U.S. Army Corps of Engineers

Galveston District
Southwestern Division

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

Final Integrated Feasibility Report–Environmental Impact Statement

APPENDIX P-1

MITIGATION PLAN FOR OYSTER REEF HABITAT

November 2019

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1.0 BACKGROUND

Implementation of the National Economic Development (NED) or the Locally Preferred Plan (LPP) for the Houston Ship Channel (HSC) Expansion Channel Improvement Project (ECIP) would permanently impact the oyster reef within the footprint of the proposed channel modifications. These plans would consist of channel modification measures to widen the HSC, Bayport Ship Channel (BSC), and Barbours Cut Channel (BCC), ease channel bends, expand existing turning basins and constructing new ones, and a possible anti-shoaling feature. These measures are geographically spread along the entire length of the HSC navigation system from Bolivar Roads near the entrance into Galveston Bay, to the Main Turning Basin in the Buffalo Bayou reach of the HSC near the center of Houston. Currently, the HSC-ECIP has completed the Feasibility-Level Analysis milestone phase of the U.S. Army Corps of Engineers (USACE) Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process. The LPP includes features of the NED Plan, additional widening of the HSC from Barbours Cut to south of Red Fish Island and the proposed shoaling attenuation feature.

The large majority of reef impacts would occur along the margins of the HSC within Galveston Bay, because that is where the most extensive, contiguous reef is mapped. The proposed HSC channel widening through the Bay would result in the majority of the impacts. The proposed channel width was determined to be 700 feet, using ship simulation conducted with the participation of the Houston Pilots Association (HPA) during two simulation rounds during the previous planning phases. Sufficient width to realize the economic benefits necessary to justify the plan depends on having enough width for safe two-way traffic meeting of design vessels. The Bay widening is also divided lengthwise into the 3 straight segments of the existing HSC alignment. The need to replace the existing shallow draft barge lanes directly adjacent to the main channel of the HSC and shift them outward of the revised channel also accounts for a majority of potential reef impact.

Oyster reef locations are not available above Morgans Point at the head of the Bay to determine potential reef impacts of the NED Plan or LPP. However, adequate salinity and unmaintained, shallow depth needed to support reef growth is limited in the NED areas above Morgans Point. Most of these areas are in portions of the existing HSC, turning basins, or adjacent to berths where waters are deepened and periodically maintained by dredging. Therefore, the potential for reef acreage is small compared to the potential impacts in the Bay. The limited areas above Morgans Point that have potential to contain reef were identified using side-scan sonar (sound navigation and ranging) and surveyed July through October 2018 for the presence of oyster reef habitat, (Oyster Groundtruthing Report. 2018, attached). Prior to the 2018 survey, the Powell et al. historical reef mapping (circa 1991) was initially reviewed to determine impacts below Redfish Reef. Included in the survey, were potential areas for siting new Placement Areas (PA) or Beneficial Use (BU) sites, following planning for the specific dredged material management plan (DMMP) that would provide for the placement of dredged material during construction ("new work") and provide for long term periodic incremental maintenance of the channel improvements.

The USACE Civil Works CECW-PC Memorandum for *Implementation Guidance for Section 2036(a) of the Water Resources Development Act of 2007 (WRDA 07) - Mitigation for Fish and Wildlife and Wetlands Losses*, dated 31 August 2009 (hereafter referred to as the WRDA 2007

Implementation Memo), reiterates mitigation requirements for any report being submitted to Congress for approval, but also adds the requirement for mitigation plans to comply with the mitigation standards and policies of the USACE Regulatory Program including specific mitigation plan components. The memo is applicable to Civil Works water resources projects that require specific authorization. The content and structure of this Final Mitigation Plan are being developed to meet the requirements for Regulatory Program compensatory mitigation plans in 33 CFR 332.4(c). The functional habitat modeling for this Final Mitigation Plan has been conducted to identify the mitigation amounts associated with the varying habitat quality (driven by the salinity regime) to comply with USACE Civil Works policy.

2.0 OBJECTIVES

The primary objective of the mitigation project is to replace the significant net losses of Average Annual Habitat Units (AAHUs) of oyster reef habitat that would be removed during modifications made to the HSC to implement the NED or the LPP through restoration of oyster habitat at one or more of the sites identified in Galveston Bay, shown in **Figure 1**. Specifically, the mitigation plan proposes to provide the sufficient area of elevated relief and hard substrate surface for oyster attachment to compensate for the direct impacts associated with dredging the NED or the additional areas of the LPP. The restoration would replace the existing oyster habitat in Galveston Bay by providing the needed acres of hard surface area available for natural recruitment of oyster larvae. Restoration would take place at sites selected from several sites impacted by Hurricane Ike-induced sedimentation in 2008 that were identified in the initial phase of planning for the NED and LPP. Texas Parks and Wildlife Department (TWPD) has estimated that more than 50% of the reef in Galveston Bay was impacted by hurricane-induced sedimentation, and the Bay's oyster reef is a vital component of the commercial fishery of the State and Gulf Coast region. The restoration would also replace the oyster reef that contributes important ecological benefits to Galveston Bay, including provision of aquatic habitat structure for several fish and invertebrate species, improvement of water quality and clarity, as well as general re-establishment of essential fish and invertebrate habitat.

Though the primary objective is restoring reef for its habitat function, the natural reef in Galveston Bay is a harvestable resource responsible for the majority of State oyster production. The proposed project dredging would remove public reef acreage open to harvest that would remove not only live oysters, but also hard substrate that forms the necessary surface for annual recruitment, growth and seasonal harvest. Despite partial regrowth that may eventually occur in part of the relocated barge lanes as discussed in Section 5.3, the deepest parts of the new channel would not support oyster reef, and the barge lanes need to be periodically dredged. Without substrate replacement, reef may not predictably or fully grow back. Therefore, if reef that is harvested annually is permanently lost or only may temporarily reappear in between dredging cycles, replacing that resource that the oyster fishery depends on is a secondary objective.

3.0 SITE SELECTION CRITERIA

Potential mitigation sites in Galveston Bay were identified in consultation with the local resource agencies including TWPD, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Texas General Land Office (TGLO), Natural Resource Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA), Texas Water Development Board

(TWDB) and others during the Tentatively Selected Plan (TSP) phase of planning. Primary potential site identification was focused on sites targeted by TPWD for reef restoration as part of their ongoing effort to restore areas of previous reef impacted by Hurricane Ike in 2008. The proposed mitigation method discussed in Section 7 involves beneficially using project-dredged new work material to construct part of the topographical relief needed to restore reef. After initial collection of salinity data discussed later in this section and initial habitat modeling, two of the sites (San Leon and Dollar) were deemed more optimal for restoration due to the more favorable salinity. These sites identified two general areas to more specifically locate the required area of oyster reef mitigation pads. Also, more site-specific geotechnical information to assess bottom foundation conditions for placement and reef building may be collected in the next planning phase that could inform site selection. Therefore, more detailed mitigation site planning would take place during the Preconstruction Engineering Design (PED) to refine the location of padss considering dredging and foundation factors as well as further resource agency input.

Some of the candidate sites (Trinity and Fishers Reef, Dollar Reef, and San Leon Reef) were selected based on indication that they were impacted by sedimentation according to post-Hurricane Ike TPWD side-scan sonar data and sub-bottom profiling data collected by Texas A&M University at Galveston. The sub-bottom data indicated these reefs were silted over by 6 or more inches of sediment, and would be conducive to restoration by cultch placement. The candidate site footprints are in waters variously restricted or conditionally approved for shellfish harvesting by the Texas Department of State Health Services (TDSHS). This means the areas are closed to commercial harvesting for direct marketing (restricted) or subject to approval status changes based upon meteorological or hydrological (e.g. salinity) conditions. The majority of reef that would be impacted by the NED or the LPP are similarly in restricted or conditionally approved waters.

Following Hurricane Ike, the TPWD side-scan sonar surveys found that as much as 60 percent of the reefs in Galveston Bay were covered by hurricane-induced sedimentation eliminating or substantially reducing their function. This triggered an ongoing restoration effort by TPWD to reverse these losses. Because the candidate sites are in Galveston Bay, the mitigation would occur in the same bay system that the impacts would occur, and where restoration efforts have been planned and targeted by the resource agency with primary responsibility for oyster reef conservation. Direct on-site mitigation is not applicable in this situation as replacement reef cannot be appropriately located in the deepened navigation channel of the NED or the LPP. The restoration relies on natural oyster larvae recruitment and growth, and would be self-sustaining. This method has been successfully used on past similar restoration projects in Galveston Bay and around the nation (TPWD. 2011, TPWD. 2017, and LDWF. 2019). Monitoring of a similar restoration at Fisher's Reef, one of the candidate sites, indicated successful recruitment and sustained growth, even after two years of historically high freshwater inflows into the Bay, and accompanying depressed salinity, in 2015 and 2016. The two selected sites of San Leon and Dollar Reefs have remaining natural reef that would ensure a nearby source of larvae for recruitment to the nearby mitigation pads. Because these areas having been places of reef accretion, these are areas where bay currents would likely carry larvae whether from adjacent reef, or downdrift from other reef in the Bay. Also, based on experience of less than expected settlement during recent mitigation reef construction, the buried reef may provide a better structural foundation for new reef than soft bay bottom without buried reef.

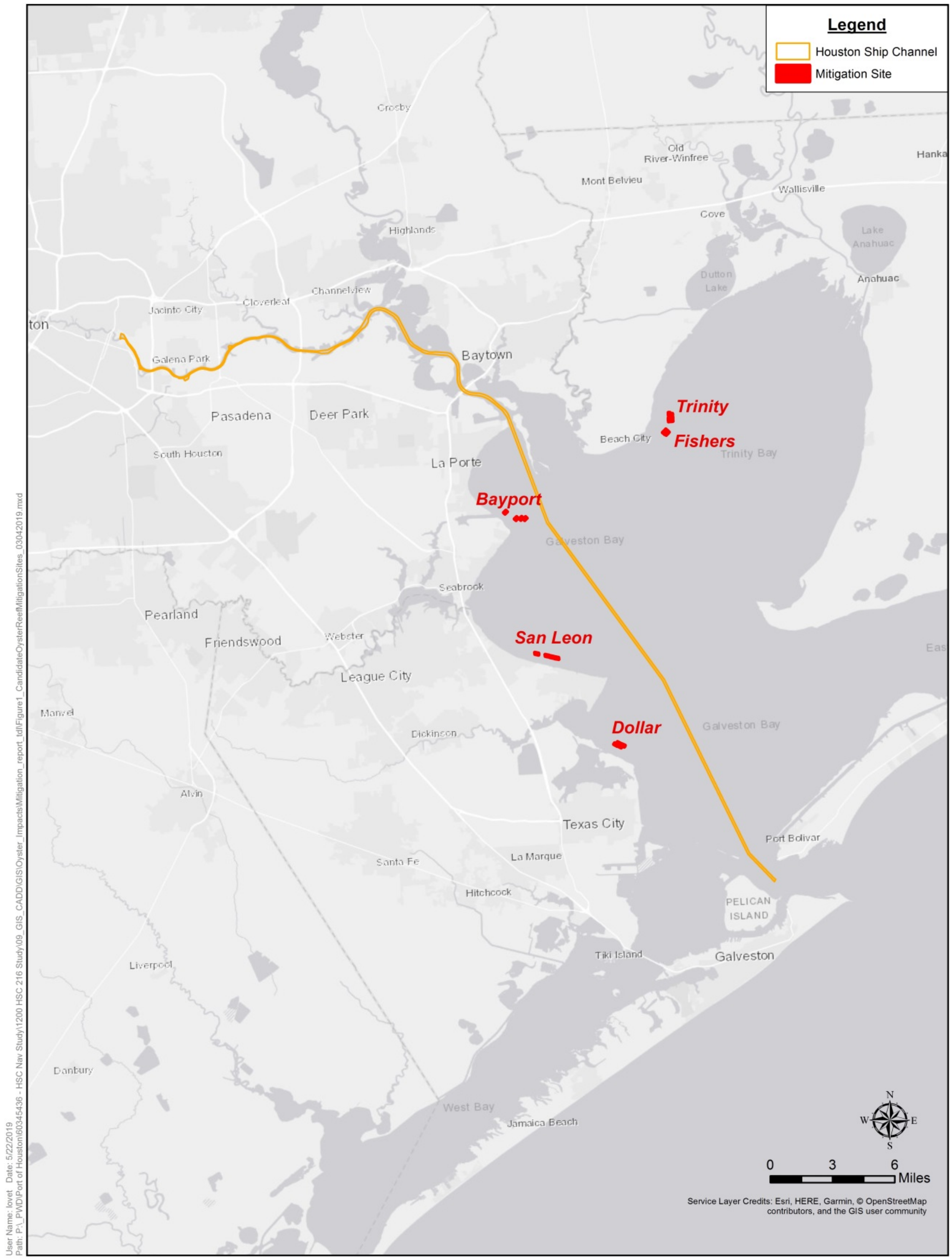

Figure 1 Candidate Oyster Reef Mitigation Sites

The candidate sites are located in different salinity regimes that influence their relative quality for restoring reef when assessed by oyster habitat models, **Figure 1**. Salinity from five of the long-term data sites was used to determine the baseline Habitat Suitability Index (HSI) within various parts of the bay **Table 1** and **Figure 2.** The specifics of the habitat model are discussed in Section 6, and assume 100% restored cultch density. As shown, the highest relative scores occur lower in the Bay, and are a product of the optimal average, monthly and spawning season salinities. With the highest relative scores, Dollar and San Leon sites were determined to best locations for the oyster mitigation.

The USACE's Engineering Research and Development Center (ERDC) have prepared a hydrodynamic model of Galveston Bay that assessed the hydrodynamic impacts of the TSP, including salinity (McAlpin et al. 2018). The TSP modeled was the 650-foot wide alternative equivalent of the LPP, which was selected to be 700 feet wide through the Bay. The model analyzed the salinity at 29 locations along the HSC and in the surrounding bay and, on average; the salinity did not vary by more than 2 parts per thousand (ppt) between the with and without project conditions at any location including the candidate sites (Trinity and Fishers Reef, Dollar Reef, and San Leon Reef). The model included changes in sea level rise of 1.914 ft (0.583 m) and a reduction of 12 percent freshwater flow from coordination with TWDB over the 50 year project life. Typically, there is a larger change in salinity (mean and salinity percentiles) with the projected future changes in sea level rise and reduced freshwater flow than between the changes with and without the project. The results of ERDC modeling, reconfirms that the Dollar and San Leon reef locations are best locations for oyster mitigation. The model also included average flow velocities for surface and bottom. These velocities and their direction were used for placement and orientation on the mitigation pads.

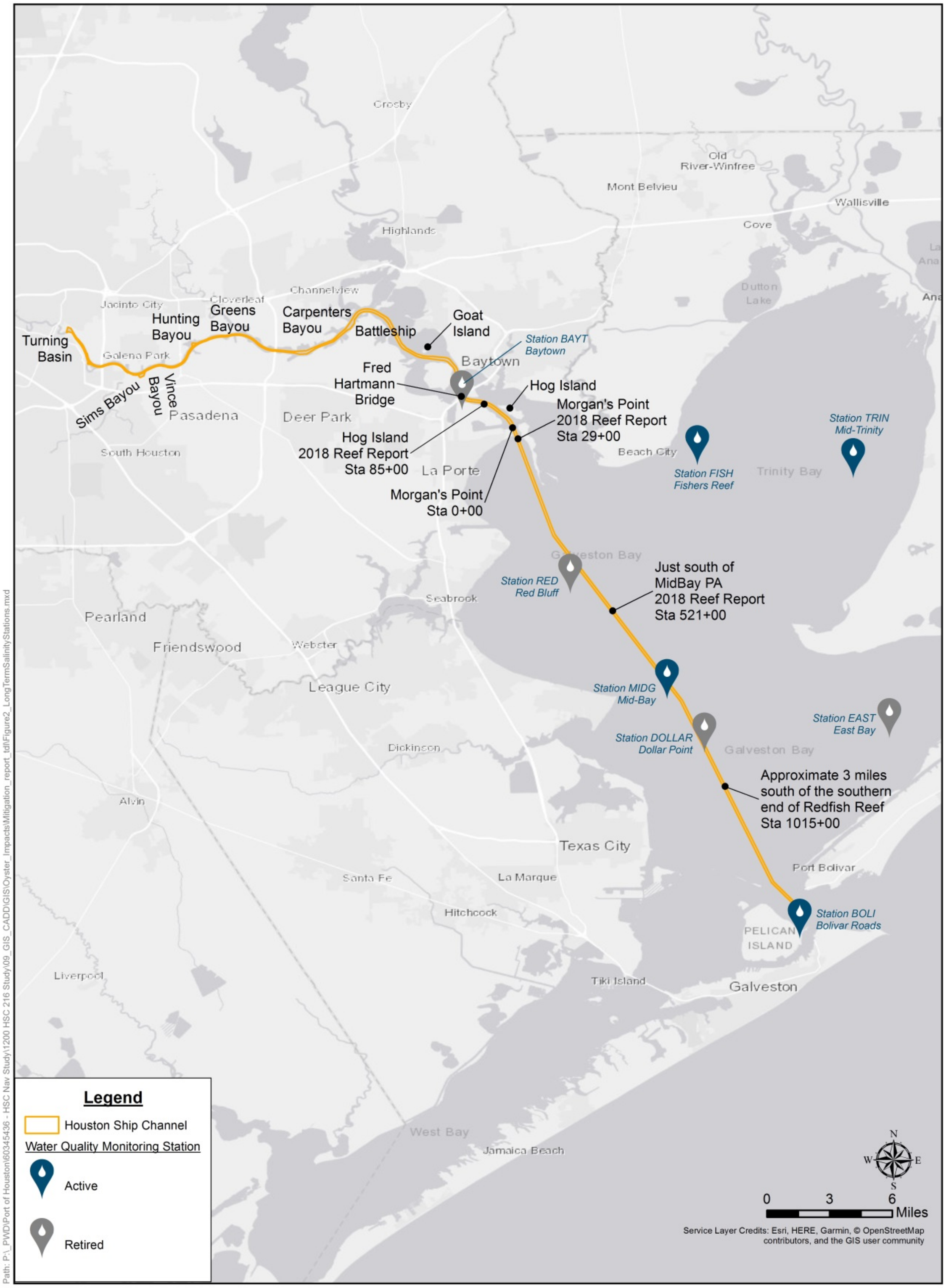

Figure 2 Texas Water Development Board Long Term Salinity Stations

Table 1 Candidate Oyster Reef Mitigation Sites

Site	Baseline HSI	Long-Term Salinity Station
Trinity	0.850	Fisher Reef (FISH)
Fishers	0.850	Fisher Reef (FISH)
Bayport*	0.715	Red Bluff (RED)
San Leon*	0.928	Mid-Bay (MIDG)
Dollar*	0.928	Mid-Bay (MIDG)

*Used for Determining Salinity Values for Modeling

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4.0 SITE PROTECTION INSTRUMENTS

The selected sites are located within Galveston Bay, for which, in general, the submerged land is State-owned and managed by the TxGLO. Natural resource use or impact is subject to regulation by various governmental agencies including but not limited to TPWD, USACE, NMFS, and the EPA. In addition, natural oyster reefs are public resources managed by TPWD, and subject to compensation for losses under the Restitution and Restoration Rule, Chapter 69 of Title 31 of the Texas Administrative Code (TAC) to seek restoration of fish, wildlife and habitat loss occurring as a result of human activities, pursuant to enforcement powers in the Parks and Wildlife Code and Water Code. Any activity impacting the resources regulated by those agencies within the proposed mitigation area would be regulated by these governmental agencies. This would include development or fill of the Waters of the U.S., and oyster reefs that would be present or restored there. Additionally, once the appropriate interest is acquired for the selected site(s) for restoration, the restored reef would become part of the Federal Civil Works project, subject to regulation under Section 408 of Title 33 of the U.S. Code for any modifications to a Federal project in navigable waters.

Because the reef being impacted would include publicly available reef that is currently commercially harvestable, the restored reef would have to consider eventual harvesting access to the restored reef to replace the resources lost to commercial harvesting from NED Plan or the LPP impacts. This coordination and eventual access would be determined in coordination the resource agencies, the State and Federal agencies charged with managing fishery resources. The impacted reefs are State-owned and managed public resources, and by current State law cannot be prohibited from allowable commercial harvest within season and applicable restriction conditions. The State passed legislation in 2017 to reduce commercial harvesting pressure to aid in reef recovery, including a license buyback program, stiffer harvesting rule violation penalties, and cultch replacement requirements. TPWD also recently adopted new regulations, including closing Saturdays to harvest during the season, reducing the rate of unintentional harvesting of below-market-size oysters, reduced sack limit, and closing of shoreline reef (within 300 feet) and certain bays (including Christmas Bay in the Galveston Bay system). Due to the market-size restrictions, the practical outcome of constructing a reef is that it would not be harvested for 3 years until recruited oysters reach market size.

5.0 BASELINE INFORMATION AND IMPACTS

Galveston Bay is characterized as a relatively large shallow bay with an extensive interconnected system of deeper navigational ship channels. With the exception of ship navigation channels and the MidBay constriction caused by Redfish Bar, both natural and anthropogenic oyster reefs constitute the largest physiographic feature in Galveston Bay. Remaining portions are comprised of sand, mud, silt and clay particles, and shell, with little bottom relief. Only very small portions of the Bay contain any sea grasses, limited to the West Bay and Smith's Point area of the Bay, which excludes the area impacted by the NED Plan, LPP, and the candidate mitigation sites. The project area in the vicinity of the NED Plan or the LPP within the Bay, and the candidate mitigation sites, are typical of Galveston Bay habitat.

5.1 Baseline Benthic Habitat Characterization and Mapping

The baseline condition of the benthic habitat within the NED Plan or the LPP footprint that would be impacted was determined primarily by three reef mapping datasets, briefly described below and shown in **Figure 3**. These mapping datasets relied primarily on sonar which is a robust method for detecting and characterizing the hard and soft nature of bay bottom and distinguishing oyster reef from soft mud bottom, the two prevalent conditions in Galveston Bay. As discussed at the beginning of this section, sea grasses in the Bay are limited to the West Bay and Smith's Point area of the Bay and therefore are not targeted for characterization in this Federal study or mitigation plan. The mapping datasets used were the following:

1. TPWD Post-Hurricane Ike Survey– Mapping provided to USACE Galveston District, produced from post-Ike damage assessment side-scan sonar surveys collected between 2010 and 2012, with coverage of Galveston Bay west of Atkinson Island, from approximately Morgans Point, station 29+00, down to just south of MidBay PA, station 521+00 (TPWD. 2012). This covers the NED and LPP footprints from MidBay PA to Morgans Point

2. Powell Historical Mapping (Powell et al. 1997) – Mapping conducted by Texas A&M University (TAMU) for the Galveston Bay National Estuary Program (GBNEP). Produced from sonar surveys collected in 1991, with coverage of central Galveston Bay, West Galveston Bay, portions of Trinity Bay, and most of East Bay. This mapping was originally used to assess the potential for impacts below MidBay, but was supplanted by 2018 surveillance. It was subsequently used to establish the lack of historical reef along the HSC within the NED and LPP Plan footprint from approximately below Redfish Reef to the study limit at Bolivar Roads. During the 2018 survey, the first 3 miles below Redfish Reef were surveyed where only very small sporadic reef patches grew near the channel but not lining it to confirm the absence of channel adjacent reef. This was confirmed.

3. 2018 Oyster Groundtruthing Report survey provided additional side-scan sonar and groundtruthing below MidBay PA from approximately station 521+00, to station 1015+00, located approximately 3 miles south of the southern end of Redfish Reef. Also, the 2018 Oyster Groundtruthing Report provided additional side-scan sonar data along the HSC above the TPWD survey from approximately station 29+00 northward to station 0+00 and then from 0+00 northwestward to approximately station 85+00 near Hog Island. One area

above Hog Island at Station 520+00 near the Battleship shown in Figure 3, was covered in the side-scan survey but not groundtruthed due to the measure MM1-520+00 being dropped from the plans. The Powell Historical Mapping indicated that south of station 1015+00, no additional oyster reef was observed and the 2018 survey above that for 3 miles confirmed the lack of channel-side reef accretion in areas of more favorable salinity.

The TPWD and the 2018 Oyster Groundtruthing Report survey mapping used newer side-scan sonar techniques and data processing, and more accurate positioning than the Powell mapping, and would therefore have higher resolution and detail for the reef extent map. The extent mapped by the TPWD survey north of the BSC and west of the HSC had a high degree of visual agreement with mapping performed for the PHA's BSC Improvements Project (Department of the Army permit SWG-2011-1183) in the same part of the Bay. The PHA permit surveys were conducted in 2011 by side-scan sonar surveys groundtruthed by aquatic science divers, with mapping produced by similar raster analysis techniques. This agreement helps validate the accuracy and confidence in the mapping used by the TPWD survey. The 2018 Oyster Groundtruthing Report side-scan sonar survey was groundtruthed in December 2018 by dredging to confirm the presence or absence of oyster habitat. The dredging validated the sonar survey was accurate in determining oyster habitat. The Powell mapping relied on older sonar techniques and earlier, less accurate Global Positioning Systems (GPS), but did have groundtruthing where equivocal reef signatures were encountered. The Powell mapping showed no oyster reefs along the HSC below Station 1015+00, approximately 3 miles south of the southern end of Redfish Reef. The Powell mapping is conservative, because it was conducted before Ike, likely accurate, and indicates no oyster habitat is present from Station 1015+00 to Bolivar Roads. As discussed in Section 1, oyster reef mapping is not available above Hog Island which is needed to determine potential reef impacts of measures upstream of Galveston Bay. However, conditions to support reef growth are limited, salinity levels are below 15 ppt ≥10 percent of the time (McAlpin et al. 2018) and efforts to identify the few areas with potential for reef is discussed in the next subsection.

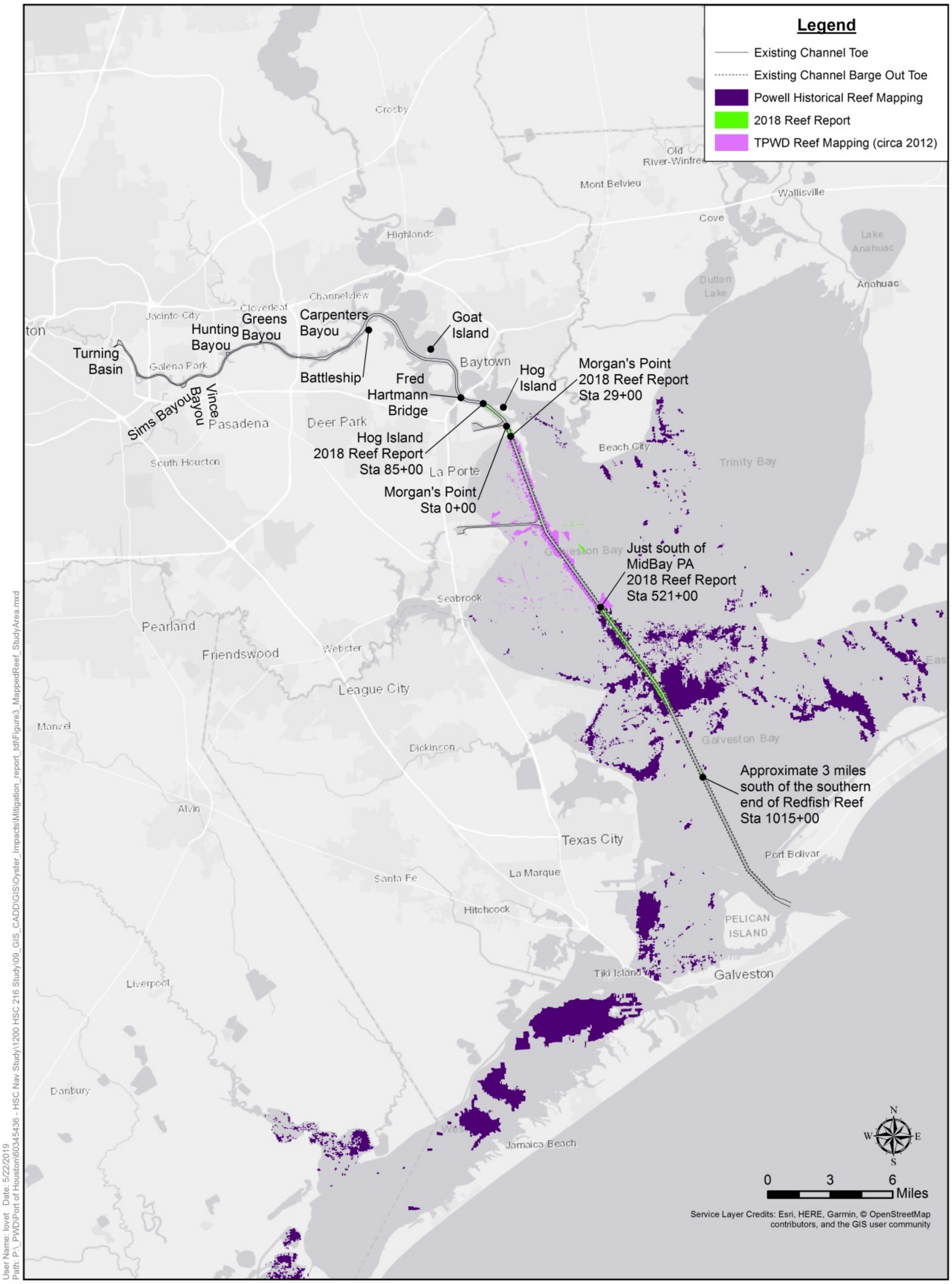


Figure 3 Mapped Reefs in the Study Area

5.2 Reef Potential Above Hog Island

To determine potential reef and any reef impacts upstream of Hog Island, various information that would indicate conditions conducive (or not) to reef development were reviewed to identify areas in the NED Plan or LPP footprint that would have the potential to support oyster reef growth.

Salinity

Though oysters can survive in salinities from 5 to 40 ppt, they grow and spawn most successfully when salinity is between 10 and 30 ppt, and dissolved oxygen is greater than 5 ppm (NRCS, 2011, Volety et al, 2009, Cake, 1983, Butler, 1954). Below prolonged salinities of 5 ppt, oysters would die of osmotic stress (Cake 1983). Data from the Texas Commission (TCEQ) Surface Water Quality Monitoring (SWQM) Program, and from the TWDB's Bays and Estuaries monitoring program as well from the McAlpin et al. 2018 modelling were examined.

Modelling McAlpin et al. 2018

McAlpin et al. 2018 modelled the salinity at 29 locations including HSC at Morgans Point and 6 additional locations upstream within the HSC (**Table 2**, **Figure 3**) At Sims Bayou the model predicts that the existing bottom salinity would be <5 ppt approximately 70% of the time. At Greens Bayou the McAlpin et al. 2018 predicted the existing bottom salinity would be <5 ppt approximately 22% of the time and at Goat Island approximately 4% of the time and approximately 18% of the time <10 ppt. These data indicate that oysters would have no to low potential of long term survival at and upstream of Greens Bayou within HSC. Below Greens Bayou to Fred Hartmann Bridge the potential of long-term oyster survival is low and increases to good chance of survival at Morgans Point.

Table 2 McAlpin et al. 2018 Data for Minimum Salinity, % of Time for <5 ppt and <10 ppt

Station Number	Location Along HSC	Minimum ppt*	% of time <5 ppt*	% of time <10 ppt*
29	Turning Basin	0	95	100
28	Sims Bayou	0	70	95
27	Greens Bayou	0	22	65
26	Carpenters Bayou	0	5	30
25	Goat Island	0	4	18
24	Fred Hartmann Bridge	2	3	5
1	Morgans Point	9	0	1

*Values Interpolated from Grafts

Typically in Galveston Bay, there are two major spawning/spat set peak periods in the year: the greatest peak is from April to June, and a smaller one around August. The McAlpin et al. 2018 showed that Sims Bayou and above, the salinity between April and June is at or below the 5 ppt needed for oyster long-term survival and for August only the Sims Bayou ranges above 5 ppt. At Greens Bayou the April-June ranges from 4 to 8 ppt and 5-14 ppt for August. This indicates that spanning set at Greens Bayou is marginal for the two spanning periods: April-June and August. However, the modelling data indicates that over 20% of the time the salinity is below 5 ppt at

Greens Bayou. At Carpenters Bayou, the April-June salinity ranges from 5 to 13 ppt and August salinity ranges from 7 to 14 ppt. With only 5% of the time below 5% salinity at Carpenters Bayou, the long-term survival of oysters is marginal at Carpenters Bayou.

The results in McAlpin et al. 2018 indicated the following would be expected:

- Greens Bayou to Morgans Point – conditions range from too fresh at Greens Bayou to a lower potential for thriving reef downstream to Fred Hartmann Bridge to increasing probability for long-term growth and survival at Morgans Point.

- Greens Bayou to Main Turning Basin – too fresh; long-term growth not expected

Grab Samples

Data from the TCEQ SWQM for stations along the HSC was obtained and analyzed within a database and Geographic Information System (GIS). The TCEQ data contains many years' worth of grab samples that typically reflect monthly sampling at many locations throughout the Bay and upstream along the HSC. The TWDB program operates continuously monitoring data sondes; however, this only covers 10 locations throughout the Bay, and not upstream of Morgans Point. To address concerns that the TCEQ monthly grab sample would not capture the variability of salinity that occurs with tidal cycling, short freshwater inflow events, and other causes, data were compared between TCEQ and TWDB datasets at common stations with similar periods of record. This is shown in **Table 3** below. As shown, the difference in average salinity is within 1.5 ppt. Therefore, TCEQ salinity data upstream of Morgans Point was deemed useful for assessing average and prevailing conditions for supporting reef growth for the purposes of prioritizing surveys in the next planning phase. It should also be noted that the Fred Hartmann Bridge grab sample average of 13.2 ppt, **Table 3**, is for the upper part of the salinity profile and not bottom part of the profile as modelled in McAlpin et al. 2018. The results in McAlpin et al. 2018 average value is approximately 20 ppt in the bottom part of the profile at Fred Hartmann Bridge. The results in McAlpin et al. 2018 showed a typical salinity profile for the Hartmann Bridge with an average value of approximately 11 ppt for the upper section of the profile. The model value and the average grab sample value at Fred Hartmann Bridge of the upper part of the profile are roughly equivalent.

Table 3 Comparison of TCEQ and TWDB Salinity at Common Locations

	TCEQ			TWDB		
Location	Station	Avg. Salinity (ppt)	Year Range of Data	Station	[1]Avg. Salinity (ppt)	Year Range of Data
Redfish Reef	13364	16.9	1980-2016	MIDG	18.1	2001-2016
Upper Bay near Seabrook	17091	12.8	1996-2003	RED	11.9	1990-1999
Fred Hartmann Bridge	11254	13.2	1999-2015	BAYT	12.5	2001-2016

1. TWDB data was actually provided in practical salinity units (PSU), but the numerical difference between ppt and PSU is negligible and ppt is shown for consistency with the rest of the document

Of 35 grab stations between Morgans Point and the upstream study limit at the Main Turning Basin, key stations were selected along the HSC to observe the expected downward average salinity trend moving upstream. Only stations with long periods of records and greater than 100 samples were considered. Data were averaged by depth and month to observe seasonal conditions related to the high inflow (i.e. spring) and spawning seasons. Data at numerous stations were reviewed and observed to be reflecting a decreasing average salinity across months moving upstream. It was expected that the lower reaches of the HSC above Morgans Point would have sufficient salinity, as reef growth on the shallow bottom was observed in side-scan sonar data and low tide observations in the shallow bay south of Alexander Island for a recent proposed liquid natural gas terminal project (Judith, personal communication 2016). Therefore stations above there were focused on. **Table 4** summarizes the monthly salinities at the key stations, ordered from downstream to upstream, left to right.

Table 4 Average Monthly Salinity at Key Locations Upstream of Morgans Point

	Average Salinity (ppt) at Indicated Station			
	HSC at Battleship	HSC at Greens Bayou	HSC at Vince Bayou	HSC at Main Turning Basin
Month	11264	11271	11299	11292
Jan	11.7	9.8	5.2	6.6
Feb	11.7	9.8	7.1	6.8
Mar	8.5	8.9	7.5	5.2
Apr	8.2	6.4	3.9	4.0
May	8.4	5.9	4.2	3.7
Jun	8.5	5.9	8.9	3.7
Jul	10.2	9.0	5.3	5.2
Aug	12.4	10.2	7.6	6.4
Sep	13.6	11.0	12.1	6.2
Oct	13.7	11.4	8.0	7.6
Nov	13.0	11.1	5.1	6.5
Dec	13.7	12.0	4.3	7.6

As stated earlier, in Galveston Bay, there are typically two major spawning/spat set peak periods in the year: the greatest peak from April to June, and a smaller one approximately around August. As seen, the HSC salinity at the Battleship, while not at the optimal range at 10 ppt and above during both spat set periods, it approaches optimal during the first peak, is in the preferred range during the second August peak, and the average values are well above 5 ppt. The Battleship location is near the Carpenters Bayou McAlpin et al. 2018 location and has similar conclusions. The conditions for long-term oyster habitat are marginal. The sole side-scan survey done in this area here for measure MM1_520+00 indicated some hard return signature in the shallows adjacent to the HSC. However, this is a known area of former subsided land and old pilings. Because this measure was eliminated, it was not groundtruthed, and it could not be ascertained whether the signature was scattered debris or reef. For salinity near Greens Bayou, the values are lower during the first peak and approach but are above 5 ppt; however, they are in the optimal range during the second August peak. Once at Vince Bayou however, the HSC average salinity is below the lethal level of 5 ppt for most of the first peak spawning months, and decrease almost to 5 ppt in several later months. This is also true at the upmost station at the Main Turning Basin. With an average below lethal levels for 2 or more months, this salinity would cause mortality, especially during the key spawning period.

Considering the grab data, HSC salinity above Vince Bayou would be suspected to be too fresh to sustain any appreciable reef growth. No reef is expected above Vince Bayou. Between Greens Bayou and Vince Bayou, the average salinity, although not optimal during peak spawning, it is not lethal. However, the results from McAlpin et al. 2018 indicated that greater than 20% of time the salinity is below 5 ppt. The salinity condition makes the probability of developing reef growth low to none. Between the Battleship and Greens Bayou, HSC salinity during peak spawning moves away further away from lethal values, and although not optimal, approaches the preferred range of 10 ppt. The salinity condition increases the likelihood of developing some reef growth, and thus is qualitatively assigned a medium probability with respect to salinity. Below the Battleship, salinity would be expected to reach the preferred range above 10 ppt during the first and second peak spawning periods, and therefore the probability for reef development, given all the other needed factors, would be higher. In summary, the HSC salinity condition for reef growth above Morgans Point can be summarized as follows:

- Morgans Point to the Battleship – higher probability for growth
- Battleship to Greens Bayou – medium probability for growth
- Greens Bayou to Vince Bayou – low probability for growth
- Vince Bayou to Main Turning Basin – too fresh; growth not expected

These grab sample results are in rough agreement with the McAlpin et al. 2018 results. However the McAlpin et al. results indicate that adequate oyster habitat is limited to below the Fred Hartman Bridge approximately 3 miles up gradient from Morgans Point.

Depth and Disturbance

Besides salinity, depth and disturbance factor into the likelihood for reef development. The American oyster has been documented to occur as deep as anywhere between 40 feet and 100 feet (Cake 1983, SCDNR 2015), but are known to thrive in depths less than 15 feet (SCDNR 2015, NOAA Fisheries Eastern Oyster Biological Review Team 2007). Most reef along the Gulf Coast occurs at 10 feet or less of depth with a preferred depth of approximately 13 feet or less (Kilgen and Dugas 1989, NOAA Fisheries Eastern Oyster Biological Review Team 2007).

However, 2011 side-scan imagery for reef surveillance around the BSC to 3 miles north along the HSC in support of the PHA’s BSC Improvements and the HSC Project Deficiency Report (PDR) projects showed signature indicative of continuous reef at locations on the BSC and HSC side slopes. This imagery indicates reef signature on side slopes that would be at depths between 15 and 20 feet, and in the existing HSC barge lane bottom that would be at approximately 12 feet of depth upon reviewing NFS project and Galveston District hydrographic data. In isolated cases, the imagery along the HSC indicated signature in depths between 30-35 feet, but prevailingly reef appears in side slopes at less than 20 feet, and in no cases appears in navigation channel bottoms. This is mainly due to the periodic maintenance dredging of the channels that focuses on the deepest parts of the channel, including the bottom.

Other factors such as local dissolved oxygen (DO) and phytoplankton (oyster's food source) distribution in deeper water could limit growth deeper within the navigation channels. The presence of reef development from the 20-foot depth contour and out towards shallower depths along the HSC is consistent with observations of reef habitat extent along the channel margins contained in the Fish and Wildlife Coordination Act Report (FWCAR) for the 1995 Houston and Galveston Navigation Channels (HGNC) Limited Reevaluation Report [LRR] (Appendix E, USACE 1995). The FWCAR specifically recognized the prime channel-side habitat as occurring from the 20-foot depth and outward of the channel. This clear depth breakpoint is also observed in the recent TPWD reef mapping data discussed in Section 5.1.

Using the 20-foot depth as the practical limit for supporting reef development, the most current National Oceanic and Atmospheric Administration (NOAA) bathymetric charts, 2015-2016 aerial imagery, and geospatial footprints for the NED and LPP measures were used to assess which measures below Vince Bayou were located in sufficiently shallow and undisturbed bathymetry to support growth. Most of the measures are in portions of the existing HSC, turning basins, or adjacent to berths where waters are deepened and periodically maintained by dredging. Besides the 20-foot contour, the presence of existing berths or deepened waters to access them for both deep and shallow draft vessels were also considered as areas of disturbance that would not support growth, due to the periodic disturbance from maintenance dredging.

Above Vince Bayou, a combination of conditions that are too fresh and only deepened bathymetry adjacent to the HSC plan measures indicated survey wasn't warranted. Areas within the NED Plan or LPP measure footprints above Boggy Bayou and below Vince Bayou are located in the area of marginal (grab sample data) to low (grab and salinity modelling data) potential of oyster habitat. In this segment, only channel widening CW4_BB-GB from Boggy to Greens Bayou had any appreciable areas of shallows. Those areas overlapped the dredged extent of the permitted Deepwater Texas future terminal just upstream of Beltway 8. During a meeting for project coordination through this segment, Deepwater Texas staff indicated that side-scan surveillance for that project did not indicate reef present. Other areas of less than 20 feet of depth and no sign of active vessel berthing were identified for post-ADM surveillance to determine the presence or potential to contain reef through probings, side-scan sonar, or other exploratory means. Below Boggy Bayou, all but three measures were eliminated from plan considerations. Of the remaining three, the mooring measure MM1_520++00 was surveyed, but not groundtruthed, as it was eliminated. The other two, bend easings BE1_153+06 and BE1_246+54 were not justified for plan inclusion, but are measures that may be considered for safety reasons in detailed ship simulation that would occur during PED, as they are minor features. The proposed survey extent, including areas above Morgans Point, was coordinated with agencies during the March 22, 2018 Beneficial Uses Group (BUG) meeting.

5.3 Direct Impacts

Oyster reef would be directly impacted by new work dredging necessary to construct the NED Plan or the LPP, to widen and deepen channels, excavate turning and ease bends and channel flares and anti-shoaling feature within Galveston Bay, **Figure 4, Sheets 1 - 9**. It is expected that none of the new work of the remaining measures above Morgans Point will impact any oysters. All of these features in Galveston Bay, except for the anti-shoaling would be dredged to 40 or 45-foot depths over the majority of their footprint, with side slopes excavated at depths greater than the existing bay bottom. The details for anti-shoaling feature have not been determined at this time, and would be analyzed in greater detail and refined in the PED planning phase. However for planning purposes one of the proposed locations of the anti-shoaling feature is shown on **Figure 4, Sheets 5** and **9**. This anti-shoaling feature is approximately 9,400 feet long and would be armored with appropriate rock for erosion control. The shown footprint would impact approximately 0.5 acre of existing oyster reef, but would have over 12 acres of rock below high tide that would provide appropriate substrate for oyster recruitment, mitigating the loss of minor patches of reef. The approximately 0,5 acre of existing reef would have approximately 0.35 AAHU over the 53-year life of the project. The approximately 12 acres of rock would provide approximately 8.2 AAHU over the 53-year period (Table 5). The AAHU/acre values were estimated from AAHU/acre ratio of the RED salinity regime for acres impacted and modified for acres provided because of the three-year time lag from new cultch (rock) to oyster reef. Therefore, the anti-shoaling feature would be self-mitigating. Once the appropriate sediment transport modeling is conducted to design this measure more specifically during the PED phase, the need to conduct surveys will be determined to confirm whether separate mitigation would be necessary. For more information on the anti-shoaling feature see Section 7.4 Mitigation Work Plan.

Table 5 Shoaling Attenuation Feature AAHU Calculations

Shoaling attenuation feature		
acres impacted	AAHU/ac	AAHUs
0.5	0.701	0.3504
acres provided	AAHU/ac mit	
12	0.687	8.242

To estimate direct impacts of the NED Plan and the LPP measures, georeferenced Computer Aided Design and Drafting (CADD) files were used with the existing bathymetry of Galveston Bay and channels, to clip the geospatial mapping data from the TPWD and 2018 Oyster Groundtruthing surveys. From the outer extent of the toe of the proposed 40 to 45-foot depth, the side slope was projected a 3H:1V side slope up to the proposed barge lane. Using the existing width of the barge lanes, the outside toe of the barge lanes were extended and a 3H:1V side slope was projected from the outside toe until it met the existing bay bottom. As a result of the deep existing bathymetry below Redfish Reef, the actual dredging extent is less than the required replacement barge lane width for part of the length of this reach of the HSC reducing reef dredging impacts in these areas.

Attachment 1 to this plan includes a report of groundtruthing conducted over 2 days of key areas not covered by the TPWD mapping. This was the reef that relied on the Powell mapping initially south of MidBay, and above Morgans Point, where there was no existing mapping. The groundtruthing was conducted by an oyster dredge mounted to a boat's davit, and conducted test drags to pull of oysters and enumerate and observe them. The 2018 Groundtruthing surveys indicated four classes of hard bottom resulting from analysis from the side-scan sonar results and observations in the field. The consolidated reef class was classified as 100% cultch in the habitat analysis for function and services of the oyster reefs. Approximately 55 acres primarily in the middle leg was observed in the field to consist of only scattered shell with very little or no spat recruitment or other live oysters. The scattered shell, with little recruitment classifications were determined to be 50% cultch for the function and services modeling. The scattered shell, no recruitment was also determined to be 50% cultch. To simplify the calculations, the acreage of 50% cultch classification was divided in half and added to the acreage of 100% clutch. This simplifies the calculations without changing the final determinations because the model uses the percent clutch linearly – 50% cultch is ½ reduction of the function and services. This adjustment for scattered, sparse shell with little or no recruitment was discussed with the BUG during the February 21, 2019 meeting. See Section 6 Determination of Credits for more details.

The existing barge lanes had permanent mitigation for 54 acres of oyster reef when they were constructed in association with the 1995 HGNC LRR project. The permanent mitigation was performed to allow the USACE to maintain the depth in those barge lanes as necessary. The impacts from the barge lane additions are documented in 2003 *Final Environmental Assessment, Houston - Galveston Navigation Channels, Texas Project, Upper Bay Barge Lanes*. As discussed under the Depth and Disturbance subsection of Section 5.2, regrowth has occurred in the barge lanes. The mapping indicates approximately 208 acres of reef within the existing barge lanes, which exceeds the 54 acres originally mitigated. Likely, much of this represents new reef growth into the barge lane, while some of the extra acreage is also likely due to not having a need to actually dredge during planning and construction of the existing barge lanes due to adequate natural depth. As part of the resource agency coordination for this study, periodic subcommittee meetings focusing on oyster reef impact and mitigation have been conducted. Coordination during the January 19 and March 24, 2017 oyster subcommittee meetings confirmed the need to enumerate and mitigate for acreage in the existing barge lanes in excess of the 54 acres already mitigated. Widening of the main channel would extend into most or the entire existing barge lane footprint, and shifting of the barge lane outwards would impact the remainder of the existing barge lane footprint. The total impacts within the existing barge lane were calculated by subtracting the 54 acres previously mitigated from the total mapped reef acreage.

Two recent NFS and Federal projects to modify the BSC and the HSC near the BSC were completed that had reef impacts and mitigation that had to be accounted for in enumerating reef impacts of the HSC-ECIP due to the TPWD mapping used reflecting conditions before these were dredged. The PHA's BSC Improvements Project had impacts along the northern margin of the BSC from the 100-foot widening, and the USACE HSR PDR project (now being executed as part of a Deferred Environmental Restoration project) had impacts at the margins of the BSC Flare and in the widener at the Station 28+605 bend. The HSC ECIP measures for further widening the BSC and the Flare would be outward of these projects' features. The GIS features for the outer extent of the BSC Improvements and PDR projects footprints used to determine reef impacts and mitigation for those projects were used as the inner boundaries of ECIP measures for reef impact determination purposes.

Table 6 shows the results of determining the direct impacts by NED Plan and the increment of the LPP measures not included in the NED plan. **Figure 4 Sheets 2** through **9** displays the reef impact footprint of the NED Plan and LPP. As indicated in the table results, oyster reef within the NED Plan and the LPP footprint is found primarily in the Bay channel widening measures ("CW1" measures and Bayport Flare Easing) accounting for approximately 70 percent of the NED Plan and all of the increment LPP. To determine the AAHUs for the CW1_Redfish_BSC_700 (middle leg segment), the segment was divided into two salinity regimes (MIDG and RED) because the salinity changes within the bay.

There are two areas that increment LPP differs from the NED Plan. The first is the where the NED transitions from the 700-foot wide channel back to the existing 530-foot wide channel. This transition would not be necessary with the LPP and therefore subtracted from impacts the middle leg of the increment of the LPP. The second area is where the HSC meets BSC. The NED Bayport Flare Easing is located on the western bank and BE_28+605 located on the eastern bank. With the LPP both would not be necessary because of the wider LPP channel resolves this navigation restriction. The impacted areas of both measures that were included in the NED were subtracted from the LPP, **Table 5**.

The NED would impact approximately 88 acres of oyster reef with a total of approximately 73 average annual habitat units (AAHUs). The increment LPP would impact approximately 321 acres of oyster reef with a total of approximately 260 AAHUs. Explanation of the model and calculations are discussed in **Appendix O**.

Salinity

The salinity model, McAlpin et al. 2018, showed that the salinity does not vary greatly when the project is in place. Changes to salinity are 2 ppt or less. The tidal prism increases by less than 2% when the project is included and the tidal amplitudes increase by no more than 0.01 m (0.4 inches). The residual velocity vectors do vary in and around areas where project modifications are made – along the HSC, BSC, and BCC. The model shows there is a greater impact to salinity over the life of the project (2029-2079) caused by expected changes to sea level rise and freshwater inflows than from the project. However, the report states "it is not recommended to compare present and future results directly unless careful consideration is given to understanding the difference in the present and future input parameters." Therefore, the project changes to salinity should have only minimal to no effect to long-term oyster habitat.

Table 6 Direct Impacts of NED and LPP Measures and Mitigation Needed

NATIONAL ECONOMIC DEVELOPMENT MITIGATION		
National Economic Development Measure	**Acres Impacted**	**AAHUs Impacted**
CW1_BR-Redfish_700 (lower leg w/ standalone bend transition)	52.8	-48.0
BSC Widening to 455' wide channel	5.0	-3.5
Bayport Flare Easing	13.5	-9.4
BE_28+604 for ex. 530' channel	13.7	-9.6
BETB3_BCCFlare_1800NS	3.3	-2.7
Total National Economic Development mitigation needed	**88.2**	**-73.2**
Mitigation Chosen	**Acres**	**AAHUs Provided**
6 ac Long bird island oyster mitigation acreage	4.0	3.6
3-Bird Island oyster mitigation acreage	14.1	9.9
Dollar Mitigation Site	67.0	59.8
Total Replacement Oyster Reef Provided	**85.1**	**73.2**
LOCALLY PREFERRED PLAN INCREMENT MITIGATION		
Locally Preferred Plan Measure	Acres Impacted	AAHUs Impacted
Transition (overlap) of National Economic Development into the lower section of the middle leg of Locally Preferred Plan		
National Economic Development lower leg	52.8	48.0
CW1_BR-Redfish_700 (lower leg) of Locally Preferred Plan	35.0	31.8
Transition of National Economic Development into Locally Preferred Plan to be subtracted from Locally Preferred Plan middle leg	17.8	16.2
CW1_Redfish-BSC_700 (middle leg, MIDG regime) minus National Economic Development overlap	97.5	-88.7
CW1_Redfish-BSC_700 (middle leg, RED regime)	107.7	-75.8
Total CW1_Redfish-BSC_700 with 28+604 Bend	**205.2**	**-164.6**
CW1_BSC-BCC_700 (upper leg)	143.3	-114.4
Total CW11_BSC-BCC_700 with 28+604 Bend	**143.3**	**-114.4**
Minus Bayport Flare Easing	13.5	-9.4
Minus BE_28+605 Acreage in the National Economic Development	13.7	-9.6
Total Locally Preferred Plan incremental mitigation needed	**321.3**	**-259.9**
Mitigation Chosen	**Acres**	**AAHUs Provided**
San Leon and Dollar Mitigation Sites	**290.9**	**259.6**

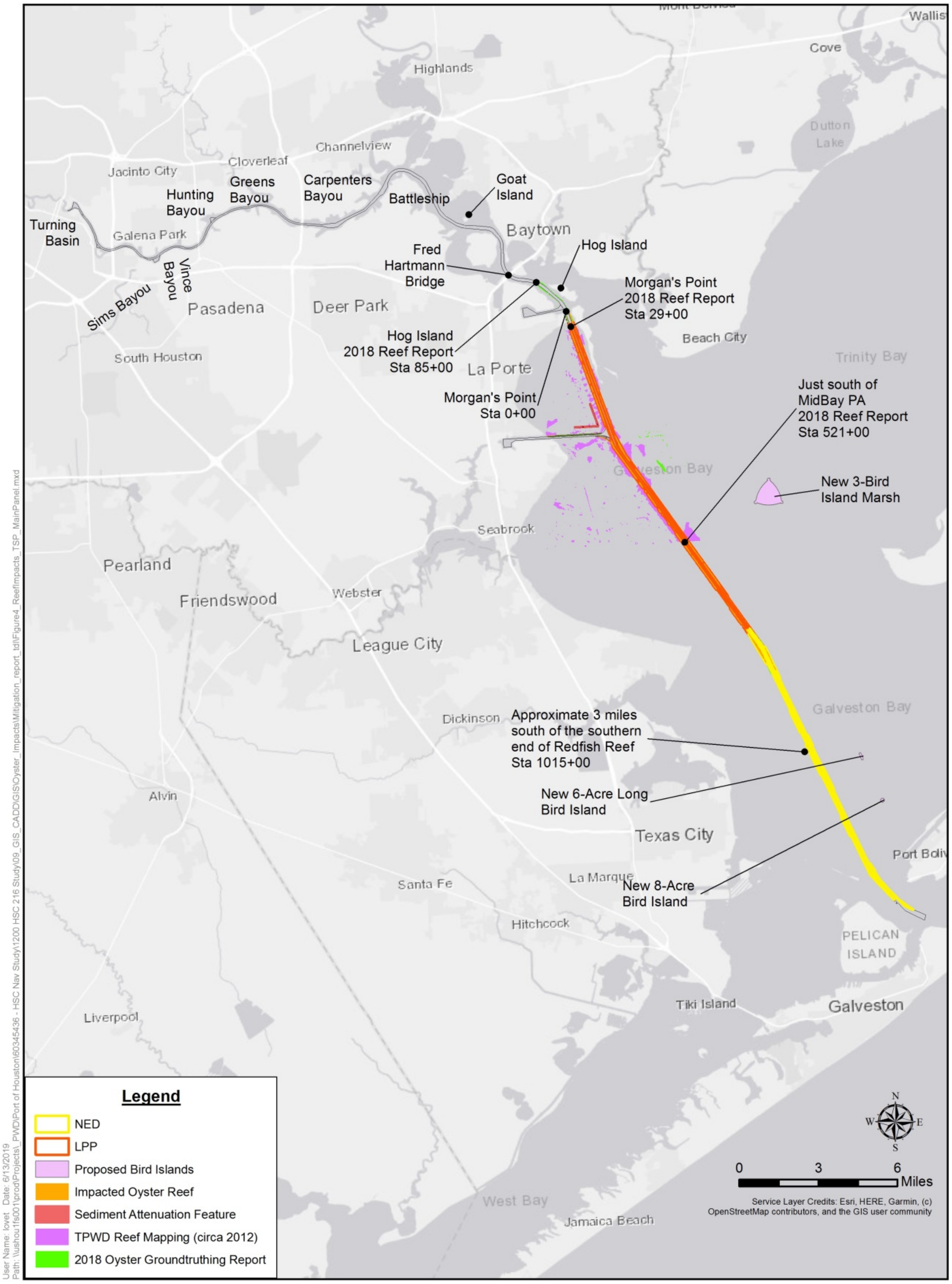


Figure 4 NED and LPP Oyster Reef Impacts Overview for Sheets 1 – 9

Figure 4 Sheet 2 NED and LPP Oyster Reef Impacts - Bolivar Roads

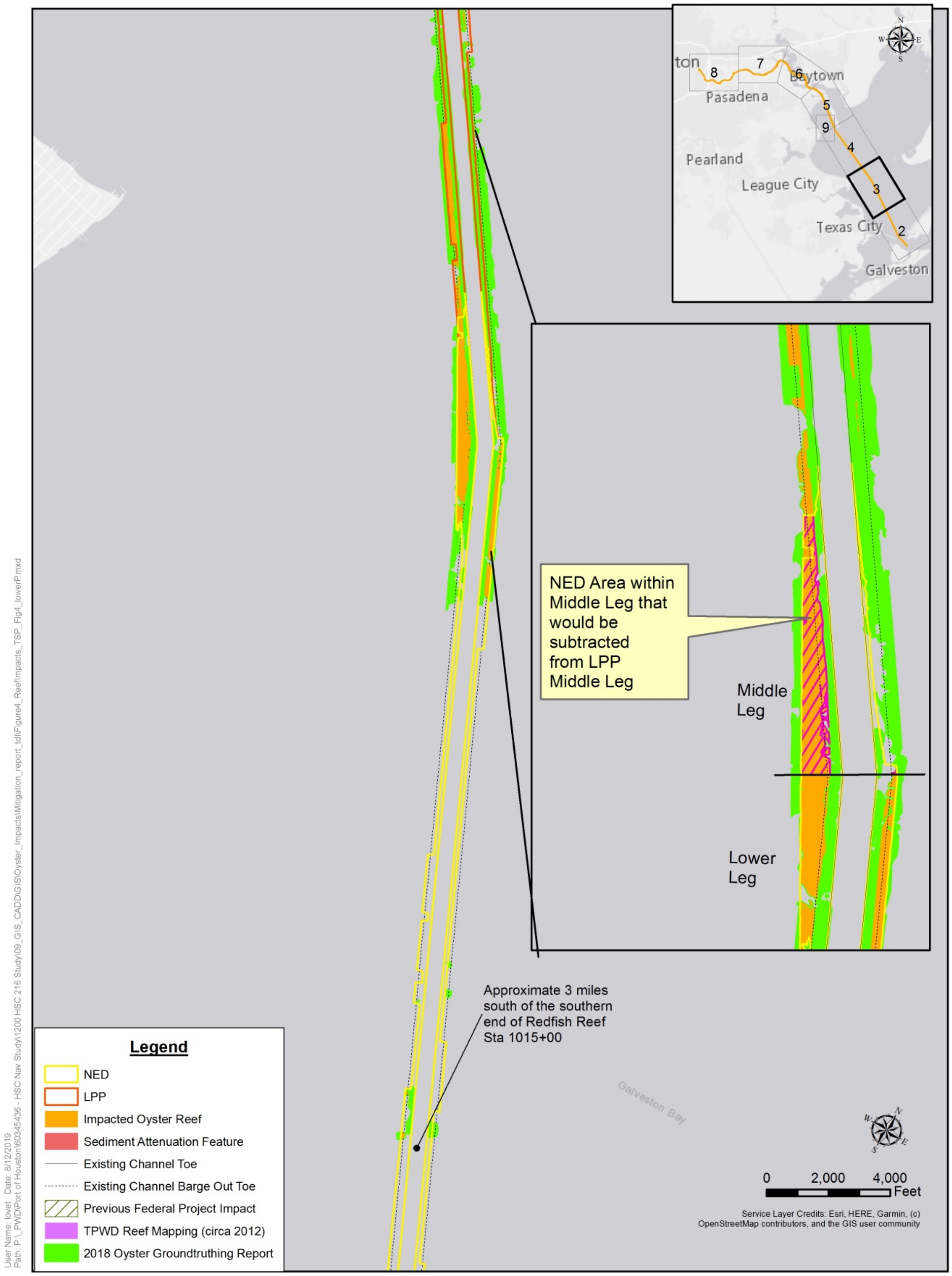


Figure 4 Sheet 3 NED and LPP Oyster Reef Impacts – Lower Panel

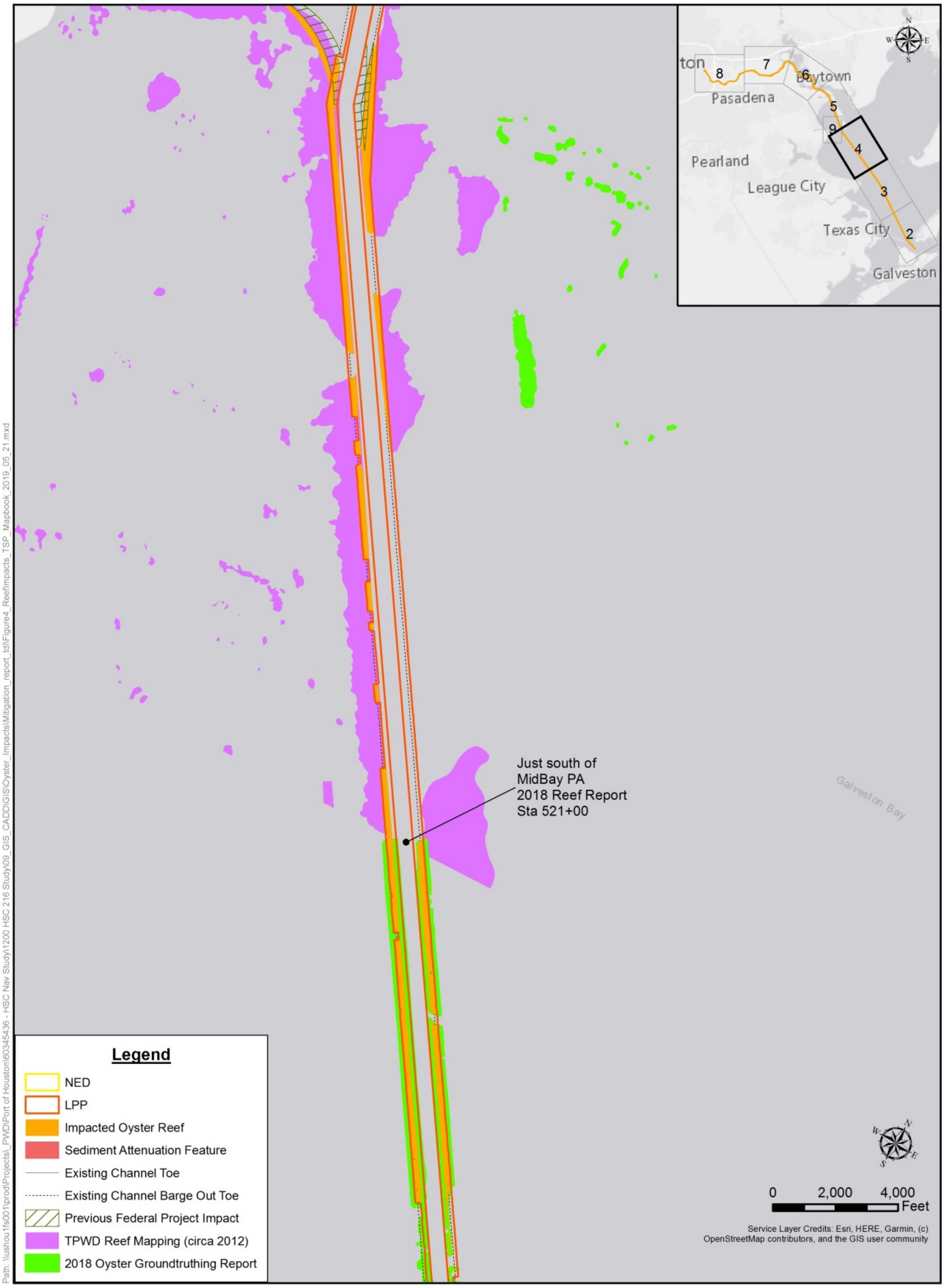


Figure 4 Sheet 4 NED and LPP Oyster Reef Impacts – MidBay

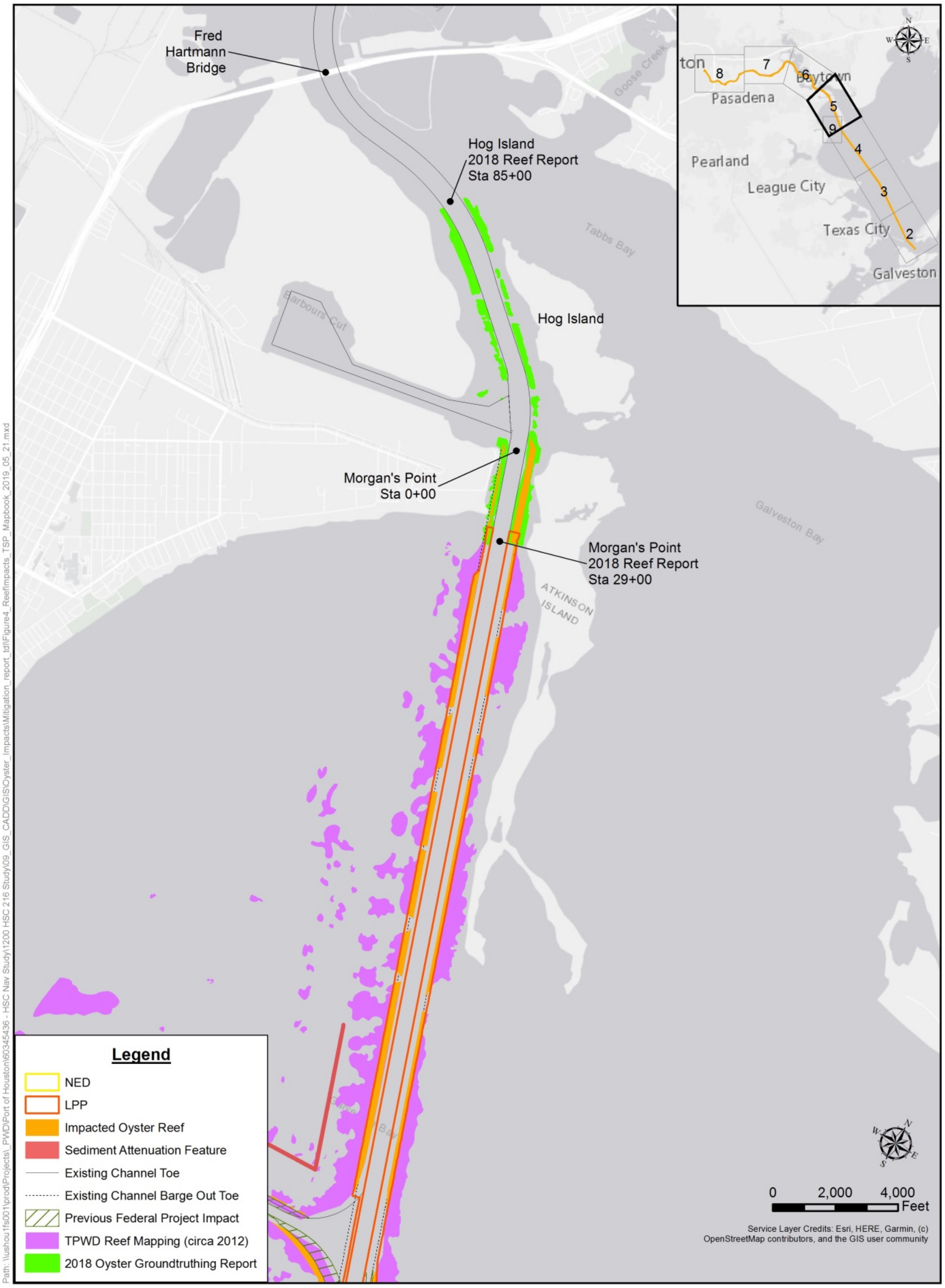


Figure 4 Sheet 5 NED and LPP Oyster Reef Impacts –Upper Panel

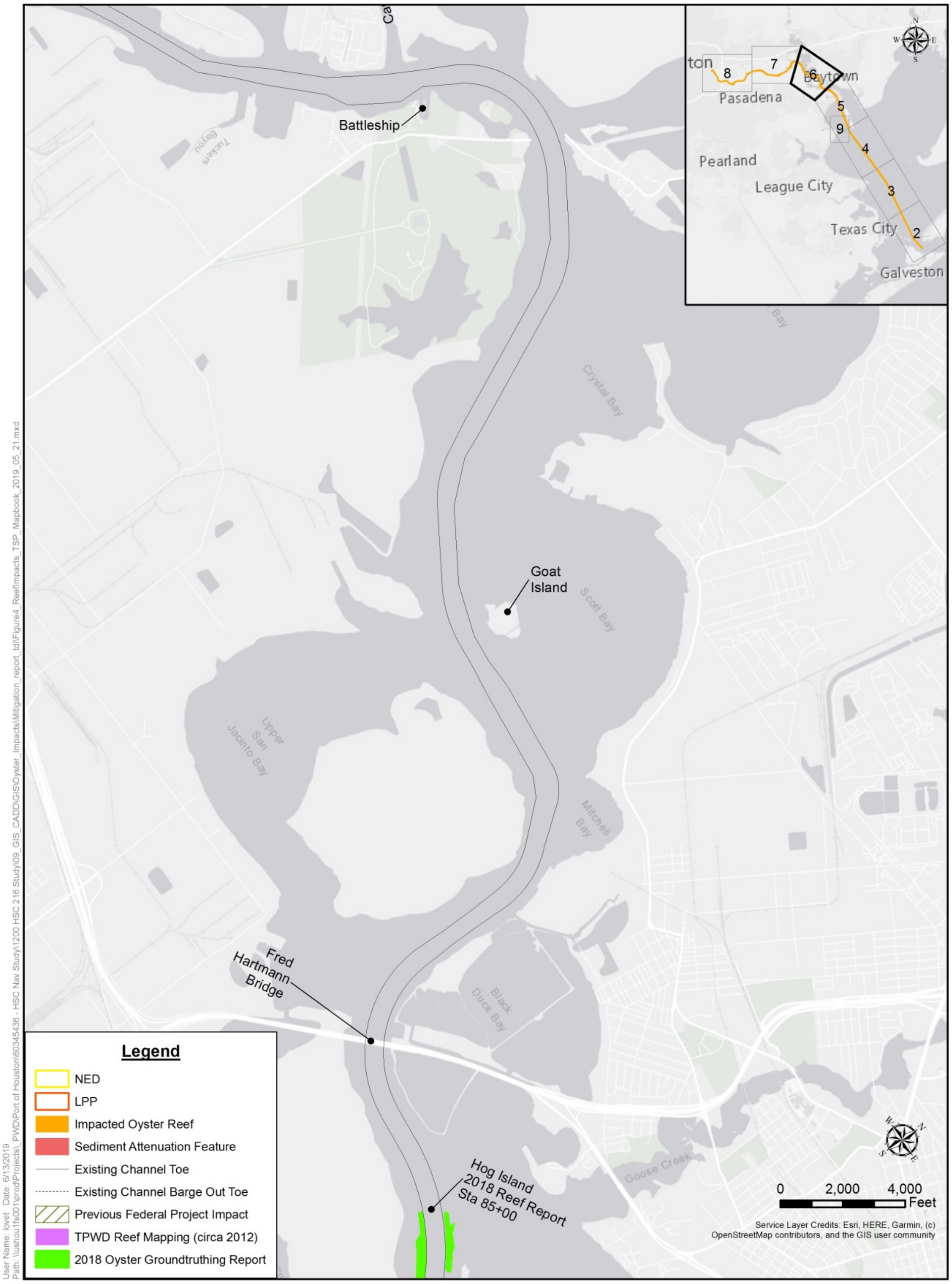


Figure 4 Sheet 6 **NED and LPP Oyster Reef Impacts Goat Island**

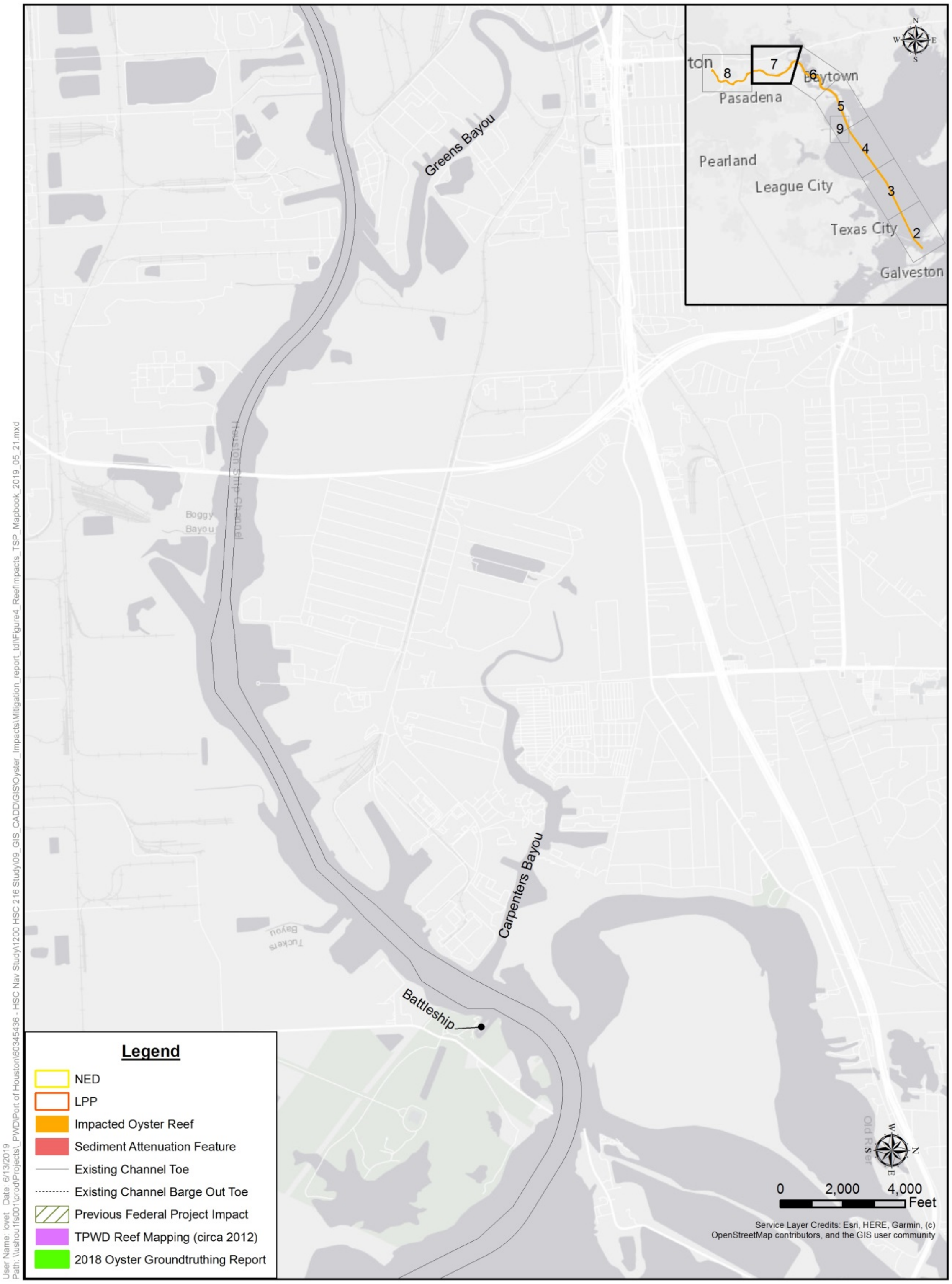


Figure 4 Sheet 7 **NED and LPP Oyster Reef Impacts Greens Bayou**

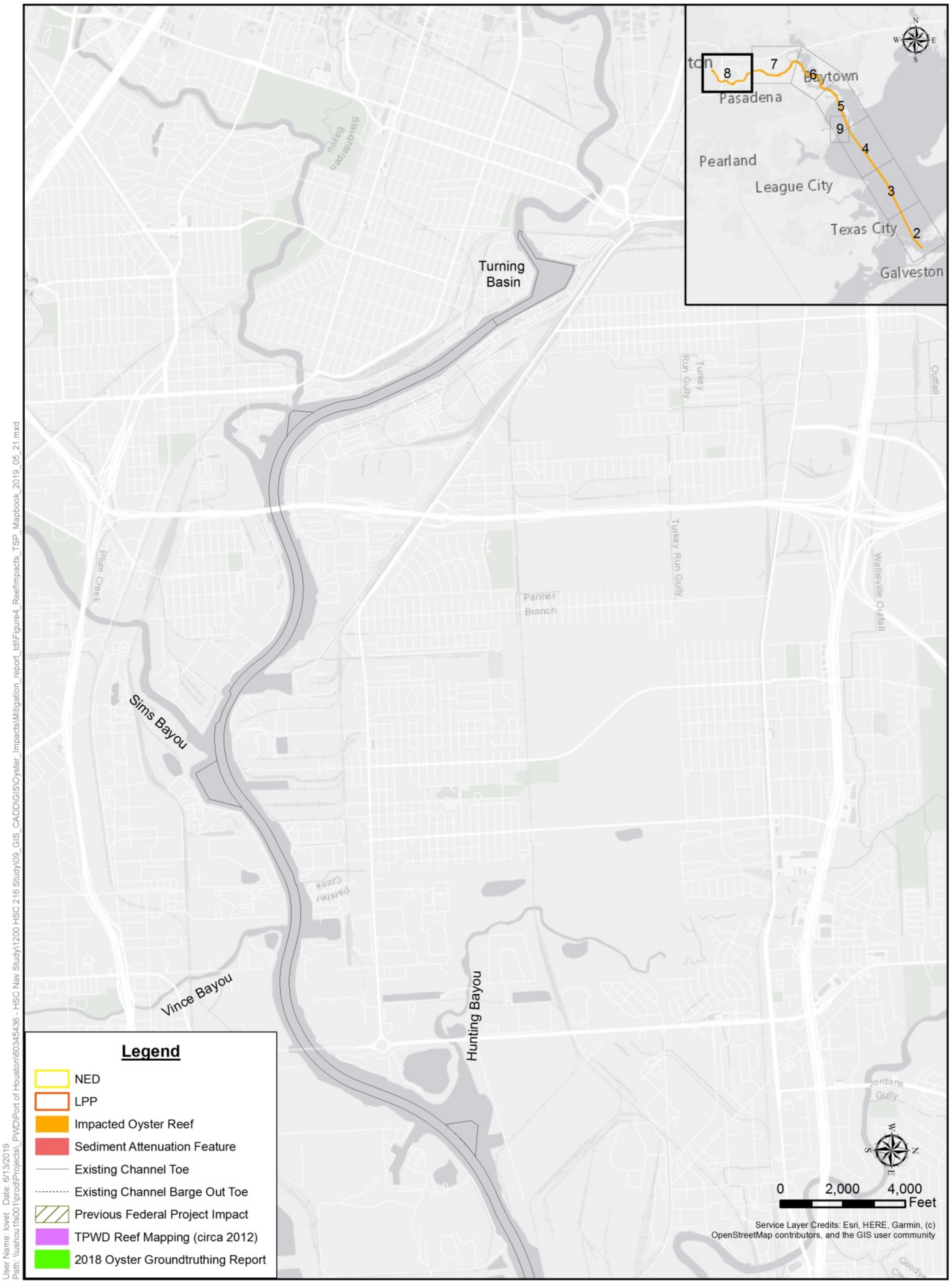


Figure 4 Sheet 8 **NED and LPP Oyster Reef Impacts Turning Basin**

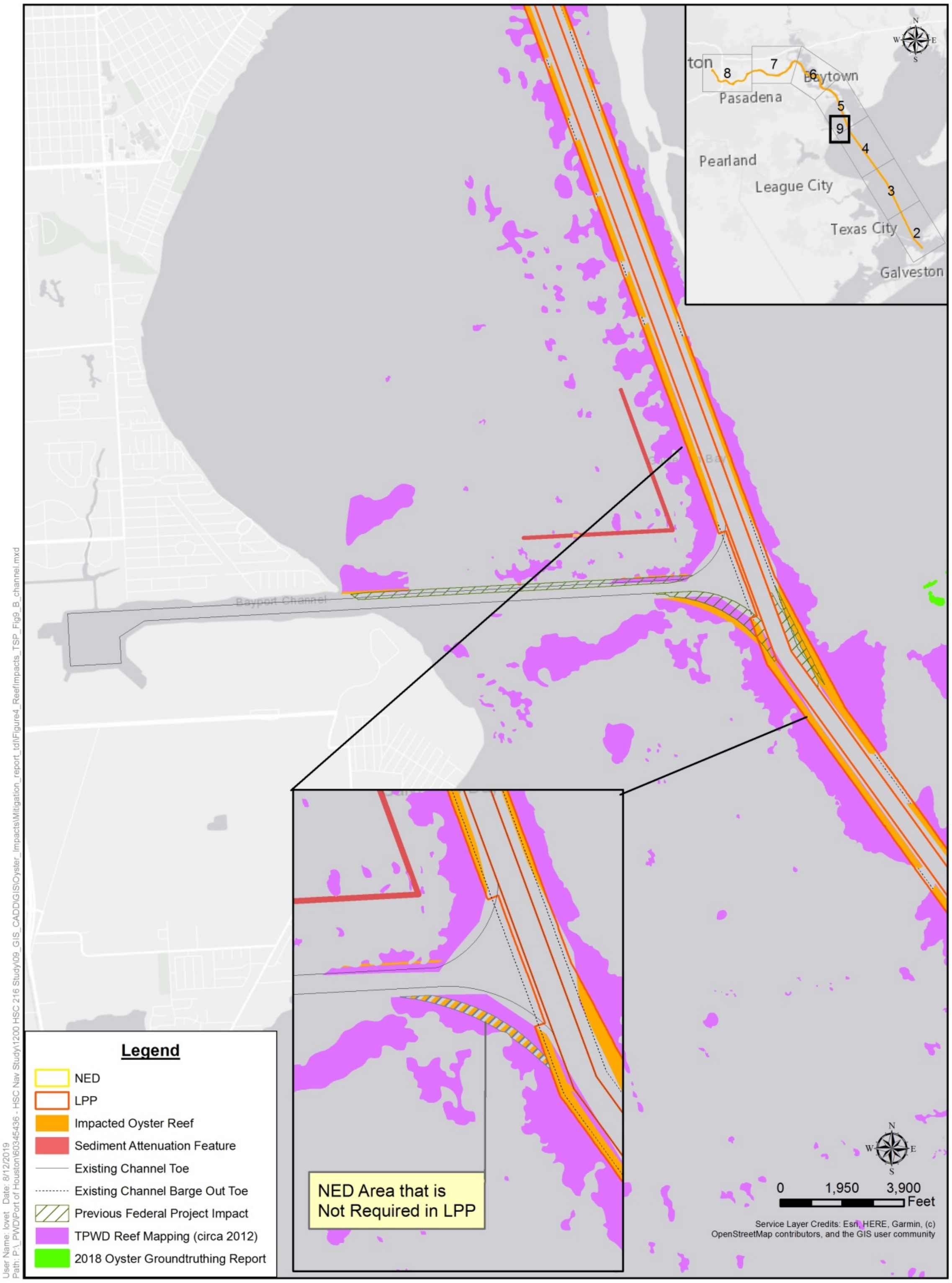


Figure 4 Sheet 9 NED and LPP Oyster Reef Impacts Turning Basin Bayport Channel

5.4 Indirect Impacts

Indirect impacts to oyster reefs from turbidity from new work dredging required for construction of the NED Plan or the LPP are expected to be minimal.

Numerous studies indicate that dredge-induced turbidity plumes are, more often than not, localized, spreading less than a thousand meters from their sources and dissipating to ambient water quality within several hours after dredging is completed (Higgins et al., 2004). A literature review performed for the California Coastal Commission found that most studies indicated that in almost all cases, the vast majority of re-suspended sediments resettle close to the dredge within an hour (Anchor Environmental CA L.P., 2003). Observations from this report included that sediment concentrations are greater at the bottom of the water column, and rapidly decrease with distance from the dredge. When properly operated, suspended concentration levels away from the cutterhead dissipate exponentially towards the surface with little turbidity actually reaching surface waters, and in many cases, at concentrations no greater than those generated by commercial shipping operations or during severe storms (Higgins et al., 2004). One recent study measuring total suspended solids (TSS) concentrations during dredging of the Calcasieu Channel and Pass found no discernible differences in concentrations upstream, parallel to, and downstream of the dredge, indicating the dredging operation had no influence on TSS (USACE New Orleans District 2007). Results of earlier densitometry surveys from this study indicated silt suspension during maintenance dredging was confined to the deep parts of the channel.

The vast majority of suspended particles would settle close to the dredge, which greatly reduces the volume available for re-deposition at distances from the dredge. Therefore the amount of material that would be available for resettling on reef at distance would be expected to be small and only have minimal effects in terms of covering reef.

With the exception of a few smaller complexes, oyster reef in Upper Galveston Bay north of Redfish Reef, is almost exclusively located directly adjacent to the navigations channels of the HSC and BSC. This is clearly observed in the modern TPWD mapping, 2018 Oyster Groundtruthing Report, and Powell historical reef mapping shown in **Figure 3**. This trend was corroborated in the side-scan sonar data that was later groundtruthed by divers for the BSC Improvements Project. The channel margins are covered with extensive reef. The HSC was widened and deepened under the HGNC LRR project between 1998 and 2008, and extensive HSC adjacent reef was still observed in the newer mapping and sonar data from the TPWD and the BSC Improvements Project. The FWCAR for the 1995 LRR described the channel margin as prime oyster producing area, from the 20-foot depth contour of the HSC to the edge of the old disposal berms developed from sidecast material during construction of the HSC earlier in the 20th century. This conclusion followed the findings of the GBNEP study which led to the historical Powell mapping (Powell et al. 1997). The study identified reef along the HSC was one of the 3 most noticeable areas of new accretion.

Considering the previous information discussed, and considering that these channels are periodically dredged for maintenance (which would involve higher percentages of unconsolidated fines), the new work dredging required for construction of the NED Plan or LPP and subsequent maintenance dredging would not be expected to result in reef losses due to turbidity effects. Only minimal impacts would occur, and pre- and post-construction monitoring for indirect turbidity impacts is not proposed for the new work dredging.

6.0 DETERMINATION OF CREDITS

In accordance with USACE planning policy, credit for mitigation was determined by using USACE-certified habitat models to determine functional losses from impacts and functional gains (or "lift") from mitigation. USACE Civil Works policy contained in the CECW-CP policy memo *Policy Guidance on Certification on Ecosystem Output Models*, dated August 13, 2008, requires that only standard models already certified by the USACE Ecosystem Planning Center of Excellence (PCX) be used to determine mitigation, or that models proposed for use undergo the model certification process outlined by the USACE. The Oyster Habitat Suitability Index Model (OHSIM) developed by Swannack *et al.* (Swannack *et al.* 2014) was certified and was selected for use in this mitigation plan (Young. 2018). This model is a modification of a 2012 suitability index model that follows the methodology in the USFWS habitat suitability indices (HSI) model for the Gulf of Mexico American Oyster (Cake 1983) Reefs in Galveston Bay are predominantly American oyster. The Swannack et al. model was used for the determination of HSI scores. OHSIM HSI scores were calculated using the certified spreadsheet based on the following four OHSIM variables to calculate AAHUs under various with and without project scenarios and timelines:

- annual mean salinity (AS)
- minimum annual salinity (MAS)
- mean salinity during the spawning season (MSSS)
- percent of oyster cover (percent of Cultch)

These variables are used to calculate four oyster suitability indices (OSI) using formulas detailed in the model literature (Swannack *et al.* 2014). The resulting OSIs range from 0.0 to 1.0, with 0.0 denoting unsuitable habitat, while 1.0 represents optimal habitat. The four OSI are used in the following formula to obtain the Restoration Suitability Index (RSI) which is synonymous with the HSI:

$$RSI = (OSI_{AS} \times OSI_{MAS} \times OSI_{MSSS} \times OSI_{Cultch})^{\frac{1}{4}}$$

A certified spreadsheet coordinated through the Ecosystem Restoration Planning Center of Expertise (PCX) was used to implement the calculations for the OHSIM model. Because the three OHSIM salinity variables vary at different parts of the Bay and result in differing habitat qualities, modeling of measures was conducted according to the different salinity regimes. Also, a key assumption for the progression of the restored mitigation reef was adopted following consultation with the resource agencies during the initial oyster subcommittee meeting, explained following the bullets. The following were the general cover types defined to represent existing, impacted, and restored habitat, with a synopsis of key assumptions:

- Existing Reef– Reef that would be impacted in the different salinity regimes represented by Mid-Galveston, Red, and Baytown station salinity data from the TWDB datasonde data described in Section 5.2 under Salinity.
  - Exists in the without-project condition through the 50-year period of analysis. Disappears in first year of the with-project (i.e. with dredging) condition
  - Values for the salinity variables were taken from the TWDB datasonde data
  - Acreages of mapped reef were broken into amounts for each salinity regime using GIS and station locations
  - Percent cultch coverage conservatively assumed to be 100% in areas that groundtruthing indicated extensive shell bottom with spat and young oysters and 50% where groundtruthing indicated shell bottom was marginal in coverage with shell and with little to no spat or young oysters (see attached 2018 Oyster Groundtruthing Report).
- Degraded Habitat – Bay bottom devoid of reef following the direct impacts of dredging, reflects a clay bottom with no oysters or hard substrate.
  - Appears in first year of the with-project (i.e. with dredging) condition in place of existing reef and exists for the rest of the 50-year period
  - Percent cultch coverage assumed to be 0%
  - Salinity regime does not matter since cultch index makes RSI zero anyway
- Pre-restoration Mitigation Site– Bay bottom devoid of reef at a mitigation site before cultch is placed, indicative of a mud bottom with no hard substrate.
  - Exists in the without-mitigation project condition through the 50-year period of analysis. Disappears by the 3rd year of the with-mitigation project condition
  - Salinity regime does not matter since cultch index makes RSI zero anyway
  - Percent cultch coverage assumed to be 0%
- Post-restoration Mitigation Site
  - Does not exist in the without-mitigation project condition through the 50-year period of analysis. Appears by the 3rd year of the with-mitigation project condition
  - Values for the salinity variables of the modeled mitigation sites were taken from the TWDB datasonde data. Two mitigation site scenarios were modeled, described three paragraphs below.
  - Percent cultch coverage assumed to be 100%. Mitigation reef cultch would be placed at this density.

One key expectation and assumption incorporated into the modeling was that a functional reef would not be present until Year 3, until initial oyster recruits could reach full adult stage and harvestable sizes. This was implemented following resource agency input during the initial oyster subcommittee meeting held on January 19, 2017 that renewed an assumption used in the HGNC oyster mitigation determination. The basis for the HGNC assumption is described in the FWCAR of the 1995 HGNC LRR, which documents the expectation of functional recovery in 3 years and supporting observations from oyster ecology experts from experimental reefs and oil exploration shell drilling pads. This is consistent with modern observations and literature for the American oyster growth in the Gulf of Mexico (TPWD 2010, NOAA undated). Because the OHSIM does not have a live oyster density-based variable, the assumption was implemented by making the restored reef cover type appear in Year 3, to reflect the attainment of functional reef and the maximum relative score for the conditions being modeled. Additional

The OHSIM formulas and OSI score curves are included in the certified spreadsheet. The existing reef acreages for each measure (shown in Table 5) and salinity variable values, as appropriate for the salinity regime for the various measures of the NED and the LPP, and the target year changes in cover type acreage described earlier, were also entered. The approved spreadsheet was then run to calculate the change in AAHUs for existing reef being impacted, which is shown in Table 5. This defines the AAHUs that needed to be restored with mitigation. The spreadsheet calculates the change in AAHUs through the full 50-year period, with net losses reflected as negative numbers.

Then, acreage of mitigation reef was estimated for the mitigation sites using the numerical method software add-in Solver® in the Excel spreadsheet, along with the target year changes in cover type acreage described earlier for mitigation cover types. Solver was used to converge on the acreage where AAHU loss from impacts were offset by the positive changes from mitigation reef acreages to result in a net AAHU change of zero. For this NED or pre-LPP approval phase of planning, the following two mitigation site assumption scenarios were ran to provide the most optimal salinity range of mitigation amounts that would be possible:

- Mid-Galveston (San Leon) site mitigation – This site provides the one of most optimal salinity according to the OHSIM model and would therefore results in identifying the one of the sites for the least mitigation acreage possible.

- Dollar Reef sites mitigation – This site provides one of the most optimal salinity according to the OHSIM model and would therefore results in identifying the one of the sites for the least mitigation acreage possible.

Figure 5 shows potential mitigation sites for NED and LPP. For more details on the determination of each feature impacts and replacement function and services see **Appendix O**.

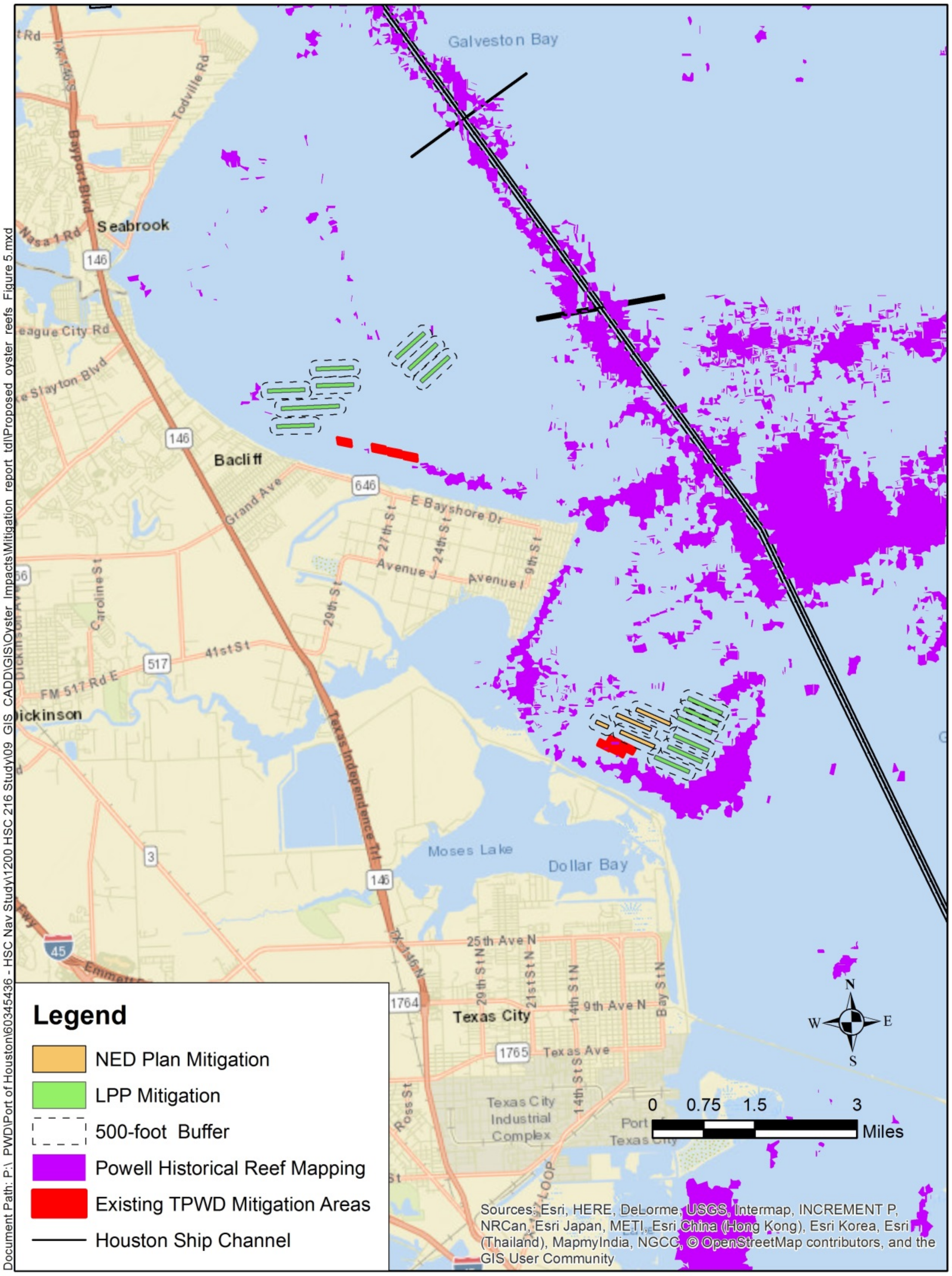


Figure 5 Proposed Locations for Mitigation Oyster Reefs for NED and LPP

7.0 PROPOSED MITIGATION METHOD AND MITIGATION WORK PLAN

The proposed mitigation method is to beneficially use dredged material to build relief above the surrounding bay bottom and cap it with a veneer of suitable cultch, which would provide the hard substrate for natural recruitment and settlement of oysters during the spat set season. This beneficial use (BU) technique to restore oyster reef has been successfully used by the USACE and others in the Chesapeake Bay estuary and in New York/New Jersey Harbor. Several variations of this method have been used or proposed including use of contained dredged maintenance material vs dredged new work material, and elevation of relief to provide an intertidal bar vs subtidal reef. However, all have beneficially used dredged material to build relief capped by a thinner cultch layer. The previous mitigation technique used locally in Galveston Bay involved using rock or other hard substrate to build the base of the reef to provide relief off of bay bottom, and to provide the spat settlement cultch layer at the surface. This uses a lot of hard material for non-recruitment volume at significantly more cost than beneficially using dredged material. Using the dredged material to raise the bottom of the bay provides a means to beneficially use dredged material generated which helps fulfill the BU objective for this project, and reduces costs by using less rock material, helping to increase the navigation project net benefit. The DMMP developed for the NED Plan and LPP considered the existing geotechnical data for the dredge prism of the channel that will provide the new work material, and dredging cost factors such as hydraulic pumping distance, to plan how new work material could be used in a cost effective and feasible manner to construct the mitigation pads. Chief considerations were the material type and ability to provide stable relief, which makes cohesive, stiff clays more desirable to use versus softer, unconsolidated sediments. Also, pumping distance is a factor since longer distance will increase costs, and the DMMP must follow the Federal standard for least cost, feasible and environmentally acceptable dredge material placement.

For the NED Plan, there is not enough desirable dredged material within an acceptable distance to raise the bottom of the bay, since that plan is limited to the lower leg of the HSC below Redfish Reef. The more desirable material in this leg is lower in the Bay, and planned for use in building proposed bird islands, and would require a greater pump distance to the Dollar Reef area, the closest selected site. Therefore, the current design for the NED Plan would use rock or other hard substrate to build the reef. This would be similar to the pads constructed for the HSC Deferred Environmental Restoration (DER) of Atkinson Marsh Cells M7/8/9 & M10 project, with a typical cross section shown in **Figure 8**. However, the final design would be determined in the PED phase, which would conduct geotechnical review of the pad locations and review other pad design that could reduce the amount of rock required. This would reduce the costs of creation of these pads and would have a beneficial use if dredged material could be used. Other options such as placing a confining ring of rock and filling the inside with available unconsolidated material that would settle to become dense enough to support the 4- to 6-inch layer of rock may be considered in the PED phase. Two projects, Manteo, Old House Channel and Denton Oyster Reef discussed in the next section have used this approach. The LPP has enough appropriate material within acceptable distance to create all the required mitigation pads. The following sub-sections described the proposed mitigation method in more detail.

7.1 Other Projects Implementing the Proposed Method

As mentioned, several projects have implemented or proposed the beneficial use of dredged material (BUDM) method of constructing oyster reef in a variety of ways. However, two projects are most commensurate with the specific way this method is proposed to be implemented for the HSC ECIP, which is to use more robust or new work dredged material to build a stable mound or berm capped by a cultch veneer. The Slaughter Creek restoration project was a joint effort by NOAA, Maryland and the USACE whose construction was completed in June 1987 (Clarke *et al.* 1999). Approximately 14,000 cubic yards (CY) of dredged material consisting of 60 percent fine sand and 40 percent silt was deposited to build a 3-foot thick 2.1 acre mound capped by 2,256 cubic yards of oyster shell to provide an 8-inch thick cultch layer. The three year post construction monitoring of Slaughter Creek project showed that oyster spat recruitment and densities of juvenile oysters were above or equal to nearby natural oyster bars, and was deemed successful. The placement of shell over what was perceived to be soft material did not subside into the dredged material. Bathymetric surveys at one and two years post-construction demonstrated the dredged material mound with oyster veneer was still stable. Since Slaughter Creek reef's construction, Chesapeake Bay has experienced several hurricanes and tropical storms with varying surge effects in the bay, including Hurricane Isabel (2003), Tropical Storm Lee (2011), and Hurricane Sandy (2012) [Fincham 2010, Dennison *et al.* 2012]. The State of Maryland's annual reef survey of Chesapeake Bay still collects oysters for their survey at this site today (Smith 2014). It also appears on a recreational fishing website list of artificial reef coordinates (Mid Atlantic Fishing 2017). Despite the occurrence of several tropical events since its construction, the continued surveillance and use in recreational fishing indicate the reef still exists and is productive today.

Using cultch veneer over dredged material has also been approved on November 5, 2010 for oyster mitigation for the Matagorda Ship Channel Improvement Project (MSCIP) and EIS. The approved plan calls for creating approximately 163 acres of oyster reef over mercury-impacted bottom sediments within Lavaca Bay, Texas by hydraulically placing 1.4 million CY (MCY) of new work stiff clay material to construct 2-foot mound over the bottom sediments to provide a minimum of 1 feet of relief above surrounding bay bottom. This new work material would be capped with 3 inches of cultch material (crushed limestone or similar material) to create oyster reefs. The HSC ECIP would similarly use stiff new work clays to construct relief, and cap it with a cultch veneer.

Other projects that have proposed using BUDM for oyster reef using different construction include the 1) Manteo, Old House Channel, North Carolina Section 204 Project, and 2) Denton Oyster Reef Restoration in Mobile Bay, Alabama. In the Manteo project, which is a USACE BU project, a confining stone containment structure is proposed to contain approximately 5 acres of sandy dredged maintenance material capped with appropriate cultch material, to provide an oyster reef base with 4 feet of relief. In the Denton Oyster Reef project, an existing ring of concrete piles that were originally used to contain 75-acre of an artificial cultch reef on the bay bottom, 2 feet below the perimeter ring height. Due to low productivity attributed to low dissolved oxygen, the project proposes to use river-dredged maintenance sediments to elevate relief to the perimeter ring height and recap it with cultch to restore 75-acrea of productive reef. In both cases, a confining structure is proposed to contain maintenance sediments, which tend to be non-cohesive, unconsolidated material. This could be a technique for materials found to be too soft to be used for stable relief.

7.2 Selected Relief and Cultch Thickness

Previous research of reef structure and success had identified that reefs should have sufficient vertical relief so that recruitment, growth and survival outpace local sedimentation, and should provide elevation above low oxygenated areas (Chesapeake Bay Program 2000). Reef height above the seabed in particular, is an important factor driving restoration success (Lenihan 1999, Chesapeake Bay Program 2000). Crests of reef height above 3.3 feet above bay bottom were found to have the highest oyster growth and survival. Reefs from 0.82 to 1.5 feet in elevation from the bottom had higher abundances and tended to persist [Schulte et al. (2009) and Lipcius et al. (2015)]. Also, cultch interstitial thickness was determined to be an important factor in oyster survival with a minimal 6 inches of interstitial space important in enhancing the survival of new oyster recruits (Luckenbach 2000). Options of raising the elevation from the bay bottom were discussed such as adding suitable cultch material such as clean, crushed limestone or concrete, oyster hash, or beneficially using dredged new work material to provide vertical relief above the bay bottom, and cap it with a veneer of suitable cultch material. The suitable cultch material should be of suitable size and cleanness to maintain interstitial spaces.

7.3 Agency Coordination of Proposed Methods

The proposed BU method was first coordinated with the BUG on May 17, 2017. Initial concerns consisted of cultch vertical stability and settling into soft pumped material. Long term monitoring of the Slaughter Creek project discussed in the previous section which made use of silt and sand maintenance material indicated stability more than a decade later. Pumped new work material would be allowed to undergo short term consolidation. Design during PED could verify the bearing pressure and strength of hydraulically pumped clays and expected strength following short term consolidation.

Following a review of literature on the recommended minimum elevation and sufficient minimum cultch thickness, a minimum relief of 1.5 feet was indicated in the literature and coordinated with the local resource agencies during the February 22, 2018 BUG meeting. Also discussed at that meeting was a sufficient height for an adequate cultch recruitment layer of 6 inches. TPWD provided feedback that during PED, one or more pads be considered for a 9-inch thick layer for comparison purposes, initially stemming from settlement concerns. Also discussed at this meeting was the concept of using taller subtidal reef to act as wave trips. Literature has shown the efficacy 2 to 3 feet and greater height restoration reefs in reducing incident storm wave heights by greater than 50 percent in projects in Mobile Bay and Coffee Island. Agencies agreed with the idea, as well that such features incorporated as natural shore protection could serve as oyster reef mitigation for project impacts.

During the February 22, 2019 BUG meeting, the agencies recommended to following the previous basic design criteria for size and orientation used during the HGNC oyster reef mitigation design. This included orientation to currents, and maximum 300-foot crest widths.

The initial orientation and layouts of the mitigation pads were presented to the BUG on March 21, 2019. NMFS cautioned that the proposed use of hydraulically pumped material in proximity to existing oyster leases and other existing reef would raise siltation concerns with the oyster industry if it is not addressed with adequate monitoring or studies of turbidity control. This resulted in the initial plan for NED Plan reef mitigation to be constructed with rock for relief rather than BU. Subsequent design, coordination, and proposed monitoring would be considered during PED to address these concerns to enable LPP mitigation construction with BU material.

In response, a thorough literature review of the available discharge control technologies was conducted and presented at the April 25, 2019 BUG meeting. The following synopsizes this review. The application of a submerged diffuser is a well-studied technique and has been shown to decrease the average turbidity from a discharge plume by more than 80% when employed precisely (Costello 2019). “Multiple Tremie” diffusers have been used to increase the accuracy of placement and decrease turbidity concurrently with a submerged diffuser by taking advantage of sediments cohesive rheological characteristics, slowing flow velocity and turbulence. The tremie/diffuser system was used to great effect during submerged placement in Lake Zevenhuizerplas, where the technique brought total suspended solids down to 20-25 mg/l within 100 meters of the diffuser, compared to 150 mg/l using a common bell diffuser (Mastbergen 2004). Furthermore, in the USACE 1990 New Bedford Harbor Study a submerged diffuser was used in a very shallow bay with a tidal range of 0.43 to 1.54 meters and found to limit total suspended solids to less than 100 mg/l within a 500-foot radius of the diffuser (USACE 1990). In many cases, the pads will be more than 1,000 feet away from these areas. Given the Galveston Bays’ average tidal depths of 2.33 to 3 meters and typical background total suspended solids between 20 to 25 mg/l, it is proposed that the submerged multiple tremie/diffuser combination techniques be used for hydraulic placement of BU material for the proposed relief. The control of turbidity and minimization of sediment resuspension is critical to addressing concerns of potential impact for the existing reef in the area. An example of the submerged diffuser technology, excerpted from Engineer Manual (EM) 1110-2-5025, *Dredging and Dredged Material Management*, is shown in Figure 6.

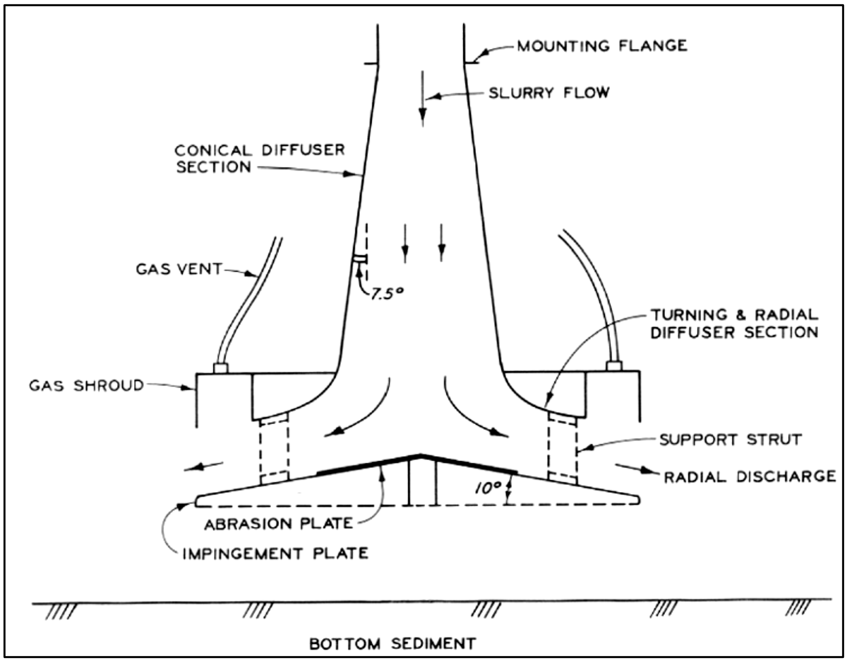


Figure 6 Submerged Diffuser Profile View (Source: EM 1110-2-5025)

7.4 Mitigation Work Plan

The following are elements of the mitigation work plan to implement the proposed mitigation method:

Geographic boundaries of the project – The candidate mitigation sites and approximate boundaries are shown in **Figure 4 Sheet 1** and **Figure 5**. The boundaries shown are nominal footprints that total approximately 85 acres in one location for the NED and approximately 290 more acres for the increment required for the LPP in two locations (for a total of 376 acres), shown in **Figure 5**. Mitigation is proposed to occur at these sites to offset the 88 acres of impact of the NED Plan, and the 321 more acres of incremental impact of the LPP (a 406 acre-total impacted). Currently, a total of approximately 376 acres of mitigation are anticipated for the LPP with 700-foot widening, and is dependent on the mitigation sites used, but the acreage may undergo minor change with the refinement of the NED Plan and LPP features during PED. It should be noted that the impacted acreage differs from the mitigation required due to the difference in salinity regimes between where acreage is impacted and where it is mitigated and the effect on the OHSIM modeling, as explained in Appendix O, Habitat Modeling Report and Cost Effectiveness/Incremental Cost Analysis, Section 7.2.

The candidate mitigation sites were located in areas that are currently owned by TGLO, avoiding existing pipelines, active oil wells, existing channels, placement areas, oyster leases, and Powell et. al oyster reefs mapping by a minimum of 500 feet. The orientation, width, and size of each oyster pad would follow the recommended guidelines per FWCAR in HGNC. The orientation of each reef would be perpendicular to the bottom flow as determined by USACE modeling (McAlpin, J., C. Ross, and J. McKnight, 2018).

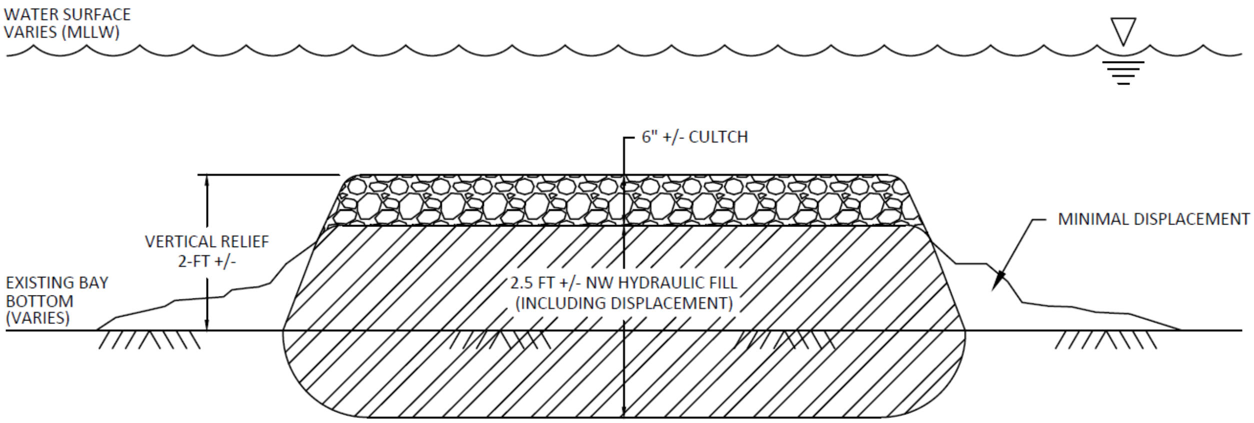
The final configuration and footprint of the mitigation sites would be determined during the PED planning phase that would consider reviewing of detailed local site condition information such as geotechnical information, presence and proximity of existing remnant reef, and consultation with resource agencies to determine the most desirable arrangement and location at or around these sites.

Construction methods – The mitigation work plan proposes to add the necessary volume of clean, crushed limestone or other suitable hard substrate over the necessary volume of project-dredged new work materials to create the needed mitigation acreage. If only the NED Plan is constructed, only limestone or other hard substrate would be placed on the bottom of the bay. If the LPP is constructed, stiff, new work clays dredged from the construction of the LPP would be hydraulically placed to build the berm or mound to provide the needed relief with a hard substrate veneer placed on the berm or mound.

- The specific relief would be at least 1.5 foot above the surrounding bay. Factors such as site-specific available water depths, more detailed dredging planning such as new geotechnical information on dredged materials would be considered in PED to adjust the final elevation above bay bottom, but 1.5 feet of relief with 6 inches of cultch on top is the proposed minimum target. With the volume of new work material to be generated by LPP construction, having sufficient material to produce the target relief for the needed acreage would not be an issue. With only the NED Plan is constructed, not enough of suitable dredge material is available within practical distance. So the proposed NED oyster mitigation areas would use only limestone or other suitable hard substrate to create the mounds. However, alternate construction methods discussed previously such as the confining structure that allow softer materials to be used, will be considered in PED, and could be used of found to be cost effective and feasible with the specific construction dredge planning.
- To mitigate for the NED approximately 88 acres of reef impacts, approximately 85 acres of oyster reef would be created in three locations: 4 acres (3.6 AAHUs) as part of the 6-acre Long Bird Island, 14.1 acres (9.9 AAHUs) for part of the 3-Bird Island and 67 acres (59.8 AAHUs) offshore of Dollar Bay with three 20-acre pads approximately 300 feet by 2171 feet and one 12.1-acre pad approximately 300 feet by 1,757 feet of rock (**Figure 4 Sheet 1** and **Figure 5**). The rock would be a layer approximately 1.5- to 2-feet thick.
- To mitigate for the 321 acres of incremental LPP oyster reef impacts (approximately 260 AAHUs), approximately 291 acres of oyster reef would need to be constructed. Fourteen oyster reefs would be constructed located in two locations: offshore of Bacliff and offshore of Dollar Bay (**Figure 4 Sheet 1** and **Figure 5**). Offshore of Bacliff, seven 20-acre reefs and one approximately 31-acre reef would be constructed. Offshore of Dollar Bay, six 20-acre pads would be constructed. A draft oyster reef design is shown in **Figure 6**.
- The construction of the oyster reefs would hydraulically place dredged material using precautions and placement techniques to prevent the dredged material from dispersing beyond the intended placement site and avoid impacting existing reef. The oyster reef mitigation pads would be constructed using the dredge discharge control technologies discussed in the previous section such as submerged diffusers and variants using multiple tremies that would be employed to control suspended solids and turbidity to minimize impacts to other existing reef complexes and oyster leases in the general area. The reef

pads employing new work have been spaced to provide a minimum of 500 feet from previously mapped reef, and existing oyster leases mapped by the TPWD (**Figure 5)**. Proper sloping for stability would be determined for the side slope ratio of the mounds during PED.

- The cultch veneer would be clean crushed, limestone or concrete, or other suitable substrate as deemed acceptable by the TPWD. Both materials have been successfully used in Galveston Bay reef restoration including those by USACE, the NFS and TPWD. The cultch would most likely be barged in and then placed evenly over the dredged material. For planning purposes, a 6-inch thick cultch layer has been assumed in consideration of local reef restoration target relief for the recruitment layer that has been successfully implemented recently, including at Fisher’s Reef for the NFS’s BSC Improvements Project.
- Timing and sequence – The mitigation would be constructed concurrent or prior to the construction of the proposed channel modifications. There are portions of the NED, such as widening in the lower Bay that would not impact reef and could allow mitigation construction prior to impacts. The timing for mitigation to occur concurrent with the construction and impacts was conservatively assumed in the habitat modeling described in Section 6. The final mitigation amount and ratio would be remodeled based on the selected mitigation sites and construction schedule, and mitigation would either occur concurrent or prior to construction. With the area and volume of material involved, it is anticipated the mitigation would be constructed in a phased approach in conjunction with the NED or LPP construction. Seasonally, if possible, the mitigation construction would be timed to target completion before or during the spawning season to ensure recruitment of spat soon after the substrate is available. Spawning season is late spring to early fall in Galveston Bay. Ideally, completion would be timed before one of the two spat set peaks that typically occur in the Bay, the larger, first one being between April and June, and the second, smaller peak around August.



OYSTER MITIGATION FEATURE

ASSUMPTIONS:

1. GENERAL CONCEPT INCLUDES HYDRAULIC PLACEMENT OF NW DREDGE MATERIALS (SANDS AND CLAYS) TO CREATE A FOUNDATION PAD FOR CULTCH MATERIAL.
2. 6-INCH CULTCH VENEER CONSISTING OF 3-INCH CRUSHED LIMESTONE OR SIMILAR MEDIA SUITABLE FOR OYSTER RECRUITMENT/COLONIZATION.
3. VERTICAL RELIEF ABOVE PRE-CONSTRUCTION BAY BOTTOM WILL VARY. TARGET RELIEF TO BE 2-FEET +/-.
4. HYDRAULIC PLACEMENT OF MATERIAL TO MINIMALLY DISPLACE BAY BOTTOM DURING FILLING THROUGH USE OF DIFFUSERS/SPREADERS ALONG WITH FREQUENT SWING/MOVEMENT OF DISCHARGE FROM A SPILLBARGE.
5. WITH LOSSES, ESTIMATED NW MATERIAL REQUIREMENT EQUALS 6,644 CY PER MITIGATION ACRE.
6. NW DREDGE MATERIAL PORTION ESTIMATED BY PRODUCTION ANALYSIS BETWEEN DREDGE LOCATIONS AND POTENTIAL MITIGATION SITE AT SAN LEON. UNIT COSTS VARY FROM $8.69-12.20/CY, VARYING BY DISTANCE TO PROJECT VICINITY.
7. CULTCH MATERIAL/INSTALLATION ESTIMATED BY REVIEW OF HISTORICAL PROJECTS DATA AND INFLATED TO 2018 PRICES AT $66,881 PER ACRE.

Figure 7 Oyster Reef Mitigation Feature

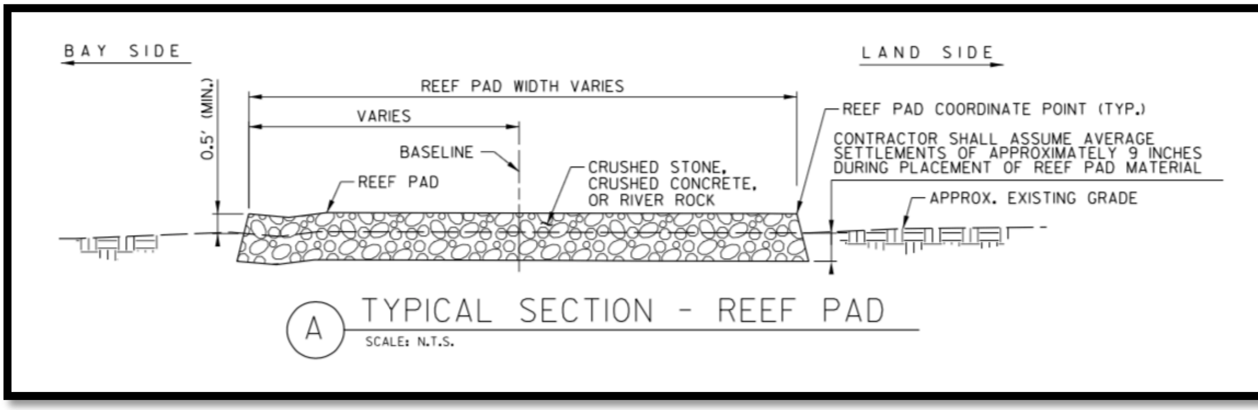


Figure 8 Typical Section of HSC DER Reef Pads Currently Assumed as NED Plan Pad Design

- Foundation – Proper analysis would be performed and measures taken to determine and provide vertical stability of the placed berm and cultch layer. Geotechnical studies and analysis during the PED of the final selected sites would be performed to position mitigation footprints at the selected site(s) to reduce risks of settlement. Most of the candidate sites are areas of formerly exposed reef buried by Hurricane Ike-induced sedimentation. Experience during the BSC Improvements Project mitigation at Fisher's Reef, which was also former reef buried by Ike-induced sedimentation, indicates that settlement into soft surficial sediments was less than expected, possibly due to the underlying shell from the former reef.
- Other elements considered – Other mitigation work plan elements listed in 40 CFR 230.94(c)(7), such as source of water or methods to establish the desired plant community, are not applicable.

Construction details for the elements of the mitigation work plan would be developed during the PED phase of the mitigation project, as part of the development of plans and specifications for the procurement of services to construct the proposed mitigation. Final design dimensions and construction specifications would be shared and coordinated with TPWD, and other resource agencies, as requested.

8.0 MAINTENANCE PLAN

Once the cultch has been placed, no further maintenance of the site that is predictable would be required. The cultch should stay exposed for colonization by oyster larvae and other aquatic organisms. Post construction bathymetric surveys would confirm that the reef would be vertically stable. Periodic monitoring in Section 10 would confirm that substrate remains exposed. As discussed in Section 7, the mitigation method has been used in restoration with long term success. Also, 2 years of successful post-mitigation monitoring results for the NFS's Fisher's Reef mitigation in Galveston Bay with thicker cultch layers (>12") employed, and similarly restored over former reef, indicate long term settlement should not be an issue. The substrate would develop on its own into mature reef with market-size oysters expected in two to three years similar to that experienced with reef mitigation for the HGNC project. However, other unusual events, such as another major hurricane like Hurricane Ike could cover the area, as well as natural reefs. No specific long term maintenance for these unusual events is planned.

9.0 ECOLOGICAL PERFORMANCE STANDARDS

Pre-restoration and post-restoration side scan-sonar data would be collected and processed into ArcGIS data layers. This would determine the acres of reef habitat available for colonization. The purpose of pre-restoration side-scan sonar data is to determine the presence/absence of existing exposed reef within the mitigation site foot print, with the aim of confirming that existing reef is zero acres, since mitigation construction should avoid placing dredged material and cultch over existing reef. As a structural endpoint, the restored cultch acreage would be quantified from the post-restoration hard-bottom acreage indicated in the side-scan data. These data would determine the amount of hard bottom habitat restored that would be available for oyster recruitment.

10.0 MONITORING REQUIREMENTS

Monitoring of the restoration sites would be conducted pre- and post-restoration to assess the success of the mitigation. Criteria for restoration success would include one structural and one functional endpoint. The structural endpoint would be the number of hard-bottom acres restored. The functional endpoint would be a measure of the live oyster density or recruitment onto the cultch that would be determined in coordination with TPWD. The specific method and techniques would be adapted to the scale of mitigation required and would follow TPWD sample methods, where applicable and suitable for large acreages of restoration. A proposed approach was coordinated with resource agencies during the August 22, 2019 BUG meeting. The proposed methodology recommended is use of patent tongs or similar grab sample method on a randomly stratified grid over each mitigation pad. The functional endpoint monitoring would be conducted starting 2 years after the placement of the cultch and continue for 3 years. The functional monitoring would be timed after spat peak periods, when possible, to ensure the selected success criteria are met. Both the amount of spat, live growth (market size - ≥3 inches and sub-market size - <3 inches), and amount and size of dead shell would be determined using grab sample tongs or other similar recommended methodology by TPWD. The enumeration of spat, juvenile and adult live growth would be compared with nearby mapped natural reef comparison sites that would be confirmed to present by side-scan sonar and grab sampling. Use of a specific target live reef density of oysters per square meter (oysters/m^2) is not practical because year-to-year recruitment and live reef density is highly variable with climatic variations in salinity and annual storm and other freshwater inflow events. Therefore, sampling of mitigation reef and the comparison natural reef would be conducted contemporaneously. When the success criteria are met of the required structural hard-bottom acres constructed, and functional endpoint result of 80 percent of total live density of nearby natural reef, the monitoring would cease and the mitigation project would be determined to be successful. The USACE would be responsible for conducting this monitoring. A total monitoring cost per event was estimated for the NED Plan pads ranging between $25,000 and $40,000, and between $90,000 and $135,000 for the LPP increment pads, for a range of total cost for the LPP (NED + LPP increment) ranging between $115,000 and $135,000. A total of three events would range from $345,000 to $520,000. This was based on the following basic assumptions:

No. sample points for each standard 20-acre pad	20-30
time at each data point	20 minutes
Average burdened specialist hourly wage	$120
Work hours/day	10

No. of staff	3
Boat cost/day	$6,000

Rounding to the nearest $100,000 for report writing and coordination, the expected cost would be between $400,000 and $600,000A total cost for all monitoring events would 1 percent or less of the approximate total fully-funded mitigation cost of $60 million for the entire LPP described in Table 6-6 of the Final Integrated Feasibility Report – Environmental Impact Statement.

11.0 LONG-TERM MANAGEMENT PLAN

After the mitigation project is determined to be successful, management of the mitigation site area would be returned to the owners of the site and regulators of the bottom of Galveston Bay, which are the various governmental agencies including but not limited to TPWD. No specific long term management activities are planned. However, these reefs would be subject to the same regulations that govern Galveston Bay oyster reefs.

12.0 ADAPTIVE MANAGEMENT PLAN

Any time during the monitoring period, if the success of the mitigation plan appears not to be meeting the success criteria, the USACE would notify the TPWD and other resource agencies, so that the mitigation can be evaluated and measures pursued to address deficiencies of the mitigation. Discussions on meeting the success criteria would be included in each monitoring report. Corrective actions would depend on the assessed or probable cause of the failure. The most relevant actions that could be used for adaptive management in the context of oyster reef mitigation are re-placing cultch if substrate has subsided or is otherwise not exposed, and seeding with oyster larvae if all other factors such as salinity and cultch were not at issue. Based on the past local reef restoration projects that account for proper design, the risk of full subsidence is low. The risk of not having adequate recruitment compared to natural reef when annual ambient salinity has not been an issue, is low. For example, initial recruitment observed at mitigation at Fishers Reef for the Bayport Ship Channel Improvements project during a year with prolonged low salinity averaged more than 10 times the live density of the impacted reef surveyed the year before, when salinity was not depressed. Accordingly, the risk of not meeting the desired outputs or results is not expected to be high. These factors are not expected to present the need for a costly adaptive management plan as discussed in the WRDA 2007 Implementation Memo.

13.0 FINANCIAL ASSURANCES

The USACE is a U.S. federal agency under the Department of Defense and a major Army command made up of approximately 37,000 civilian and military personnel. The USACE is one of the world's largest public engineering, design, and construction management agencies. The Corps' missions are: 1) Planning, designing, building, and operating locks and dams; 2) Design and construction of flood protection systems; 3) Design and construction management of military facilities; and, 4) Environmental regulation and ecosystem restoration. This mission is required to be accomplished in a manner that 1) complies with all applicable Federal, State, and local environmental regulations, including those for mitigation, and 2) provides sufficient funds to cover the mitigation operational expenses and capital investments. USACE Civil Works project planning policy, including Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook (PGN), and the aforementioned USACE Civil Works CECW-PC Memorandum, explicitly require that all significant losses of significant resource from a proposed USACE project be mitigated. As a matter of policy and procedure, all Civil Works projects, or portions impacting resources requiring mitigation, would not get funded unless the mitigation is also funded. Therefore, projects would not be implemented without the required mitigation as part of the project. It is anticipated the mitigation funding source would be the same as that for the proposed project construction. It is anticipated that the project would be executed with funds appropriated by Congressional Approval of the President of the United States' Budget proposed in a given fiscal year. The USACE has a long track record of successfully participating in and funding mitigation and ecosystem restoration (e.g. beneficial use) as part of its sponsored projects.

14.0 REPORTING

The first report to the resource agencies would include the findings of the restored reef acreage as determined by side-scan sonar, and would be submitted no later than 90 days after placement of the reef substrate. The functional monitoring results would be summarized annually starting after year 2. The subsequent five annual reports over the 5-year monitoring period would include the oyster density findings of the grab samples as compared to the natural reefs, including when the post-restoration oyster density success criteria was met.

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