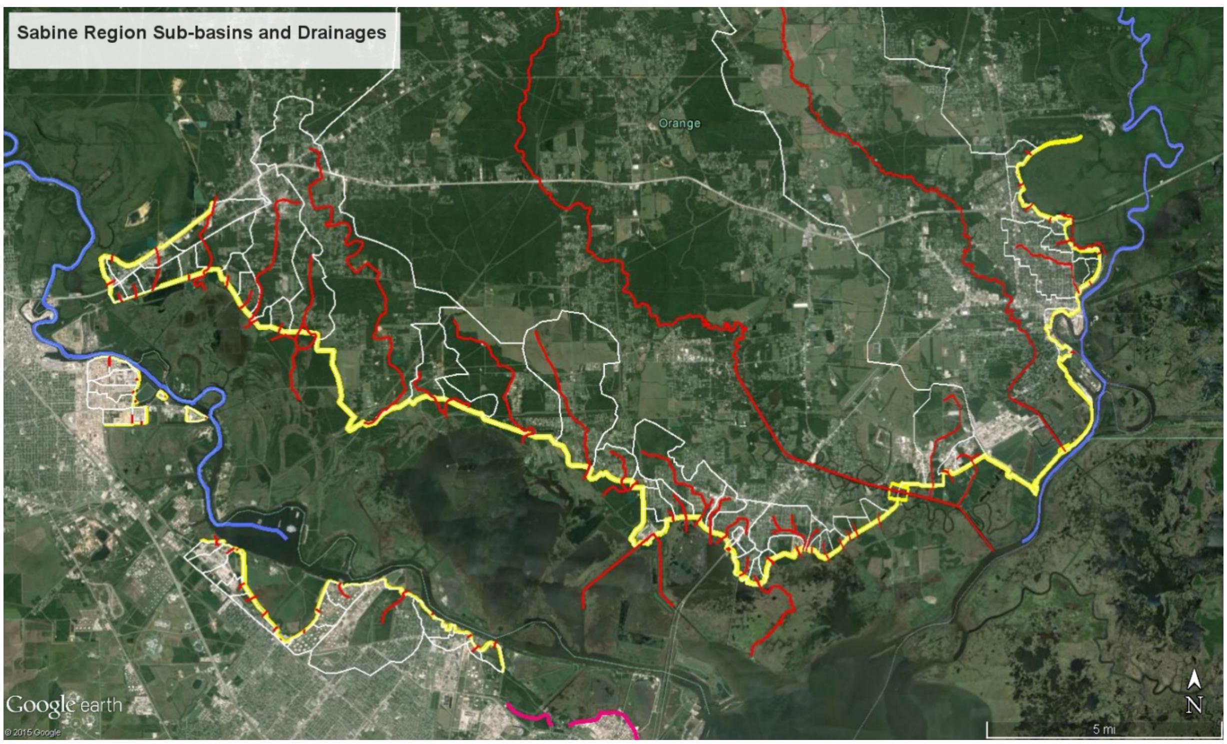

Figure 7-5. Sabine Region Sub-basins and Drainages

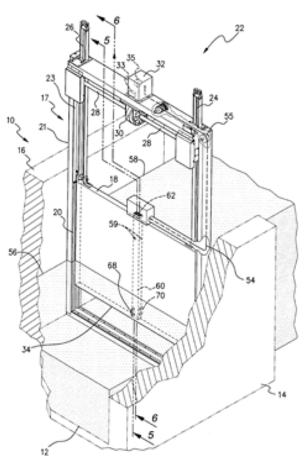

Figure 7-6. Sluice Gate Example

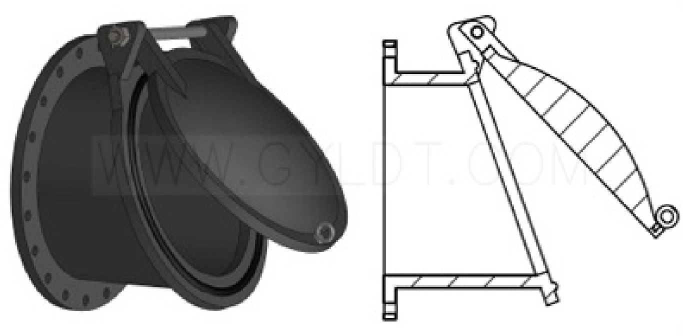

Figure 7-7. Flap Gate Example

Impacts on the floodplain, both upstream and downstream of the levee system, would be minimized such that remaining impacts are negligible. Culverts have been designed to maintain existing flows for a 100-year rainfall event, with an additional 10 percent to account for the predicted increase in rainfall due to climate change over the period of analysis. In addition, they will be designed with longer spans and lower heights than would typically be used in an attempt to replicate the natural openings. In the existing condition, freshwater inflows from the upland areas to marshes and forested wetlands in the floodplain are being conveyed primarily through existing stream channels. The majority of the time, flows are directed toward channels and ditches that discharge into the floodplain through existing drainages. Water flows through these channels into minor drainages with incised beds, and in some cases flows spread out directly into wetland areas. Overland sheet flow is temporary, occurring during intense or long duration rain events, as the majority of the area upstream of the levee is undeveloped and permeable. The degree to which shallow groundwater aquifers may contribute flows to the floodplain is unknown, but they are assumed to be a minor contributor. It is believed that marshes in the floodplain rely primarily on rainfall and tidal push for inundation.

During a surge event the sluice gates would be closed, pumps would be used to pump rainfall runoff from the interior to the exterior. The pumps are being conservatively sized to avoid floodplain impacts to the interior of the levee system, and to allow overbank flooding in the streams in the floodplain outside of the levee during high flow events. Hydrologic flows, as well as the exchange of sediment, nutrients and organic material would thus be very similar to FWOP flows and in location, duration and magnitude, both upstream and downstream of the levee system. Like the Cow and Adams Bayou structures, it is assumed that these gates would need to be closed for one week for each storm event or up to two weeks for periodic maintenance. The operating plan for the gates has not yet been developed, but even a worst case estimate of closure time would result in only minor and temporary impacts on fisheries access for gates with tidal flows. Groundwater flow from shallow aquifers may be affected by compaction of aquifer sediments due to the weight of the overlying levee, or by construction of seepage barriers beneath the levee. The location and extent of these will not be known until final levee design.

Based on these assumptions, it was determined that the levee would have minor impacts on the hydrology of the floodplain and sediment/nutrient exchange both inside and outside of the levee system. Because this determination rests heavily on these assumptions, resource agencies have requested to be involved in the development of Operating Manuals during the PED Phase and during subsequent periodic reviews when operating plans are reevaluated to determine project performance under future conditions, including potentially higher than anticipated rates of RSLC. Requirements that the surge gates, sluice gates, and culverts remain open except during storm events would be incorporated into the Operating Manual, as requested by NMFS Conservation Recommendation 4. Should future conditions change to the extent that more frequent closure of these features becomes necessary, coordination with the NMFS and other resource agencies would be initiated as requested by NMFS Conservation Recommendation 5 to determine if additional hydrologic and fish passage modeling is warranted and if additional compensatory mitigation is needed.

The levee alignment, drainage basins and proposed culvert locations were evaluated in detail using Google Earth 2015 imagery to check for smaller, secondary drainages where culverts would also be needed to ensure that flows to adjacent wetlands are maintained. At a minimum, 13 new culverts have been incorporated into the project design where additional connectivity appeared to be needed. With the exception of the Cow and Adams Bayou basins discussed above, the majority of the wetlands in the uplands behind the levee alignment are swamp or bottomland hardwoods. A few small areas of marsh are scattered inside of the levee alignment. Since drainage and tidal connections would be maintained in essentially the FWOP condition as described above, no indirect impacts were identified on most of the marshes, bottomland hardwoods and swamps located inside and outside the levee system.

The potential for indirect impacts related to induced development was also considered. The general area is vulnerable to storm surge impacts, and construction of this alternative would reduce the risk of storm surge damages in the future. Development has been occurring in the area because of the concentration of petro-chemical industries and the Port of Beaumont, and this development is expected to occur with or without the project. A study of the potential for induced development in coastal areas due to shoreline protection projects found that the existence of such projects is not statistically significant in generating changes in the pattern and growth of development (Cordes and Yezer 1995). For this study, therefore, it is assumed that the existing patterns of employment and income would persist, and that the pattern and extent of development would be similar in both the FWOP and FWP conditions.

However, impacts were identified for wetland areas immediately adjacent to the levee that would be impounded between the levee and the higher elevation upland terrace margin. In many areas, the transition between the floodplain and the upland is an abrupt bluff, averaging from 4 to 8 feet high. Marsh or forested wetlands caught between the new levee and bluff would be cut-off from daily tidal inundation, denied nutrients and sediments; the health of the wetlands would decline and they would eventually die. For the marshes, it was assumed that this process would occur quickly with emergent marsh converting to open water by TY 1; for swamps, it was assumed that the disrupted hydrology and impounded rainwater would result in a slow decline in the health of cypress and tupelo, with eventual loss of the entire stand by TY61. For bottomland hardwoods, however, the soil would become saturated due to the impoundment of rainfall and it was assumed that the trees would die off quickly, with a complete loss by TY2.

In addition, the construction zone impacts for the Cow Bayou gate and one levee segment would block the flow of small channels feeding adjacent marsh or swamp. For these areas, it was assumed that tidal connectivity would be disrupted permanently and that wetland vegetation would no longer be supported in the FWP condition. Similar to the impoundment impacts, it was assumed that marsh would be lost by TY1. Bottomland hardwoods and swamps would survive longer under these conditions because the soils would not be saturated; however, lower water availability would create stress and increase susceptibility to pests and diseases. These stands were assumed to be totally lost by TY25. The indirect impact areas and the acres of impacts are listed in Table 7-5 and shown on Figures 7-8 through 7-12. The WVA outputs for indirect impacts are provided in Attachment 5.

Table 7-5. Indirect Impact Areas for Orange 3 CSRM Plan

Hydro-unit	Area ID	Acres						Total Wetland Acres	Impact Description
		Swamp	BH	Fresh Marsh	Int Marsh	Brackish Marsh	Water in Wetland		
TX 10	F Indirect-2			421.0			253.6	674.6	Fishery access primarily controlled by Cow Bayou surge gate
TX 10	I Indirect-1				5.7		1.2	6.9	Hydrologic access permanently disrupted
TX 10	I Indirect -2				11.4		1.3	12.7	Hydrologic access permanently disrupted
TX 10	I Indirect-3				168.7		101.6	270.3	Fishery access primarily controlled by Cow Bayou surge gate
TX 10	B Indirect-2					18.9	7.2	26.1	Hydrologic access permanently disrupted
TX 10	B Indirect-3					14.1	4.3	18.4	Hydrologic access permanently disrupted
TX 10	B Indirect-3					34.0		34.0	FWOP marsh migration (Intermediate RSLC)
TX 10	B Indirect-4					181.3	109.2	290.5	Fishery access primarily controlled by Cow Bayou surge gate
TX 10	S Indirect-2	1.9						1.9	Hydrologic access permanently disrupted
TX 11	F Indirect-3			63.1			47.5	110.6	Fishery access primarily controlled by Adams Bayou surge gate
TX 11	I Indirect-4				35.8		16.4	52.2	Fishery access primarily controlled by Adams Bayou surge gate
TX 11	B Indirect-5					578.7	160.3	739.0	Fishery access primarily controlled by Adams Bayou surge gate
TX 11	BH Indirect-2		12.7					12.7	Hydrologic access permanently disrupted
	Totals*	1.9	12.7	484.1	221.6	827.0	702.6	2249.5	

*Totals may not add due to rounding

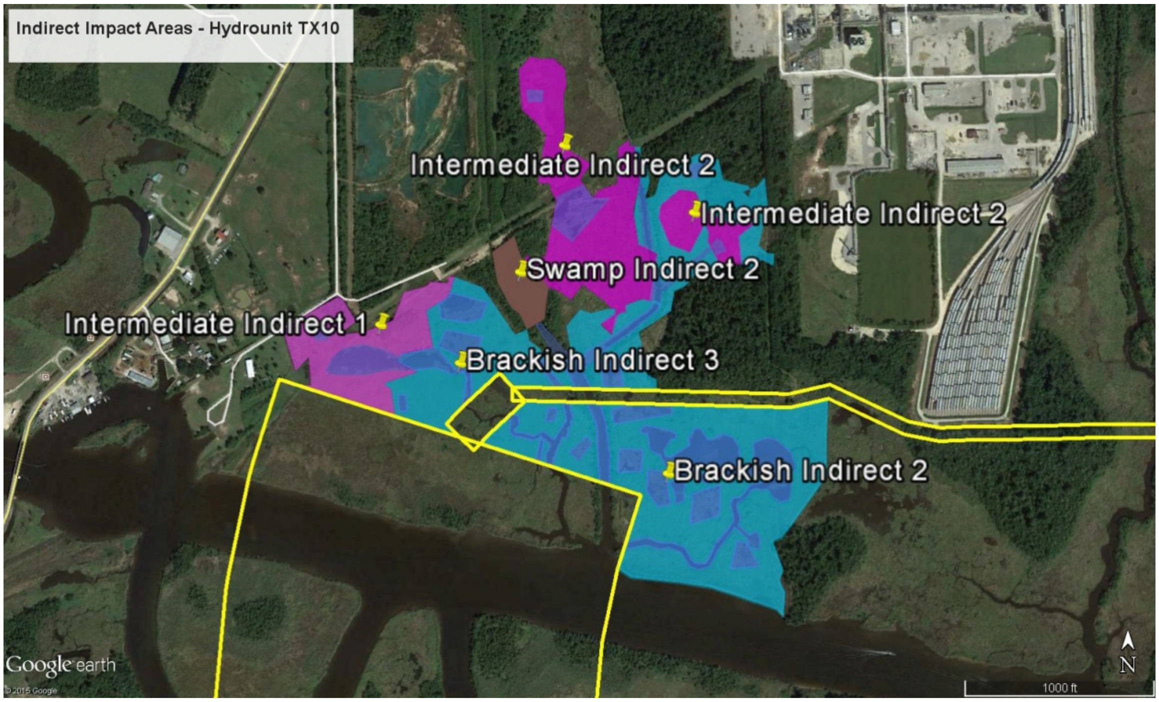

Figure 7-8. Indirect Impact Areas in Hydro-unit TX10 (Historic RSLC Scenario)

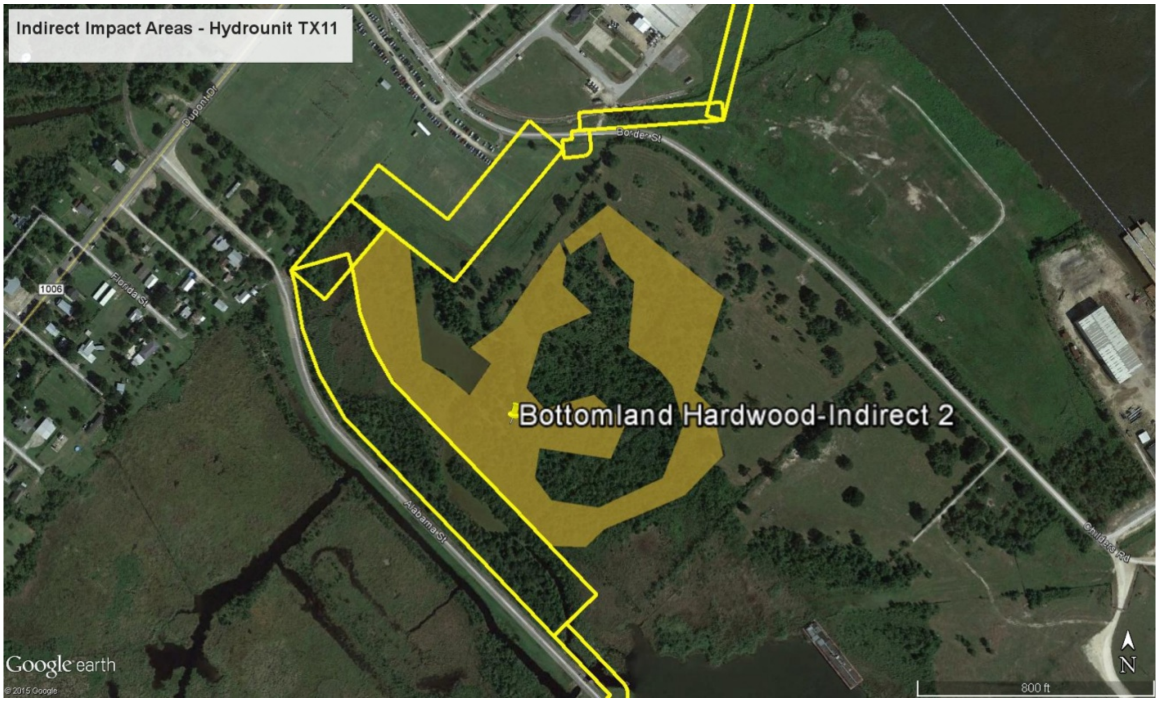

Figure 7-9. Indirect Impact Area in Hydro-unit TX11 (Historic RSLC Scenario)

7.2.2 Intermediate and High RSLC Scenarios

7.2.2.1 Method for Evaluating Impacts

The general area of the levee alignment was carefully evaluated to identify areas into which wetlands would have migrated under the intermediate or high RSLC scenarios in the FWOP condition. The NOAA Sea-Level Rise Viewer (NOAA 2015) was used to identify new tidally-influenced areas and the NOAA marsh impacts/migration viewer was used to map changes in marsh type and extent. The data and maps in this NOAA tool illustrate the scale of potential flooding and a general location, and do not account for erosion, subsidence, or future construction. Water levels are shown as they would appear during the highest high tides or MHHW, and do not include wind driven tides.

The NOAA method for mapping marsh migration due to RSLC assumes that specific wetland types exist within an established tidal elevation range, based on an accepted understanding of what types of vegetation can exist given varying frequency and time of inundation, as well as salinity impacts from such inundation (NOAA 2012). The viewer maps changes associated with sea-level rise from the current MHHW up to 6 feet, in 1-foot increments. The potential changes associated with intermediate and high RSLC by TY61 in the Sabine region were evaluated using the 2- and

4-foot Sea Level Rise and Marsh Impacts views. Marsh impacts were evaluated with no accretion rate, as data for this is unavailable, and this will provide a conservatively high impact evaluation.

7.2.2.2 FWOP Condition

Natural areas vulnerable to sea level rise and marsh migration in the FWOP condition were mapped in Google Earth and are shown relative to the Orange 3 CSRM Plan alignment in Figures 7-10 through 7-12. Developed areas and leveed areas were excluded from this analysis, as the purpose was identify wetland impacts. RSLC migration of wetlands into formerly upland zones would be expected to occur with increasing RSLC where the migration is not blocked by existing hard structures, natural bluffs or development. The significant elevation difference between the floodplain and the uplands in this study area (approximately 7 to 10 feet) would block this migration is most areas. However, increasing sea levels would also increase the tidal prism in the smaller bayous and streams which cut from the upland to the floodplain. The higher water levels would flood low lying areas adjacent to these bayous and streams, creating new wetlands in the areas shown in the following figures.

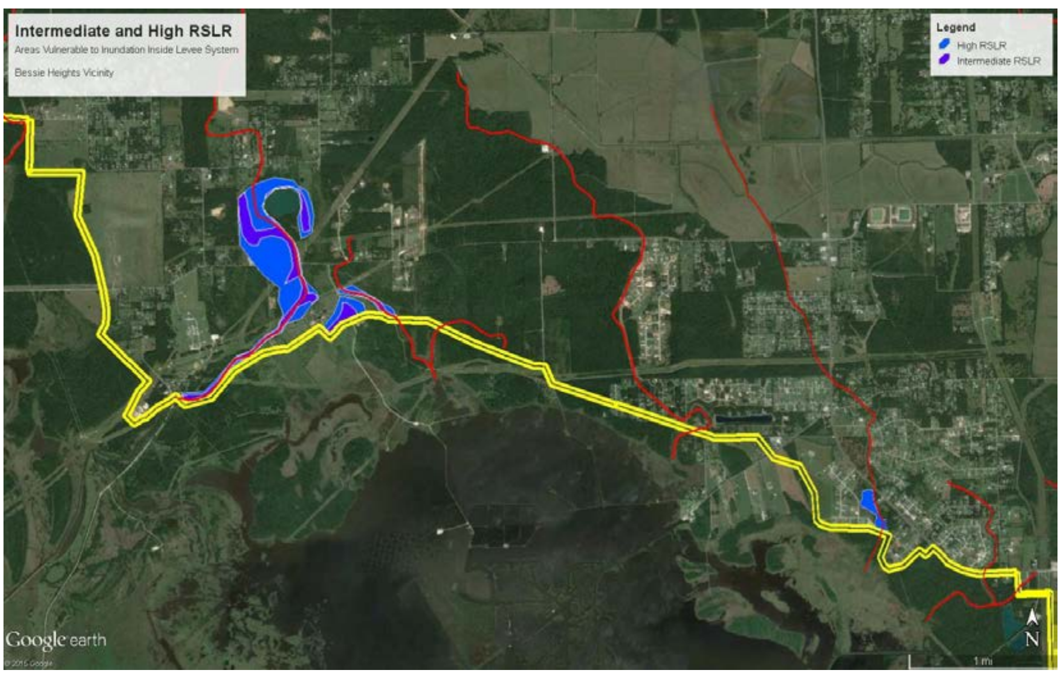

Figure 7-10. Bessie Heights–Areas Vulnerable to RSLC and Wetland Change/Migration

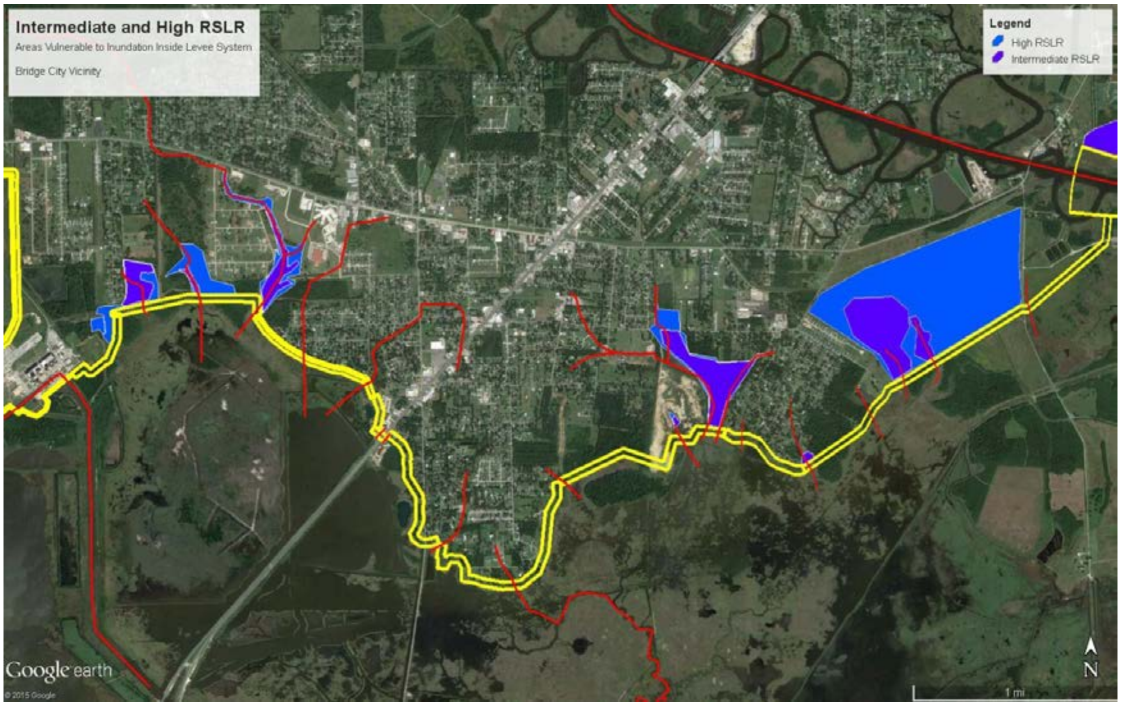

Figure 7-11. Bridge City Vicinity–Areas Vulnerable to RSLC and Wetland Change/Migration

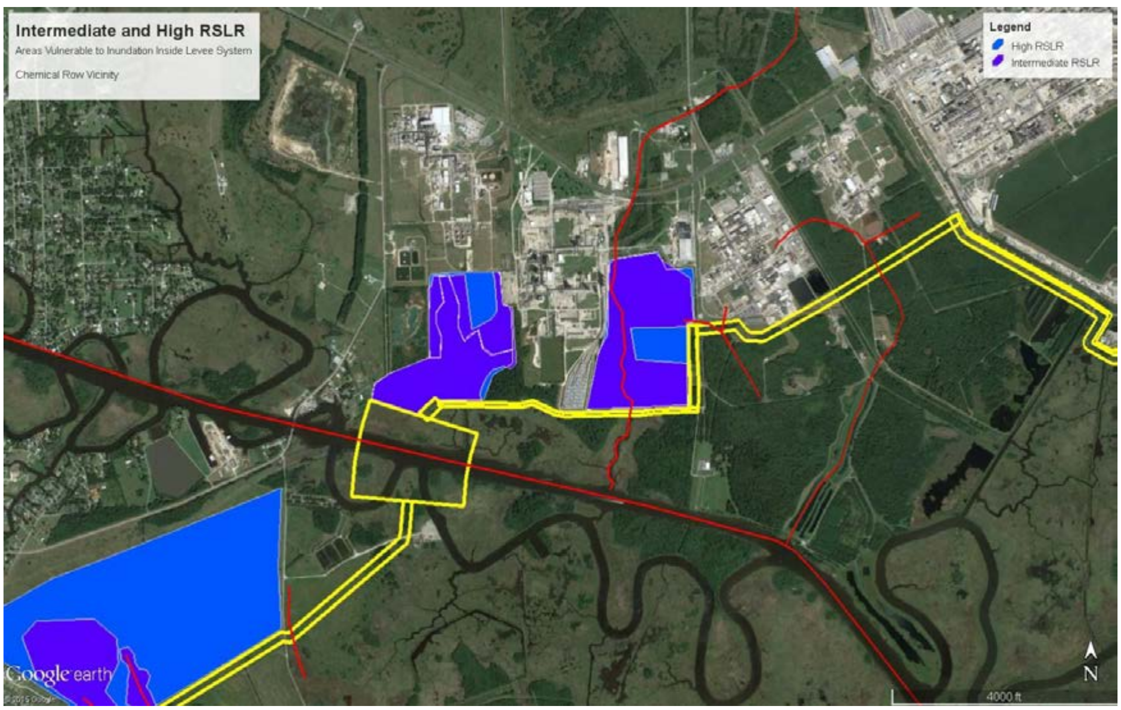

Figure 7-12. Chemical Row Vicinity–Areas Vulnerable to RSLC and Wetland Change/Migration

In general, bluffs on the upland terraces of the Sabine and Neches River prevent large-scale overland flooding over the period of analysis. The most vulnerable areas are located within the lower reaches of bayous and streams that would be flooded to greater depths and inland extent with RSLC. As sea level rises, higher elevations will become more frequently inundated, allowing for marsh migration landward. At the same time, some lower-lying areas will be so often inundated that the marshes will no longer be able to thrive, becoming lost to open water. Depending upon elevation and projected salinities, in the intermediate RSLC scenario wetlands would switch from swamps to intermediate scrub-shrub marshes, or from fresh/intermediate to brackish/saline marshes. Significant areas of open-water would develop only in the high RSLC scenario, and these were located primarily in the Bridge City and Chemical Row vicinities. With high RSLC, swamps and intermediate marshes would switch to brackish or saline marshes. Because of generally higher elevations, bottomland hardwoods would generally persist in their existing locations through the period of analysis.

Conversion from one wetland type to another would result from changing water elevations and salinities associated with RSLC. The exact conditions and rate under which this change would occur are difficult to predict and thus an even rate of change was assumed in the WVA modeling of the FWOP condition. This is achieved by assuming that the conversion from one wetland type to another occurs at the midpoint of the period of analysis (TY31). The existing wetland was assumed to persist through TY30, with increased loss rates for emergent marsh and gradually increasing salinities. The annual FWOP wetland loss rate was gradually increased by a percentage change of 0.012 feet/year and 0.05 feet/year for intermediate and high RSLC, respectively, based on the negative relationship that has been observed between wetland loss rates and RSLC in Louisiana. For intermediate RSLC, salinity was increased by 6.5 percent and 11.3 percent for intermediate and brackish marsh, respectively, over the period of analysis based upon a modeled relationship between RSLC and salinity. For high RSLC, salinity was increased by 8.0 percent for intermediate and 22.7 percent for brackish marsh. Methods and calculations for these projections were described in Sections 3.5 and 3.6 above.

7.2.2.3 FWP Condition

Indirect impacts associated with construction of the Recommended Plan in the intermediate and high RSLC scenarios would be minimized by maintaining flows in tidal bayous and streams equivalent to the FWOP condition. New levees would be constructed to reduce the risk of storm surges damages under the intermediate RSLC scenario. The temporary and permanent construction right-of-way used to determine direct impacts was drawn large enough to encompass the construction right-of-way width required for Intermediate RSLC.

Culverts would be modified as described for indirect impacts in the historic RSLC scenario to provide for increased tidal flows. Daily flooding of natural areas and wetland creation would occur as they would have under the FWOP condition. With tidal access maintained at FWOP flows, RSLC-related landscape and wetland changes to areas within the levee system would occur for FWP as they would have occurred in the FWOP condition with only minimal differences. Most of the areas vulnerable to RLSR inundation are currently undeveloped but are located immediately adjacent to ongoing current development. It is assumed that this development would continue in the FWOP condition, and therefore the alternative would cause no impacts related to induced development.

One exception to the negligible impacts described above was identified in the vicinity of the Cow Bayou surge gate structure (Figure 7-13). It is assumed that extensive construction in the gate area would permanently disrupt tidal streams and prevent daily flooding of areas in which marsh migration would have occurred under the intermediate and high RSLC scenarios. Under the Intermediate RSLC scenario, existing intermediate marsh and a small area of swamp would convert to brackish marsh and existing brackish marsh would persist and expand inland, adding 34.0 acres that was not impacted under the Historic RSLC scenario. Under the high RSLC scenario, existing intermediate and brackish marsh, and the same small area of swamp, would convert to saline marsh, and the same 34 acres of brackish marsh would be added as it migrates inland. In addition, 11.7 acres of new saline marsh would be created from inundated upland areas. Table 7-6 describes the indirect impact areas and impact assumptions for the Orange 3 CSRM Plan under the intermediate and high RSLC scenarios.

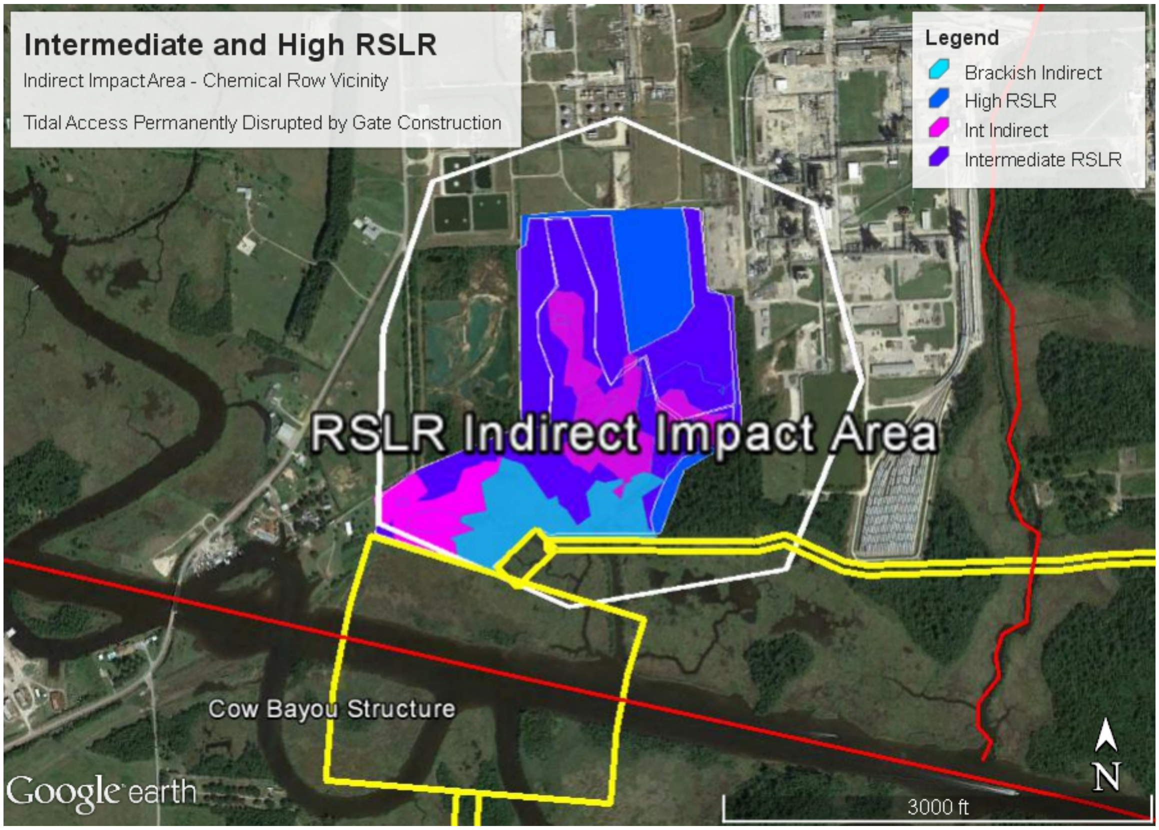

Figure 7-13. Chemical Row Indirect Impact Area, Intermediate and High RSLC

The indirect impact areas described above would be affected as tidal elevations rise under the intermediate and high RSLC scenarios, as they would remain open to the effects of RSLC. For the other indirect impact areas, impacts under the intermediate and high RSLC scenarios would be the same as those under the low RSLC scenario because tidal access would be permanently altered by construction of the Orange 3 CSRM Plan, and thus the effects would be the same across all RSLC scenarios. Table 7-1, above, includes all of the areas permanently removed from tidal access in all three scenarios, as well as the area near Chemical Row that will remain open and be affected differently under the three scenarios. Fisheries access impacts in the Cow and Adams Bayou watershed are also included. Total indirect impacts could range from about 2216 acres and a loss of 94.4 AAHUs for the low RSLC scenario, to about 2276 acres and a loss of 133.3 AAHUs for the high RSLC scenario. Mitigation will be calculated using the impacts from the Intermediate RSLC scenario which would impact about 2271 acres and result in the loss of 101.1 AAHUs.

Table 7-6. Description of Indirect Impact Areas – Intermediate and High RSLC Scenarios

		Wetland Type - TY0						
Hydrounit	Indirect Impact Area ID	Upland	Swamp	Intermd Marsh	Brackish Marsh	Water in Wetland	Group Total Acres	Impact Assumptions
Intermediate RSLR Indirect Impact Areas								
TX10	I Indirect-1 and 2			17.1		2.5	19.6	Persists as intermediate through TY30; switches to brackish TY 31-61
	B Indirect 3				14.9	3.5	18.4	Persists as brackish TY0-TY61
	New Brackish Migration	34.0					34.0	Brackish marsh gradually migrates into former upland TY0-61
	S-Indirect 2		1.9			0.0	1.9	Persists as swamp through TY30; switches to brackish scrub-shrub TY31-61
Totals			1.9	17.1	14.9	6.0	73.9	
High RSLR Indirect Impact Areas								
TX10	I Indirect-1 and 2			17.1		2.5	19.6	Persists as intermediate through TY30; converts to saline TY31-61
	B Indirect 3				14.9	3.5	18.4	Persists as brackish thru TY30; converts to saline TY31-61
	New Brackish Migration	34.0					34.0	Brackish marsh gradually migrates into former upland TY0-61
	New Saline Migration	11.7					11.7	Saline marsh gradually migrates into former uplands TY0-61
	S-Indirect 2		1.9			0.0	1.9	Persists as swamp through TY30; switches to brackish scrub-shrub TY31-61
Totals		45.7	1.9	17.1	14.9	6.0	85.6	

8 MITIGATION PLAN

8.1 MITIGATION TARGETS

The WVA modeling evaluated and quantified direct and indirect impacts of the Orange 3 element of the Recommended Plan under the intermediate RSLC scenario. The Port Arthur and Freeport and Vicinities CSRM Plans would result in no wetland impacts and require no mitigation. See Figure 2-6 for a map of the Recommended Plan. Direct and indirect impacts are summarized in Table 8-1.

Table 8-1. Recommended Plan Total Direct and Indirect Impacts

Wetland Type	Direct Impacts		Indirect Impacts				Total Impacts (acres)	Total AAHUs Lost
	Direct Wetland Impacts (acres)	AAHUs	Indirect Wetland Impacts (acres)	AAHUs	Functional Impacts (affected acres)	AAHUs		
Forested Wetlands								
Swamp	10.6	-7.2	1.9	-0.1	0.0	0.0	12.5	-7.3
Bottomland Hardwood	44.3	-30.3	12.7	-5.1	0.0	0.0	57.0	-35.4
Subtotal	54.9	-37.4	14.6	-5.2	0.0	0.0	69.5	-42.7
Coastal Marsh								
Fresh Marsh	24.3	-11.4	0.0	0.0	785.2	-18.8	809.5	-30.2
Intermediate Marsh	6.8	-4.0	19.2	-8.5	322.5	-4.1	348.5	-16.6
Brackish Marsh	74.2	-33.7	78.5	-35.2	1029.5	-27.6	1182.2	-96.5
Subtotal	105.3	-49.0	97.7	-43.7	2137.2	-50.5	2340.2	-143.3
Total Impacts*	**160.2**	**-86.5**	**112.3**	**-48.9**	**2137.2**	**-50.5**	**2409.7**	**-186.0**
* Totals may not add exactly due to rounding.								

Under the Intermediate RSLC scenario, the new levee system would negatively impact approximately 2,410 acres in Orange and Jefferson Counties. Total direct impacts (wetland loss), affecting approximately 160.2 acres, would result from construction of the levee system. Indirect impacts (wetland loss) related to construction of the levee system would impact about 112 acres. Functional loss to fisheries access would affect about 2,137 acres.

Mitigation would be needed to compensate for a loss of 7.3 AAHUs for cypress tupelo swamp impacts, 35.4 AAHUs for bottomland hardwood impacts, 30.2 AAHUs for fresh marsh impacts, 16.6 AAHUs for intermediate marsh impacts, and 96.5 AAHUs for brackish marsh impacts. Adverse impacts on ecological resources resulting from construction of the Recommended Plan have been avoided or minimized to the greatest extent practicable. Planning for the avoidance and minimization of impacts began with the layout of the first draft alignment, with additional rounds of alignment revisions to minimize wetland impacts to the greatest extent possible. The levee was located as close to the upland-wetland margin as possible to minimize wetland impacts, while also minimizing social effects and maximizing economic impacts. Remaining unavoidable impacts are fully compensated with in-kind mitigation. The quantification of required compensatory mitigation for the loss of wetlands and functional impacts to fisheries access was accomplished by applying the same WVA models that were used to determine impacts. All areas of Essential Fish Habitat (EFH) (estuarine emergent marsh, estuarine submerged aquatic vegetation, and estuarine mud/soft bottoms) impacted from construction have been captured by the impacts modeling, and compensation for those impacts will be provided by the in-kind emergent marsh mitigation plans developed with the WVA modeling and selected using the Institute for Water Resource (IWR) Planning Suite.

8.2 MITIGATION MEASURES AND ALTERNATIVES

8.2.1 Mitigation Measures

USACE and the S2G resource agency team met numerous times to identify types of mitigation measures and alternatives, agree on specific locations where these mitigation alternatives could be located, discuss assumptions underlying WVA modeling of the mitigation benefits, and select an evaluation array of mitigation alternatives. The IWR Planning Suite was utilized to perform a cost-effective/incremental cost analysis and select the Best Buy mitigation plan for each of wetland types adversely affected by the Recommended Plan. Mitigation measures considered in developing the initial array of mitigation alternatives are presented in Table 8-2.

Table 8-2. Mitigation Measures

Measure Type	Measure Description
Marsh Restoration	Fresh, intermediate and brackish marsh restoration utilizing maintenance material from the adjacent Sabine-Neches Waterway to create marsh in open water areas of degraded marsh or in former borrow pits
Hydrologic Restoration	Restoration of natural riverine, tidal, and overland flows to all wetland types by degrading levees, canal berms, roads, filling or blocking small channels which facilitate salinity intrusion, and/or installing culverts to restore connectivity.

Preservation	Preservation of forested wetland areas or emergent marsh.
Forested Wetland Restoration	Replanting cypress-tupelo or bottomland forest vegetation in degraded wetland areas or in former borrow pits, and/or removal and long term control of Chinese tallow or other invasive vegetation species.

8.2.2 Development of Mitigation Alternatives

Mitigation alternatives were developed based on one mitigation measure, or a combination of measures. In total, 161 mitigation alternatives were discussed and analyzed for inclusion in the evaluation array. These alternatives are listed and described in Attachment 6, along with the screening decision. They are located throughout the Neches and Sabine River bottomlands surrounding the Orange CSRM project area. Reasons for exclusion from the evaluation array varied but generally were based on small benefits relative to amount of compensation needed, lack of need for the restoration, incompatibility with existing land use, contamination concerns, or combination/incorporation with other mitigation alternatives.

Three measures (marsh restoration, preservation, and forested wetland restoration) were used to build the seventeen mitigation alternatives that were advanced for screening in the evaluation array. The identification numbers of the alternatives were retained from the initial array. In those cases where measures were combined into one alternative, the first (lowest) number of the measures was retained as the identifier. Mitigation alternatives 11, 12, 14 and 15 would purchase and preserve in perpetuity large areas for swamp and/bottomland hardwood mitigation north of Interstate 10 in the Sabine River bottomlands. Mitigation alternatives 17, 22, and 24 would implement hydrologic restoration for large swamps in the Tony Houseman WMA. Mitigation alternatives 27, 28, 29, 31, 32, 42, 52 and 143 would restore marsh in the Old River, Bessie Heights and Rose City areas of the Neches River bottomlands. All but three (28, 29 and 31) would also need to be purchased and preserved in perpetuity. Mitigation alternatives 28 and 29 are located in the Lower Neches River WMA's Old River and Nelda Stark Units. Mitigation alternatives 26 and 161 would preserve in perpetuity BH acreage along the upland/wetland interface of the Neches River and Scale 2 of Mitigation alternative 161 would implement a tallow removal and control program in the same area. The locations of these alternatives are shown in Figures 8-1 through 8-3.

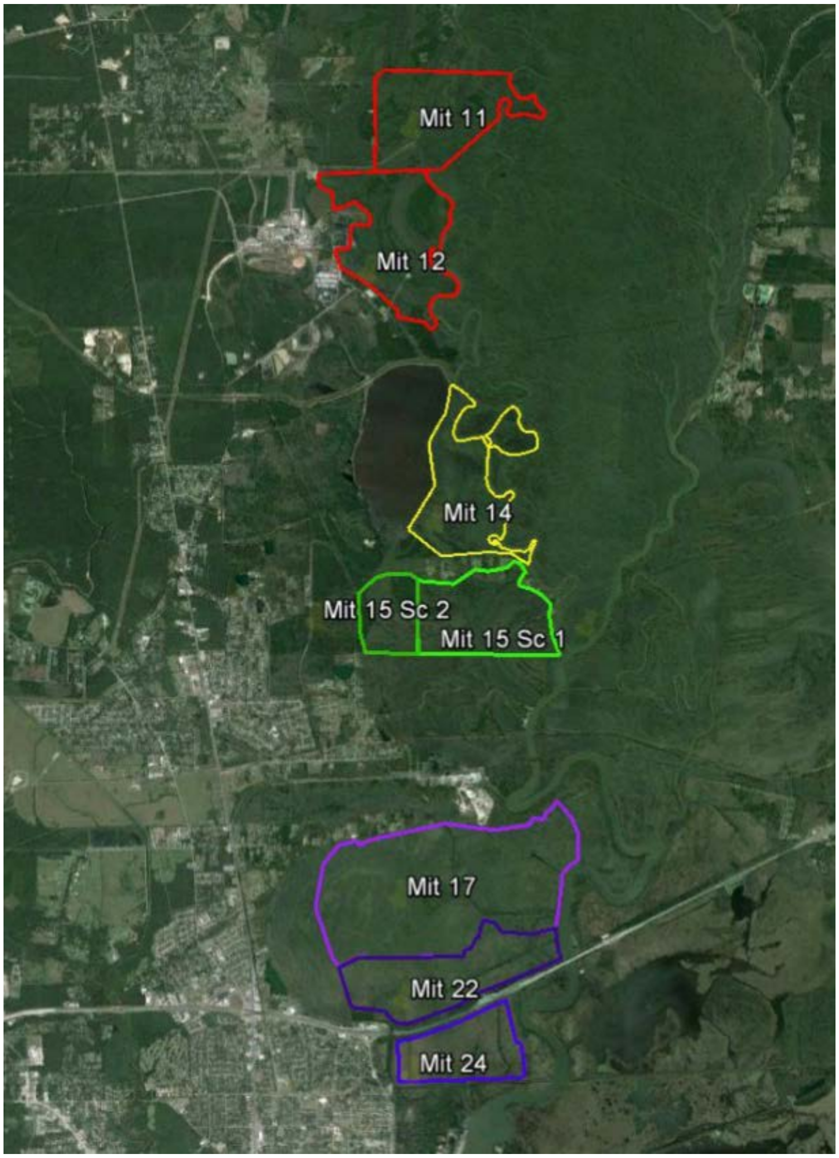

Figure 8-1. Mitigation Alternatives 11, 12, 14, 15, 17, 22, and 24

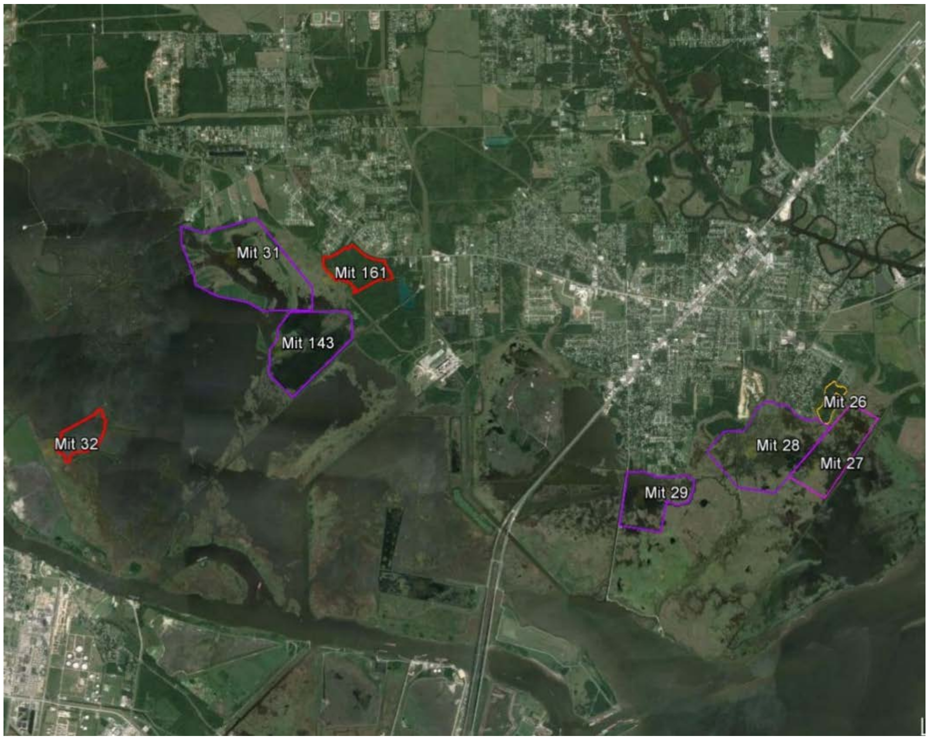

Figure 8-2. Mitigation Alternatives 27-29, 31, 32, 143 and 161

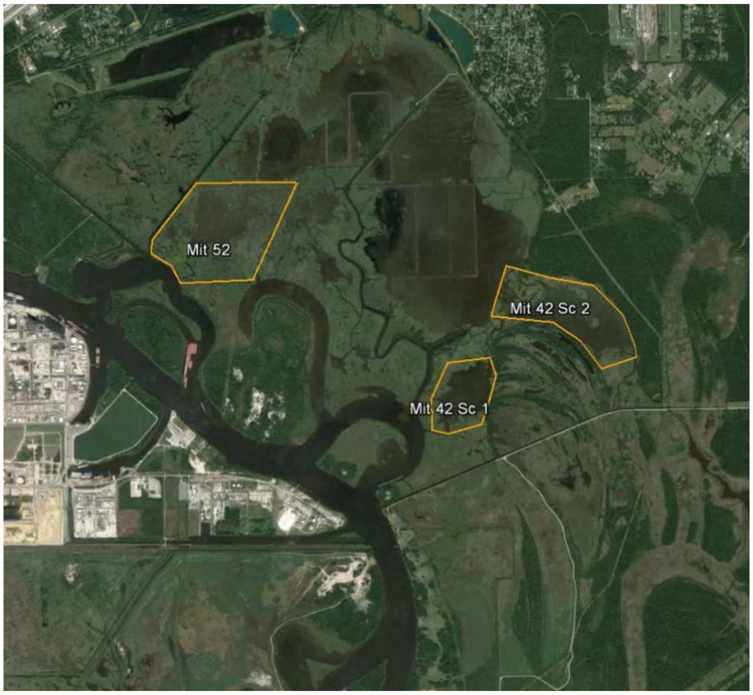

Figure 8-3. Mitigation Alternatives 42 and 52

8.3 WVA MODELING OF MITIGATION EVALUATION ARRAY

8.3.1 Assumptions for Forested Wetland Mitigation Alternatives 11, 12, 14 and 15

These mitigation alternatives, located in the Sabine River bottomlands north of Interstate 10, would preserve the forested wetlands in perpetuity, preventing projected future losses of forested wetlands in these areas. They are large tracts of largely undeveloped floodplain swamps, interspersed with ridges covered by bottomland hardwoods, and some forested uplands. Acreages of BH and swamp were tracked separately within each alternative area, and the WVA Swamp and BH models were applied to the applicable wetland acreage within each area; upland areas were excluded. Alternative 15 was developed with two scales. Scale 1 is a larger area adjacent to the Sabine River that is owned by individuals. Scale 2 in located between Scale 1 and the upland margin; it was identified as a separate scale because it is owned by a large paper products company. Lands comprising the other alternatives are either owned by individuals (11) or owned by the same paper products company (12 and 14). They were evaluated separately because of estimated sizable differences in property values.

Most of the virgin growth timber stands in the lower Sabine and Neches River floodplains were harvested in the late 19th and early 20th century, with the last harvesting occurring in the 1950s (UT, 2004; USACE, 1997). Commercial logging of managed forest stands is currently practiced in the floodplain forests north of Interstate 10 on the Sabine River. Logging may be conducted without mitigation under a Department of Army Nationwide permit if silviculture is ongoing or established and specific best management practices are followed. Given the prevalence of silviculture in the lower Sabine River watershed and the industry practice in this region of clearcutting forest stands (Stovall, 2016), WVA modeling assumed that there would be some clear-cut logging losses of the BH and swamp forested wetlands in areas not preserved by the state or Federal government. A GIS analysis of forested wetlands in this area compared indicators of logging disturbance or silviculture (i.e. clearcutting or linear plantation plantings) between 1989 and 2015 aerial images of the area. This analysis found that an average of 3.28 percent of the forested wetland areas had been disturbed prior to 1989 and an average of 4.27 percent had been disturbed between 1989 and 2015. Based on these analyses, the future without-project (FWOP) condition assumed a 3.28% loss of forested wetlands for the years TY5 through TY31, and a 4.37% loss of forested wetlands fromTY32 through TY61.

Cypress-tupelo swamp and bottomland hardwood acreages were determined with the same USGS (2014) classification utilized for the impacts mapping. The future with-project (FWP) condition assumed no loss of forested wetland acreage. The non-Federal sponsor responsible for constructing and managing the project would be responsible for acquiring areas selected for inclusion in the mitigation plan, and ensuring their preservation. Ownership of the selected mitigation areas could also be transferred to a state agency, such as TPWD. Ownership and management arrangements would be finalized during PED.

Existing conditions for stand structure and tree size were estimated using data from the most similar reference sites, as described for the impact analysis. Changes in the percentage of overstory, midstory and herbaceous or understory cover were estimated for TY 61 using the dbh growth estimates for cypress and tupelo applied for the impacts analysis. Since existing silviculture is likely to continue in the future, the FWOP condition assumed that Chinese tallow (*Triadica sebifera*) would rapidly encroach into cleared or disturbed sites over the period of analysis (USGS, 2000). Increases in Chinese tallow have been observed within canopy gaps in relatively closed-canopy, mixed-BH forests in the region (USFS, 2016; USGS, 2000). A recent field study along the Neches River in southeast Texas evaluated the effects of Chinese tallow on stand dynamics in forested ecosystems. The study found that variables associated with stand structure (density, basal area, and quadratic mean diameter) were about 25 percent higher in native bottomland hardwood plots than in tallow plots (Camarillo et. al., 2015).

To reflect this tallow effect in localized areas of Mitigation Alternatives 11, 12, 14 and 15, the growth rate of BH diameter breast height (dbh), cypress-tupelo dbh and basal area (V2 for both Swamp and BH Models) over all swamp or BH acres in each mitigation measure area were reduced by 25 percent over the 50-year period of analysis. For BH V3, midstory coverage was increased by 30 percent by TY61 in the FWOP condition to reflect increase tallow presence in the midstory. Understory coverage was assumed to drop by about 50 percent because the denser overstory would reduce light reaching the forest floor. In the BH model, V1 (Species Association) was also changed to reflect a change from Class 5 to Class 4 at the midpoint of the period of analysis. Since the presence of tallow in BH stands has been documented as reducing the diversity of overstory species (Camarillo et al 2015), the class was assumed to change from 5 to 4 at TY31, reflecting a predicted gradual drop in hard mast-producers in the overstory below 20 percent of the canopy. In the FWP condition, it is assumed that the effects of tallow on stand structure would continue as in the FWOP, even though silviculture would no longer be permitted, since the existing tallow would remain and serve as seed sources into the foreseeable future.

All of the inputs for the other variables described below were the same for both the FWOP and FWP conditions as no changes were predicted due to implementation of the mitigation alternatives. For the BH stands in Mitigation Alternatives 11 and 12, model inputs for V4 Hydrology assumed limited riverine or tidal water exchange. For Mitigation Alternatives 14 and 15, moderate riverine and tidal water exchange was assumed because they are located further downstream and are more subject to tidal influence. For all four areas it was assumed that the areas were seasonally flooded. For the swamp areas, V3 (Water Regime) assumed moderate riverine and tidal water exchange because the swamp areas occur in the low sloughs between the BH ridges, and thus experience higher flows. Flooding duration was assumed to be temporary during the growing season. The remaining variables (BH model - V5 Size of Contiguous Forested Area, V6 Surrounding Land Use, and V7 Disturbance; and Swamp Model -V4 Mean High Salinity) for all of the BH and Swamp mitigation measures were developed using the methods and data described for the impacts modeling.

8.3.2 Assumptions for Swamp Mitigation Alternatives 17, 22 and 24

These mitigation alternatives, located in Sabine River bottomland just north and south of Interstate 10, would provide hydrologic restoration of primarily cypress-tupelo swamps by removing berms which prevent and divert overland flows. All of the areas are located within the Tony Houseman Wildlife Management Area (WMA) which is jointly managed with the Texas Department of Transportation (TXDOT). The Blue Elbow Mitigation Bank was established on these lands for the sole use of TXDOT for compensatory mitigation credits needed to compensate for forested wetland impacts of highway construction projects. Implementation of any of these measures would require TXDOT approval and additional agency review. During resource agency coordination for this study, TPWD has expressed support for these restoration activities.

The berms are relicts of past logging activities. Evidence of logging in the distant past is present throughout Mitigation Alternatives 17, 22 and 24. “Star-shaped” canal patterns are discernable on satellite images and in the field throughout this area. The 2016 resource agency field visit determined that the small, radial “star-shaped” canals did not have berms adversely affecting overland flows. However, the larger, longer logging access canals were typically lined on one or both sides with side-cast berms ranging from 35 to 50 feet wide and 0.5 to 3.5 feet tall. The berms along the canal prevent overbank flooding during seasonal high tides and frequent, low elevation flooding events, preventing sediments and nutrients from routinely reaching into the swamps beyond the canal. The boundary of each area was drawn to capture the full geographic extent of the hydrologic effects of the main access canal leading into that area; this was determined by evaluating elevations of the swamp areas relative to the berm heights.

Existing conditions for BH and swamp in Mitigation Alternatives 17 and 22 were based on data collected by the S2G resource agency team at two locations near the main access canal in Mitigation Alternative 17. Existing conditions for Mitigation Alternative 24 were based on data collected in this area by the SNWW resource agency team in 2004, and augmented with observations from the 2016 field visit. For the FWOP condition, changes in stand structure (V1) were based on expected growth of the overstory and midstory, assuming the same overstory species growth rates utilized for the impacts analysis. No tallow effects were projected for swamp areas because no significant tallow presence was noted in these areas during the 2016 field visit. WVA modeling input for V2 assumed a dbh growth rate 20 percent less than optimum based on the effects of the modified hydrology. The AAHUs were calculated using the entire acreage of each alternative as the entire area was assumed to be adversely affected by the reduced flows.

The area is exposed to seasonal flows, influenced by releases from the Toledo Bend Reservoir and seasonal rain. Variable input for V3 (Water Regime) was based on observations at the alternative areas which indicate they are currently subject to limited riverine and tidal input, and surface water is present for extended periods in the growing season. Due to generally low elevations and tidal connectivity, intermediate RSLC would likely increase flow exchange in the area from low to moderate by TY61. Although the annual number of coastal flooding events for intermediate RSLR would rise from an average of 1 day per year to about 50 days per year at the projected intermediate RSLR rate (NOAA, 2015), flooding duration would remain seasonal. For V4 (Mean High Salinity during the Growing Season), salinity projections are based on a hydrodynamic-salinity model (USACE 2009) which incorporates the effects of RSLR. Salinity is estimated to increase from around 0 parts per thousand (ppt) currently to about 1-2 ppt by TY 61.

In the FWP condition, vegetation growing on berms along the major logging access canals would be removed, working from a barge in the canal, and berms would be degraded to the same elevation of adjacent marsh. The berm sediment, which is sidecast material from canal construction, would be placed in the water along the edge of the canal, slightly reducing the canal cross-sections. The resource agency field visit observed tallow on high natural ridges and levees in BH areas within Mitigation Alternative 17, but tallows did not have a significant presence in the swamp bottomlands in this area or in Mitigation Alternatives 22 and 24. The BH acreages were not included in the swamp acreage to which WVA modeling was applied. With hydrology restored to more natural conditions, optimum growth estimates equivalent to those used for the impacts analysis were applied to V1 (Stand Structure) and V2 (Stand Maturity) through TY61. FWP inputs for V3 (Water Regime) and V4 (Mean High Salinity during the Growing Season) were the same as FWOP inputs.

8.3.3 Assumptions for BH Mitigation Alternatives 26 and 161

Mitigation Alternatives 26 and 161 are BH stands located on the upland/wetland interface in the Old River and Bessie Heights areas, respectively. These alternatives would preserve the forested wetlands, preventing projected future losses of forested wetlands in these areas. No evidence of silviculture in these locations was observed in satellite images dating from 1989 to 2015, but immediately adjacent residential developments are assumed to expand and result in the loss of all BHs in both areas. Autumn satellite images show the characteristic red leaf color of tallow scattered throughout both areas. A tallow removal and control scale was included as Scale 2 of the Mitigation Alternative 161 to see if this restoration action could produce a sufficient boost in compensation to be cost effective.

Existing conditions at Mitigation Alternatives 26 and 161 for stand structure and tree size were estimated using data from the most similar reference sites, as described for the impact analysis. For the FWOP condition, assumptions about the effect of tallows on stand structure and tree growth were the same as those applied for Mitigation Alternatives 11, 12, 14 and 15. However, these effects are limited to the period between TY0 and TY20 for Mitigation Area 26 and between TY0 and TY15 for Mitigation Area 161, after which it is assumed that both BH areas would be totally lost to suburban development. The area surrounding Mitigation Alternative 161 is developing faster than Mitigation Alternative 26, and modeling team believed it would likely be developed earlier. These projections are based on growth and development patterns in the Bridge City vicinity. The FWP condition assumed no loss of forested wetland acreage through the period of analysis since the areas would be permanently preserved. Input for all of variables in the FWOP and FWP conditions were based on those developed for BH impact areas located immediately adjacent to the mitigation areas.

For Mitigation Alternatives 26 and 161, Scale 1, the FWP condition assumed that the effects of tallow on stand structure and tree growth would continue as in the FWOP, since the existing tallow would remain and serve as seed sources into the foreseeable future. For Mitigation Alternative 161, Scale 2, a tallow removal and control effort was added which assumed annual aerial application of a specific herbicide (which has minimal effects on other overstory and understory species) for 3 consecutive years, with a follow-up application after the last of the three initial applications, and repeated aerial applications of the herbicide every 5 years through the period of analysis. FWOP assumptions for inputs reflecting tallow effects for V1 (Species Association), V2 (Maturity) and V3 (Understory/Midstory) were the same as those applied for Mitigation Areas 11, 12, 14, and 15. FWP inputs for these variables also were based on the assumptions for these variables; optimum growth estimates equivalent to those used for the impacts analysis were applied through TY61.

8.3.4 Assumptions for Marsh Mitigation Alternatives 27, 28, 29, 31, 32, 42 and 52

These mitigation alternatives would restore emergent marsh in degraded marshes with large areas of open water, using maintenance material from adjacent channels of the SNWW. High levels of marsh loss have occurred on the lower Neches River where large areas of open water have developed within former marsh and swamp lands due a combination of many factors, including subsidence, logging, saltwater intrusion, oil and gas withdrawals, and sea level rise (White et.al., 1987; Morton and Paine, 1990; Sutherlin, 1997). These historical rates of loss have slowed in recent years, as described in Section 5.3. However, it was assumed that the low baseline land loss rates shown in Table 5-3 would continue in the FWOP condition, with the increase in land loss attributable to RSLC shown in Table 4-2.

For the FWP condition, marsh restoration alternatives were developed in the Bessie Heights, Old River Cove and Rose City vicinities. Areas considered for mitigation excluded areas already identified for beneficial use or mitigation in conjunction with other projects. Specifically, authorized improvements to the SNWW navigation project include the restoration of large areas within both Bessie Heights and Old River Cove marshes with the beneficial use of dredged material. In addition, areas targeted for restoration by TPWD have also been excluded, as well as private mitigation sites that could be identified. Any mitigation alternatives evaluated for this project would augment, not replace, these other restoration or mitigation activities.

Mitigation Alternatives 28, and 29 and 131 are located wholly on TPWD property. TPWD has indicated a preference that wetland impacts from the Orange 3 CSRM Plan be mitigated in areas encompassed by Mitigation Alternatives 28 and 131. Mitigation Alternatives 27, 32, 42 and 52 are located on private property. The non-Federal sponsor responsible for constructing and managing the project would also be responsible for acquiring mitigation areas selected for inclusion in the mitigation plan, and ensuring their preservation Ownership and management arrangements would be finalized during PED.

Marsh and water acreages were determined with the same USGS (2014) classification utilized for the impacts mapping (see Section 5.3). To ensure in-kind mitigation, several alternatives were developed for each marsh type that would be adversely impacted. Mitigation Alternatives 27, 28 and 29 were developed to provide compensation for impacts to brackish marsh in the Old River Cove vicinity. Mitigation Alternatives 42 (Scales 1 and 2) and 52 were developed in the fresh marsh areas of Rose City. The salinity regimes and associated marsh types in these areas match historical and current data for these areas. Mitigation Alternatives 31, 32 and 143 were developed to provide compensation for impacts to intermediate marsh. The USGS classification identified a majority of the marshes in Mitigation Alternative 31 as brackish. The resource agencies noted that this classification was determined based upon field work completed at the end of a lengthy drought. Historical and current TPWD salinity and vegetation data in adjacent areas of the Nelda Stark Unit support an intermediate marsh classification. For these reasons, the area was evaluated with the intermediate marsh model. Mitigation Alternative 143 is comprised of two adjacent leveed areas which are managed as a freshwater fishing club. If marsh were to be restored in these areas, the surrounding levees would be degraded to marsh elevation and the restored marsh type would be determined by prevailing salinities. Based on the salinity data provided by TWPD, it was determined that this area also would be modeled using the intermediate marsh model.

The construction and cost estimates assume that sediments from maintenance dredging of the adjacent SNWW would be used to restore marsh to an elevation of about 1.5 feet (NAVD88) in areas of open water within the outlined areas shown on Figures 8-2 and 8-3. This is a conservatively high elevation estimate. The target elevation for construction will be reevaluated during PED in coordination with the resource agencies, utilizing comparisons to nearby reference marshes to determine the appropriate post-settlement elevation. Temporary containment dikes, constructed with in-situ materials excavated from immediately adjacent open water areas, would hold dredged material slurry while it decants and consolidates to form new marsh in open water areas. For all of the marsh mitigation alternatives, it was assumed that marsh would be restored in 65 percent of the open water, and that sinuous channels and ponds would be created in the remaining 35 percent of open water. Dredged material would be allowed to flow into existing marsh surrounding the open water areas within the containment dikes; marsh vegetation would winnow the fine-grained material and nourish existing marsh. Temporary erosion control measures (such as concrete mats or riprap) for the containment dikes may be installed where needed.

It was assumed that construction would take 2 years (TY 1-2), beginning at the start of the 10-year construction period for the overall project. It was assumed that settlement and consolidation of the material would take 3 years (TY 3-5), and that channels and ponds would be created in TY 4-5. *Spartina patens* would be planted on 5-foot centers in TY 6, and it is assumed that 50 percent of the patens would need to be replanted in TY 7 based on TPWD's recent restoration experience in the general area. *Spartina alterniflora* would likely also establish itself in the mitigation areas within 1-2 years, as nearby seed sources are abundant. Containment dikes or temporary erosion control features would be removed in TY 6 to maximize edge for aquatic organisms to utilize exterior and interior marsh areas.

In the WVA model, V1 (Emergent Marsh) input assumed that one quarter of the total amount of marsh to be created (e.g. one quarter of the total marsh acreage determined by calculating 65 percent of the open water) would be functioning as a marsh in TY 6, and that the remainder would be functioning in TY10. For V2 (Percent SAV), it was assumed that all SAV within the mitigation area would die-off in TY 2 due to turbidity associated with dredged material placement, gradually rebound to pre-construction levels by TY 6, and increase by about 20-30 percent by TY 61. V3 (Interspersion) classes were changed in the FWP condition based on the overall percentage of marsh fill by TY 6; this generally resulted in a one or two class improvement over the FWOP condition. For V4 (percent shallow open water), it was assumed that approximately 85-95 percent of the open water remaining after dredged material placement in TY 2 would be less than or equal to 1.5 feet deep and that this would persist through TY 61 with a 5 to 10 percent decrease in shallow water, based on the background land loss rate and RSLC in each area. V5 (Salinity) values were based on the SNWW salinity modeling as described for the impacts analysis. V6 (Access Value) was based on knowledge of access to the general vicinity of the mitigation area. It was assumed to be reduced to “0” from TY 1 to TY 6 while containment dikes are in place, and then restored to the FWOP value (generally a “1’) when containment dikes would be removed and access restored.

The construction estimate assumes that shoaled material from Sabine-Neches Canal B, which extends across the north end of Sabine Lake from the mouth of the Neches River to the mouth of the Sabine River, would be used to construct mitigation alternatives 27, 28 and/or 29 in the Old River area. This is the closest segment of the SNWW to the Old River mitigation sites. This channel is not regularly dredged, so cost estimates included the full cost of maintenance dredging to hydraulically dredge the material and pump it into targeted open water areas. Maintenance material from the Neches River Channel might be used instead of, or in addition to, the Sabine-Neches Canal B material for the Old River alternatives. Material from regularly scheduled maintenance dredging of nearby reaches of the Neches River Channel is proposed for construction of mitigation alternatives 31, 32, 42, and 52. Only the incremental cost of additional hydraulic pipeline, pumping and pipe movement needed to create the marsh is included in the cost estimates for these alternatives.

SNWW sediment quality is generally of good quality and suitable for beneficial use. New work and maintenance material has already been approved for extensive beneficial use (marsh restoration) at Bessie Heights and Old River in conjunction with the authorized deepening of the Sabine-Neches Waterway (USACE, 2011). Recent testing and analysis of water and sediment in the Neches River (SOL/Atkins 2013), concluded that there is no concern with the placement of these sediments, under the guidance provided by Inland Testing Manual (EPA/USACE, 1998).

8.4 COST EFFECTIVE/INCREMENTAL COST ANALYSIS

8.4.1 Final Mitigation Alternative Array

Results of the WVA modeling for each of the mitigation alternatives are shown in Table 8-3, along with estimated real estate, construction, and monitoring/adaptive management cost for each alternative. Per-acre acquisition costs for each tract were developed by a USACE real estate appraiser. Preliminary construction costs were developed by Galveston District Engineering Division based upon the construction assumptions described above. Acquisition costs are based

Table 8-3. Mitigation Alternatives Estimated Costs

Mitigation Alternative No.	Description	Wetland Type	Total Wetland Acres	Total Estimated Real Estate Cost	Total Estimated Construction Cost	Preliminary Monitoring/ Adaptive Management Cost	Total Present Value Cost
11	Preservation	Cypress-Tupelo Swamp	291.2	$ 132,822	$ -	$ 16,000	$ 148,822
		Bottomland Hardwood	155.7				
12	Preservation	Cypress-Tupelo Swamp	207.3	$ 508,680	$ -	$ 16,000	$ 524,680
		Bottomland Hardwood	221.4				
14	Preservation	Cypress-Tupelo Swamp	291	$ 716,220	$ -	$ 16,000	$ 732,220
		Bottomland Hardwood	153.1				
15 Scale 1	Preservation	Cypress-Tupelo Swamp	213.1	$ 216,656	$ -	$ 16,000	$ 232,656
		Bottomland Hardwood	223.5				
15 Scale 2	Preservation	Cypress-Tupelo Swamp	264.8	$ 309,936	$ -	$ 16,000	$ 325,936
		Bottomland Hardwood	312.2				
17	Hydrologic Restoration	Cypress-Tupelo Swamp	1320.9	$ 918,720	$ 12,438,875	$ 19,200	$ 13,376,795
22	Hydrologic Restoration	Cypress-Tupelo Swamp	367	$ 357,060	$ 1,086,024	$ 19,200	$ 1,462,284
24	Hydrologic Restoration	Cypress-Tupelo Swamp	284	$ 199,420	$ 7,404,250	$ 19,200	$ 7,622,870
26	Purchase and Preserve	Bottomland Hardwood	34.9	$ 34,368	$ -	$ 16,000	$ 50,368
27	Marsh Restoration	Brackish Marsh	224.8	$ 69,750	$ 4,375,466	$ 315,000	$ 4,760,216
28	Marsh Restoration	Brackish Marsh	410.7	$ 128,030	$ 5,867,374	$ 315,000	$ 6,310,404
29	Marsh Restoration	Brackish Marsh	189.6	$ 60,450	$ 3,418,416	$ 315,000	$ 3,793,866
31	Marsh Restoration	Intermediate Marsh	371.5	$ 162,130	$ 7,342,385	$ 315,000	$ 7,819,515
32	Marsh Restoration	Intermediate Marsh	87.8	$ 27,466	$ 6,936,787	$ 315,000	$ 7,279,253
42 Scale 1	Marsh Restoration	Fresh Marsh	73.5	$ 45,323	$ 2,306,554	$ 315,000	$ 2,666,877
42 Scale 2	Marsh Restoration	Fresh Marsh	210.8	$ 132,553	$ 8,303,746	$ 315,000	$ 8,751,299
52	Marsh Restoration	Fresh Marsh	206.8	$ 89,010	$ 2,379,557	$ 315,000	$ 2,783,567
143	Marsh Restoration	Intermediate Marsh	305.1	$ 94,860	$ 17,611,630	$ 315,000	$ 18,021,490
161 Scale 1	Preservation	Bottomland Hardwood	112.4	$ 71,875	$ -	$ 16,000	$ 87,875
161 Scale 2	Forested Wetland Restoration (Tallow Removal & Control)	Bottomland Hardwood	112.4	$ 71,875	$ 128,040	$ 1,312,000	$ 1,511,915

on the total acreage of each tract, which in most cases is larger than the wetland acreage utilized in the WVA modeling. Acreages shown under the "Wetland Acreages" column, are those determined by the USGS wetlands classification. Preliminary monitoring and adaptive management costs were developed for each type of mitigation alternative, and the same costs were applied to all of the alternatives for each wetland type. Average annualized costs were calculated using the IWR Planning Suite Annualizer tool. For alternatives with scales (15, 42 and 161), scale 2 acreages, costs and AAHUs are cumulative amounts, representing the totals of Scale 1 and 2. Monitoring/adaptive management plans will be developed for each of the mitigation alternatives selected for inclusion in the Mitigation. The details and costs of those plans will likely differ from the preliminary assumptions applied here. The CE/ICA would still have resulted in the same best buy plan selection, because these new costs would be applied equally to all of the alternatives for each wetland type.

8.4.2 IWR-Planning Suite Application

The Mitigation Plan was selected using the certified IWR Planning Suite V 2.0 software, following instructions in the User's Guide (CDM and USACE-IWR, 2006). The IWR Planning Suite uses a cost effectiveness/incremental cost analysis (CE/ICA) to weigh the costs of mitigation plans against their nonmonetary output. Cost-effectiveness analysis is used to identify least-cost plans, and incremental cost analysis identifies the subset of cost-effective plans that are superior financial investments, called "best buys plans." Best buys plans are the most efficient plans at producing the output variable (in this case, AAHUs); they provide the greatest increase in AAHUs for the lowest incremental cost.

Mitigation alternatives advanced for final screening with the IWR Planning Suite are listed in Table 8-4. For the CE/ICA, the mitigation alternatives were coded with a letter(s) indicating wetland type (i.e, S for swamp, BH for bottomland hardwood, F for fresh marsh, I for intermediate marsh and B for brackish marsh) followed by the mitigation alternative number shown in the first column of Table 8-3 (for example, B27). In a few cases, alternatives were evaluated at different scales. The scales for S15 and BH15 (Preservation) reflected an estimated significant difference in real property costs for sections of a large area of mixed BH and Swamp immediately adjacent to the Tony Houseman WMA. The area identified as Scale 2 (western portion of Mitigation Alternative 15) is owned by a large paper products company. This alternative was of particular interest because it could be more easily incorporated into the existing WMA than the other BH/Swamp Preservation alternatives (11, 12 and 14). The scales for F42 (Marsh Restoration) were based on the assumption that construction would be accomplished sequentially, with the Scale 2 costs reflecting the additional costs needed to extend pumping from the Scale 1 area to the Scale 2 area. The cost to reach the Scale 2 would not include costs to reach the Scale 1 area, and therefore the incremental cost would be lower. The scales for BH161 assumed different solutions applied sequentially to the same area. Scale 1 would purchase and preserve the area in perpetuity; Scale 2 would restore the BH by removing and controlling Chinese tallow through the period of analysis. Mitigation outputs from the WVA models for each of the alternatives in the final evaluation array are presented in Attachment 7.

The analysis was structured to ensure that the Best Buy Plans would provide sufficient in-kind mitigation for each wetland type. To achieve this, separate planning sets were developed for swamp, BH, and each of the marsh types (fresh, intermediate and brackish). Present value costs presented in the last column are simple additions of real estate, construction and monitoring/adaptive management costs. These costs were annualized using the IWR-Plan Annualizer. Construction costs include construction of containment dikes, pumping dredged material into open water areas, dewatering, marsh plantings and containment dike removal.

Table 8-4. IWR Planning Suite Sets and Scales

Mitigation Alternative Code	Measure Description	Scale Number	Scale Acres	Habitat Benefits (AAHUs)	Avg Annual Costs ($1,000)**
Cypress Tupelo Mitigation Planning Set*					
S11	Swamp Preservation	1	291.2	13.2	$ 4.4
S12	Swamp Preservation	1	207.3	9.5	$ 16.4
S14	Swamp Preservation	1	291.0	13.1	$ 23.0
S15	Swamp Preservation	1	231.1	9.6	$ 7.1
S15	Swamp Preservation	2	282.8	11.9	$ 10.1
S17	Hydrologic Restoration-Swamp	1	1,320.9	40.0	$ 425.3
S22	Hydrologic Restoration-Swamp	1	367.0	11.1	$ 46.2
S24	Hydrologic Restoration-Swamp	1	284.0	5.8	$ 242.2
Bottomland Hardwood Mitigation Planning Set*					
BH11	BH Preservation	1	155.7	6.2	$ 4.4
BH12	BH Preservation	1	221.4	6.7	$ 16.4
BH14	BH Preservation	1	153.1	6.8	$ 23.0
BH15	BH Preservation	1	223.5	9.5	$ 7.1
BH15	BH Preservation	2	312.2	13.4	$ 10.1
BH26	BH Preservation	1	34.9	18.4	$ 1.3
BH161	BH Preservation	1	112.4	49.3	$ 2.5
BH161	BH Restoration -Tallow Control	2	112.4	55.7	$ 14.2
Fresh Marsh Mitigation Planning Set					
F42	Fresh Marsh Restoration	1	73.5	14.6	$ 79.1
F42	Fresh Marsh Restoration	2	210.8	45.0	$ 197.9
F52	Fresh Marsh Restoration	1	206.8	33.4	$ 82.9
Intermediate Marsh Mitigation Planning Set					
I31	Intermediate Marsh Restoration	1	371.5	60.4	$ 243.1
I32	Intermediate Marsh Restoration	1	87.8	22.7	$ 225.9
I143	Intermediate Marsh Restoration	1	305.1	75.6	$ 567.6
Brackish Marsh Mitigation Planning Set					
B27	Brackish Marsh Restoration	1	224.8	40.2	$ 145.7
B28	Brackish Marsh Restoration	1	410.7	58.5	$ 195.1
B29	Brackish Marsh Restoration	1	189.6	41.9	$ 114.0
*	Total cost of tracts 11, 12, 14 and 15 used for both swamp and BH measures because swamp and bottomland hardwood are intermingled in each tract.				
**	Annualized using IWR-Plan Annualizer at rate of 3.125% over 60 year period of analysis; first cost of construction entered at year 5 (midpoint of 10 year construction period); monitoring/adaptive management costs added in year cost expected to be incurred.				

The costs were entered into the Annualizer program in the year they are projected to be expended. For the marsh restoration alternatives, regular field inspections would be held during the construction period to ensure attainment of appropriate marsh elevations and vegetation growth. It was assumed that 50 percent of the *Spartina paten* plants would require replanting in TY 7 to ensure establishment of the marsh vegetation. Subsequent to construction, satellite photo analysis and field vegetation surveys would be conducted every 5 years through the period of analysis. For the forested wetland areas to be preserved in perpetuity, it was assumed that regular inspection visits would be conducted through the period of analysis. O&M costs were not included as they are believed to be negligible. Neither the preservation areas nor the marsh restoration areas include construction features that would require periodic maintenance.

8.4.3 Selection of Best Buy Plans

The result of the incremental analysis is illustrated on Table 8-5. The IWR Planning Suite identified multiple best buy plans for each of the wetland types (8 each for Swamp for BH; 3 each for fresh, intermediate and brackish marsh). Column 3 “Best Buy Plan #” identifies the plan number from the Planning Suit’s “Incremental Cost of Best Buy Plans” table. Plan 1 is always the No-Action Plan, with no cost and no output. For all wetland types, the Best Buy Plan with the lowest incremental cost (Plan 2) was selected for inclusion in the Mitigation Plan. The fourth column “Best Buy Plans” lists all of the wetland alternative codes in that planning set for the indicated Best Buy Plan, with a “0” following those that were not included in the Best Buy Plan, and a “1” after those codes which are included. The codes with the number “1” indicator are shown in bold. Each Plan 2 provided compensation greater than the target for that specific wetland type. Other Best Buy plans were evaluated to determine if they were worth the additional cost. When considered together, the Best Buy plans for all of the affected wetland types provide 262.9 AAHUs of compensation for a total mitigation target of -186.0 AAHUs.

Table 8-5. Best Buy Plans

Wetland Type	Mitigation Target	Best Buy Plan #	Best Buy Plan(s)	Best Buy Alternatives	AAHUs	Average Annual Cost ($1,000)
Swamp	-7.3	2	**S111**S120S140S150H170H220H240	S11	13.2	$ 4.4
Bottomland Hardwood	-35.4	2	BH110BH120BH140BH150BH260**BH1611**	BH161, Scale 1	49.3	$ 2.5
Fresh Marsh	-30.2	2	F420**F521**	F52	33.4	$ 82.9
Intermediate Marsh	-16.6	2	**I311**I320I1430	I31	60.4	$ 243.1
Brackish Marsh	-96.5	3	B270**B281B291**	B28 and B29	100.4	$ 310.1
Totals	-186.0				262.9	$ 643.0
*S11 provides bottomland hardwood (BH) benefits of 6.2 AAHUs at no additional cost because BH are intermingled with swamp.						

8.5 MITIGATION PLAN

The mitigation plan for the S2G Recommended Plan consists of preservation of 559.3 acres of swamp and bottomland hardwoods in Mitigation Area 11 in the bottomlands of the Sabine River, and in Mitigation Area 161 on the upland/wetlands margin of the Neches River in the Bessie Heights area (Figures 8-4 and 8-5). In addition, the plan would restore 452.8 acres of marsh (fresh, intermediate and brackish) and shallow ponds and sinuous channels within the marsh in Mitigation Areas 28, 29, 31 and 52 (Figures 8-6, 8-7 and 8-8). The mitigation plan is summarized in Table 8-6 and summarized below.

Table 8-6. Mitigation Plan Summary

Mitigation Area ID	Wetland Type	Total Wetland Acres Preserved in Perpetuity	Total Restored Wetland (acres)*	Total Compensation (AAHUs)	Mitigation Target (AAHUs)
11	Cypress-Tupelo Swamp	291.2		13.2	-7.3
	Bottomland Hardwood	155.7		6.2	
161	Bottomland Hardwood	112.4		49.3	-35.4
	Subtotal	559.3		68.7	-42.7
28	Brackish Marsh	**	133.2	58.5	-96.5
29	Brackish Marsh	**	106.0	41.9	
31	Intermediate Marsh	**	150.7	60.4	-16.6
52	Fresh Marsh	206.8	62.9	33.4	-30.2
	Subtotal	206.8	452.8	194.2	-143.3
	Total	**766.1**	**452.8**	**262.9**	**-186.0**

* Total acres of restored marsh and water

** Property already owned by TPWD so it is already in preservation status.

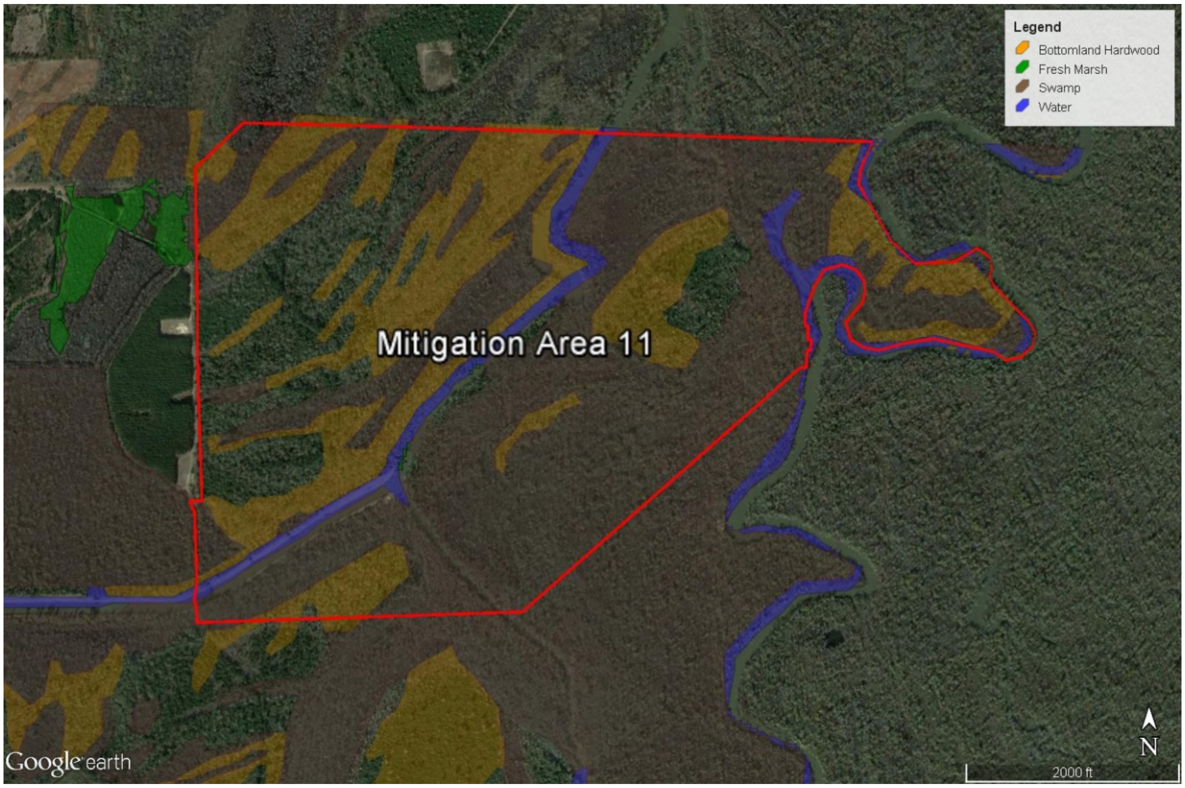

Figure 8-4. Mitigation Area 11

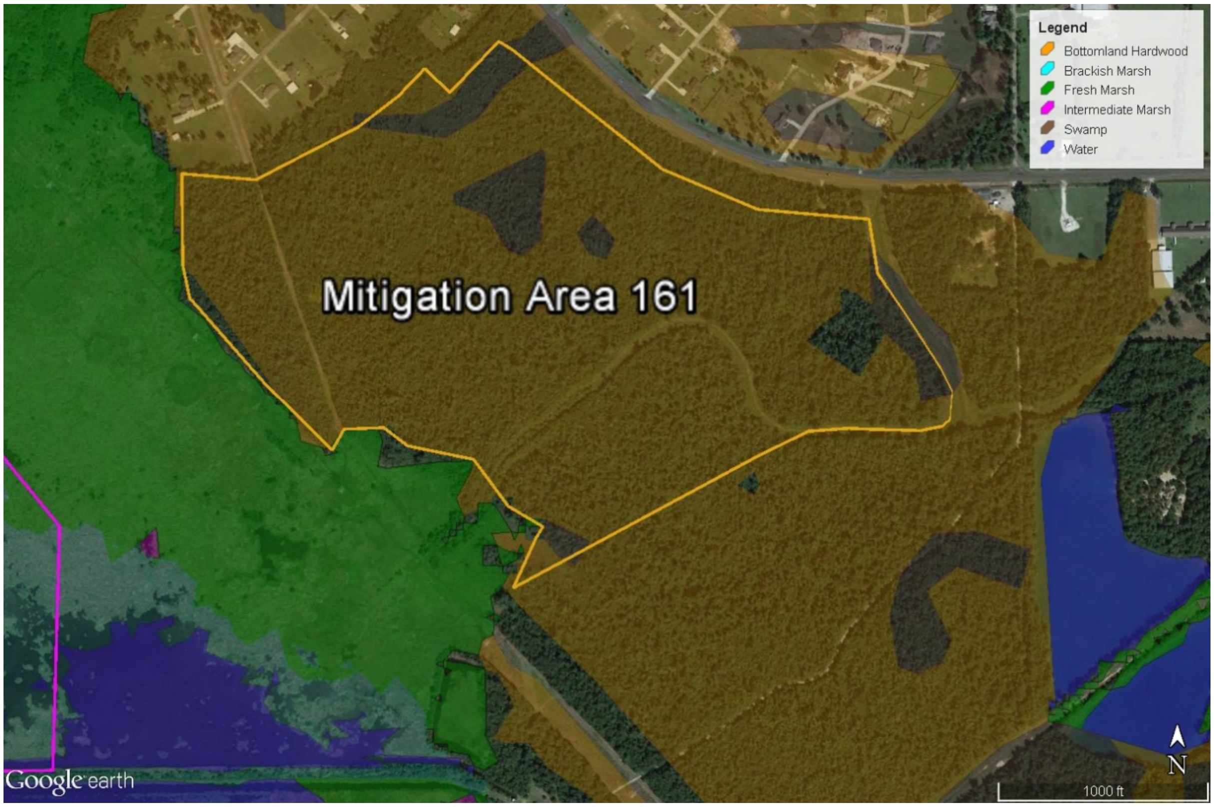

Figure 8-5. Mitigation Area 161

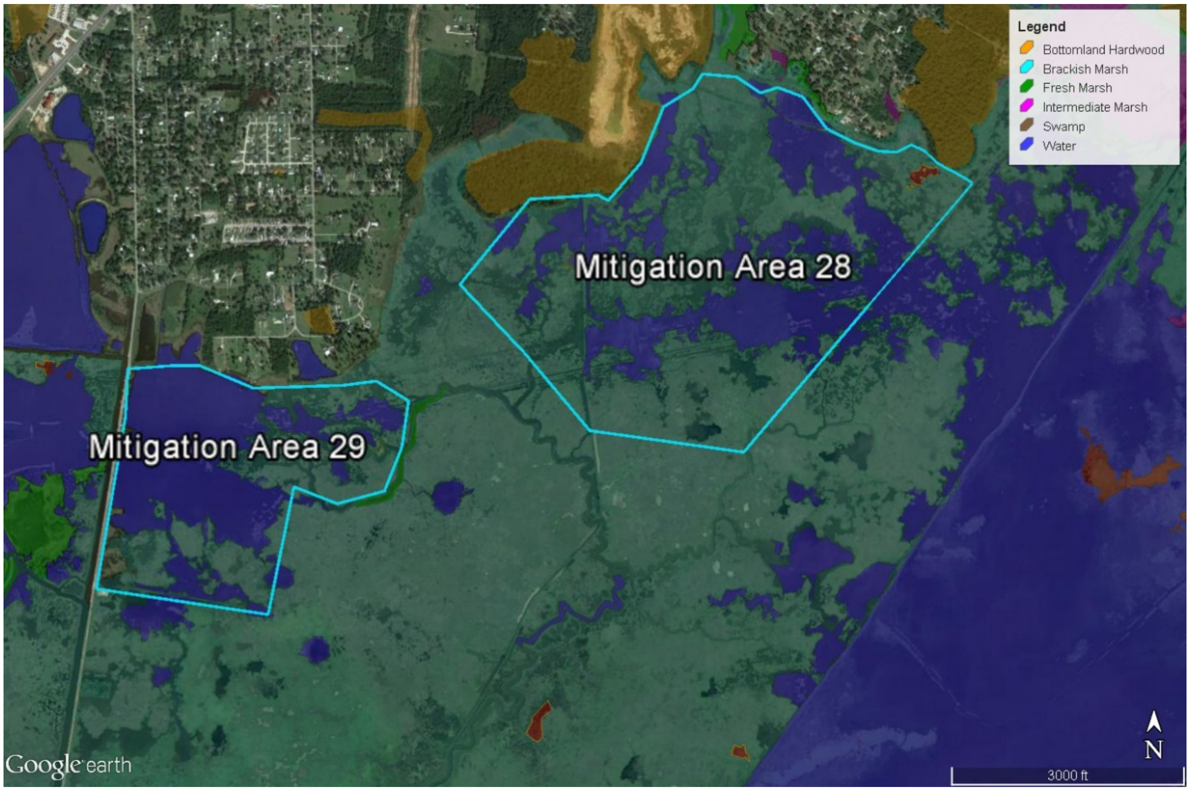

Figure 8-6. Mitigation Areas 28 and 29

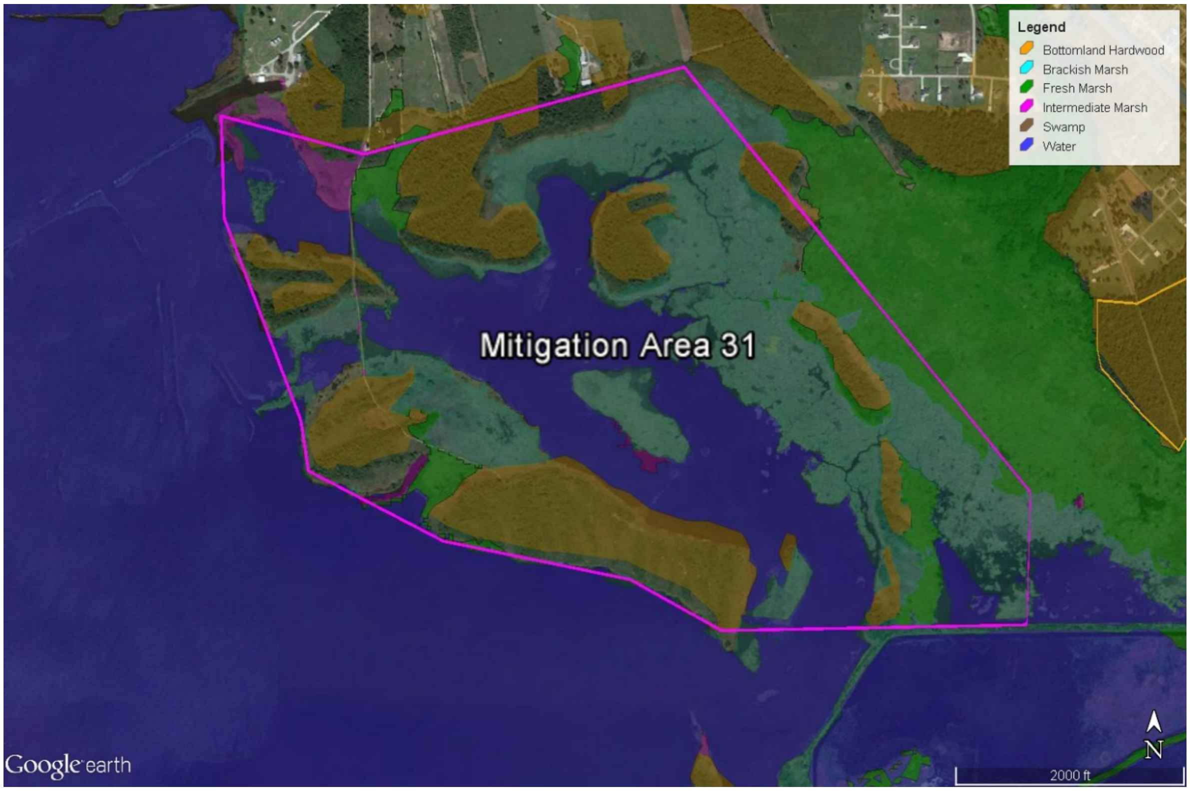

Figure 8-7. Mitigation Area 31

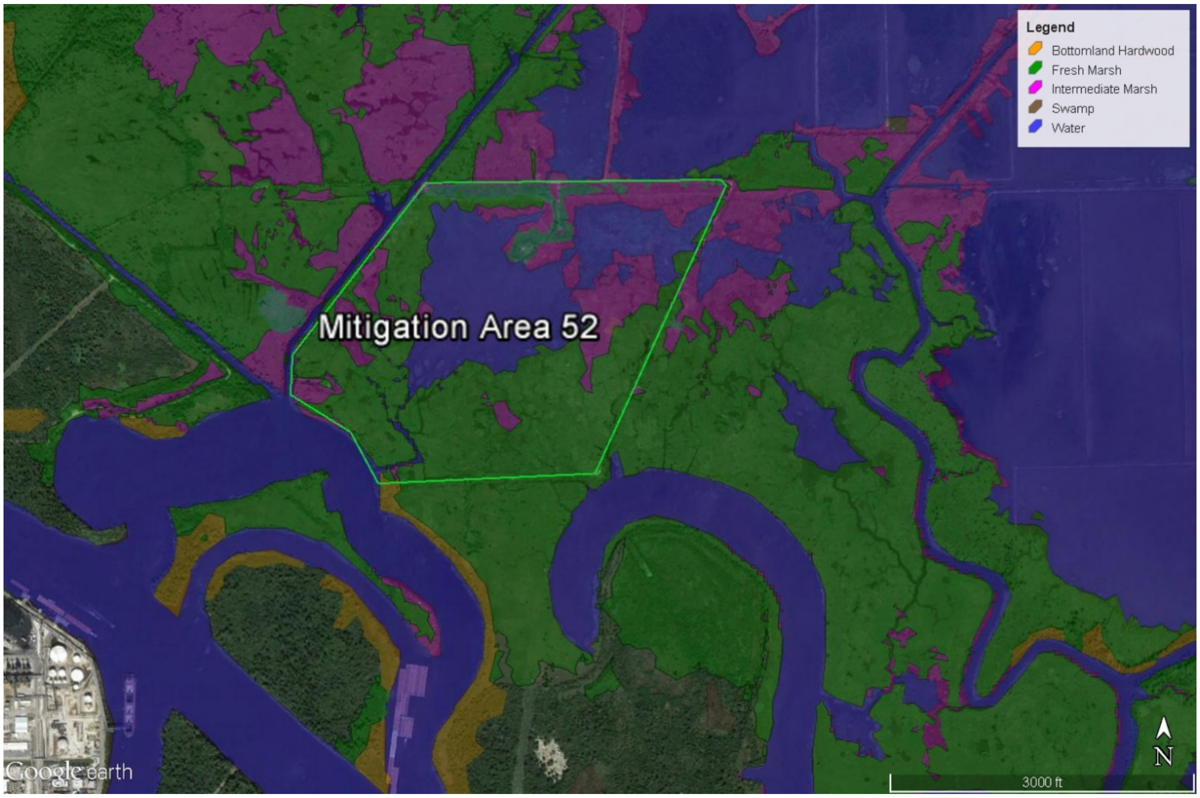

Figure 8-8. Mitigation Area 52

8.5.1 Forested Wetlands Mitigation

This plan would provide compensatory mitigation of 13.2 AAHUs for impacts of -7.3 AAHUs to cypress-tupelo swamp, and it would also provide incidental benefits of 6.2 AAHUs to bottomland hardwoods. Mitigation Area 161 would provide 49.3 AAHUs to compensate for -35.4 AAHUs total impacts to bottomland hardwoods. The mitigation plan consists of preservation in perpetuity of approximately 447 acres of swamp and bottomland hardwoods in Mitigation Area 11 in the bottomlands of the Sabine River and about 112.5 acres of bottomland hardwood forest in Mitigation Area 161 on the upland/wetlands margin of the Neches River in the Bessie Heights area. These lands would be acquired during the PED or construction phases by the NFS for project implementation. Baseline surveys of the forested wetland mitigation areas would be conducted during PED to determine the extent of Chinese tallow cover of selected areas. Extensive existing tallow cover is not anticipated, but baseline information is needed to track changes over the 50-year period of analysis.

A perpetual conservation easement would be placed on the property to ensure that the forested wetlands are protected and preserved in perpetuity. The NFS would manage the property and grant USACE right of entry for monitoring to verify preservation through the 50 year period of analysis. In lieu of managing the property itself, the NFS may arrange to transfer the property to a state conservation agency, such as TPWD.

8.5.2 Emergent Marsh Mitigation

Mitigation Areas 28 and 29 would provide 100.4 AAHUs to compensate for impacts of -96.5 AAHUs to brackish marsh. Mitigation Area 31 would provide 60.4 AAHUs to compensate for impacts of -16.6 to intermediate marsh. Mitigation Area 52 would provide 33.4 AAHUs to compensate for impacts of -30.2 AAHUs to fresh marsh. The mitigation plan would restore approximately 63 acres of fresh marsh and associated shallow ponds and sinuous channels in Mitigation Area 52, 151 acres of intermediate marsh and associated waters in Mitigation Area 31, and 239 acres of brackish marsh and associated waters in Mitigation Areas 28 and 29. Mitigation Areas 28, 29 and 31 are owned by TPWD. An interagency agreement would be negotiated with TPWD during the PED phase that would allow USACE to construct and monitor the mitigation features. Mitigation Area 52 is privately owned; acquisition and preservation of this area would be accomplished as described for Mitigation Areas 11 and 161.

Shoaled sediments from maintenance dredging of the adjacent deep-draft navigation channels of the Sabine-Neches Waterway (SNWW) would be used to restore marsh in areas of open water within the outlined areas shown on Figures 8-6 through 8-8. Marsh would be constructed to target elevations determined during the PED phase in coordination with the resource agencies, utilizing comparisons to nearby reference marshes to establish the optimum post-settlement elevation range.

The construction estimate assumes that shoaled material from SNWW's Sabine-Neches Canal B would be used to construct mitigation areas 28 and 29 as this is the closest segment of the SNWW. This channel is not regularly dredged, so cost estimates include the full cost of maintenance dredging to hydraulically dredge the material and pump it into targeted open water areas. Maintenance material from the SNWW's Neches River Channel might be used instead of, or in addition to, the Sabine-Neches Canal B material for these areas. Material from regularly scheduled maintenance dredging of nearby reaches of the Neches River Channel is proposed for construction of mitigation areas 31 and 52. Only the incremental cost of additional hydraulic pipeline, pumping and pipe movement needed to create the marsh is included in the cost estimates for these alternatives.

Existing canals provide access routes for floating hydraulic pipelines into all of the mitigation areas. If deepening of the access canals is required, that material would be used to restore marsh elevation in the mitigation areas or in adjacent open water areas acceptable to resource agencies.

Temporary board roads may be constructed along access corridors and staging areas wherever emergent marsh exists. Fill material may be deposited to offset damage to underlying marsh caused by soil compression under the board road. Details of construction/flotation access corridors and staging areas would be developed during the PED phase. Every effort would be made to avoid and minimize environmental impacts to the extent practicable. Any unavoidable wetland impacts would be determined in consultation with resource agencies and the mitigation areas would be enlarged as needed to compensate for impacts which exceed AAHUs provided by the Best Buy Mitigation Plans.

Temporary containment dikes, constructed with in-situ materials excavated from immediately adjacent open water areas, would hold dredged material slurry while it decants and consolidates to form new marsh platforms in open water areas. For all of the marsh mitigation alternatives, it was assumed that marsh would be restored in 65 percent of the open water, and that sinuous channels and ponds would be created in the remaining 35 percent of open water. Dredged material would be allowed to flow into existing marsh surrounding the open water areas within the containment dikes; marsh vegetation would winnow the fine-grained material and nourish existing marsh. Temporary erosion control measures (such as concrete mats or riprap) for the containment dikes may be installed where needed.

Construction of the mitigation areas would begin as soon as possible after project construction is initiated. Construction would need to proceed on several areas concurrently because it is estimated that the total construction period for each area, from initiation through establishment of marsh vegetation would be 8 years. It is estimated that initial construction of each area would take 2 years; settlement and consolidation of the dredged material would take up to 3 years; and channels and ponds would be created within 4-5 years of beginning construction. Containment dikes or temporary erosion control features would be removed in the sixth year of the construction period to encourage marsh plant growth and to maximize edge for aquatic organisms. *Spartina patens* would be planted on 5-foot centers in the year following completion of pond/channel construction, and replanted the following year as needed. It is also expected that *Spartina alterniflora* and other native wetland vegetation would grow in the mitigation areas within 1-2 years, as nearby seed sources are abundant. Invasive and nuisance vegetation would be removed in the last year of the mitigation construction period to facilitate growth of native vegetation over the restored marsh areas.

8.5.3 Mitigation Summary

In total, the mitigation plan would provide 262.9 AAHUs to fully compensate for losses totaling –186.0 AAHUs due to direct and indirect impacts of the Recommended Plan. This mitigation plan fully compensates for all impacts to significant resources, as required by Section 2036(a) of WRDA 2007 and ER 1105-2-100 (USACE, 2000). In addition, Mitigation Areas 28, 29 and 31 complement on-going state conservation and restoration actions of TPWD in the Lower Neches River WMA, as encouraged by Section 1040 of WRDA 2014. The plan also fulfills recommendations by USFWS (August, 2016), and letters from EPA (Oct 30, 2015), NMFS (October 26, 2015), TCEQ (October 21, 2015) and TPWD (October 26, 2015). However, EPA Section 404 "CWA" comments (provided as an attachment to their Oct 30, 2015 letter) indicate that "preservation only" mitigation plans are the "lowest priority, and thus least desirable option." No other resource agencies provided similar comments indicating that "preservation only" was the least desirable solution.

A Monitoring and Adaptive Management Plan for the Mitigation Plan has been developed and is presented in Appendix P of the FIFR-EIS. Monitoring/adaptive management measures and costs (see Table 8-3) and total mitigation costs (see Table 8-5) were developed for screening purposes only. Changes in final costs would apply proportionately to all mitigation alternatives for each wetland type, and thus would not affect plan selection. Final plans and costs are presented in Appendix P. In addition, Appendix Q presents sensitivity analyses of the WVA coastal marsh models using a sensitivity spreadsheet prepared by the ERDC Environmental Lab. These sensitivity analyses provide additional information to assist in the investigation of several unresolved issues related to the suitability graphs for Variables 1, and 2, and the aggregation method used to combine the marsh habitat units and open water habitat units.

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ATTACHMENT 1
ECOPCX MEMO – APPROVAL TO USE WVA MODELS

ATTACHMENT 2
HQUSACE MEMO – SINGLE USE APPROVAL FOR WVA MARSH MODEL

ATTACHMENT 3
WVA MODEL OUTPUT OF DIRECT IMPACTS

ATTACHMENT 4
FISHERIES FRIENDLY DESIGN CONSIDERATIONS

ATTACHMENT 5
WVA MODEL OUTPUT OF INDIRECT IMPACTS

ATTACHMENT 6
INITIAL ARRAY OF MITIGATION ALTERNATIVES

ATTACHMENT 7
WVA MODEL OUTPUT – FINAL ARRAY OF MITIGATION ALTERNATIVES

ATTACHMENT 1
ECOPCX MEMO – APPROVAL TO USE WVA MODELS

DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

REPLY TO
ATTENTION OF:

CEMVD-PD-N 07 April 2014

MEMORAMDUM FOR CECW-SWD (Gore)

SUBJECT: Wetland Value Assessment Models – Marsh Model, Recommendation for Single-use Approval on Sabine Pass to Galveston Bay, Texas, Coastal Storm Damage Risk Management and Ecosystem Restoration Feasibility Study

1. References

a. Engineering Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.

b. Coastal Marsh Community Models, CWPRRA Wetland Value Assessment Methodology, 19 March 2010 (Encl 1)

c. Final Model Review Report for the Wetland Value Assessment Models, dated 31 August 2010, Battelle Memorial Institute (Encl 2)

d. CECW-P Memorandum dated 28 Feb 2012 Subject: Wetland Value Assessment Models – Costal Marsh Model Version 1.0- Approval for Use (Encl 3)

e. Sample output of sensitivity analyses, Analysis of the WVA Model Outputs for the Mitigation of Lake Pontchartrain and Vicinity (LPV) and West Bank and Vicinity (WBV) projects of the Hurricane Storm Damage Risk Reduction System. ERDC Environmental Lab, dated 28 August 2011 (ftp://ftp.usace.army.mil/usace/mvd/ECO-PCX/Model Certification/WVA/WVA_Mitigation_Sensitivity082911.pdf)

2. The National Ecosystem Planning Center of Expertise (ECO-PCX) recommends single-use approval of the Wetland Value Assessment (WVA) Coastal Marsh Community Models 1.0 on the Sabine Pass to Galveston Bay, Texas, Coastal Storm Damage Risk Management and Ecosystem Restoration Feasibility Study. The Coastal Marsh Community model is one of seven WVA community models that were developed by the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Environmental Work Group, an interagency team including US Fish and Wildlife Service, National Marine Fisheries Services, US Environmental Protection Agency, Natural Resources Conservation Service, USACE, and Louisiana Office of Coastal Protection and Restoration. The WVA Community model point of contact is Mr. Kevin Roy, US Fish and Wildlife Service, Lafayette Ecological Services Field Office.

3. The Coastal Marsh Community Models consist of sub-models for fresh marsh, brackish marsh/intermediate and saline marsh. The three sub-models have the same variables, but there are variations in the form of the suitability graphs and aggregation formulas. Model documentation consists of the Coastal Marsh Community Models (Encl 1) and 3 Excel spreadsheets (one for each sub-community). The Coastal Marsh Models were approved for use on a specific list of New Orleans District studies by CECW-P

memorandum dated 28 February 2012 (Encl 2). The subject project was not included in this list of projects as the ECO-PCX not coordinate with the Galveston District regarding anticipated use of the WVA Marsh Models in SWG.

4. Battelle Memorial Institute conducted a review of all the WVA community models and associated spreadsheets to assess the technical quality and usability of the model. Review results are found in the Final Model Review Report for the Wetland Value Assessment Models dated 31 August 2010 (Enclosure 3). The models were reviewed in accordance with EC 1105-2-412 Assuring Quality of Planning Models. The model review panel included 6 individuals with expertise in Habitat Evaluation Procedures, planning, hydraulic engineering, coastal wetland ecology, coastal ecosystems, and software programming/spreadsheet auditing. All panel members had PhDs in relevant fields of study.

5. Technical Quality. The recommended models meet the technical quality criterion. The models are based on the well-established contemporary theory that habitat quality can be estimated using key physical parameters. The model represents the key critical components of the system and properly incorporates key analytical requirements with the exception of Sea Level Rise. The model can be used to assess impacts of Sea Level Rise through separate model runs for each sea-level rise scenario. The model documentation has been revised to include literature citations and assumptions to support the selection, form and aggregation of the model variables. The model is in line with USACE policies and accepted procedures. It doesn't include any non-compliant components. The spreadsheet formulas were thoroughly checked for accuracy.

6. There are a few of unresolved issues related to the technical quality of the model. The unresolved issues are related to the form of suitability graphs for Variables 1, 2 and 3 and the aggregation methods used to combine the marsh habitat units and open water habitat units for each sub-model. The interagency user group and the ECO-PCX are working together to increase understanding of the sensitivity of the model to the unresolved issues and the impact the model differences may have on decision-making.

The PDT is directed to conduct sensitivity analyses for application of the marsh models to the subject project using the sample sensitivity analysis and spreadsheets prepared by ERDC Environmental Lab (Reference e). A summary of the sensitivity analyses should be presented in the project report or appendices. The Agency Technical Review team will be charged with reviewing the adequacy and findings of the sensitivity analysis.

7. The ECO-PCX planned to work with the users group and ERDC to compile findings of multiple sensitivity analyses and describe the impact the unresolved issues have on decision-making and facilitate resolution of issues. Progress on this effort has been slow due to inactivity on numerous studies that planned to use these models.

8. System Quality. Excel spreadsheets are used to run the model. Significant improvements were made to the spreadsheets in response to the model review. All spreadsheets are computationally correct, have a notes sheet with instructions, cue users for input including units, have data validation for input cells, and all non-input cells are locked for editing.

9. Usability. The model meets the usability criteria. The model inputs are readily available and model outputs are easily understandable and useful in supporting USACE civil works planning activities. The model is transparent – calculations and outputs can be easily verified. The user documentation is available and user friendly. The spreadsheets are also user-friendly. While formal training is not currently available, members of the CWPPRA Environmental Work Group provide on-the-job training to new and junior staff, as needed.

10. In summary, the ECO-PCX recommends single use approval of Wetland Value Assessment Coastal Marsh Community Model 1.0 on the Sabine Pass to Galveston Bay, Texas, Coastal Storm Damage Risk Management and Ecosystem Restoration Feasibility Study. Model application shall address model sensitivity associated with Variables 1-3 and the marsh/open water aggregation methods. Please notify the ECO-PCX of the findings of the Model Certification Panel.

Encls (3)

Jodi K. Creswell
Operational Director, Ecosystem Restoration
Planning Center of Expertise

CF:
CF (without enclosures):
CECW-PC (Coleman, Matusiak, Bee, Ware)
CECW-CP (Kitch, Hughes)
CECW-PB (Carlson)
CECW-SWD (Haberer, Brown)
CESWD-PDP (Clay, Conley, Johanning, Kelly, Varghese)
CESWF-PEC (Verwers)
CESWF-PEC-T (Davee)
CESWF-PEC-P (Laird)
CESWF-PEC-PF (Willey, Heinly)
CESWF-PEC-TN (Stokes, Murphy, Sims)
CEMVD-PD-N (Wilbanks, Lachney, Creswell)
CENAD-PD-X (Cocchieri)
CEERD-EE-E (Fischenich)
CEMVN-PDN-CEP (Dayan)
CEMVP-PD-P (Richards)

ATTACHMENT 2
HQUSACE MEMO – SINGLE USE APPROVAL FOR WVA MARSH MODEL

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P 6 May 2014

MEMORANDUM FOR MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: Recommendation for Single-use Approval of the Wetland Value Assessment (WVA) Coastal Marsh Community Models for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Damage Risk Management and Ecosystem Restoration Feasibility Study

1. The HQUSACE Model Certification Panel has reviewed the WVA marsh model in accordance with EC 1105-2-412 and has determined that the model and its accompanying documentation are sufficient to approve the model for use on the Sabine Pass to Galveston Bay, Texas, Coastal Storm Damage Risk Management and Ecosystem Restoration Feasibility Study. Adequate technical reviews have been accomplished and the HQUSACE panel has considered the assessments of the technical reviews and the recommendations of the ECO-PCX in making this determination.

2. The Coastal Marsh Community Models consist of sub-models for fresh marsh, brackish marsh/intermediate and saline marsh. The three sub-models have the same variables, but there are variations in the form of the suitability graphs and aggregation formulas. Model documentation consists of the Marsh Community Models and three Excel spreadsheets (one for each sub-community). Several unresolved issues exist related to the suitability graphs for Variables 1, 2 and 3 and the aggregation methods used to combine the marsh habitat units and open water habitat units for each sub-model. The model developers and the ECO-PCX are working together to resolve these issues and to evaluate the potential effects of the model outputs on the planning process.

3. In response to the unresolved issues discussed in paragraph 2 above, the Sabine to Galveston study is directed to conduct sensitivity analyses for application of the marsh models project using the sample sensitivity analysis and spreadsheets prepared by ERDC Environmental Lab. These sensitivity analyses shall be coordinated with the ECO-PCX. In addition, a summary of the sensitivity analyses should be presented in the Sabine to Galveston project report. The Agency Technical Review team will be charged with reviewing the adequacy and findings of the sensitivity analyses.

APPLICABILITY: This approval for use of the WVA is limited to the subject study.

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

ATTACHMENT 3
WVA MODEL OUTPUT OF DIRECT IMPACTS

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Direct Impacts
Cypress-Tupelo Swamp Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
0.3	**S2G S-1 Recommended Plan Impacts Bessie Heights 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project AAHUs=	0.19	0.00	0.18	0.19
	Net Benefit (FWP - FWOP)=	-0.18	0.00	-0.18	-0.18
0.35	**S2G S-2 Recommended Plan Direct Impacts Old River**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project AAHUs=	0.24	0.00	0.24	0.24
	Net Benefit (FWP - FWOP)=	-0.24	0.00	-0.24	-0.24
3.81	**S2G S-3 Recommended Plan Impacts Cow Bayou 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.05	0.00	0.05	0.05
	B. Future Without Project AAHUs=	2.78	0.04	2.77	2.79
	Net Benefit (FWP - FWOP)=	-2.73	0.04	-2.74	-2.72
1.94	**S2G S-4 Recommended Plan Impacts Adams Bayou 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.03	0.00	0.03	0.03
	B. Future Without Project AAHUs=	1.18	0.01	1.18	1.19
	Net Benefit (FWP - FWOP)=	-1.16	0.01	-1.16	-1.16
4.13	**S2G S-5 Recommended Plan impacts Blue Elbow 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.06	0.00	0.06	0.06
	B. Future Without Project AAHUs=	2.85	0.02	2.85	2.86
	Net Benefit (FWP - FWOP)=	-2.79	0.02	-2.80	-2.79

0.11	S2G S-6 Recommended Plan Impacts Port Arthur Addition 2016		Statistics		
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT		**SD**	**95% C.I.**	
				Lower	**Upper**
	A. Future With Project AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project AAHUs=	0.07	0.00	0.07	0.07
	Net Benefit (FWP - FWOP)=	-0.07	0.00	-0.07	-0.07

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Direct Impacts
Bottomland Hardwood Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
9.34	**S2G BH-1 Recommended Plan Impacts Bessie Heights 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.99	0.00	0.99	0.99
	B. Future Without Project AAHUs=	7.12	0.02	7.12	7.13
	Net Benefit (FWP - FWOP)=	-6.13	0.02	-6.14	-6.13
19.62	**S2G BH-2 Recommended Plan Impacts Old River 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	2.11	0.00	2.11	2.12
	B. Future Without Project AAHUs=	17.12	0.03	17.11	17.12
	Net Benefit (FWP - FWOP)=	-15.00	0.03	-15.01	-15.00
9.34	**S2G BH-3 Recommended Plan Impacts Cow Bayou 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	1.01	0.00	1.01	1.01
	B. Future Without Project AAHUs=	7.44	0.02	7.43	7.44
	Net Benefit (FWP - FWOP)=	-6.43	0.02	-6.43	-6.42
4.27	**S2G BH-4 Recommended Plan Impacts - Adams Bayou Unit 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.42	0.00	0.42	0.42
	B. Future Without Project AAHUs=	2.25	0.03	2.24	2.25
	Net Benefit (FWP - FWOP)=	-1.83	0.03	-1.84	-1.83
1.28	**S2G BH-5 Recommended Plan Impacts - Blue Elbow 2016**		**Statistics**		
			SD	**95% C.I.**	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project AAHUs=	0.14	0.00	0.14	0.14
	B. Future Without Project AAHUs=	0.85	0.01	0.85	0.85
	Net Benefit (FWP - FWOP)=	-0.71	0.01	-0.71	-0.71

0.42	S2G BH-6 Recommended Plan Impacts - Port Arthur Addition 2016		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	0.04	0.00	0.04	0.04
	B. Future Without Project AAHUs=	0.21	0.00	0.21	0.21
	Net Benefit (FWP - FWOP)=	-0.17	0.00	-0.17	-0.17

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Direct Impacts
Fresh Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
1.83	**S2G F-1 Revised Impacts Bessie Heights 2016**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.02	0.00	0.02	0.02
	B. Future Without Project Emergent Marsh AAHUs=	1.70	0.00	1.70	1.70
	Net Change (FWP - FWOP)=	-1.67	0.00	-1.67	-1.67
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	Net Change (FWP - FWOP)=	0.00	0.00	0.00	0.00
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-1.67	0.00	-1.67	-1.67
	B. Open Water Habitat Net AAHUs=	0.00	0.00	0.00	0.00
	Net Benefits=	-1.13	0.00	-1.13	-1.13
8.6	**S2G F-2 Recommended Plan Impacts Old River Cove 2016**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.11	0.00	0.11	0.11
	B. Future Without Project Emergent Marsh AAHUs=	7.34	0.01	7.34	7.35
	Net Change (FWP - FWOP)=	-7.24	0.01	-7.24	-7.24
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.25	0.00	0.25	0.25
	Net Change (FWP - FWOP)=	-0.25	0.00	-0.25	-0.25
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-7.24	0.01	-7.24	-7.24
	B. Open Water Habitat Net AAHUs=	-0.25	0.00	-0.25	-0.25
	Net Benefits=	-4.98	0.01	-4.99	-4.98

0.62	S2G F-3 Recommended Plan Impacts Chemical Row 2016	Version 1.0			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.01	0.00	0.01	0.01
	B. Future Without Project Emergent Marsh AAHUs=	0.54	0.00	0.54	0.54
	Net Change (FWP - FWOP)=	-0.53	0.00	-0.53	-0.53
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	Net Change (FWP - FWOP)=	0.00	0.00	0.00	0.00
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-0.53	0.00	-0.53	-0.53
	B. Open Water Habitat Net AAHUs=	0.00	0.00	0.00	0.00
	Net Benefits=	-0.36	0.00	-0.36	-0.36

13.28	S2G F-4 Recommended Plan Impacts Adams Bayou 2016	Version 1.0			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.09	0.00	0.09	0.09
	B. Future Without Project Emergent Marsh AAHUs=	6.44	0.01	6.44	6.45
	Net Change (FWP - FWOP)=	-6.35	0.01	-6.36	-6.35
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.03	0.00	0.03	0.03
	B. Future Without Project Open Water AAHUs=	1.85	0.02	1.85	1.86
	Net Change (FWP - FWOP)=	-1.83	0.02	-1.83	-1.82
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-6.35	0.01	-6.36	-6.35
	B. Open Water Habitat Net AAHUs=	-1.83	0.02	-1.83	-1.82
	Net Benefits=	-4.89	0.01	-4.89	-4.89

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Direct Impacts
Intermediate Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
0.32	**S2G I-1 Recommended Plan Impacts Old River Cove 2016**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Emergent Marsh AAHUs=	0.26	0.00	0.26	0.26
	Net Change (FWP - FWOP)=	-0.26	0.00	-0.26	-0.26
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	Net Change (FWP - FWOP)=	0.00	0.00	0.00	0.00
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-0.26	0.00	-0.26	-0.26
	B. Open Water Habitat Net AAHUs=	0.00	0.00	0.00	0.00
	Net Benefits=	-0.18	0.00	-0.18	-0.18
5.02	**S2G I-2 Recommended Plan Impacts Cow Bayou 2016**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.06	0.00	0.06	0.06
	B. Future Without Project Emergent Marsh AAHUs=	4.37	0.01	4.37	4.37
	Net Change (FWP - FWOP)=	-4.30	0.01	-4.31	-4.30
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.02	0.00	0.02	0.02
	Net Change (FWP - FWOP)=	-0.02	0.00	-0.02	-0.02
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-4.30	0.01	-4.31	-4.30
	B. Open Water Habitat Net AAHUs=	-0.02	0.00	-0.02	-0.02
	Net Benefits=	-2.92	0.01	-2.92	-2.92

1.46	S2G I-3 Recommended Plan Impacts Adams Bayou 2016	Version 1.0			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.02	0.00	0.02	0.02
	B. Future Without Project Emergent Marsh AAHUs=	1.30	0.00	1.30	1.30
	Net Change (FWP - FWOP)=	-1.29	0.00	-1.29	-1.29
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	Net Change (FWP - FWOP)=	0.00	0.00	0.00	0.00
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-1.29	0.00	-1.29	-1.29
	B. Open Water Habitat Net AAHUs=	0.00	0.00	0.00	0.00
	Net Benefits=	-0.87	0.00	-0.87	-0.87

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Direct Impacts
Brackish Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
6.2	**S2G B-1 Recommended Plan Impacts Old River Cove 2016**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.08	0.00	0.08	0.08
	B. Future Without Project Emergent Marsh AAHUs=	5.21	0.02	5.21	5.21
	Net Change (FWP - FWOP)=	-5.13	0.01	-5.14	-5.13
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.19	0.00	0.19	0.19
	Net Change (FWP - FWOP)=	-0.19	0.00	-0.19	-0.19
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-5.13	0.01	-5.14	-5.13
	B. Open Water Habitat Net AAHUs=	-0.19	0.00	-0.19	-0.19
	Net Benefits=	-4.04	0.01	-4.04	-4.03
67.8	**S2G B-2 Revised Impacts Cow Bayou 2016**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.48	0.00	0.48	0.48
	B. Future Without Project Emergent Marsh AAHUs=	35.06	0.12	35.03	35.08
	Net Change (FWP - FWOP)=	-34.57	0.12	-34.59	-34.55
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.16	0.01	0.16	0.16
	B. Future Without Project Open Water AAHUs=	11.81	0.09	11.79	11.83
	Net Change (FWP - FWOP)=	-11.65	0.09	-11.67	-11.63
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-34.57	0.12	-34.59	-34.55
	B. Open Water Habitat Net AAHUs=	-11.65	0.09	-11.67	-11.63
	Net Benefits=	-29.48	0.09	-29.50	-29.46

0.2	S2G B-3 Revised Impacts Adams Bayou 2016	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Emergent Marsh AAHUs=	0.20	0.02	0.20	0.21
	Net Change (FWP - FWOP)=	-0.20	0.02	-0.20	-0.20
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.00	0.01	0.00	0.00
	Net Change (FWP - FWOP)=	0.00	0.01	0.00	0.00
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-0.20	0.02	-0.20	-0.20
	B. Open Water Habitat Net AAHUs=	0.00	0.01	0.00	0.00
	Net Benefits=	-0.16	0.02	-0.16	-0.15

ATTACHMENT 4
FISHERIES FRIENDLY DESIGN CONSIDERATIONS

NATIONAL MARINE FISHERIES SERVICE BATON ROUGE FIELD OFFICE
April 2008 Version

FISHERIES FRIENDLY DESIGN AND OPERATION CONSIDERATIONS FOR HURRICANE AND FLOOD PROTECTION WATER CONTROL STRUCTURES

SUMMARY

The purpose of this document is to: 1) identify design and operational guiding principles that would optimize passage of estuarine dependent marine fisheries species, or at least, minimize adverse impacts to their passage through hurricane and flood protection water control structures planned for the New Orleans District of the U.S. Army Corps of Engineers; and, 2) provide background literature for environmental justification and documentation. Specific projects for which this guidance should be considered include the Mississippi River and Tributaries, Morganza to the Gulf of Mexico Hurricane Protection Project; Donaldsonville to the Gulf Project; Supplemental Appropriations Projects, and the Louisiana Coastal Protection and Restoration Project (LACPR). However, these guiding principles would also pertain to any civil works projects that could include combinations of levees and/or water control structures. Project delivery teams should remain flexible to adapt these design principles on a case-by-case basis as new fishery resource information and project-specific hydraulics data become available.

In general, the ability of estuarine dependent marine fishery organisms to migrate to and from coastal habitats decreases as structural restrictions increase, thereby reducing fishery production. The physical ability (i.e., swimming speed) to navigate through a structure is not the only factor influencing fish passage. Both behavioral and physical responses govern migration and affect passage of fishery organisms through structures. These responses may vary by species and life stage. In addition, most marine fishery species are relatively planktonic in early life stages and are dependent on tidal movement to access coastal marsh nursery areas. For this reason, in general, the greater the flow through a structure into a hydrologically affected wetland area, the greater the marine fishery production functions provided by that area.

Data on marine fishery species migrations in the Gulf of Mexico are too limited to allow the development of definitive design and operational considerations for water control structures that would guarantee the protection of marine fishery production. Anecdotal comparisons can be made with data from water intake and fish passage studies from the west and east coasts. It should not be assumed that structures that have been determined to provide sufficient drainage capacity also optimize or provide adequate fishery passage. More investigation is warranted to refine and adaptively manage water control structure design and operations to minimize adverse impacts to fishery passage. Case specific recommendations for some features under the Mississippi Tributaries, Morganza to the Gulf of Mexico Hurricane Protection Project and LACPR are provided in the appendices. In addition, biological background information is provided in the appendices to assist in preparation of environmental documents required by the National Environmental Policy Act (NEPA).

Summary of guiding principles for designing and operating flood protection water control structures to maintain marine fishery passage:

- Generally, bigger and more numerous openings in hurricane and flood protection levees better maintain estuarine dependent fishery migration. As much opening as practicable, in number, size, and diversity of location should be considered.
- Flood protection water control structures in any watercourse should maintain pre-project cross section in width and depth to the maximum extent practicable, especially structures located in tidal passes.
- Flood protection water control structures should remain completely open except during storm events.
- Any flood protection water control structure sited in canals, bayous, or navigation channels that does not maintain the pre-project cross section should be designed and operated with multiple openings within the structure. This should include openings near both sides of the channel as well as an opening in the center of the channel that extends to the bottom.
- The number and siting of openings in flood protection levees should be optimized to minimize the migratory distance from the opening to enclosed wetland habitats.
- Structures should include shoreline baffles and/or ramps (e.g., rock rubble, articulated concrete mat) that slope up to the structure invert to enhance organism passage. Various ramp designs should be considered.
- To the maximum extent practicable, structures should be designed and/or culverts selected such that average flow velocities during peak flood or ebb tides do not exceed 2.6 feet/second. This may not necessarily be applicable to tidal passes or other similar major exchange points.
- To the maximum extent practicable, culverts (round or box) should be designed, selected, and installed such that the invert elevation is equal to the existing water depth. The size of the culverts should be selected that would maintain sufficient flow to prevent siltation.
- Culverts should be installed in construction access roads unless otherwise recommended by the natural resource agencies. At a minimum, there should be one, 24-inch culvert placed every 500 feet and at natural stream crossings. If the depth of water crossings allow, larger sized culverts should be used. Culvert spacing should be optimized on a case-by-case basis. A culvert may be necessary if the road is less than 500-feet long and an area would hydrologically isolated without that culvert.
- Water control structures should be designed to allow rapid opening in the absence of an offsite power source after a storm passes and water levels return to normal.
- Levee alignments and water control structure alternatives should be selected to avoid the need for fishery organisms to pass through multiple structures (i.e., structures behind structures) to access an area.
- Operational plans should be developed to maximize the cross-sectional area open for as long as possible. Operations to maximize freshwater retention or redirect

freshwater flows could be considered if hydraulic modeling demonstrates that is possible and such actions are recommended by the natural resource agencies.

INTRODUCTION

Various flood protection and environmental water control structures in hurricane protection levees are being designed and considered for inclusion with ongoing local and federal civil works projects within the boundaries of the New Orleans District. Design purposes of the structures vary and may include maintaining safe navigation and optimizing drainage and passage of fishery organisms. For the Morganza to the Gulf of Mexico hurricane protection project, an interagency Habitat Evaluation Team (HET) and NOAA's National Marine Fisheries Service (NMFS) identified economically important fishery species that should be considered when assessing structure impacts on estuarine fisheries migration. Both the federal and state governments manage some of these species. Primary species that could be affected by flood protection structures in Louisiana include brown shrimp, white shrimp, blue crab, red drum, black drum, spotted seatrout, sand seatrout, southern flounder, and gulf menhaden. Some information is included herein on forage species, the production of which is important to maintain as they serve as important links of the aquatic food web for many of the managed fishery species.

The Baton Rouge office of NMFS has developed preliminary design principles for hurricane and flood protection water control structures to reduce impacts to living marine resources, especially related to migrations of estuarine dependent species. The basis for the following recommended guiding principles is briefly discussed where supporting literature is available. Case specific examples for some features under the Mississippi River and Tributaries, Morganza to the Gulf of Mexico hurricane protection project and the Louisiana Coastal Protection and Restoration Project are provided in the appendices. Basic behavior and physiology effects on the passage of fishery organisms are discussed in detail in appendices C and D, to aid federal agencies in environmental evaluations and descriptions under NEPA.

This document has been developed in consideration of input from the interagency HET, university faculty, fish passage staff of various agencies, and cursory literature reviews. These design considerations are intended to address potential impacts to living marine resources pursuant to the Fish and Wildlife Coordination Act and the Magnuson-Stevens Fishery Conservation and Management Act. Impacts to resources managed under other authorities, such as the Endangered Species Act or the Marine Mammal Protection Act, are not addressed in this document.

GUIDING PRINCIPLES FOR DESIGNING FISHERIES FRIENDLY FLOOD PROTECTION WATER CONTROL STRUCTURES

1. Generally, bigger and more numerous openings in hurricane and flood protection levees better maintain estuarine dependent fishery migration. As much

opening as practicable, in number, size, and diversity of location should be considered.

Most of Louisiana's commercial and recreational fishery species must have access to estuarine marshes to successfully complete some part of their life cycle (i.e., they are estuarine-dependent). Estuarine-dependent fishery productivity is a measure of standing crop (the number of fishery organisms present at a point in time) and the turnover rate (the rate at which the population is replaced). All things being equal, fishery production would be lower following levee and water control construction if structures retard turnover rate. This would be the case even while standing crop may appear normal. Restrictions in tidal movement caused by water control structures and levees would result in degraded or substantially changed species composition, which could alter fishery production and/or displace fisheries.

Marine transient species emigrate (i.e., move from coastal marshes towards Gulf waters) towards higher salinity water; therefore, a structure that maintains the greatest degree of opening while allowing the project objectives to be met would be desirable (Rogers et al. 1992).

2. Flood protection water control structures in any watercourse should maintain pre-project cross section in width and depth to the maximum extent practicable, especially structures located in tidal passes.

Water control structures should be designed to have a water flow capacity (and similar dimensions where possible) comparable to the waterway before construction. Restricted water exchange in marshes enclosed by levees and water control structures diminishes recruitment and standing stocks of species that must migrate from coastal spawning sites to marsh nurseries (Rogers et al. 1994). As the amount of hydrologic control increases, the effect on migration and production of marine transients and residents increases. Greater restriction decreases turn over rate of estuarine-dependent fishery organisms, which decreases their production (Rogers et al. 1992[a]). Slotted and fixed crest weirs have been found to delay immigration. As the degree of restriction increased from slotted weirs, to low elevation weir, and to fixed crest weirs, greater impacts to different fisheries species and their emigration were observed.

Design considerations for hurricane and flood protection water control structures should include features to accommodate vertical and horizontal fishery distribution patterns within interior marsh tidal pathways and coastal passes. Fishery organisms exhibit preferences by species, life stage, and in some cases tide cycle, for vertical and horizontal distribution within smaller or interior marsh tidal connections (Table 1). Behavioral and physiological responses, such as diel vertical migration, affect these preferred distribution patterns.

Study of Keith Lake Pass in Texas revealed that all portions of the water column, both vertically and horizontally, are used by fishery organisms (Hartman et al. 1987). Most estuarine-dependent fishery species preferred the bottom or shore zones during flood tides, but were much more dense near the shores of the pass, in slower moving water, on ebb tide. This lateral movement on slack to ebb tides appears to be a behavioral action to prevent displacement from the pass during ebb tide to accelerate movement to marsh nursery areas. The study identified the response to light cycles with midday densities greatest at bottom and densities greatest at surface during dawn to dusk. Similar within pass distribution patterns were reported by Sabins and Truesdale at Grand Isle, Louisiana (1974) .

Table 1. Table on fishery preference within the water column (Marotz et al. 1990; Herke and Rogers 1985; Hartman et al. 1987; Sabins and Truesdale 1974). "[a]" denotes juveniles; "[b]" denotes immigrating; "[c]" denotes emigrating; "[e]" denotes ebb tide; "[f]" denotes flood tide.

	Vertical Distribution			Horizontal Distribution
Species	Surface	Mid-depth	Bottom	Shore/Nearshore
brown shrimp[b]	X	X		X[e]
white shrimp[b]	X	X		
white shrimp[c]		X		X[e]
blue crab	X			Xe
red drum[a]				X[e]
red drum[b]		X	X	
red drum[c]			X	
bay anchovy	X			
striped mullet	X			
Atlantic croaker[a]	X	X		X[e]
Atlantic croaker		X	X	X[e]
spotted seatrout		X	X	
sand seatrout		X	X	X[e]
gulf menhaden	X	X		
southern flounder				X[f]
black drum				X[e]

3. Flood protection water control structures should remain completely open except during storm events.

Fish passage should be optimized by the duration that structures remain fully open. Rozas and Minello (1999) reported that even when water-control structures were open, the densities of transient species were low inside areas enclosed by levees and water control structures as compared to natural areas.

Fisheries migration that temporarily may be impacted with storm related closures are listed in Table 2. The degree of impact would be influenced by the timing and duration of a structure closure relative to peak migration.

Table 2. Migration of economically important fisheries in Louisiana that temporarily may be impacted with storm related closures.

Species	Migration Period Overlapping with Hurricane Season
brown shrimp	April - mid July
white shrimp	July – November
blue crab	June – September
spotted seatrout	April – October
sand seatrout	April – October
red drum	August - December
black drum	March – July
southern flounder	September - October

4. Any flood protection water control structures sited in canals, bayous, or navigation channels that do not maintain the pre-project cross section should be designed and operated with multiple openings within the structure. This should include openings near both sides of the channel as well as an opening in the center of the channel that extends to the bottom.

Hartman et al. (1987) recommended structures not be constructed in a tidal pass. If a structure was constructed, they recommended the incorporation of several gates at several vertical and horizontal locations, with baffles near shore. Baffles near shore are to direct shore or near shore fish passage on ebb tides through the available structure opening(s) (e.g., gates in wing walls).

Structures should be designed and operated with multiple openings if the pre-project water depth and widths of a channel are not maintained. Multiple openings are necessary to optimize passage of fishery organisms that prefer to migrate along the sides, bottom, and top of channels. For example, Rogers et al. (1992[a]) recommended opening some vertical slots and top, middle, and bottom gates in a structure with multiple slots and gates.

5. The number and siting of openings in flood protection levees should be optimized to minimize the migratory distance from the opening to enclosed wetland habitats.

The location and number of structures likely affects the abundance and distribution of estuarine fishery species within habitats that would be located on the protected side of levees and water control structures. Rogers et al. (1992[c]) determined that marine transient species were most numerous nearest the structures, partially due to the proximity of the openings with respect to the area enclosed. Similarly, other studies have shown there is a decrease in fishery species abundance and diversity the greater the distance from the access point (Peterson and Turner 1994). This can become more pronounced if an environmental gradient (e.g., salinity) exists between an access point and the interior habitat located on the protected side of structures (Cashner 1994).

6. Structures should include shoreline baffles and/or ramps (e.g., rock rubble, articulated concrete mat) that slope up to the structure invert to enhance organism passage. Various ramp designs should be considered.

Study of Keith Lake Pass in Texas revealed vertical and horizontal distribution patterns of fishery organisms in the pass (Hartman et al. 1987). Estuarine-dependent fishery organisms preferred the bottom or near shore zones on flood tides. Most organisms appeared near shores of the pass on ebb tide in slower moving water. Baffles near shore are to direct shore or near shore fish passage through the structure.

Many fish migrate along the water bottom. Water control structures with crests or inverts higher than the lower portion of a channel could impede migration through the deep-water portions of channels. Ramps can provide a means to guide organisms over and through structures and increase access of fisheries organisms to enclosed habitat (Lafleur 1994). Various ramp designs need to be investigated.

7. To the maximum extent practicable, structures should be designed and/or culverts selected such that average flow velocities during <u>peak</u> flood or ebb tides do not exceed 2.6 feet/second.

In this preliminary investigation, no studies were located that evaluated the impacts of swimming speeds for the fishery species and life stages of concern in Louisiana. To avoid preventing or reducing ingress or egress of fishery organisms, preliminary guidance on water velocities through structures in Louisiana could be based on anecdotal comparisons with data available on general swimming speeds from studies on the west and east coasts (Tables 3 and 4).

Swimming speeds of estuarine and marine fish and crustaceans is a function of shape, stage of development, length, ambient temperature, light, and duration required for swimming performance. For most species, absolute speed increases as size increases. Generally, fish swimming speeds range from 2-4 body lengths/second with burst speeds up to 5 body lengths/second (Meyers et al. 1986).

Water intake studies have shown that maintaining water velocities less than 0.5 ft/sec would protect most fish and their life stages from being adversely affected by those flows (USEPA 2004). The species and life stages of fish for that study could not be located at this time and further investigation for Gulf of Mexico species is warranted. They also recommended creating horizontal velocity fields to avoid adverse affects on fish because fish are better able to orient to horizontal verses vertical flow. This could allow selective avoidance of water flows not preferred by fish or minimize disorientation or mortality rates caused by flows.

Eberhardt (personal communication) reported velocities exceeding 0.82 feet/second began to impede fish passage. Fish passage was decreased by 50% for velocities exceeding 2.6 feet/second. Based on evaluation of freshwater species, Gardner (2006) recommends keeping velocities through round culverts less than 1.8 ft/sec during 90% of the fish migration season. To improve fish passage through culverts, installing baffles within culverts should be considered to reduce flow velocity barriers for fish (Pacific Watershed Associates 1994).

Table 3. Water flow velocity thresholds for affecting fish passage or avoiding impingement within flows or on screens.

Source	Water Flow Velocity (ft/sec)	
Alyson Eberhardt, personal communication	0.82	Begin to impede
	2.62	Decreased fish passage by 50%
Gardner 2006	1.8	Critical velocity (freshwater fish)
Meyers et al. 1986	<0.49	To avoid impingement
USEPA 2004	<0.50	Protected 96% of the fish tested from impingement

Table 4. Sustained fish swimming speeds. Adapted from Meyers et al. (1986). Note that no data was located for the fisheries species and life stages for the Gulf of Mexico.

Fish/life stage	Swimming Speeds (ft/sec)
Atlantic herring	0.19 – 0.3
Mullet	4.19
Horse mackerel	4.46
Sole	0.19 - 0.3
most larvae	0.82 – 0.98

Based on these limited data, larval fish could be adversely impacted by water flow rates exceeding 0.82 feet/second. Post-larval and juvenile stages of flounders could be impacted by flow rates around 1.0 ft/sec. Other species or larger life stages likely would not be adversely impacted until flow rates exceed 2.62 feet/second based on inferences from these data. Water flow velocity monitoring in the Terrebonne Basin by the U.S. Fish and Wildlife Service has found <u>maximum</u> flows through existing open channels exceeding 1.0 feet /second and in larger saline marsh channels and passes exceeding 2.0 feet/second.

If the spatial extent of flow velocity fields exceed the distance that can be traveled with sustained or burst swimming speeds of fishery organisms, those flows could prevent or reduce ingress or egress during the time which those flows exist. However, the degree of mortality from not being able to access nursery and foraging habitat is not known. High flow rates may aid passage of larval fish that primarily depend on passive transport for migratory distribution and access to estuarine habitat on the protected side of levees, if the high flows do not induce mortality from injury or fatigue. Water flow could exceed the fish swimming rates for short periods and still provide passage during low flows or during still water.

8. To the maximum extent practicable, culverts (round or box) should be designed, selected, and installed such that the invert elevation is equal to existing water depth. The size of the culverts should be selected that would maintain sufficient flow to prevent siltation.

Design considerations should include installing baffles within culverts to reduce flow velocity barriers (Pacific Watershed Associates 1994). Passage of salmon and herring species has been shown to be impaired by culverts. With baffles or other similar features, still water areas could be created to enhance fish passage.

If water control structures include plunge pools, the invert elevation of the structure could be equal to the depth of the plunge pool if the plunge pool is deeper than the pre-project water depth. This deeper invert would optimize passage of fisheries species, in particular bottom dweller species.

Fish often require visual cues for orientation and exhibit faster swimming speeds at increased light levels. Herring type fish (e.g., gulf menhaden) are particularly sensitive to light levels. However, although herring exhibited a preference for unshaded portions of treatments during both day and night periods, as little as 1.4% of the ambient light was necessary for their passage through a culvert (Mosser and Terra 1999).

9. Culverts should be installed in construction access roads unless otherwise recommended by the resource agencies. At a minimum, there should be one, 24-inch culvert placed every 500 feet and at all water crossings. If the depth of water crossings allow, larger sized culverts should be used. Culvert spacing should be optimized on a case-by-case basis. A culvert may be necessary, even if the road is less than 500 feet long, if an area would be hydrologically isolated without that culvert.

10. Water control structures should be designed to allow rapid opening in the absence of an offsite power source after storm passage and return of normal water levels.

Regardless of structure size, designs and contingency plans should include means to rapidly open the water control structures when flooding risks subside after a storm. Designs and plans should include infrastructure, equipment, and staff necessary to open the structures even if offsite electricity is not available. Design safeguards should be developed to protect the structures from being damaged rendering them inoperable and locked in a closed configuration after passage of a storm.

11. Levee alignment and water control structure alternatives should be selected to avoid the need for fishery organisms to pass through multiple structures (i.e., structures behind structures) to access an area.

12. Operational plans should be developed to maximize the cross-sectional area open for as long as possible. Operations to maximize freshwater retention or redirect freshwater flows could be considered if hydraulic modeling demonstrates that is possible and such actions are recommended by the natural resource agencies.

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APPENDIX A - Mississippi River Tributaries, Morganza to the Gulf of Mexico Hurricane Protection Project Recommendations

The following are some case specific comments for features under the Morganza to the Gulf project. Formal and complete guidance will be provided through Project Delivery Team and Habitat Evaluation Team coordination procedures on all features for that project.

BAYOU GRAND CAILLOU

All design alternatives evaluated thus far for the Bayou Grand Caillou Floodgate would decrease the present cross sectional area of the bayou and therefore reduce passage of fishery organisms. Because dredging of the bayou is being considered to maintain existing water flows, enlarging the channel by dredging also could be considered to allow the present cross section not to be reduced with the floodgate in place. Vertical slots in the structure wing walls could be considered. Alternatively, baffles could be considered to direct fishery species that prefer to migrate along the shorelines through the structure. An operation plan that minimizes closure of the structure to avoid adversely impacting fishery migration should be developed with consideration of the potential dual purpose of the project to reduce salt water intrusion. Closing the structure to reduce saltwater intrusion only should be considered if modeling demonstrates that benefit could be achieved.

REACH J1

In addition to the existing open culverts under the highway. Trenassing was recommended along the levee toe to prevent isolating enclosed wetlands from fishery access. Culverts (24-inch) were recommended to be installed under the temporary and permanent access roads. In the future for other reaches or projects, culverts should be installed when the road is constructed rather than later if compaction from construction equipment is not expected to be problematic. Installing culverts or gapping an existing road dump also was recommended to prevent isolating enclosed wetlands. The P2 plug along Island Road was recommended to be removed to allow additional connection with Bayou Pointe aux Chenes.

REACH J2

The crest of the environmental water control structures (NAWCA Unit) should be equal to or less than the pre-project water elevation. Structures designs with invert elevations equal to or lower than the depth of the plunge pool could be considered if the necessary plunge pool is deeper than the pre-project water depth. This deeper invert would optimize passage of fish species, in particular bottom dwelling species. The articulated concrete mat integrated to armor the plunge pool could serve as a ramp to improve fishery passage, if sloped to the structure crest.

ENVIRONMENTAL WATER CONTROL STRUCTURES

The number, size, and location of environmental water control structures identified during planning should be reconsidered as the project progresses into advanced design phases. Inclusion and operation of flap gates to prevent saltwater from entering the system should be considered only after water salinity data and modeling demonstrate the benefit of that feature balanced against the reduction in fishery passage. Specifically, the design and operation should be re-evaluated in this regard for the environmental water control structures planned in the levee at the south end of the Lake Boudreaux basin.

Operation

Programmatic and contingency plans should be developed to open the structures as soon as practicable after storm events. This is particularly critical in instances when utility services are offline, if the structures are damaged, or access to the structures is restricted by storm debris.

APPENDIX B - CATEGORY 5/LOUISIANA COASTAL PROTECTION AND RESTORATION PROJECT (LACPR)

In addition to the above design consideration, the following are case specific recommendations for some representative structures if they are included as components to the LACPR Project.

SEABROOK, CHEF MENTEUR, AND RIGOLETS

If structures are included in the LACPR Project for these connections with Lake Pontchartrain, they should be floodgates designed to maintain the size and dimensions of the existing openings with the gates in place and open. The structures should only be closed during storm events of sufficient magnitude that flooding is a concern. Sector or tainter gates should be considered prior to more restrictive structure designs. If unsafe flow velocities for navigation are determined would exist during a high head differential requiring consideration of a lock, incorporation of openings (e.g., gates) in the wing walls with the combination of baffles and ramps should be considered to maintain or enhance fish passage while the lock is open and closed, respectively. The need to maintain Seabrook open will continue to be evaluated with consideration of the effects on the lake ecology given different levee alignments and closure options for the Mississippi River Gulf Outlet whether under LACPR or supplemental appropriations funding.

BAYOU BOEUF

If any water control structure is included in Bayou Boeuf, the structure should be a floodgate that does not reduce the present size and dimension of the bayou. Prior to consideration of a pump station and lock to minimize backwater flooding and potential enhancement of forested wetlands, fisheries studies should be re-initiated to document the degree (i.e., diversity and density) and timing of use of the lakes sub-basin by estuarine transient species. If the preferred alternative consists of a pump and lock, sluice gates should be included with some level of structure opening. Mitigating measures to offset the loss of estuarine fishery habitat would be necessary if estuarine-dependent fishery migration is reduced or eliminated.

BAYOU DES ALLEMANDS

If a water control structure is included in Bayou Des Allemands, only a floodgate should be considered. The floodgate should be designed to not reduce the present size and dimensions of the bayou and should remain open except during storm events. Bayou Des Allemands should not be plugged and replaced by Bayou Gauche as the main connection with Lac Des Allemands.

RESTORATION FEATURES

Ridges of bay shoreline armorment could impede fishery ingress/egress. For ridges constructed in open water, gaps should be included on average at least every 1,000 feet.

The gap should be no less 25-feet wide (bottom width) and the pre-project water depth or a depth –2 feet NAVD 88, which ever is deeper, should be maintained. Deviations from this general guidance may be evaluated on a case-by-case basis. For example, if storm surge modeling suggests the number of gaps undermine the surge suppression function, fewer, but larger gaps might be an option.

If a foreshore rock dike is included for shoreline protection, fish gaps should be included at least every 1,000 feet. These openings should be 25-feet wide and the pre-project water depth should be maintained.

If a revetment is included for shoreline protections, fish dips should be included at least every 1,000 feet. These dips are lower sections in the rock that should be 25-feet wide and with a depth of 0.0 ft NAVD88.

APPENDIX C

BEHAVIOR

The physical ability (i.e., swimming speed) to navigate a structure is not the only factor influencing fish passage, especially for small structures. Behavioral responses to stimuli individually or interactively affect passage with physiological constraints or responses. Behavior generally can be categorized as schooling and non-schooling behavior.

Schooling Behavior

Schooling behavior consists of strategies that provide hydrodynamic efficiency, reduced predation, increased efficiency in finding food, and increased reproductive success. Water control structures for flood protection impact large numbers of fishery organisms due to this group response. This could be because fish exhibit the tendency to approach and orient to other members of the species (i.e., biotaxis). This orientation confers a hydrodynamic advantage that is more efficient than individuals due primarily to vortices setup by lead fish. Schools function as a living organism where the group reacts to stimuli as an individual. It is this group reaction that influences greater affect on passage through water control structures.

Non-schooling behavior

Agonistic, territorial, and hierarchical behavior are examples of non-schooling behavior exhibited by fish. Agonistic and territorial behaviors are largely unknown for the listed estuarine and marine fishery species of concern and their life stages. Structures that create physically taxing water flow velocities and some low flow areas may encourage these behaviors as fish compete for resting areas similar to competition seen with fish competing for resting areas within shrimp trawls or behind rocks in river riffle/pool habitat. It is possible these behavioral responses overall may not be that influential on fish passage through a structure, but may come more into play during low flow conditions such as lower tides or slack tide. Hierarchical behavior can often be driven by a combination of physiological responses and will be discussed in that section. Overall, investigation on behavioral responses to water control structures is needed to avoid and minimize adversely impacting fishery passage if not optimizing it.

APPENDIX D

PHYSIOLOGICAL

Fishery species and life stages react differently to a current of water (i.e., rheotaxis). Generally, fish are better able to orient to horizontal verses vertical flow (Meyers et al. 1986).

LOCOMOTION

There are two means for migratory transport of estuarine and marine fish and crustaceans: passive and active transport. Passive transport is drift of organisms carried by the tides and currents. Larval and post-larval fish and crustacean life stages are predominately transported passively by tides and currents. Passive transport via tidal forcing can play a strong role in migration of sub-adult and adult brown shrimp, white shrimp, and blue crabs. Active transport is movement by swimming, which is the primary means of locomotion for sub-adults and adult fish.

SWIMMING SPEED

Refer to guiding principles number 7 for details on swimming speeds relative to impacts on fish passage.

BEHAVIORAL/PHYSIOLOGY INTERACTION

Many fishery organisms exhibit hierarchical behavior. This is a direct response to stimuli, such as astronomical (e.g., tidal rhythm) or meteorological driven flows. For example, brown shrimp mediate transport by circadian or diel vertical migration. Brown shrimp move down in the water column or cease activity as the become negatively buoyant when low salinity and temperature water develop in estuaries with north winds associated with spring fronts. Brown shrimp activity resumes with their movement up in the water column with increasing water temperature, salinity, and hydrostatic pressure associated with the southerly gulf return following after a cold front (Rogers et al. 1993). Similar selective tidal stream transport was reported by Hartman et al. (1987). Fishery organisms identify tide changes by detecting altered velocity, salinity, temperature, all of which can cue staging for immigration with an incoming tide. Future tidal pass or inlet studies are needed for better information on vertical distribution, depth preferences, and changes in buoyancy or behavior to evaluate active and passive transport of fishery organisms.

APPENDIX E - Reference Websites, Fish Passage Agency Representatives, and University Faculty

Baker, C. and J. Boubee. 2003. Using ramps for fish passage past small barriers. Water and Atmosphere 11(2). June.
http://www.niwascience.co.nz/pubs/wa/11-2/passage

USACE Portland District, Fish Passage Team
http://www.nwp.usace.army.mil/pm/e/en_fish.asp

USACE, ERDC, Coastal Hydraulics Lab
http://chl.erdc.usace.army.mil/CHL.aspx?p=s&a=ResearchAreas;22

USFWS Fish Passage Decision Support System
http://fpdss.fws.gov/index.jsp

NC State's Center for Transportation and the Environment website:
http://www.itre.ncsu.edu/

http://itre.ncsu.edu/CTE/gateway/downloads/Culvert%20Impact%20Study(December2002).pdf

http://itre.ncsu.edu/CTE/gateway/downloads/FishPassage.pdf

FishXing software and learning systems for fish passage through culverts. This software is intended to assist engineers, hydrologists, and fish biologists in the evaluation and design of culverts for fish passage. It is free and available for download.
http://stream.fs.fed.us/fishxing/

- Allows for comparison of multiple culverts designs within a single project.
- Calculates hydraulic conditions within circular, box, pipe-arch, open-bottom arch, and embedded culverts.
- Contains default swimming abilities for numerous North American fish species.
- Contains three different options for defining tailwater elevations.
- Calculates water surface profiles through the culvert using gradually varied flow equations, including hydraulic jumps.
- Outputs tables and graphs summarizing the water velocities, water depths, outlet conditions, and lists the limiting fish passage conditions for each culvert.

USFWS Fish Passage National Coordinator
thomas_sinclair@fws.gov

NOAA, NMFS
Eric.Hutchins@noaa.gov
James.G.Turek@noaa.gov
Richard.Wantuck@noaa.gov

Louisiana State University Coastal Fisheries Institute
Jim Cowan; jhcowan@lsu.edu

University of Texas Marine Science Institute
Lee Fuiman; lee@utmsi.utexas.edu

ATTACHMENT 5
WVA MODEL OUTPUT OF INDIRECT IMPACTS

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Indirect Impacts
Swamp Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area		Statistics		
1.9	S2G S Indirect-2 thru TY30		SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	0.30	0.01	0.30	0.30
	B. Future Without Project AAHUs=	0.39	0.01	0.39	0.39
	Net Benefit (FWP - FWOP)=	-0.09	0.01	-0.09	-0.09

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Indirect Impacts
Bottomland Hardwood Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area		AAHUs	Statistics	95% C.I.		Net Mean AAHUs
			Mean	SD	Lower	Upper	
12.7	BH Indirect-2						
		Future With Project =	1.57	0.01	1.57	1.57	
		Future Without Project =	6.69	0.10	6.67	6.71	
		Net Benefit (FWP - FWOP)=	-5.12	0.10	-5.14	-5.11	-5.12
							-5.1

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Indirect Impacts
Fresh Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
674.6	**S2G F Indirect-2 Cow Bayou Fisheries Access**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	291.05	1.75	290.71	291.40
	B. Future Without Project Emergent Marsh AAHUs=	299.07	1.73	298.73	299.41
	Net Change (FWP - FWOP)=	-8.02	2.38	-8.48	-7.55
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	125.61	1.58	125.30	125.92
	B. Future Without Project Open Water AAHUs=	130.78	1.48	130.49	131.07
	Net Change (FWP - FWOP)=	-5.18	2.25	-5.62	-4.74
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-8.02	2.38	-8.48	-7.55
	B. Open Water Habitat Net AAHUs=	-5.18	2.25	-5.62	-4.74
	Net Benefits=	-7.10	1.78	-7.45	-6.75

110.6	**S2G F Indirect-3-Adams Bayou Fisheries Access**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	37.27	0.23	37.22	37.31
	B. Future Without Project Emergent Marsh AAHUs=	43.02	0.25	42.97	43.07
	Net Change (FWP - FWOP)=	-5.76	0.31	-5.82	-5.69
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.63	0.03	0.62	0.63
	B. Future Without Project Open Water AAHUs=	24.94	0.30	24.89	25.00
	Net Change (FWP - FWOP)=	-24.32	0.30	-24.38	-24.26
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-5.76	0.31	-5.82	-5.69
	B. Open Water Habitat Net AAHUs=	-24.32	0.30	-24.38	-24.26
	Net Benefits=	-11.74	0.25	-11.79	-11.69

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Indirect Impacts
Intermediate Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
19.2	**S2G I Indirect-1 and 2 Thru TY30**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.34	0.00	0.34	0.34
	B. Future Without Project Emergent Marsh AAHUs=	11.92	0.11	11.90	11.94
	Net Change (FWP - FWOP)=	-11.58	0.11	-11.61	-11.56
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.06	0.00	0.06	0.06
	B. Future Without Project Open Water AAHUs=	2.20	0.03	2.20	2.21
	Net Change (FWP - FWOP)=	-2.14	0.03	-2.15	-2.14
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-11.58	0.11	-11.61	-11.56
	B. Open Water Habitat Net AAHUs=	-2.14	0.03	-2.15	-2.14
	Net Benefits=	-8.54	0.08	-8.55	-8.52

270.3	**S2G I Indirect-3-Cow Bayou Fisheries**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	123.23	0.70	123.09	123.37
	B. Future Without Project Emergent Marsh AAHUs=	127.03	0.69	126.89	127.17
	Net Change (FWP - FWOP)=	-3.80	0.95	-3.99	-3.61
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	52.92	0.63	52.79	53.04
	B. Future Without Project Open Water AAHUs=	55.35	0.59	55.23	55.46
	Net Change (FWP - FWOP)=	-2.43	0.89	-2.60	-2.25
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-3.80	0.95	-3.99	-3.61
	B. Open Water Habitat Net AAHUs=	-2.43	0.89	-2.60	-2.25
	Net Benefits=	-3.36	0.71	-3.50	-3.22

52.2	S2G I Indirect-4-Adams Bayou Fisheries Access	Version 1.0			
	Marsh **NET CHANGE IN AAHUs DUE TO PROJECT**	**Mean**	**SD**	**95% C.I.**	
				Lower	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	26.91	0.16	26.88	26.94
	B. Future Without Project Emergent Marsh AAHUs=	27.76	0.15	27.73	27.79
	Net Change (FWP - FWOP)=	-0.85	0.20	-0.89	-0.81
	Open Water **NET CHANGE IN AAHUs DUE TO PROJECT**				
	A. Future With Project Open Water AAHUs=	8.51	0.10	8.49	8.53
	B. Future Without Project Open Water AAHUs=	8.90	0.09	8.88	8.92
	Net Change (FWP - FWOP)=	-0.39	0.15	-0.42	-0.36
	Total **TOTAL BENEFITS IN AAHUs DUE TO PROJECT**				
	A. Emergent Marsh Habitat Net AAHUs=	-0.85	0.20	-0.89	-0.81
	B. Open Water Habitat Net AAHUs=	-0.39	0.15	-0.42	-0.36
	Net Benefits=	-0.70	0.14	-0.73	-0.68

Sabine Pass to Galveston Bay Feasibility Study
Recommended Plan Indirect Impacts
Brackish Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Impact Area	Version 1.0			
*	**S2G B Indirect-Intermediate 1 and 2 Switch to Brackish TY31**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Emergent Marsh AAHUs=	6.10	0.06	6.09	6.12
	Net Change (FWP - FWOP)=	-6.10	0.06	-6.12	-6.09
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	1.35	0.02	1.34	1.35
	Net Change (FWP - FWOP)=	-1.35	0.02	-1.35	-1.34
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-6.10	0.06	-6.12	-6.09
	B. Open Water Habitat Net AAHUs=	-1.35	0.02	-1.35	-1.34
	Net Benefits=	-5.05	0.05	-5.06	-5.04

26.1	**S2G B Indirect-2 Cow Bayou**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	0.21	0.01	0.21	0.21
	B. Future Without Project Emergent Marsh AAHUs=	14.49	0.07	14.47	14.50
	Net Change (FWP - FWOP)=	-14.28	0.07	-14.30	-14.27
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.08	0.01	0.08	0.08
	B. Future Without Project Open Water AAHUs=	5.80	0.04	5.79	5.81
	Net Change (FWP - FWOP)=	-5.72	0.04	-5.73	-5.71
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-14.28	0.07	-14.30	-14.27
	B. Open Water Habitat Net AAHUs=	-5.72	0.04	-5.73	-5.71
	Net Benefits=	-12.38	0.06	-12.39	-12.37

18.4	S2G B Indirect-3 Persistent	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	0.17	0.00	0.17	0.17
	B. Future Without Project Emergent Marsh AAHUs=	11.79	0.07	11.77	11.80
	Net Change (FWP - FWOP)=	-11.62	0.07	-11.63	-11.60
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.04	0.00	0.04	0.04
	B. Future Without Project Open Water AAHUs=	2.81	0.02	2.81	2.82
	Net Change (FWP - FWOP)=	-2.78	0.02	-2.78	-2.77
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-11.62	0.07	-11.63	-11.60
	B. Open Water Habitat Net AAHUs=	-2.78	0.02	-2.78	-2.77
	Net Benefits=	-9.65	0.06	-9.66	-9.64

34.0	S2G B Indirect-3 Marsh Migration	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Emergent Marsh AAHUs=	9.53	0.12	9.51	9.56
	Net Change (FWP - FWOP)=	-9.53	0.12	-9.56	-9.51
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.00	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.21	0.00	0.21	0.21
	Net Change (FWP - FWOP)=	-0.21	0.00	-0.21	-0.21
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-9.53	0.12	-9.56	-9.51
	B. Open Water Habitat Net AAHUs=	-0.21	0.00	-0.21	-0.21
	Net Benefits=	-7.46	0.10	-7.48	-7.44

290.5	S2G B Indirect-4 Cow Bayou Fisheries Impact	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	129.21	0.70	129.07	129.35
	B. Future Without Project Emergent Marsh AAHUs=	135.85	0.67	135.72	135.99
	Net Change (FWP - FWOP)=	-6.64	0.89	-6.82	-6.47
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	55.64	0.85	55.47	55.81
	B. Future Without Project Open Water AAHUs=	60.53	0.85	60.36	60.70
	Net Change (FWP - FWOP)=	-4.89	1.22	-5.13	-4.65
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-6.64	0.89	-6.82	-6.47
	B. Open Water Habitat Net AAHUs=	-4.89	1.22	-5.13	-4.65
	Net Benefits=	-6.25	0.78	-6.41	-6.10

739	S2G B Indirect-5 Adams Bayou Fishery Access	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	478.19	2.14	477.77	478.61
	B. Future Without Project Emergent Marsh AAHUs=	503.45	2.17	503.03	503.88
	Net Change (FWP - FWOP)=	-25.27	2.93	-25.84	-24.69
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	88.39	0.94	88.21	88.58
	B. Future Without Project Open Water AAHUs=	95.88	0.94	95.70	96.07
	Net Change (FWP - FWOP)=	-7.49	1.38	-7.76	-7.22
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-25.27	2.93	-25.84	-24.69
	B. Open Water Habitat Net AAHUs=	-7.49	1.38	-7.76	-7.22
	Net Benefits=	-21.32	2.31	-21.77	-20.86

**	S2G B Indirect-S-2 Switch TY31	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	0.00	0.01	0.00	0.00
	B. Future Without Project Emergent Marsh AAHUs=	0.74	0.02	0.74	0.74
	Net Change (FWP - FWOP)=	-0.74	0.01	-0.74	-0.74
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	0.00	0.01	0.00	0.00
	B. Future Without Project Open Water AAHUs=	0.01	0.01	0.01	0.02
	Net Change (FWP - FWOP)=	-0.01	0.01	-0.01	-0.01
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	-0.74	0.01	-0.74	-0.74
	B. Open Water Habitat Net AAHUs=	-0.01	0.01	-0.01	-0.01
	Net Benefits=	-0.58	0.01	-0.58	-0.58

* Same acreage as Intermediate Indirect-1 and 2 Thru TY30

** Same acreage as Swamp Indirect 2

ATTACHMENT 6
INITIAL ARRAY OF MITIGATION ALTERNATIVES

Sabine Pass to Galveston Bay Study - Mitigation Target Areas - Screening of Initial Array

#	Location	Acres	Veg	Action	Notes	Screening Result
1	Upper Neches	297	Swp	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
2	Upper Neches	266	Swp	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
3	Upper Neches	266	Swp	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
4	Upper Neches	271	Swp/BH	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
5	Upper Neches	213	Fr Mrsh/Swp/BH	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
6	Upper Neches	483	Swp/BH/Fr Mrsh	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
7	Upper Neches	410	Fr Mrsh/Swp	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
8	Upper Neches	345	Swp/BH/Fr Mrsh	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
9	Upper Neches	246	Fr Mrsh/Swp	Already preserved/HydroRest (berms not restricting hydrology per field observation)	in Big Thicket National Preserve (BTNP)	Out
10	Upper Neches	378	Fr Mrsh/Swp/BH	Preservation/HydroRest-benefits to marsh/uplands; would be few hydrologic benefits from 67 and 68	Degraded swamp; any restoration would provide few benefits to forested wetlands;would be few hydrologic benefits from 67 and 68; higher priority marsh mitigation areas available south of I10	Out
11	Upper Sabine	758	Swp/BH	Preservation	major Sabine River Authority (SRA) facility on canal; could not fill canal which is only hydrologic restoration possibility; excellent for preservation only	In
12	Upper Sabine	818	Swp/BH	Preservation only - no hydro restoration opportunities	High RE costs; owned by Temple-Inland, subsidiary of International Paper	In
13	Upper Sabine	300	BH/Swp	Preservation only - no hydro restoration opportunities; already planted as pine silviculture; now overgrown with other species; little restoration opportunity	High RE costs; owned by Temple-Inland, subsidiary of International Paper	Out
14	Upper Sabine	519	Swp/BH	Preservation only - no hydro restoration opportunities	High RE costs; owned by Temple-Inland, subsidiary of International Paper	In
15	Upper Sabine	705	BH/Swp	Preservation/Connectivity to WMA - no hydro restoration opportunites	Western portion owned by Temple-Inland; remainder multiple ownership; TPWD would support adding to WMA	In
16	Houseman WMA/Blue Elbow Mitigation Bank	95	Swp	Hydrologic restoration-remove high berms (avg 2-4 ft) along large logging canal to restore overland flow; small radial scars/ditches have no impact; EPA suggests that filling canals to natural wetland elevation would provide additional benefits (restoration of wetland acreage and slower drainage); elevation of areas beyond the berms (max set at 2km based on Turner and Rao 1990); higher natural BH ridge excluded from influence acreage. Areas 17-21 merged under Mit Measure 17.	Located too far from canal for significant hydrologic affect	Out
17	Houseman WMA/Blue Elbow Mitigation Bank	672	Swp/BH		TPWD supports removing the spoil banks; this large canal appears to provide drainage	In; TXDOT approval required to include in recommended mitigation plan
18	Houseman WMA/Blue Elbow Mitigation Bank	195	Swp			
19	Houseman WMA/Blue Elbow Mitigation Bank	80	Swp			
20	Houseman WMA/Blue Elbow Mitigation Bank	151	Swp			

#	Location	Acres	Veg	Action	Notes	Screening Result
21	Houseman WMA/Blue Elbow Mitigation Bank	211	Swp		this large canal appears to provide drainage for north section of Orange. Measure located within Blue Elbow Mitigation Bank which is controlled by TXDOT. TXDOT permission and resource agency approval required for implementation. USACE-Regulatory review determined that measure could be implemented in compliance with existing banking instrument .	
22	Houseman WMA/Blue Elbow Mitigation Bank	349	Swp	Hydrologic restoration-remove high berms (avg 2 ft) along logging canal to restore overland flow; EPA suggests that filling canals to natural wetland elevation would provide additional benefits (restoration of wetland acreage and slower drainage); extent of influence based on elevation of berms and elevation of areas beyond the berms (max set at 2km based on Turner and Rao 1990). Areas 22 and 23 merged under Mit Measure 22.		In; TXDOT approval required to include in recommended mitigation plan
23	Houseman WMA/Blue Elbow Mitigation Bank	180	Fr Mrsh/Swp			
24	Houseman WMA/Blue Elbow Mitigation Bank	270	Swp	Hydrologic restoration to restore overland flow-remove high berms (avg 2-3 ft high east and 3-4 ft high west of Little Cypress Bayou) along southern perimeter logging canal; no significant berms on east, west and north perimeter canals; EPA suggests that filling canals to natural wetland elevation would provide additional benefits (restoration of wetland acreage and slower drainage); extent of influence based on elevation of berms and elevation of areas beyond the berms (max set at 2km based on Turner and Rao 1990).		In; TXDOT approval required to include in recommended mitigation plan
25	Houseman WMA/Blue Elbow Mitigation Bank	88	Swp	small radial scars/ditches have no impact; no other hydrologic restoration possible; already preserved		Out
26	Old River/Bridge City	47	BH	Preservation/Connectivity to WMA	Alignment deliberately placed to avoid impacts to BH; immediately adjacent to developed upland; one large private residence affected-wasn't affected in DIFR-EIS but was outside levee; strong chance all would be lost to development; TPWD would support adding to WMA	In
27	Old River/Bridge City	937	Br Mrsh	Preservation/Mrsh Restoration/Connectivity to WMA	TPWD would support adding to WMA	In
28	Old River Unit/WMA	583	Br Mrsh	Mrsh Restoration on WMA; TPWD identified this area a location of mitigation for project impacts to TPWD property.		In
29	Old River Unit/WMA	881	Br Mrsh	Mrsh Restoration on WMA		In
30	Nelda Stark Unit/WMA	91	Br/Fr Mrsh	Preservation/Minor Mrsh Restoration/Connectivity to WMA	Onlyh small area would benefit from marsh restoration; too small for scale-up of Area 31	Out
31	Nelda Stark Unit/WMA	631	Br/Fr Mrsh/BH	Mrsh Restoration on WMA; TPWD identified this area a location of mitigation for project impacts to TPWD property.		In
32	Bessie Heights	537	Br Mrsh	Pres/Mrsh Restoration/Connectivity to proposed beneficial use/marsh restoration area planned in conjunction with authorized deepening of Sabine-Neches Waterway.		In
33	Bessie Heights	542	Br/Int Mrsh	Pres/Mrsh Restoration/Connectivity to WMA	combined with 147 ; good potential but not needed; adjacent Area 32 providing more than sufficient AAHUs.	In

EPA Mitigation Suggestions

34	Beaumont1-A	25	Upland	Hydrologic Restoration-degrade levees	Encircled by industry; USGS veg layer does not identify this as wetland;	Out
35	Beaumont1-B	380	Marsh	Hydrologic Restoration-degrade levees	Exising PA 24 for SNWW nav channel	Out
36	Beaumont1-C and D	1300	Marsh	Hydrologic Restoration-degrade levees	Existing PA25 and 25A for SNWW nav Channel	Out
37	Beaumont1-E	10	Marsh	Hydrologic Restoration-Bridges, culverts)	Have no info that there actually is a problem	Out
38	Beaumont1-F		Marsh, forested	Hydrologic Restoration-Bridges, culverts)	All land west of road to be new PA24A; would not have much benefit	Out
39	Beaumont1-G	63	Marsh	marsh restoration	Former PA, planned for port development	Out
40	Beaumont1-H		Marsh	Hydrologic Restoration-degrade levees	Former PA, planned for port development	Out
41	Beaumont1-I		Marsh	Hydrologic Restoration-Bridges, culverts)	All land south of road planned for Port development; little benefit	Out

#	Location	Acres	Veg	Action	Notes	Screening Result
42	Beaumont1-J	74	Marsh	marsh restoration; becomes Scale 1 to combination with Measure 4	Large pond in fresh marsh near Bessie Heights.	In
43	Beaumont1-K	2.5	Marsh	Hydrologic Restoration, Backfill channel	Channel leads into area planned for marsh restoration under SNWW project and mitigation by others; would be part of SNWW Rose City BU design	Out
44	Beaumont1-L	113	Marsh	Marsh restoration, combined as Scale 2 with Measure 42, referenced as Measure 42	Large pond in fresh marsh near Neches River	In
45	Beaumont1-M		Canal in Marsh	Hydrologic Restoration to fresh/brackish marsh, Backfill channel	Affected area would be very small.	Out
46	Beaumont1-N		Marsh/BH	Hydrologic Restoration,degrade road	Have no info that there actually is a problem; benefits would be smaller than marsh restoration measures; BH benefits would also be limited	Out
47	RoseCity1-A	580	Marsh	marsh restoration	SNWW BU site; mitigation by others	Out
48	RoseCity1-B		Marsh	Hydrologic Restoration, Backfill channel	Leads into terrace field; mitigation by others	
49	RoseCity1-C	86	Marsh	marsh restoration	Restoration being conducted by others.	Out
50	RoseCity1-D	195	Marsh	marsh restoration	Marsh restoration combined with Measure 52 as Scale 2; Scale 2 ultimately dropped because sufficient compensation provided by Measure 52.	Out
51	RoseCity1-E		Marsh	Hydrologic Restoration, Backfill channel	Restoration would be accomplished in conjunction with Measure 52.	Out
52	RoseCity1-F	204	Marsh	Hydrologic Restoration,degrade levee road	Marsh restoration (Scale 1) combined with Measure 50 as Scale 2; Scale 2 ultimately dropped because sufficient compensation provided by Measure 52.	In
53	RoseCity1-G		Marsh	Hydrologic restoration, degrade pads, roads	Effects of hydrologic restoration would be small compared to marsh restoration measures in area.	Out
54	RoseCity1-H		Marsh	Hydrologic Restoration, Backfill channel		
55	RoseCity1-I		Marsh	Hydrologic restoration, degrade pads, roads		
56	RoseCity1-J		Marsh	Hydrologic restoration, degrade pads, roads		
57	RoseCity1-K		Marsh	Hydrologic Restoration, Backfill channel		
58	RoseCity1-L	119	Marsh	marsh restoration	owned by SNND and E Arnaud; would be expensive to fill;	Out
59	Beaumont2hires-A	90	Pond in Borrow Pit	forested wetland restoration would require filling, hydrologic access, long term management	pond bordered by houses/boat ramps - screened out based on cost to fill and slow benefits to reforest ;	Out
60	Beaumont2hires-B	24	Pond in Borrow Pit			
61	Beaumont2hires-C	70	Pond in Borrow Pit			
62	Beaumont2hires-D	61	Pond in Borrow Pit			
63	Beaumont2hires-E	29	Pond in Borrow Pit			
64	Beaumont2hires-F	46	Pond in Borrow Pit			
65	Beaumont2hires-G	97		forested wetland restoration would require filling, hydrologic acces	active borrow pit ; screened out based on cost to fill and slow benefits to reforest	Out
66	Beaumont2hires-H		Swp/Marsh	Hydrologic Restoration, Backfill channel	In Mitigation area 8 and BTNP	Out
67	Beaumont2hires-I		Marsh/Swp	Hydrologic Restoration, Backfill channel	In Mitigation area 10	Out
68	Beaumont2hires-J		BH/Swp	Hydrologic Restoration, Backfill channel	could have benefit for forested habitat in northern part of area; benefits expected to be low	Out
69	Beaumont2hires-K	93	BH/.Swp	forested wetland restoration	fill pond, in mitigation area 7	Out
70	Beaumont2hires-L		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation area 7 and BTNP	Out
71	Beaumont2hires-M		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation area 5 and BTNP	Out
72	Beaumont2hires-N		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation areas 4 and 6 and BTNP	Out
73	Beaumont2hires-O		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation area 6 and BTNP	Out
74	Beaumont2hires-P		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation area 3 and BTNP	Out
75	Beaumont2hires-Q		BH/Swp	Hydrologic Restoration, Backfill channel	In mitigation area 2 and BTNP	Out
76	Beaumont3hires-A		BH/Swp	Hyrdologic restoration, bridges, culverts	road to Neches Saltwater Barrier	Out
77	Beaumont3hires-B	21	Borrow Pit Ponds/Swp	Forested wetland restoration, backfill borrow pits; lowest priority due to cost and time it takes for benefits - thru 83	Parkwood Land company	Out
78	Beaumont3hires-C	9	Borrow Pit Ponds/Upland forest	Forested wetland restoration, backfill borrow pits	hydologic restoration needed provide flow; privately owned	Out
79	Beaumont3hires-D	11				
80	Beaumont3hires-E	10				
81	Beaumont3hires-F	17				

#	Location	Acres	Veg	Action	Notes	Screening Result
82	Beaumont3hires-G	25	forest			
83	Beaumont3hires-H	40				
84	Beaumont3hires-I		Road in upland forest	Hyrdologic restoration for upland forest, bridges, culverts	screened out - county or state road	Out
85	NOrange	529	Man-made lake in BH/Swp	Forested wetland restoration, backfill lake	Named "Tailings Lake"; HTRW concerns	Out
86	Orange1hires-A		Logging Channel in Swp	Hydrologic Restoration for Swp; Backfill channel	WMA, In mitigation area 18 TWPD does not support backfilling of channel	Out
87	Orange1hires-B		Logging Channel in Swp	Hydrologic Restoration for Swp, Backfill channel	WMA/mit bank, In mitigation areas 17, 20, 21; provides city drainage: TPWD does not support backfilling of channel	Out
88	Orange1hires-C		Logging Channel in Swp	Hydrologic Restoration for Swp/Marsh, Backfill channel	WMA/mit bank, In mitigation areas 22, 23; TPWD does not support backfilling of channel	Out
89	Orange1hires-D	12	Borrow pit pond in swp	Forested wetland restoration, backfill borrow pits	WMA, Existing marina/boat repair;	Out
90	Orange1hires-E	5.5	Channel in marsh/swp	Hydrologic Restoration, Backfill channel	WMA, Channel from existing marina/boat repair/ Could put gap in spoil bank to help area drain; benefits would likely be low	Out
91	Orange1hires-F		Logging Channel in Swp/marsh	Hydrologic Restoration for Swp/Marsh, Backfill channel	WMA/Blue Elbow mit bank, In mitigation area 24; TPWD does not support backfilling of channel	Out
92	Orange1hires-G		Channel in Swp/marsh	Hydrologic Restoration, Backfill channel	WMA/mit bank, TPWD and marina access channel out	Out
93	Orange3hires-A	1.1	Marsh	marsh restoration	small affected areas and small benefits	Out
94	Orange3hires-B	0.5	Marsh	marsh restoration		
95	Orange3hires-C	1	Marsh	marsh restoration		
96	Orange3hires-D	14	Marsh	marsh restoration		
97	Orange3hires-E		Marsh	Hyrdologic restoration, bridges, culverts		
98	Orange3hires-F		Marsh	Hyrdologic restoration, bridges, culverts		
99	Orange3hires-G		Marsh	Hyrdologic restoration, degrade levee		
100	Orange3hires-H	2.5	Marsh	Forested wetland restoration, backfill access channel		
101	CowBayou1-A	6.5	PEM/FW	Backfill bottow pit/FW and/or marsh restoration	Industrial treatment ponds; HTRW concerns	Out
102	CowBayou1-B	4.4	PEM/FW	Backfill bottow pit/FW and/or marsh restoration		
103	CowBayou1-C	14	PEM/FW	Backfill bottow pit/FW and/or marsh restoration		
104	CowBayou1-D		marsh	hydrologic restoration	small affected areas and small benefit	Out
105	CowBayou1-E	7	marsh	marsh restoration	Industrial treatment ponds; HTRW concerns	Out
106	CowBayou1-F	4.5	marsh	marsh restoration		
107	CowBayou1-G(1&2)	5	marsh	marsh restoration	small affected areas and small benefits	Out
108	CowBayou1-H	6	marsh	backfill/marsh restoration		
109	CowBayou1-I	1.5	marsh	backfill/marsh restoration		
110	CowBayou1-J	0.7	marsh	backfill/marsh restoration		
111	CowBayou1-K	0.5	marsh	backfill/marsh restoration		
112	BridgeCity1hires-A	5	marsh	marsh restoration, backfill channel		
113	BridgeCity1hires-C		marsh	Hydrologic Restoration, Backfill channel; degrade or add culverts to roads	Hunting club; managed for waterfowl; additional marsh mitigation not needed	Out
114	BridgeCity1hires-B	179	marsh			
115	BridgeCity1hires-B	24	marsh			
116	BridgeCity1hires-C	163	marsh			
117	BridgeCity1hires-D		marsh			
118	BridgeCity1hires-E		marsh			
119	BridgeCity1hires-F		marsh			
120	BridgeCity1hires-G	334	marsh	Marsh restoration	already included in mitigation areas 27 and 28;	Out
121	BridgeCity2hires-A		marsh	Hydrologic Restoration, Backfill channel	located in WMA and in mitigation area 28; TPWD does not support backfilling of channel	Out
122	BridgeCity2hires-B		marsh	Hydrologic Restoration, remove levee/roads	located in WMA; benefits would be small compared to marsh restoration in vicinity	Out
123	BridgeCity2hires-C	113	marsh	Marsh restoration	located in WMA; included in mitigation area 29; referenced as Measure 29	In

#	Location	Acres	Veg	Action	Notes	Screening Result
124	BridgeCity2hires-D		marsh	Hydrologic Restoration, Backfill channel	located in WMA; access channel for Bridge City; filling channel not advisable	Out
125	BridgeCity2hires-E	109	marsh	marsh restoration	leveed area owned by oil co; more marsh rest not needed	Out
126	BridgeCity3hires-A		marsh	Hydrologic Restoration, remove levees	WMA; part of TPWD restoration effort	Out
127	BridgeCity3hires-B	66	marsh	marsh restoration		
128	BridgeCity3hires-C		marsh	Hydrologic Restoration, remove levee/roads		
129	BridgeCity3hires-D	45	marsh	Hydrologic Restoration, remove levee/roads		
130	BridgeCity3hires-E	113	marsh	marsh restoration	partially in WMA; Chevron restoration site	Out
131	BridgeCity3hires-F	57	marsh	marsh restoration	located in WMA; small area and small benefits	Out
132	BridgeCity3hires-G	0.35	marsh	marsh restoration; combine with 131		
133	BridgeCity3hires-H	31	marsh	hydrologic restoration, degrade levee /backfill?	adjacent to Old River WMA; small area affected; small benefits	Out
134	BridgeCity3hires-I	2.4	marsh	backfill/marsh restoration	drainage for Hwy 73	Out
135	BridgeCity3hires-J	76	marsh	backfill/marsh restoration	inflow canal for electric power plant	Out
136	BridgeCity3hires-K	1539	marsh	marsh restoration	WMA: SNWW CIP Old River BU feature	Out
137	BridgeCity3hires-L	62	marsh	hydrologic restoration/degrade levee/rest marsh	mostly in WMA;previous restoration site	Out
138	BridgeCity3hires-M		marsh	hydrologic restoration/degrade levee/rest marsh	small additional benefits	Out
139	BridgeCity3hires-N	138	marsh	hydrologic restoration/degrade levee/rest marsh	leveed area managed for unknown purpose	Out
140	bessieheightsnehires-A	491	marsh	marsh restoration	SNWW CIP Neches BU site	Out
141	bessieheightsnehires-B	458	marsh	marsh restoration	SNWW CIP Neches BU site	Out
142	bessieheightsnehires-C	129	marsh	marsh restoration	SNWW CIP Neches BU site	Out
143	bessieheightsnehires-D	160	marsh	marsh restoration	fishing club, leveed for fresh water fish; might be better extra scale instead of 30, combined with 31	In
144	bessieheightsnehires-E	134	marsh	marsh restoration	might be better extra scale instead of 30, combined with 31	In
145	bessieheightsnehires-E	1965	marsh	marsh restoration	partially WMA; SNWW CIP Neches BU site	Out
146	bessieheightsnwhires-A	347	marsh	marsh restoration	SNND property; nearby marsh mitigation areas provided more than adequate compensation; furthest pumping distance	Out
147	bessieheightsnwhires-B	843	marsh	marsh restoration	partially within WMA; considered with 33; sufficient compensation provided by Measure 32.	Out
148	bessieheightsnwhires-C	680	marsh	marsh restoration	partially within WMA and SRA property; sufficient compensation provided by Measure 32.	Out
149	portneches1hires-A	12	marsh	Hydrologic Restoration, backfill channel/gate?	canal access to Bessie Heights; not now	Out
150	portneches1hires-B	11	marsh	Hydrologic Restoration, backfill channel/gate?		
151	portneches1hires-C	2	marsh	backfill/marsh restoration	SNWW PA 20	Out
152	portneches1hires-D	147	marsh	Hydrologic Restoration,degrade levee	SNWW PA 20	Out
153	portneches1hires-E	4	marsh	backfill/marsh restoration	small area and small benefit	Out
154	portneches2hires-A		marsh	hydrologic restoration/degrade road	road to MARAD facility	Out
155	portneches2hires-B	510	marsh	hydrologic restoration/degrade levee	existing SNWW CIP PA 23	Out
156	portneches2hires-C	254	marsh	hydrologic restoration/degradelevee	existing SNWW CIP PA 23A	Out
157	portneches3hires-D	75	former swamp	forested wetland restoration	Encircled by industry ; screened out	Out
158	bessieheights2-A	3	forested wetland	backfill/forested wetland restoration	small area and small benefit	Out
159	bessieheights2-B	11	forested wetland	backfill/forested wetland restoration	small area and small benefit	Out
160	Neches EPA add	76	Swp/BU	impounded and degraded forested wetland; remove encircling road; replant forest	small area and long time needed to earn benefits; retain as lowest priority	Out
161	Bessie Heights USACE add	209	BH/Swp	BH with small swamp sloughs.	In FWOP, area would be lost to development; has developed neighborhoods on 2 sides; Nelda Stark unit not contiguous but very close	In
161	Bessie Heights USACE add	209	BH/Swp	Tallow removal and control	Tallow removal and control difficult to maintain in long run;tallows would likely reestablish if management is ever discontinued; incremental cost is high;	Out

ATTACHMENT 7
WVA MODEL OUTPUT – FINAL ARRAY OF MITIGATION ALTERNATIVES

Sabine Pass to Galveston Bay Feasibility Study
Mitigation Plan Evaluation Array
Swamp Summary Table
Intermediate RSLR Scenario

Total Acres	Mitigation Alternative		Statistics		
291.2	S2G Mit 11 Swamp		SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	252.92	1.40	252.65	253.19
	B. Future Without Project AAHUs=	239.74	1.21	239.50	239.98
	Net Benefit (FWP - FWOP)=	13.18	1.73	12.84	13.52

207.3	S2G Mit 12 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	179.74	1.01	179.55	179.94
	B. Future Without Project AAHUs=	170.37	0.84	170.21	170.54
	Net Benefit (FWP - FWOP)=	9.37	1.24	9.12	9.61

291.0	S2G Mit 14 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	252.32	1.42	252.04	252.59
	B. Future Without Project AAHUs=	239.19	1.17	238.96	239.42
	Net Benefit (FWP - FWOP)=	13.12	1.74	12.78	13.47

213.1	S2G Mit 15 Scale 1 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	184.96	0.94	184.78	185.15
	B. Future Without Project AAHUs=	175.40	0.99	175.20	175.59
	Net Benefit (FWP - FWOP)=	9.56	1.34	9.30	9.83

51.7	S2G Mit 15 Scale 2 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	44.90	0.25	44.85	44.95
	B. Future Without Project AAHUs=	42.55	0.21	42.51	42.59
	Net Benefit (FWP - FWOP)=	2.36	0.31	2.30	2.42

1321	S2G Mit 17 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	1043.56	7.79	1042.04	1045.09
	B. Future Without Project AAHUs=	1003.61	7.43	1002.15	1005.06
	Net Benefit (FWP - FWOP)=	39.96	10.68	37.86	42.05

367	S2G Mit 22 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	289.92	2.18	289.49	290.34
	B. Future Without Project AAHUs=	278.82	2.06	278.42	279.23
	Net Benefit (FWP - FWOP)=	11.09	2.97	10.51	11.68

284	S2G Mit 24 Swamp		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	212.13	1.76	211.79	212.48
	B. Future Without Project AAHUs=	206.33	2.27	205.88	206.77
	Net Benefit (FWP - FWOP)=	5.81	2.99	5.22	6.39

Sabine Pass to Galveston Bay Feasibility Study
Mitigation Plan Evaluation Array
Bottomland Hardwood Summary Table
Intermediate RSLR Scenario

Total Acres	Mitigation Alternative		Statistics		
155.7	S2G Mit 11 BH		SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	119.99	0.38	119.91	120.06
	B. Future Without Project AAHUs=	113.81	0.41	113.73	113.89
	Net Benefit (FWP - FWOP)=	6.18	0.60	6.06	6.30

221.4	S2G Mit 12 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	124.49	0.40	124.41	124.57
	B. Future Without Project AAHUs=	117.81	0.43	117.73	117.90
	Net Benefit (FWP - FWOP)=	6.68	0.62	6.56	6.80

153.1	S2G Mit 14 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	127.63	0.27	127.58	127.69
	B. Future Without Project AAHUs=	120.83	0.25	120.78	120.88
	Net Benefit (FWP - FWOP)=	6.80	0.38	6.73	6.88

223.5	S2G Mit15, Scale 1 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	185.91	0.47	185.82	186.01
	B. Future Without Project AAHUs=	176.38	0.37	176.31	176.45
	Net Benefit (FWP - FWOP)=	9.53	0.65	9.40	9.66

88.7	S2G Mit 15 Scale 2 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	72.52	0.17	72.48	72.55
	B. Future Without Project AAHUs=	68.61	0.18	68.58	68.65
	Net Benefit (FWP - FWOP)=	3.90	0.24	3.86	3.95

34.9	S2G Mit 26 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	29.34	0.02	29.34	29.34
	B. Future Without Project AAHUs=	10.90	0.00	10.90	10.90
	Net Benefit (FWP - FWOP)=	18.44	0.02	18.43	18.44

112.4	S2G Mit 161-Scale 1 BH		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	78.89	0.43	78.80	78.97
	B. Future Without Project AAHUs=	29.55	0.10	29.53	29.57
	Net Benefit (FWP - FWOP)=	49.34	0.45	49.25	49.43

112.4	S2G Mit 161-Scale 2		Statistics		
			SD	95% C.I.	
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project AAHUs=	85.25	0.28	85.20	85.31
	B. Future Without Project AAHUs=	29.56	0.11	29.54	29.58
	Net Benefit (FWP - FWOP)=	55.69	0.31	55.63	55.76

Sabine Pass to Galveston Bay Feasibility Study
Mitigation Plan Evaluation Array
Fresh Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Mitigation Alternative	Version 1.0			
73.5	**S2G Mit 42 Scale 1 Fresh**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	45.21	0.16	45.18	45.25
	B. Future Without Project Emergent Marsh AAHUs=	19.79	0.10	19.77	19.81
	Net Change (FWP - FWOP)=	25.42	0.19	25.39	25.46
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	7.24	0.04	7.23	7.25
	B. Future Without Project Open Water AAHUs=	15.34	0.06	15.33	15.36
	Net Change (FWP - FWOP)=	-8.10	0.07	-8.12	-8.09
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	25.42	0.19	25.39	25.46
	B. Open Water Habitat Net AAHUs=	-8.10	0.07	-8.12	-8.09
	Net Benefits=	14.61	0.13	14.58	14.63

137.3	S2G Mit 42 Scale 2 Fresh	Version 1.0			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	75.87	0.29	75.81	75.93
	B. Future Without Project Emergent Marsh AAHUs=	22.41	0.05	22.40	22.42
	Net Change (FWP - FWOP)=	53.46	0.29	53.40	53.52
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	16.42	0.08	16.40	16.43
	B. Future Without Project Open Water AAHUs=	34.33	0.13	34.31	34.36
	Net Change (FWP - FWOP)=	-17.92	0.16	-17.95	-17.89
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	53.46	0.29	53.40	53.52
	B. Open Water Habitat Net AAHUs=	-17.92	0.16	-17.95	-17.89
	Net Benefits=	30.43	0.21	30.39	30.47

206.8	S2G Mit 52 Fresh	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	161.43	0.51	161.33	161.53
	B. Future Without Project Emergent Marsh AAHUs=	106.74	0.40	106.66	106.81
	Net Change (FWP - FWOP)=	54.70	0.60	54.58	54.81
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	11.96	0.07	11.95	11.97
	B. Future Without Project Open Water AAHUs=	23.41	0.13	23.39	23.44
	Net Change (FWP - FWOP)=	-11.45	0.14	-11.48	-11.42
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	54.70	0.60	54.58	54.81
	B. Open Water Habitat Net AAHUs=	-11.45	0.14	-11.48	-11.42
	Net Benefits=	33.36	0.41	33.28	33.44

Sabine Pass to Galveston Bay Feasibility Study
Mitigation Plan Evaluation Array
Intermediate Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Mitigation Alternative	Version 1.0			
371.5	**S2G Mit 31 Intermediate**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	258.86	0.88	258.69	259.03
	B. Future Without Project Emergent Marsh AAHUs=	151.36	0.66	151.23	151.49
	Net Change (FWP - FWOP)=	107.50	1.07	107.29	107.71
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	33.39	0.38	33.31	33.46
	B. Future Without Project Open Water AAHUs=	71.87	0.74	71.73	72.01
	Net Change (FWP - FWOP)=	-38.48	0.85	-38.65	-38.32
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	107.50	1.07	107.29	107.71
	B. Open Water Habitat Net AAHUs=	-38.48	0.85	-38.65	-38.32
	Net Benefits=	60.41	0.77	60.26	60.56

87.8	S2G Mit 32 Intermediate	Version 1.0			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	36.12	0.17	36.08	36.15
	B. Future Without Project Emergent Marsh AAHUs=	1.07	0.01	1.07	1.07
	Net Change (FWP - FWOP)=	35.05	0.17	35.01	35.08
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	17.16	0.21	17.12	17.20
	B. Future Without Project Open Water AAHUs=	20.31	0.08	20.29	20.32
	Net Change (FWP - FWOP)=	-3.15	0.23	-3.20	-3.11
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	35.05	0.17	35.01	35.08
	B. Open Water Habitat Net AAHUs=	-3.15	0.23	-3.20	-3.11
	Net Benefits=	22.72	0.14	22.70	22.75

305.1	S2G Mit 143 Intermediate	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	132.44	0.62	132.32	132.56
	B. Future Without Project Emergent Marsh AAHUs=	7.20	0.03	7.19	7.20
	Net Change (FWP - FWOP)=	125.24	0.61	125.12	125.36
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	61.08	1.25	60.84	61.33
	B. Future Without Project Open Water AAHUs=	89.75	1.93	89.38	90.13
	Net Change (FWP - FWOP)=	-28.67	2.39	-29.14	-28.20
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	125.24	0.61	125.12	125.36
	B. Open Water Habitat Net AAHUs=	-28.67	2.39	-29.14	-28.20
	Net Benefits=	75.59	0.89	75.42	75.77

Sabine Pass to Galveston Bay Feasibility Study
Mitigation Plan Evaluation Array
Brackish Marsh Summary Table
Intermediate RSLR Scenario

Total Acres	Mitigation Alternatives	Version 1.0			
224.8	**S2G Mit 27 Brackish**				
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	139.66	0.47	139.57	139.76
	B. Future Without Project Emergent Marsh AAHUs=	77.24	0.35	77.17	77.30
	Net Change (FWP - FWOP)=	62.43	0.57	62.32	62.54
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	35.49	0.38	35.41	35.56
	B. Future Without Project Open Water AAHUs=	72.88	0.75	72.74	73.03
	Net Change (FWP - FWOP)=	-37.39	0.86	-37.56	-37.23
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	62.43	0.57	62.32	62.54
	B. Open Water Habitat Net AAHUs=	-37.39	0.86	-37.56	-37.23
	Net Benefits=	40.24	0.47	40.15	40.34

410.7	**S2G Mit 28 Brackish**	**Version 1.0**			
	Marsh	**Mean**	**SD**	**95% C.I.**	
	NET CHANGE IN AAHUs DUE TO PROJECT			**Lower**	**Upper**
	A. Future With Project Emergent Marsh AAHUs=	281.12	0.89	280.94	281.29
	B. Future Without Project Emergent Marsh AAHUs=	191.34	0.74	191.19	191.48
	Net Change (FWP - FWOP)=	89.78	1.13	89.56	90.00
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	48.47	0.52	48.37	48.57
	B. Future Without Project Open Water AAHUs=	99.28	1.02	99.08	99.48
	Net Change (FWP - FWOP)=	-50.81	1.18	-51.04	-50.58
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	89.78	1.13	89.56	90.00
	B. Open Water Habitat Net AAHUs=	-50.81	1.18	-51.04	-50.58
	Net Benefits=	58.54	0.91	58.36	58.72

189.6	S2G Mit 29 Brackish	Version 1.0			
	Marsh	Mean	SD	95% C.I.	
	NET CHANGE IN AAHUs DUE TO PROJECT			Lower	Upper
	A. Future With Project Emergent Marsh AAHUs=	98.99	0.34	98.92	99.06
	B. Future Without Project Emergent Marsh AAHUs=	40.90	0.22	40.86	40.94
	Net Change (FWP - FWOP)=	58.09	0.40	58.01	58.17
	Open Water				
	NET CHANGE IN AAHUs DUE TO PROJECT				
	A. Future With Project Open Water AAHUs=	30.63	0.31	30.57	30.69
	B. Future Without Project Open Water AAHUs=	45.26	0.42	45.18	45.35
	Net Change (FWP - FWOP)=	-14.63	0.54	-14.74	-14.53
	Total				
	TOTAL BENEFITS IN AAHUs DUE TO PROJECT				
	A. Emergent Marsh Habitat Net AAHUs=	58.09	0.40	58.01	58.17
	B. Open Water Habitat Net AAHUs=	-14.63	0.54	-14.74	-14.53
	Net Benefits=	41.93	0.33	41.87	41.99