A-9: Monitoring and Adaptive Management Plan

Jefferson County Ecosystem Restoration Feasibility Study

Monitoring and Adaptive Management Plan

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1.0 INTRODUCTION

This document provides a feasibility-level monitoring and adaptive management plan for the Jefferson County Ecosystem Restoration (JCER) Feasibility Study. The study reviewed opportunities for ecosystem restoration (ER) in Jefferson County, which could contribute to larger ongoing efforts to improve, preserve, and sustain ecological resources along the Texas coast. The study is recommending a project that would restore coastal marshes around Keith Lake.

This plan identifies potential monitoring activities, outlines how results from the monitoring would be used to assess project success and, if needed, adaptively manage the project to achieve the desired ecosystem restoration objectives. The plan specifies who would be responsible for monitoring and adaptive management activities and provides estimated costs.

This Monitoring and Adaptive Management Plan (MAMP) was prepared by members of the JCER project delivery team (PDT) and resource agencies, including US Fish and Wildlife Service, Texas Parks and Wildlife Department, and the Texas General Land Office. The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the feasibility study. Uncertainties remain concerning the exact project features, monitoring elements, and adaptive management opportunities. Components of the MAMP, including costs, were similarly estimated using available information. Uncertainties will be addressed in the preconstruction, engineering and design (PED) phase; this plan will be revised to incorporate more detailed monitoring and adaptive management plans and cost breakdowns.

1.1 Authorization for Monitoring and Adaptive Management

In accordance with the Water Resources Development Act of 2007 Section 2036, Section 2039 and subsequent implementation guidance (CECW-PB Memorandum dated August 31, 2009), MAMPs are required for both National Ecosystem Restoration (NER) project components and for any Mitigation Plan required for the National Economic Development (NED) component.

Section 2039 specifically directs the Secretary of the Army to ensure that when conducting a feasibility study for a project (or component of a project) for ER that the recommended project includes a plan for monitoring the success of the ER. The implementation guidance for Section 2039 specifies that ER projects include plans to track and improve restoration success through monitoring and adaptive management. Guidance stipulates that the monitoring plan includes a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring. It also specifies that monitoring will be performed until restoration success is achieved.

This MAMP includes all elements required by the WRDA 2007 implementation guidance for section 2039.

1.2 Introduction to Monitoring and Adaptive Management

Monitoring and adaptive management provides a directed iterative approach to achieve restoration project goals and objectives by focusing on strategies promoting flexible decision making that can be adjusted in the face of uncertainties as outcomes from restoration management actions and other events become better understood. Initiating a formal MAMP early in the study process enables the study team to identify and resolve key uncertainties and other potential issues that can positively or negatively influence project outcomes during every stage of the planning and project implementation process. Hence, early implementation of monitoring and adaptive management will result in a project that can better succeed under a wide range of uncertain conditions and can be adjusted as necessary. Furthermore, careful monitoring of project outcomes both advances scientific understanding and helps adjust policies and/or operations as part of an iterative learning process.

Learning from the management experience is not a new idea; but the purposeful and systematic pursuit of knowledge to address identified uncertainties has rarely been practiced. Adaptive management acknowledges the uncertainty about how ecological systems function and how they may respond to management actions. Nevertheless, adaptive management is not a random trial-and-error process; it is not ad-hoc or simply reactionary. An essential element of adaptive management is the development and execution of a monitoring and assessment program to analyze and understand responses of the system to implementation of the project as restoration progresses. The MAMP was developed and will be used to:

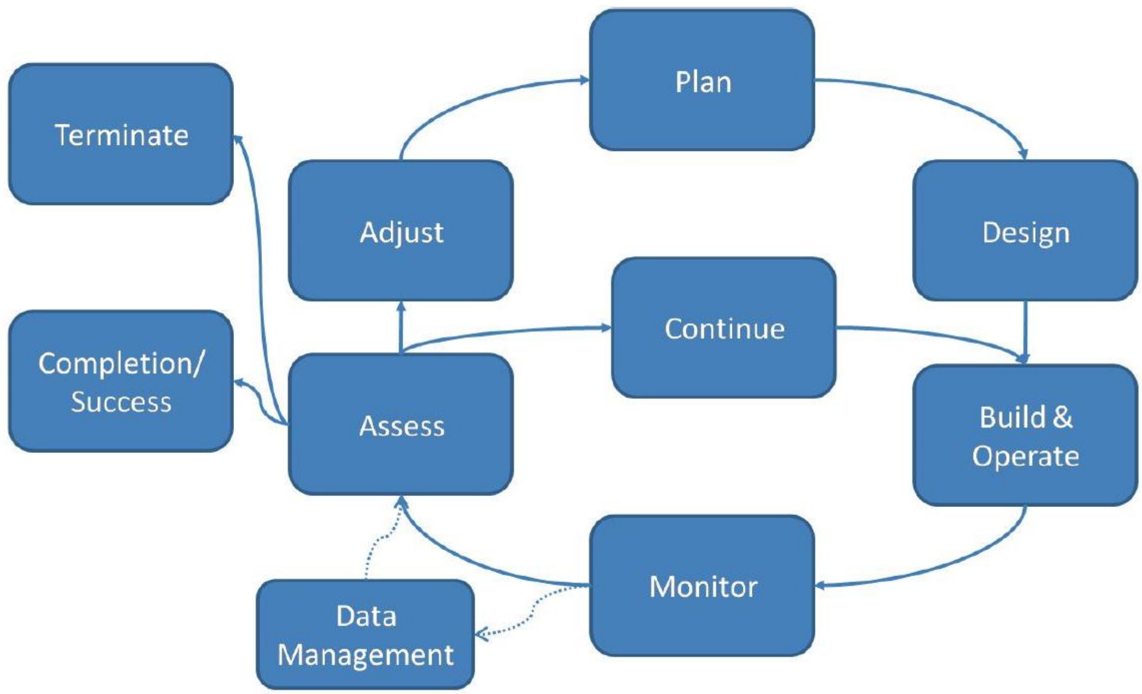
- Allow scientists and managers to collaboratively design plans for managing complex and incompletely understood ecological systems.
- Reduce uncertainty over time.
- Implement systematic monitoring of outcomes and impacts.
- Incorporate an iterative approach to decision-making.
- Provide a basis for identifying options for improvements in the design, construction and operation of restoration through adaptive management.
- Ensure interagency collaboration and productive stakeholder participation as they are key elements to success.

1.2.1 *Monitoring and Adaptive Management Process*

The developed monitoring and adaptive management program and process is complimentary to the USACE Project Life Cycle (planning, design, construction, and operation and maintenance). The process is not elaborate or duplicative and enhances activities that already take place. The basic process was adapted from a technical note published by the Engineering Research and Development Center (ERDC)[1]. Elements of the program include an iterative process involving: planning a program or project; designing the project; building the project; operating and maintaining the project; monitoring and assessing project performance; and continuing, adjusting, or terminating a project if the goals and objectives are not being achieved (Figure 1).

[1] Fischnecich, C., et al. 2012. The Application of Adaptive Management to Ecosystem Restoration Projects. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-10. Vicksburg, MS: US Army Engineering Research and Development Center. www.wes.army.mil/el/emrrp.

Figure 1. Monitoring and adaptive management process for USACE Civil Works[1].



1.2.2 *Adaptive Management Team*

As part of the monitoring and adaptive management process, a team is set up to implement the process. The MAMP provides the framework and guidance for an Adaptive Management Team (AMT) to review and assess monitoring results and consider and recommend adaptive management actions when ecological success is not achieved and decision criteria are triggered. The AMT members shall work together to make recommendations relevant to implementing the MAMP. The AMT is composed of USACE staff, the non-Federal sponsor (NFS), and interested resource agencies and/or other stakeholders. Although the USACE has coordinated with the entities that will comprise the AMT in development of the Integrated Feasibility Report and Environmental Assessment (IFR-EA), the AMT will be officially established during PED.

The AMT focuses on the ecological function of the habitats through related management actions to maintain and provide functional coastal marsh habitat within the project area. The AMT shall review the monitoring results and advise on and recommend actions that are consistent with the project goals and reflect the current and future needs of the habitat and the species they support within the project area. The USACE shall have final determination on all adaptive management actions recommended.

The USACE is responsible for ensuring that monitoring data and assessments are properly used in the adaptive management decision-making process. If the USACE determines that adaptive management actions are needed, it will coordinate with the AMT on implementation of those actions. The USACE is also responsible for project documentation, reporting, and external communication.

The AMT shall meet at a minimum of once per year, as scheduled by the USACE during the monitoring period, to review the results of monitoring and assess whether project objectives are being met. If objectives are not being met, the AMT may recommend that adaptive management actions be taken in response to monitoring results as compared to decision-making triggers.

The AMT may also consider other related projects in the hydrologic basin in determining the appropriate adaptive management actions, and may consult with other recognized experts or stakeholders as appropriate, to achieve project goals.

Recommendations for adaptive management should be based on:

- Monitoring data from previous years,
- Consideration of current habitat conditions,
- Consideration of current and potential threats to habitat establishment success, and
- Past and predicted response by target species and habitats.

1.1.1.1 Team Structure

The AMT shall include representatives from USACE, Galveston District and the Regional Planning and Environmental Center (RPEC), and the NFS responsible for cost-sharing construction and future operations and maintenance.

The USACE may be represented by the Project Biologist(s), as well as the Project Hydrology and Hydraulics (H&H) representative and the Project Geotechnical representative as needed. Other USACE attendees may include the Project Manager, Project Real Estate Specialists, and/or Operations and Maintenance designees, as needed.

For the feasibility study, the NFS is Jefferson County and the Sabine-Neches Navigation District; however, their ability to become the NFS for construction is uncertain at this time. A construction NFS would be identified prior to PED. The NFS would ultimately be responsible for all Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRRR) activities once the USACE notifies the NFS of project completion. Prior to final project completion, the USACE would transfer responsibility of functional elements of the project to the NFS as they are completed. The NFS may be represented by its designees which may include Project Managers, Planners, Design Engineers, Environmental Specialists, or other designees.

The AMT should also include representatives from resource agencies who would serve in an advisory capacity, to assist in evaluation of monitoring data and assessment of adaptive management needs. The agencies may include, but is not limited to, and upon their acceptance:

- U.S. Fish and Wildlife Service, Houston Ecological Services Office
- U.S. Fish and Wildlife Service, McFaddin National Wildlife Refuge
- Texas Parks and Wildlife Department, JD Murphree Wildlife Management Area
- Texas Parks and Wildlife Department, District 7
- Texas General Land Office, La Porte Field Office

1.3 Recommended Plan

Alternative 4Abu was selected as the recommended plan (the plan) based on preliminary analyses because it meets the study objectives, reasonably maximizes benefits for the associated costs, and includes key restoration features to restore and sustain the form and function of the coastal system in a portion of the study area. This plan incorporates marsh and shoreline restoration features which are critical to the stabilization and sustainment of the critical marsh resources in and around Keith Lake now and into the future. Marsh measures consist of marsh restoration and/or nourishment to increase land coverage in the area and improve terrestrial wildlife habitat, hydrology, water quality, and fish nurseries. Shoreline measures include construction of rock breakwater features that would mitigate some effects of erosion along the GIWW. The structures dissipate wave energies, stabilize shorelines, reduce land loss, reduce saltwater intrusion, and support reestablishment of emergent marsh along the GIWW shoreline through retention of sediments.

Measures for this alternative would be constructed on lands owned by Texas Parks and Wildlife Department (TPWD) JD Murphree Wildlife Management Area (WMA) and US Fish and Wildlife Service McFaddin National Wildlife Refuge (NWR) (Table 1).

Table 1. Scale and scope of 4Abu measures in Comparison to Land Ownership

Ownership	Marsh Measures (acres)	Shoreline Measures (linear feet)
JD Murphree WMA	5,365	5,170
McFaddin NWR	683	0
Private	0	0

Marsh Measures

Marsh restoration measures involve placement of borrow material dredged from the Sabine-Neches Waterway (SNWW) into these locations. Material placed into the marsh would have similar properties to the existing native material. Under the existing and projected future dredging cycles, there is sufficient quantities of suitable material available to meet all restoration needs without seeking other borrow sources (e.g. off-shore, upland placement areas).

4Abu would restore and nourish approximately 6,048 acres of technically significant marsh habitat surrounding Keith Lake in Jefferson County, Texas. Within each of the six marsh restoration units, material dredged from the SNWW would be hydraulically pumped into open water and low lying areas assuming that 65% of the restoration unit will have a post-construction settlement target elevation of +1.2 feet MSL. As necessary, earthen containment dikes would be employed to efficiently achieve the desired initial construction elevation. Dikes would be breached following construction to allow dewatering and settlement to the final target marsh elevation. It is estimated that 6.7 million cubic yards (MCY) of dredged material would be required to initially restore the 6,048 acres of marsh. Following marsh restoration actions, non-native/undesirable species monitoring would be implemented. If species are found, measures would be taken to stop or slow the expansion of the species within the restoration units.

Shoreline Measures

GIWW armoring would involve constructing 5,170 linear feet of breakwater structures. They structures would be built in shallow water (<3 feet deep) along the southern edge of the GIWW, at varying distances from the shoreline and where soils are conducive to supporting the weight of the stone without significant subsidence. The distance from the shoreline would be determined during PED, after site specific surveys have been completed, but sufficiently offset from the boundaries of the GIWW navigation channel to ensure continued safe navigation.

The design would be a trapezoidal structure built of rock up to a height of +3.0 MSL, which will yield approximately 1-1.5 feet of rock exposed above the mean high tide level. Other approximate features of the design include a 5-foot wide crown, a 1.5:1 slope, and a base that is roughly 29 feet wide. The base of the structure would be on filter cloth ballasted to the water bottom to secure placement and prevent displacement of the outboard edges. The number of openings and width of each would be determined during PED and dependent on the location of major channel entrances or access points required for fishery access or circulation. Initially, constructing the 6,592 linear feet of breakwaters would require 672,384 cubic feet of material which equates to about 39,800 tons of rock. It is anticipated that the breakwaters would need to be raised at least two times throughout the 50-year period of analysis to keep up with relative sea level change and remain effective. For purposes of the study materials would need to be added in year 15 (6,000 tons of rock) and year 25 (4,000 tons of rock), but timing and quantities could vary depending on observed local conditions and identified need to continue functioning as designed.

Equipment Needs and Access Routes

Sediment transport equipment would most likely include hopper or cutterhead dredges, pipelines (submerged, floating, and land) and booster pumps. Heavy machinery would be used to move sediment and facilitate construction. Heavy equipment could include bulldozers, front-end loaders, track-hoes, marshbuggy, track-hoes, and backhoes. For GIWW armoring construction, rock would be purchased from a commercial quarry and transported to the site by barge, where it would then be placed by crane or hopper barge. Various support equipment would also be used, such as crew and work boats, trucks, trailers, construction trailers, all-terrain vehicles, and floating docks and temporary access channels to facilitate loading and unloading of personnel and equipment.

Identification of staging areas, temporary access channels, and placement of floatation docks would occur during PED. Each disturbance for access and staging would be placed outside of environmentally sensitive areas to the greatest extent practicable. All ground disturbance for access and staging areas would be temporary and fully restored to result in no permanent loss.

Timing

Timing of initial construction of this project is dependent on a number of factors including: timing of authorization, duration of pre-engineering and design phase, identification of a cost-share sponsor, and Federal- and non-federal funding cycles. It was assumed that construction would take 60 months to complete all restoration actions, in which it was assumed that only one restoration unit would be undertaken at a time. For the GIWW armoring, it was assumed that dune construction and beach nourishment would occur simultaneously.

Implementation of the marsh restoration measures is highly dependent on dredging cycles. Currently, seasonal timing restrictions related to Endangered Species Act compliance includes a seasonal dredging window for hopper dredge use between December 1 and March 31, unless work outside this window cannot be completed, in which NMFS would need to approve the deviation. Hopper dredges would be used for dredging offshore areas of the entrance channel to just inside the jetties. Non-hopper dredges (e.g. cutterhead pipeline dredges) may be used from April to November. This type of dredge would be used anywhere else within the SNWW.

1.3.1 *Project Goals and Objectives*

During the initial stages of project development, the study team, with stakeholder and resource agency input, developed restoration goals and objectives to be achieved by the JCER project. These goals and objectives were subsequently refined to specifically address the features and strategies of the recommended plan. The overarching goal of the plan is to reduce degradation and deterioration of the coastal marsh system around Keith Lake. This project would complement other ecosystem restoration efforts in Jefferson County that work together to achieve and sustain a larger-scale coastal ecosystem that can support and protect the environment and culture of southern Jefferson County and thereby contribute to the well-being of the Nation. The specific restoration objectives for the recommend plan are to:

- **Project Objective 1:** Restore coastal marsh to maintain and/or improve their function as essential habitats for fish, migratory birds, and other aquatic and terrestrial species, mimicking, as closely as possible, conditions which occur naturally in the area.
- **Project Objective 2:** Increase sediment input to supplement natural transport processes and sustain the target marsh elevation.
- **Project Objective 3:** Reduce shoreline erosion and stabilize GIWW shorelines to protect adjacent wetlands.

1.3.2 *Sources of Uncertainty and Associated Risks*

A fundamental tenet underlying the adaptive management process is achieving desired project outcomes in the face of uncertainties. Scientific uncertainties and technological challenges are inherent with any large-scale restoration project with the principal source of uncertainty typically including:

1. Incomplete description and understanding of relevant ecosystem structure and function,
2. Imprecise relationships between project management actions and corresponding outcomes,
3. Engineering challenges in implementing project alternatives, and
4. Ambiguous management and decision-making processes.

It is important to determine the type of risk each uncertainty comprises and to discern what constitutes sufficient knowledge to proceed considering those risks. There is significant institutional knowledge regarding the construction of the restoration measures; therefore, there is minimal uncertainty from a construction standpoint. Uncertainties relating to measure design and performance are mainly centered on site specific, design-level details (e.g. exact sediment quantities, invasive species removal needs, extent of erosion control needs, construction staging area locations, pipeline pathways, timing and duration of construction, engineering challenges, etc.), which would be addressed during the pre-engineering and design phase (PED). Identified uncertainties with the plan include:

- **Relative Sea Level Change (RSLC)** including whether sea level rise will be greater than assumed in the design;
- **Climate Change**, such as drought conditions and variability of significant storm frequency, intensity, and timing;
- **Natural Variability** in ecological and physical processes;
- **Sediment Dynamics**, including subsidence and accretion rates;
- **Marsh Restoration Requirements** such as water, sediment, and nutrient requirements including magnitude and duration of inundation, annual sediment needs, and type and quantity of nutrients to achieve desired productivity;
- **Invasive and Nuisance Species**, including invasive *Spartina* hybrids; and
- **Project Feature Implementation Timing**, including schedule and timeline, availability of construction funds.

Issues such as climate change, sea level change, and regional subsidence are significant scientific uncertainties for most Gulf Coast restoration projects. These uncertainties were incorporated in the plan formulation process and will be monitored by gathering data on water levels, salinities, and land elevation. Specifically, for RSLC, USACE EC-11165-2-21 provides an 18-step process for developing a “low”, “intermediate” and “high” future RSLC scenario and provides guidance to incorporate these potential effects into project management, planning, engineering, design, construction, operation and maintenance. The study team evaluated and designed the TSP under the “intermediate” scenario in accordance with the EC-1165 (See Engineering Appendix). This information will be assessed and will inform adaptive management actions. In addition, procedures to evaluate sea level change impacts, response and adaptation will continue to be examined under USACE ETL 1100-2-1 which provides guidance for understanding the direct and indirect physical and ecological effects of projected future RSLC on USACE projects and systems of projects and considerations for adapting to those effects.

2.0 MONITORING

An effective monitoring program will be required to determine if the project outcomes are consistent with original project goals and objectives. The power of a monitoring program developed to support adaptive management lies in the establishment of feedback between continued project monitoring and corresponding project management. A carefully designed monitoring program is the central component of the project adaptive management program as it supplies the information to assess whether the project is functioning as planned.

Monitoring must be closely integrated with the adaptive management components because it is the key to the evaluation of adaptive management needs. Objectives must be considered to determine appropriate indicators to monitor. In order to be effective, monitoring must be able to distinguish between ecosystem responses that result from project implement (i.e. management actions) and natural ecosystem variability.

2.1 Monitoring Plan

According to the USACE implementation guidance memo for WRDA Section 2039, "Monitoring includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success have been achieved, or whether adaptive management may be needed to attain project benefits."

The following discussion outlines a monitoring plan that will support the JCER Adaptive Management Program. The plan identifies performance measures along with desired outcomes and monitoring design in relation to specific objectives. A performance measure includes specific feature(s) to be monitored to determine project performance. Additional monitoring is identified as supporting information needs that will help further understand interrelationships of restoration features and external environmental variability and to corroborate project effects.

Such criteria, or decision-making triggers, are related to each performance measure and desired outcome and identify the need to discuss potential implementation of adaptive management actions with the AMT. These criteria/triggers are identified in Section 3.3.

Overall, monitoring results will be used to evaluate the progress of habitat restoration toward meeting project objectives and to inform the need for adaptive management actions to ensure successful restoration is achieve.

2.1.1 *Monitoring Period*

Pre-construction/baseline data, during construction, and post-construction monitoring will be utilized to determine restoration success. Baseline monitoring will begin during PED prior to project construction and continue during construction when possible. Monitoring will continue until the trajectory of ecological change and/or other measures of project success are determined as defined by project-specific objectives. Section 2039 of WRDA 2007 allows ecological success monitoring to be cost-shared for up to ten years post-construction. Once ecological success has be achieved, which may occur in less than ten years post-construction, no further monitoring would be performed. If ecological success cannot be determined within the ten-year post construction period of monitoring, any additional required monitoring would be the responsibility of the NFS.

There may be issues related to sustainability of the project that would require some monitoring and adaptive management beyond achieving the project objectives. Due to the variable nature of the coastal environment, the monitoring baseline may change during the period of analysis. Consequently, it may be appropriate to consider resuming project-specific monitoring and adaptive management after project success has been achieved or beyond the 10 years particularly if there are sudden or long-term changed conditions (e.g. hurricane, drought, unusually high/low tides for extended period of time, etc.) that would contribute to the long-term success of the project.

Per USACE policy, cost-shared monitoring would cease if additional monitoring would result in monitoring costs exceeding 1 percent of the total project cost minus the costs of adaptive monitoring and adaptive management of the restoration features.

For purposes of this document, Year 0 is the period prior to construction and up to the last day of construction (even if that period of time is over multiple years) plus 12 months. In most instances, year 0 monitoring would occur during PED, except where noted it would occur just prior to construction. This would serve as the baseline condition for which to compare all future data collections. Year 1 is the first year post-construction and starts 12 months after all construction is complete. Year 1 data collection would occur between 12 and 24 months after the last placement. During this period, there is significant sediment movement from settlement, drainage, and potential erosion, so this year is critical in capturing areas where significant change has occurred as these areas would be at risk for failure.

2.1.2 *Monitoring Elements*

Defining and assessing progress towards project objectives are crucial components of the MAMP. The following section outlines the proposed performance measure metrics, desired outcomes and monitoring design needed to measure restoration progress, determine ecological success and support the adaptive management program should changes need to be made to improve project performance. The elements described in this section are based on the available project information and will be updated and refined during PED.

Project Objective 1: Restore coastal marsh to maintain and/or improve their function as essential habitats for fish, migratory birds, and other aquatic and terrestrial species, mimicking, as closely as possible, conditions which occur naturally in the area.

Performance Measure 1: Increase acreage of marsh by 6,048 acres by year 6.

Desired Outcome: Success will be measured by an increase of marsh acreage by 6,048 acres by year 6 with a target open water to emergent marsh ratio of 20%:80%.

Monitoring Design and Rationale: To determine the increase in acreage, satellite and aerial imagery will be used to identify change pre- and post-construction in TY1, TY3, and TY6. For each restoration site, the ratio of land to open water should be classified using satellite imagery scenes. Vegetated habitats should be classified using digital orthophoto aerial or satellite imagery.

Performance Measure 2: Average cover of 80% desirable vegetation on marsh restoration sites at year 5 compared to pre-construction.

Desired Outcome: One year following completion of final construction activities achieve a minimum average cover of 25%, comprised of native herbaceous species. Three years following construction, achieve a minimum average cover of 75% native species. For the period beginning 5 years post-construction and continuing through project success, maintain a minimum average cover of 80%, comprised of native herbaceous species.

Desired Outcome: Invasive noxious, and/or exotic plant species comprise less than 4% of cover of the marsh restoration unit at year 2 and is maintained at or less than 4% thereafter.

Monitoring Design and Rationale: Vegetation will be sampled annually, at the 6 restoration sites and in marsh protected by GIWW armoring. Permanent vegetation monitoring stations will be established for assessing the vegetation community at each site. In addition to community composition, these stations will be sampled for above and below ground biomass, water level, salinity, and soil characteristics. Sites will be sampled one time prior to construction to assess pre-project conditions and sampled annually post-construction until success is determined.

Project Objective 2: Increase sediment input to supplement natural transport processes and sustain the target marsh elevation.

Performance Measure: Establish marsh elevation post-construction sufficient for healthy marsh.

Desired Outcome: Based on local conditions and future rates of projected RSLC, marsh elevation in restored marsh restoration units (following de-watering and settlement) sufficient to support vegetation and marsh establishment is approximately +1.2 MSL at TY1 and sustained through TY6.

Monitoring Design and Rationale: To measure elevation (including accretion and subsidence) at each restoration site, one rod-surface elevation table (RSET), replicate feldspar marker horizon stations and settlement plates will be established within the constructed marsh footprint to measure changes in elevation. Elevation will be sampled one time prior to construction (completed as a PED task for engineering and not included as part of the monitoring costs here) and annually for a period of 10 years post-project or until desired ecological success is achieved, whichever comes first. Elevation, accretion and subsidence measured at existing stations located near each marsh restoration site will also be utilized, as appropriate. One Light Detection and Ranging (LiDAR) survey will be collected pre-construction (completed as a PED task for engineering and not included as part of the monitoring costs here) and three times post-construction at year TY1, TY3, and TY6 to determine overall elevation throughout the entire restoration unit.

Project Objective 3: Reduce shoreline erosion and stabilize GIWW shorelines to protect adjacent wetlands.

Performance Measure: Reduce post-construction shoreline erosion rates compared to pre-construction by 75% by year 6.

Desired Outcome: GIWW armoring measures are expected to reduce shoreline erosion rates by approximately 50% based on previous experiences with this type of structure throughout other areas along the GIWW shorelines in Jefferson County.

Monitoring Design and Rationale: Historic erosion rates for each shoreline protection site can be established from historic aerial photography. Photography and differential GPS surveys will be used to determine post-construction erosion rates at each shoreline protection site at years TY1, TY3, and TY6.

2.1.3 *Monitoring Procedures*

The following monitoring procedures will provide the information necessary to evaluate the previously identified project objectives for the JCER project. The monitoring procedures are described in enough detail to make the approach clear, but do not fully describe the monitoring regime. A monitoring plan with detailed methods, protocols, timing, and responsible parties will be developed in coordination with resource agencies prior to the start of monitoring. During development of the detailed MAMP, it is expected that if new, cost effective methodologies exist they would be employed. Likewise, it is expected that at that time, monitoring specifications, such as timing of the surveys (i.e. high tide, growing season, etc.), specific equipment needs, monitoring locations, etc. will be identified.

Area Change: To determine changes of vegetated and non-vegetated areas within the project area, near-vertical color-infrared digital aerial imagery will be acquired during pre-construction and used as a pre-construction standard for future changes in marsh changes and shoreline position. Three additional satellite and/or aerial photographic acquisitions will be conducted at year 1, 3, and 6. These data will be collected in conjunction with LiDAR missions and under separate acquisition in non-LiDAR years, if needed. The photography will be geo-referenced, classified, and analyzed using standard operating procedures developed during PED. Opportunities should be sought to utilize existing aerial imagery (e.g. Google Earth, county/state contracted flights, etc) if the data is comparable to previous surveys (i.e. timing is similar).

Vegetation: Vegetation sampling will occur annually at 22 sites within all restoration unit (2 sites per marsh restoration unit with less than 1,000 acres restored; 2 sites per 1,000 acres rounded to the nearest thousand for sites over 1,000 acres) and at 2 reference sites for the duration of the monitoring period. Sampling will occur during spring months, at the peak of the growing season. Permanent 1/10th-acre, field monitoring plots will be located randomly within each marsh restoration plot. The distance between plots will be dependent on the project site area and variability. Monitoring will measure percent cover of native and non-native plant species and structural diversity. Photographs stations will also be established within the plot to document vegetation conditions. All plots and photograph stations will be documented via Global Positioning System (GPS) coordinates to reoccupy in each year of sampling.

General observations, such as fitness and health of plantings, native plant species recruitment, and signs of drought stress should be noted during the surveys. Additionally, potential soil erosion, flood damage, vandalism and intrusion, trampling, and pest problems would be qualitatively identified.

A general inventory of all wildlife species observed and detected using the project area would be documented. Nesting sites, roosting sites, animal burrows, and other signs of wildlife use of the newly created habitat would be recorded. The notes would be important for early identification of species colonization patterns.

Marsh Elevation: One LiDAR topographic survey covering all restoration units will be collected prior to construction (completed as a PED task for engineering and not included as part of the monitoring costs here) and recollected three times post-construction in year 1, 3, and 6. LiDAR data will be used to assess overall marsh elevation throughout the restoration unit. The resulting data will provide a density of approximately 1 elevation point per square meter accurate to approximately +/-15 cm (root-mean-square-error [RMSE]) vertical elevation and +/-1.5 m (RMSE) horizontal position. The data would be used to identify low lying areas by surface elevation.

LiDAR is necessary to provide accurate elevation data and is significantly more accurate than photogrammetry methods with minimal post-data collection corrections. It is acknowledged that LiDAR has flaws when collecting data in marsh areas, particularly if flights are performed during high tide; however, there are currently no other methodologies available besides physical on the ground measurements, which would have a substantial cost increase over LiDAR.

Surface elevation will be measured from a RSET benchmark established within or adjacent to the vegetation survey plots using the RSET technique developed by Cahoon et al[2]. This technique provides a non-destructive process that precisely measures the sediment elevation of wetlands over long periods of time relative to a fixed subsurface datum. Marker horizons, indicated with white feldspar clay, would be used in conjunction with the RSET to measure vertical accretion. When used simultaneously, the RSET and marker horizon techniques can provide information on above and below ground processes that influence elevation change. The data will also be used to determine rates of elevation change, particularly relative to sea level change, to ground-truth LiDAR data and assess significant changes in advance of the more intensive LiDAR surveys. This methodology is a relatively inexpensive way to annually measure elevation changes in a subset of the restoration units, especially when performed in conjunction with the vegetation monitoring, and provide immediate results on the health of the system and indicate whether areas are in need of additional monitoring or adaptive management actions. Surface elevation will be sampled one time per year for the two years preceding construction and up to 10 years post-construction, or until the ecological success is achieved, whichever comes first.

Shoreline Change: To determine shoreline position changes within the project area, aerial or satellite imagery can be used as a pre-construction condition to determine the rate of change observed in the past and serve as a pre-construction standard for future changes in shoreline position. Additional aerial or satellite imagery acquisitions post-construction should be used to supplement shoreline surveys to determine the overall rate of erosion. Opportunities should be sought to utilize existing aerial imagery (e.g. Google Earth, county/state contracted flights, etc) if the data is comparable to previous surveys (i.e.

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[2] Cahoon, D.R., J.C. Lynch, and R.M. Knaus. 2002. High-precision measurements of wetland sediment elevation; II, the rod surface elevation table. Journal of Sedimentary Research 72:734—739.

timing is similar). This imagery would be collected in conjunction with the area change survey, resulting in only 1 aerial imagery data collection per survey year.

Shoreline surveys using differential GPS will be conducted for the entire length of each shoreline protection site, for approximately 1,000 feet at 2 unprotected sites in the immediate area (north side of GIWW), and for approximately 1,000 feet at 2 sites which have successfully implemented GIWW armoring. The unprotected site can serve as a baseline condition which will undergo the same future conditions as the protected site and can serve as an additional reference to success (i.e. if rate of erosion at unprotected site is at least 50% higher than the GIWW armoring measure for that protection site, the measure was a success). While sites which already have GIWW armoring can also serve as a reference site to understand the realistic potential for shoreline change (i.e. if the existing protected area is showing more or less erosion control than the new protected site, the cause and effect should be investigated to determine if the new GIWW armoring protected site is still on a trajectory to achieve success). One shoreline survey will be conducted pre-construction and three surveys will be conducted post-construction in year 1, 3, and 6.

2.1.4 *Use of Monitoring Results and Analysis*

Results of monitoring will be assessed in comparison to project objectives and decision-making triggers to evaluate whether the project is functioning as planned and whether adaptive management actions are needed to achieve project objectives. The results of the monitoring will be provided to the AMT who will evaluate and compare data to project objectives and decision making triggers. The AMT will use the monitoring results to assess habitat responses to management, evaluate overall project performance, and make recommendations for adaptive management actions as appropriate. If monitoring results, as compared to desired outcomes and decision making triggers show that project objectives are not being met, the AMT will evaluate causes of failure and recommend adaptive management actions to remedy the underlying problems.

As data is gathered through monitoring, more information will also be available to address uncertainties and fill information gap. Uncertainties such as effective operational regimes, restoration design needs, benefits generated by restored features, and accuracy of models can be evaluated to inform adaptive management actions and future restoration needs.

2.2 Cost of Monitoring

Section 2039 of the WRDA 2007 allows monitoring to be cost-shared for up to ten years post-construction. Therefore, for cost estimating purposes the maximum cost-shared monitoring period (10 years) was assumed for all features. Each monitoring metric was detailed in terms of monitoring methods, locations, frequency and duration in order to develop a cost estimate. The monitoring cost estimate of $472,450 (Table 2). This cost will vary slightly from the numbers presented in the main report, as those numbers will have a contingency cost attached that will be developed by the cost engineer.

Although the monitoring cost estimates presented in this document display activities during the proposed ten years of cost-shared monitoring after construction, monitoring may continue beyond the initial ten years, funded by the NFS, if the criteria for ecosystem success have not yet been met.

Table 2. Monitoring Costs Associated with Construction and Operation of the TSP.

Task	Assumed Task for Recommended Plan	Frequency	Cost Assumptions for Recommended Plan	Total Cost
Area Change/ Shoreline Change	Acquisition of aerial imagery flights with deliverables which include corrected, georeferenced, classified, color imagery in a raster or other dataset that is suitable for use in GIS applications. After deliverables are received, additional data processing and analysis would be required to determine type and rates of change.	4 Aerial Flights Total	**Data Collection: $8,100** 8,100 hectares of survey @ $1.00/ha = $8,100 **Data Processing and Analysis: $7,000** 56 hours @ $125/hr = $7,000 **Total for 1 year= $15,100**	$60,400
Vegetation/ Marsh Elevation—RSET	**Vegetation:** Assume monitoring of each restoration area (either 2 or 8 monitoring sites per restoration unit depending on size of unit) and two reference sites. Each monitoring site will consist of a tenth-acre plot to estimate percent cover of native, non-native, and invasive plant species, plant species composition/diversity, structural diversity, and percent canopy cover. **Marsh Elevation—RSET:** RSET benchmark monitoring stations and feldspar horizon markers will be installed and monitored to determine elevation of the site.	Annually (1 pre- and 10 post-construction)	**Data Collection: $11,250** • 18 monitoring sites = assume 4 sites/day = 4.5 days • 2 biologists @ $125/hr @ 10 hours/day = $2,500/day • 1.0 hrs/monitoring site with an average of 4 plots/day + 6.0 hrs travel to/from and between sites = 10 hours/day **Data Processing and Analysis: $7,000** 56 hours @ $125/hour = $7,000 **Total for 1 year= $18,250** **RSET/Feldspar horizon markers Installation:** • 3 RSET can be installed/day = 6 days • 3 field techs @ $100/hr @ 10 hours/day = $3,000/day • $600/station for RSET/horizon marker costs (e.g. platform, rods, concrete, feldspar clay, etc) = $10,800 • Rod SET measuring instrument = $2,500 • Dewar = $2,000 **Installation Costs (1x cost): $33,300**	$234,050
Marsh Elevation--LiDAR	Acquisition of LiDAR flights with deliverables which include corrected and georeferenced, color imagery in a raster or other dataset that is suitable for use in GIS applications. After deliverables are received, additional data processing and analysis would be required to determine elevation changes and identification of areas of concern.	3 LiDAR Flights Total (pre-construction survey part of PED needs)	**Data Collection: $31,000** 31 square miles of survey @ $1,000/$mi^2$ for the flight = $31,000 **Data Processing and Analysis: $10,000** 80 hours @ $125/hour = $10,000 **Total LiDAR for 1 year= $41,000**	$123,000

Task	Assumed Task for Recommended Plan	Frequency	Cost Assumptions for Recommended Plan	Total Cost
Shoreline Change	Shoreline position surveys using differential GPS will be conducted throughout the entire length of constructed breakwaters, in areas that are not protected by breakwaters and in areas that already have constructed breakwaters. Assume access to the sites will be easy and via GIWW.	4 Surveys (1 pre- and 3 post-construction)	**Data Collection: $8,750** • 9,170 LF to survey (5,170 LF new construction, 1,500 LF unprotected, 1,500 LF protected) = assume 2,500 LF/day = 3.5 days • 2 biologists @ $125/hr @ 10 hours/day = $2,500/day • 7 hr/2,500 LF + 3 hrs travel to/from and between sites = 10 hours/day **Data Processing and Analysis: $5,000** 40 hours @ $125/hour = $5,000 **Total for 1 year= $13,750**	$55,000
Total Monitoring Costs				***$472,450***

3.0 ADAPTIVE MANAGEMENT

Scientific, technological, socio-economic, engineering, and institutional uncertainties are challenges inherent with any large-scale ecosystem restoration project. A structured monitoring plan will be implemented to provide the feedback necessary to inform decisions about future project adjustments.

Adaptive management is distinguished from more traditional monitoring in part through implementation of an organized, coherent, and documented decision process. For JCER adaptive management program, the decision process includes

1. Anticipation of the kinds of management decisions that are possible within the original project design;
2. Specification of values of performance measures that will be used as decision-criteria;
3. Establishment of a consensus approach to decision making; and
4. A mechanism to document, report, and archive decisions made during the timeframe of the adaptive management program.

3.1 Rationale for Adaptive Management

The primary incentive for implementing an adaptive management program is to increase the likelihood of achieving desired project outcomes given project uncertainties. All ecosystem restoration projects face uncertainty due to incomplete understanding of relevant ecosystem structure and function, resulting in imprecise relationships between project actions and corresponding outcomes. Given these uncertainties, adaptive management provides an organized and coherent process that suggests management actions in relation to measured project performance compared to desired project outcomes. Adaptive management establishes the critical feedback among project monitoring, and informed project management, and learning through reduced uncertainty.

Many factors such as ecosystem dynamics, engineering applications, institutional requirements, and many other key uncertainties can change and/or evolve over a project's life. The MAMP will be regularly updated to reflect monitoring-acquired and other new information as well as resolution and progress on resolving existing key uncertainties or identification of any new uncertainties that may emerge. Specifically, the MAMP will be revised and updated and project measure specific plans developed during the feasibility level of design phase and further in pre-construction engineering and design (PED) phase as more detailed project designs are developed and uncertainties are better understood. The MAMP would then be used during and after project construction to adjust the project, as necessary to better achieve goals, objectives, and restoration/management outputs/results.

3.2 Assessment

The assessment phase of the adaptive management framework describes the process by which the results of the monitoring efforts will be compared to the project performance measures, which reflect the objectives of the restoration actions.

The results of the monitoring program will be assessed annually through the AMT. Monitoring results will be compared to the desired project outcomes and decision-making triggers as set forth by the project performance measures. This assessment process will measure the progress of the project in relation to the stated project objectives, evaluate project effectiveness and consider if adaptive management actions are needed. Assessments will also inform the AMT if other factors are influencing the response that may warrant further research.

USACE will document and report the monitoring results, assessments, and the results of the AMT deliberations to the managers and decision-makers designated for the JCER project. USACE, with assistance from the monitoring team, will also produce annual reports that show progress towards meeting project objectives as characterized by the performance measures. Results of the assessments will be used to evaluate adaptive management needs and inform decision-making.

3.2.1 *Database Management*

Database management is an important component of the monitoring plan and the overall adaptive management program. Data collected as part of the monitoring and adaptive management plans will be archived as prescribed in the refined monitoring and adaptive management plan developed during PED. The database manager will be responsible for storing final monitoring reports and other study documentation (decisions, agendas, reports) and making them available when requested. Monitoring reports will be searchable by topic and principle author.

Data standards, quality assurance and quality control procedures and metadata standards will also be prescribed in the refined monitoring and adaptive management plan. The database will be designed to store and archive the monitoring and adaptive management data. The format of each data set will vary as appropriate to the type of monitoring. Therefore, data are expected to be archived separately, rather than collated in one master database. Each dataset will include: data and metadata transfer and input policies and standards; data validation procedures; and mechanisms to ensure data security and integrity.

3.3 Decision-Making

Decisions on the implementation of adaptive management actions are informed by the assessment of monitoring results. The information generated by the monitoring plan will be used by USACE and the NFS in consultation with other AMT members to guide decisions on adaptive management that may be needed to ensure that the ecosystem restoration project achieves success. Final decisions on implementation of adaptive management actions are made by USACE.

If monitoring determines that a management trigger has been “activated” then there are three possible response pathways:

1. Determine that more data is required and continue (or modify) monitoring;
2. Identify and implement a remedial action;
3. Modify project goals and objectives (this option would only be considered as a last resort and upon careful consideration by and consensus of the PDT and AMT).

3.3.1 *Decision Criteria*

Decision criteria, also referred to as adaptive management triggers, are used to determine if and when adaptive management opportunities should be implemented. They can be qualitative or quantitative based on the nature of the performance measure and the level of information necessary to make a decision. Desired outcomes can be based on reference sites, predicted values, or comparison to historic conditions. Several potential decision criteria are identified below, based on the project objectives and performance measures. More specific decision criteria, possibly based on other parameters such as hydrology, geomorphology, and vegetation dynamics, may be developed during PED.

If assessments show that any of these triggers are met, USACE would consult with the AMT to discuss whether an adaptive management action is warranted, and if so, what that action should be. Investigations may be required to determine the cause of failure in order to inform the type of adaptive management actions that should be implemented, if needed. Additionally, prior to enacting any adaptive management measures, USACE would assess whether supplemental environmental analyses are required.

Project Objective 1: Restore coastal marsh to maintain and/or improve their function as essential habitats for fish, migratory birds, and other aquatic and terrestrial species, mimicking, as closely as possible, conditions which occur naturally in the area.

Performance Measure 1: Increase acreage of marsh by 6,048 acres by year 6.

Desired Outcome: Success will be measured by an increase of marsh acreage by 6,048 acres by year 6 with a target open water to emergent marsh ratio of 20%:80%.

Trigger: By year 1, the ratio of open water to land is greater than 35% water and less than 65% emergent marsh. By year 6, the ratio of open water is greater than 20% water and less than 80% emergent marsh.

Possible Causes for Not Meeting Desired Outcome: Immediately post-construction, the target ratios should be achieved through placement of dredged material; however, if after 1 year the ratio is not maintained, erosion and subsidence will be the most likely causes.

Potential Adaptive Management Measures: Investigations should be completed to identify why land loss is occurring. To reduce the amount of open water, open water areas and low lying marsh platforms should be renourished or filled in with dredged material to create more land. If erosion is the main cause, erosion control measures, such as vegetative plantings, straw wattles, erosion mats, breakwaters, etc., should be installed.

Performance Measure 2: Average cover of 80% desirable vegetation on marsh restoration sites at year 5 compared to pre-construction.

Desired Outcome 1: One year following completion of final construction activities achieve a minimum average cover of 25%, comprised of native herbaceous species. Three years following construction, achieve a minimum average cover of 75% native species. For the period beginning 5 years post-construction and continuing through project success, maintain a minimum average cover of 80%, comprised of native herbaceous species.

Trigger: The desired minimum average cover of desirable species within each marsh restoration unit is not achieved within the prescribed timeframe.

Possible Causes for Not Meeting Desired Outcome: Marsh vegetation may not achieve the target percent cover or structural conditions due to improper geomorphic or hydrologic conditions (e.g. erosion/scour, sedimentation, poor water quality including salinity, tidal influences), or natural events (e.g. loss during storm events or drought, herbivory or trampling).

Potential Adaptive Management Measures: Replanting may be needed if triggers for vegetative cover are met. Monitoring results should be used to assess the underlying cause of inadequate cover, which may require that additional adaptive management actions be implemented to support successful replanting. For example, scouring and higher average salinity levels may prevent successful establishment of vegetative communities. Actions would be required to address scouring and the tidal influence in the area to reduce saline levels to promote desirable conditions desirable for native species. See Objective 2 for additional adaptive management measures which could increase vegetative cover and increase overall success of the community.

Plant protection may also be required if monitoring indicates that failure is due to herbivory or trampling by wildlife or recreationists. Actions could include installing plant cages or protective fencing.

Desired Outcome 2: Invasive noxious, and/or exotic plant species comprise less than 4% of cover of the marsh restoration unit at year 2 and is maintained at or less than 4% thereafter.

Trigger: Non-native percent cover exceeds 10% after 3 years. Non-native percent cover exceeds 5% after 5 years.

Possible Causes for Not Meeting Desired Outcome: Invasive infestation may occur due to introduction of seed sources from outside the restoration unit and desirable growth conditions including lack of native vegetation.

Potential Adaptive Management Measures: Changes in invasive species management may be needed if triggers for invasive species percent cover are met. Monitoring results should be used to determine if existing invasive species control is ineffective or if the project area has been infested with a new invasive plant species. Adaptive management actions could include: modifying the herbicide and/or surfactant type, application method, or application rate; pursuing mechanical control; or introducing biological control agents, if available.

Project Objective 2: Increase sediment input to supplement natural transport processes to increase sustainability and resiliency to RSLC over the 50-year period of analysis.

Performance Measure: Establish marsh elevation post-construction sufficient for healthy marsh.

Desired Outcome: Based on local conditions and future rates of projected RSLC, marsh elevation in restored marsh restoration units (following de-watering and settlement) sufficient to support vegetation and marsh establishment is approximately +1.2 MSL at year 1 and +2.2 MSL following re-nourishment activities at year 30.

Trigger: The target elevation is not met *and* maintained by the target year and for a period of 6 years post-construction in any given area of the restoration unit.

Possible Causes for Not Meeting Desire Outcome: Some potential causes for not meeting and maintaining the target elevation include: loss of sediment through erosion or scour or higher than expected subsidence or RSLC rate.

Potential Adaptive Management Measures: Erosion control may be needed to control loss of sediment in specific areas during tidal exchanges or significant weather events. Adaptive management measures could include installation of straw wattles, erosion mats, or vegetative plantings to increase root mass and cover in areas showing the greatest sediment losses. Re-grading to support the geomorphic conditions of the marsh may be required if some areas showing excessive rates of sedimentation, erosion or scour. Additional monitoring or studies should be completed to identify the cause of soil loss/increase at the site and addressed as appropriate.

If overall elevations throughout the restoration unit are not being met, renourishment using dredged material may be required to obtain target elevation. If RSLC or subsidence are identified as the root cause, reevaluation of the target elevation should be conducted and a new target evaluation established to ensure resiliency and sustainability over the 50-year performance period.

Project Objective 3: Reduce shoreline erosion and stabilize GIWW shorelines to protect adjacent wetlands.

Performance Measure: Reduce post-construction shoreline erosion rates compared to pre-construction by 75% by year 5.

Desired Outcome: GIWW armoring measures are expected to reduce shoreline erosion rates by approximately 50% based on previous experiences with this type of structure throughout other areas along the GIWW shorelines in Jefferson County.

Trigger: The erosion rate has not been reduced by at least 50% when compared to the non-protected areas and the erosion rate is not in line with the erosion rate defined at sites which already have armoring.

Possible Causes for Not Meeting Desired Outcome: The most likely cause to not meeting the desired outcome is a deficiency in the breakwater structures. Structural deficiencies could include: the structure height or width is insufficient to attenuate wave energies due to higher wave energies (both natural and manmade), higher rate of subsidence at the placement site, or higher rate of RSLC than anticipated; loss of or insufficient size of rock; need for smaller/larger openings within and between structures; misalignment of the structure (i.e. too close/far from the shoreline); etc. If structural deficiency is not identified as the cause then other causes such as erosion coming from the marsh toward the GIWW should be investigated, although this is not anticipated.

Potential Adaptive Management Measures: A range of potential adaptive management measures may be needed from repairing the structure to increasing the height and/or width of the structure to a complete redesign of the structure which includes a new alignment.

Under this project, potential adaptive management actions will continue to be developed in consideration of the guidance provided in the USACE ETL 1100-2-1 titled "Procedures to Evaluate Sea Level Change Impacts, Response, and Adaption." The technical letter provides guidance for understanding the direct and indirect physical and ecological effects of projected future sea level change on USACE projects and considerations for adapting to those actions including consideration of a longer planning horizon and incorporating more robust management actions.

3.4 Project Close-Out

Once ecological success has been documented by the District Engineer in consultation with the Federal and State resource agencies, and a determination has been made by the Division Commander that ecological success has been achieved, no further monitoring or adaptive management will be required and the project can be closed-out. Ecological success will be documented through an evaluation of the predicted outcomes as measured against the actual results. Success would be considered to have been achieved when project objectives have been met or when it is clear they will be met based upon the trend of site conditions and processes.

The project could also be closed out when the maximum 10-year monitoring period has been reached. If that should occur prior to ecological success being achieved, the NFS would be responsible for monitoring and adaptive management beyond the 10 years.

3.5 Adaptive Management Costs

The MAMP establishes a feedback mechanism whereby monitored conditions will be used to adjust or refine construction or maintenance actions to better achieve project goals and objectives. Monitoring and adaptive management are not be used as a substitute for OMRRR. Per WRDA 1986, as amended by Section 210 of WRDA 1996, the NFS would be responsible for all OMRRR. This includes operations and maintenance (O&M) that provides day-to-day activities necessary to properly operate a component of a system and routine maintenance activities to keep the system operating as designed. This also include non-routine or beyond the scope of typical O&M activities of repair or fixing damage caused by an event; rehabilitation or fixing long-term wear and tear; and replacement of components when the useful life is exceeded.

In contrast, periodic monitoring of performance indicators which contain trigger values informs the iterative process of implementing specified adaptive management measures to help achieve ecological success. Gulf Coast marsh restoration and shoreline protection throughout Texas and Louisiana has proven to reach ecological success within 3 to 5 years post-construction. However, the project area is susceptible to several uncertainties that could significantly impact the ecological success of constructed restoration features as described in Section 3.0.

Costs for the adaptive management program were based on estimated level of effort and potential frequency of need, and include participation in the AMT and reporting. Only those actions which are most likely to be needed have associated costs. Measures included in the TSP have been successfully implemented with very similar designs within Jefferson County and throughout the coastal zone in Northern Texas and Western Louisiana; therefore, the desired outcomes are expected and reasonable based on experience. The likelihood that extreme measures, such as relocation of the breakwater structures, is very low. Other adaptive management measures that could help achieve ecological success may require significantly more modeling, design, and feasibility analysis than permits with adaptive management. These include construction or modification of tidal exchange barriers (e.g. levees, dunes, or breakwaters) and introduction of freshwater flows.

The current total estimate for implementing the adaptive management program is $1,731,750 (Table 3). This cost will vary slightly from the numbers presented in the main report, as those numbers will have a contingency cost attached that will be developed by the cost engineer.

Table 3. Estimated Adaptive Management Costs for the TSP.

Adaptive Management Measure	Assumptions	Cost
Renourishment of Marsh	• Assume 5% of each restoration unit would need thin-layer placement (assume 6” depth) of dredged material once in 6 years. (approximately 315 acres or 254,100 yd^3 of material) • Average incremental cost of placement for study is $\$5/\text{yard}^3$, with the assumption that the adaptive management would be completed on the O&M cycle using the same dredge sites as initial placement.	$1,270,500
Re-planting	• Assume that 5% of vegetation may require replanting in the 10 years. (approximately 315 acres) • $500/acre (most likely seed with a minimal plugs per acre)	$157,500
Invasive and Nuisance Plant Control	• Assume that up to 5% of acreage may require treatment beyond spot treatment or alternative control methods. (approximately 315 acres) • $250/acre	$78,750
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location in at least half of the restoration units (3 sites) at least once in 6 years • $10,00/site/year	$30,000
Re-grading	• Assume 3 sites would need to be regarded once in the 6 year period. • $25,000 for small fixes	$75,000
Total		**$1,611,750**
Adaptive Management Team and Reporting		
Team Meetings	Assume 1, 0.5-day meeting per year over 10 years @ $2,000/meeting	$20,000
Annual Report	Assume 10 reports @ $10,000	$100,000
Total		**$120,000**
Total Adaptive Management		**$1,731,750**