E C O L O G I C A L   R E V I E W

Grand Liard Marsh and Ridge Restoration
CWPPRA Priority Project List 18
State No. BA-68

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This document reflects the project design as of the 95% Design Review meeting, incorporates all comments and recommendations received following the meeting, and is current as of November 28, 2011.

ECOLOGICAL REVIEW
Grand Liard Marsh and Ridge Restoration (BA-68)

In August 2000, the Louisiana Department of Natural Resources (LDNR) initiated the Ecological Review to improve the likelihood of restoration project success. This is a process whereby each restoration project's biotic benefits, goals, and strategies are evaluated prior to granting construction authorization. This evaluation utilizes monitoring and engineering information, as well as applicable scientific literature, to assess whether or not, and to what degree, the proposed project features will cause the desired ecological response.

I. Introduction

The Grand Liard Marsh and Ridge Restoration (BA-68) project is located in the Barataria Basin along the western bank of the Mississippi River in Plaquemines Parish near Triumph, Louisiana, immediately adjacent to Bayou Grand Liard (Figure 1). The Grand Liard Ridge area has historically been brackish to saline habitat (Sasser et al. 2008). The BA-68 project area has experienced considerable wetland loss due to a variety of forces including subsidence, salt-water intrusion, a lack of sediment supply, and oil and gas activities (NMFS 2011). The area around Caprien Bay and Bayou Grand Liard was historically structured by a series of north-south bayous and associated ridges, such as Bayou Long and Dry Cypress Bayou (NMFS 2008). Dry Cypress Bayou and Bayou Grand Liard were subdeltas that were active prior to the 1800s (Wells and Coleman 1987). The majority of these bayou ridges and the marshes flanking them have disappeared (NMFS 2008). Ridge loss, combined with interior wetland loss, has resulted in large expanses of open water. The Bayou Grand Liard Ridge is the most prominent remaining ridge. The land loss rate was -1.7% per year between 1983 and 1990 and the future land loss rate is estimated to be -1.43% per year. Projections suggest that the remaining bayou bank wetlands will be completely converted to open water by 2050 (NMFS 2011).

The goals of the BA-68 project are to create and nourish 432 acres of marsh habitat and restore 16,600 linear feet (24 acres) of maritime ridge habitat along the eastern bank of Bayou Grand Liard using dredged sediment from an offshore borrow area and from Bayou Grand Liard (Fitzgerald 2011). This project will re-establish a portion of the Bayou Grand Liard bankline, partially restoring the function of the historic natural levee as a buffer for interior wetlands and infrastructure. These strategies are consistent with the *Coast 2050* plan, which recommends the dedicated dredging of sediment for wetland creation and the restoration of ridge function as Region 2 ecosystem strategies to restore and sustain wetlands (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1999). The project is also consistent with *Louisiana's Comprehensive Master Plan for a Sustainable Coast* (CPRA 2007), which includes goals for marsh restoration with dredged material and ridge habitat restoration in Barataria Basin.

II. Project Features

The Design Report (Fitzgerald 2011) and Draft Operations, Maintenance, and Monitoring Plan (Hymel and Richard 2011) should be referred to for a detailed description of the project; however, the project features are briefly described below.

<u>Offshore Borrow Areas</u>: Two borrow areas, Grand Liard East and Grand Liard West, were

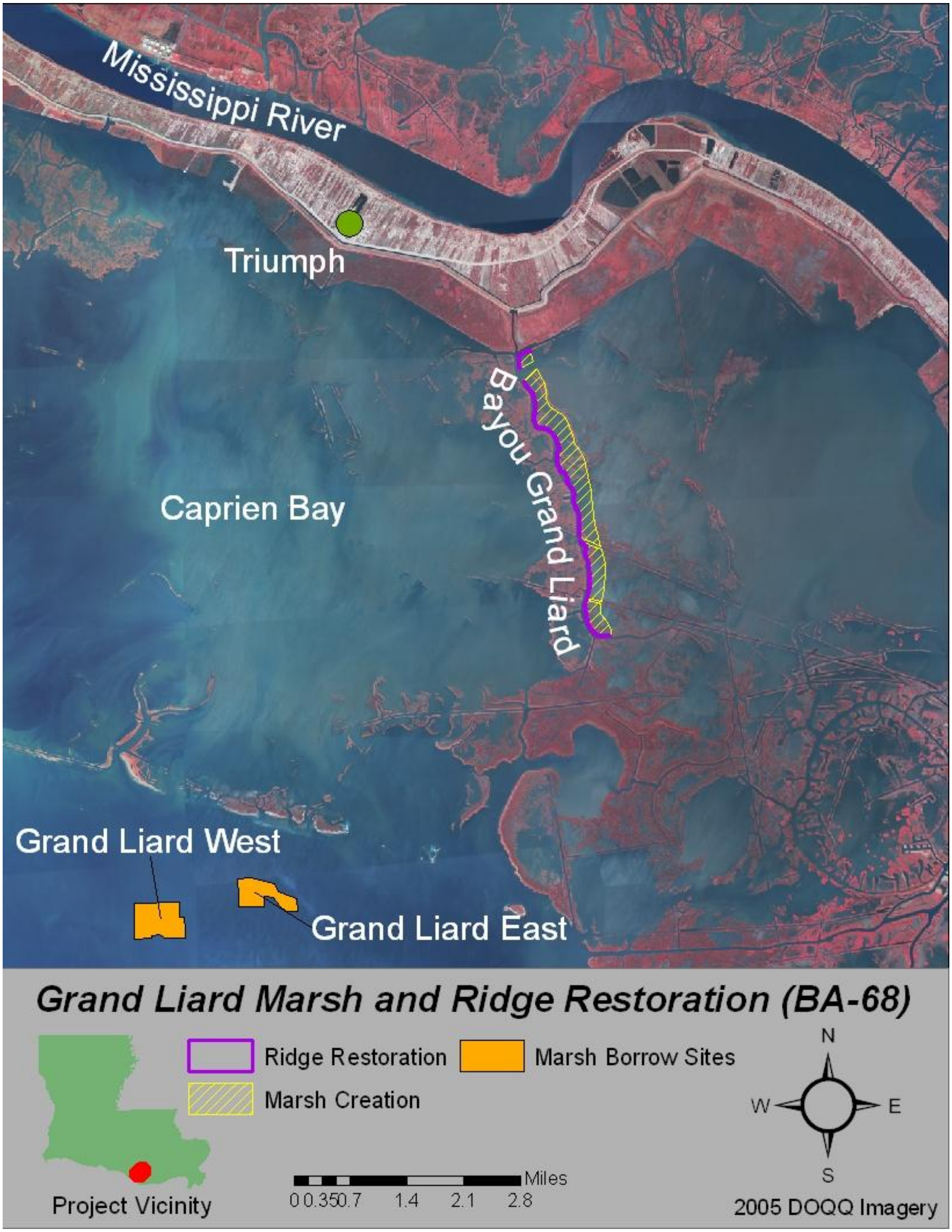

Figure 1. Grand Liard Marsh and Ridge Restoration (BA-68) project location and restoration features.

considered for this project. The proposed borrow areas contain 5.3 million and 4.7 million cubic yards of soft clay, respectively, and lie approximately 7 miles from the project area in the Gulf of Mexico (Figure 1). Grand Liard East has been selected as the preferred borrow area because it is closer to shore and to the project area. This project will require approximately 3.5 million cubic yards of borrow material for marsh creation. Therefore, the volume of material identified in the preferred borrow area exceeds the project's needs.

- Containment Dikes: Approximately 29,175 linear feet (28 acres) of earthen containment dikes will be constructed around the marsh creation sites. The dikes will have a crest elevation of +5.0 feet NAVD 88 and crown width of 5 feet, and will be constructed using dredged sediment from within the marsh fill areas and from the back bayou on the northeastern end of the project area. The dikes will be gapped at TY3; each of approximately 10 gaps will be 25 feet wide and will be cut to an elevation of -1.0 feet NAVD 88.
- Marsh Creation and Nourishment: Material from an offshore borrow area will be hydraulically dredged to create and nourish 432 acres of marsh, with a 20-year target elevation of +1.4 feet NAVD 88. Approximately 90% of the marsh restoration will be marsh creation in open water areas, and approximately 10% will consist of marsh nourishment. Deteriorated marsh in the project area will be nourished by placing about 2.3 feet (70 cm) of sediment over existing marsh. Because of high initial settlement, the marsh creation area will be constructed in two lifts in order to meet the target elevation. The construction elevation for lift 1 will be +3.5 NAVD 88 and will range from +2.8 to +3.5 feet NAVD 88 for lift 2. The marsh is expected to reach intertidal elevations by target years 3-4 and remain intertidal for the remainder of the 20 year project life.
- Ridge Borrow Area: Bayou Grand Liard will be dredged to -12.0 feet NAVD 88 for material to construct the ridge. Some material will also be borrowed from within the marsh creation cells. The proposed borrow areas predominantly consist of peat, organic clay, silty clay, and clay, with intermittent layers of silt, sandy silt, silty sand, and sand. Approximately 236,342 cubic yards of material will be required for ridge restoration.
- Ridge Restoration: 16,600 linear feet (24 acres) of ridge will be constructed using material from Bayou Grand Liard and from within the marsh fill areas. The ridge will have a base width of 90 feet, a crown width of 20 feet, and a construction target elevation of +5.0 feet NAVD 88. The TY20 ridge elevation will be approximately +3.0 feet NAVD 88. The target elevation was determined by calculating what construction elevation would allow the ridge to still be above marsh elevation and function as a ridge at TY20.
- Ridge Closure Structures: There are 8 cuts in the proposed ridge and containment dike alignments that were either man-made or were formed hydraulically by tidal exchange. These cuts vary from 6.5 to 21 feet deep and from 60 to 225 feet wide. Due to water depths and flows, these gaps must be closed to construct the marsh fill platform. If they were left open, then the slurry material would flow out of the project area and into the adjacent bayous. The cuts will be closed with a combination of sheet pile and earthen closure structures and will be encased in the restored ridge or containment dike. These structures will be covered with sand or in-situ material following construction and at TY5 if maintenance is necessary.
- Vegetation Plantings: Vegetative plantings will occur at TY1 and TY3. Year 1 plantings will include smooth cordgrass (*Spartina alterniflora*), marshhay cordgrass (*Spartina patens*), crowngrass (*Paspalum* sp.), matrimony vine (*Lycium barbarum*), switchgrass (*Panicum virgatum*), marsh elder (*Iva frutescens*), and groundselbush (*Baccharis halimifolia*). Year 3

plantings will include additional plantings of smooth cordgrass and marsh elder, in addition to woody seedlings and saplings on the ridge, such as wax myrtle (*Morella cerifera*), hackberry (*Celtis* sp.), red mulberry (*Morus rubra*), yaupon (*Ilex vomitoria*), and persimmon (*Diospyros virginiana*). Control for Chinese tallow (*Triadica sebifera*) will be conducted at TY1, TY3, TY5, and TY10.

III. Assessment of Goal Attainability

When addressing the likelihood that the proposed project features will provide the desired ecological response, it is important to evaluate the lessons learned from scientific research and past projects that are similar in scope to the Grand Liard Marsh and Ridge Restoration (BA-68) project.

<u>Marsh Creation</u>

Marsh creation through the use of dredged material has been practiced in the United States for decades (Streever 2000). There have been a number of successful marsh creation projects constructed in Louisiana under such programs as CWPPRA, the United States Army Corps of Engineers (USACE) dredged material beneficial use program (USACE 1995), and the LDNR Dedicated Dredging program (LDNR 2000). Design parameters of some of these projects are summarized in Appendix A.

Achieving proper elevation is critical to the success of marsh creation projects. The elevation of the marsh surface controls the frequency and duration of flooding, which in turn affects vegetation zonation and productivity (Broome et al. 1988). Marsh platforms built too high may become dominated by upland vegetation, whereas platforms built too low may be excessively-inundated and unsuitable for vegetation establishment. For example, the Barataria Bay Waterway Wetland Restoration (BA-19) project, completed in 1996, was intended to create 9 acres of vegetated wetlands on Queen Bess Island using sediment from maintenance dredging of the Barataria Bay Waterway. The elevation of the marsh was projected to be +1.22 feet NGVD 29 after settlement and consolidation; however, two years after construction the elevation was only +0.79 feet NGVD 29 (Curole 2001). Because of the low elevation, the project area is constantly flooded and no appreciable vegetation growth has occurred (Curole 2001).

Based on the local tidal regime for the Grand Liard project area (Mean High Water of +1.35 feet NAVD 88 and Mean Low Water of +0.30 feet NAVD 88), surveys of the native average marsh elevation (approximately +1.2 feet NAVD 88), and estimations of expected settlement of the fill material, it was determined that a construction fill elevation of +3.5 to +2.8 feet NAVD 88 (constructed in two lifts) would yield desirable marsh elevation for most of the project life (Sigma 2010). Filling to this elevation range, and including an estimated relative sea level rise rate of +0.041 feet/year (0.492 inches per year), the created marsh platform would settle to an intertidal elevation by target year 3-4, would remain intertidal for the rest of the 20-year project life, and would have an elevation of approximately +1.4 NAVD 88 by the end of the project life. At this elevation, the platform would be inundated approximately 55% of the time, based on approximately 3 years of hourly water level data from the CRMS0163-H01gage, located about 4 miles south of the project area (29°13’ 0.224’’N, 89°25’15.822”W) (Figure 2). This level of inundation should be suitable for the locally-dominant *Spartina alterniflora*, which is tolerant of regular inundation.

It is important to quickly establish vegetation on created marsh platforms to stabilize the sediment and prevent its loss from erosive processes. Dense vegetation may also promote accretion (Streever 2000). The rate at which marsh vegetation naturally colonizes bare sediment is dependent on substrate characteristics and the availability of recruits (Broome et al. 1988). For example, the Sabine Refuge Marsh Creation (CS-28) CWPPRA project is part of an overall effort to create approximately 1,120 acres (in a total of 5 cycles) of emergent marsh using sediment from maintenance dredging of the Calcasieu Ship Channel. The goal of the first cycle, completed in 2002, was to create approximately 125 acres; however, approximately 200 acres were actually created (Sharp and Juneau 2007). The marsh was designed to have an elevation of +3.08 feet NAVD 88 at construction and +1.08 feet NAVD 88 after 5 years (Sharp and Juneau 2005). Cycle 1 included vegetative plantings around the perimeter of the marsh creation platform. Vegetation surveys found that the created marsh was densely covered by emergent vegetation within two years (Sharp and Juneau 2007). In 2005, Hurricane Rita negatively impacted vegetation cover, species richness, and plant height in the project area, but vegetation generally recovered by 2006 (Sharp and Juneau 2007). Cycle 2 was constructed in 2010 and Cycle 3 was completed in 2007 (Sharp and Juneau 2007). Plantings will not be utilized in subsequent cycles, as most of the Cycle 1 area re-vegetated naturally (Sharp and Juneau 2007). Although most of the CS-28 project has vegetated naturally, vegetative plantings may be warranted for other projects.

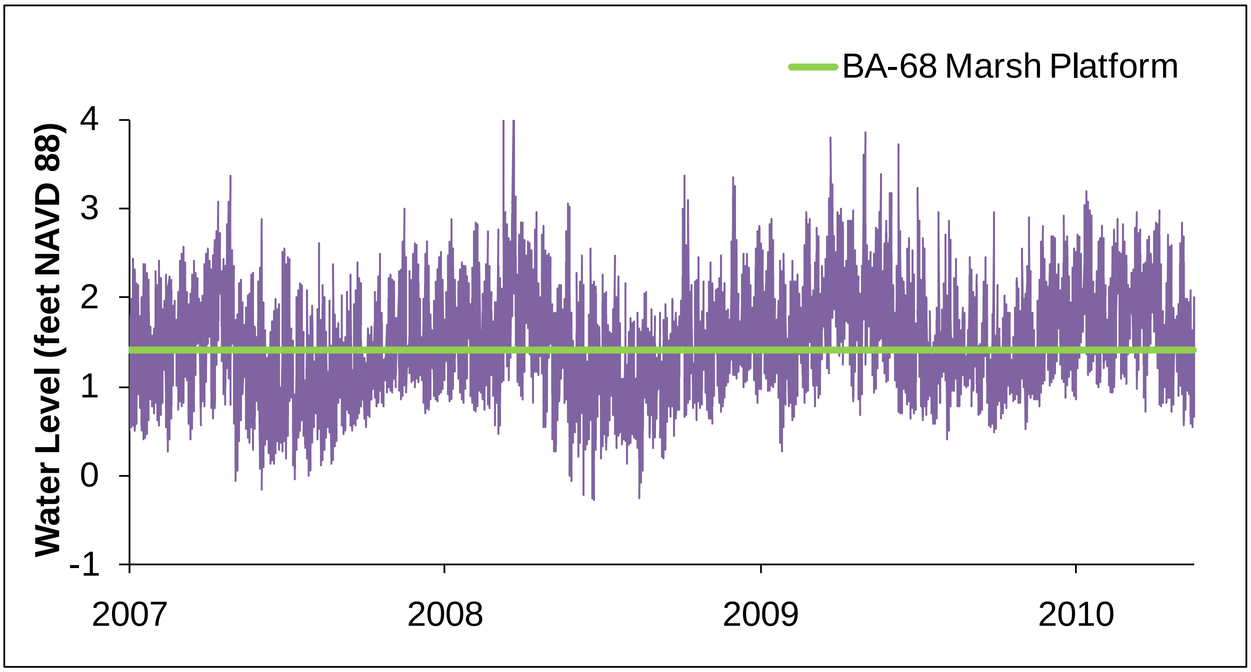

Figure 2. Water level at the CRMS0163 gage for the years 2007 to 2010 (from OCPR data).

The borrow material for marsh creation that will be used in the BA-68 project is predominantly soft clay. This fine textured material is likely to have adequate nutrient concentrations necessary for rapid plant establishment (Broome et al. 1988). However, plantings may be necessary to accelerate vegetation establishment and development, particularly along the edges of the marsh platform which are more susceptible to erosion. Furthermore, because there is broken marsh in the BA-68 project area and existing vegetation will initially be smothered by nourishment; there may be a limited supply of propagules (i.e., seeds or plant fragments) available to colonize the newly created marsh platform. Under these circumstances, plantings can greatly accelerate vegetative establishment and development (Broome et al. 1988). It has been proposed to initially plant half of the created marsh after construction of both lifts and a period of dewatering and consolidation. Once established, these plantings should provide a source of propagules for the remainder of the marsh platform, so that vegetative colonization can occur on a more natural progression. However, if development is inadequate, additional plantings may be warranted.

Vegetation and soil development in created marshes have been found to be related, in part, to tidal inundation (Craft et al. 2002). The proper development and long-term sustainability of the created marsh is dependent on maintaining natural hydrologic exchange between the marsh and adjacent water bodies. Containment dikes interrupt this exchange, resulting in prolonged flooding and drying events, reduced sediment and nutrient inputs, and ultimately marsh degradation and loss (Boumans and Day 1994, Bryant and Chabreck 1998, Kuhn et al. 1999, Swenson and Turner 1987, Turner 1987). The barriers would also block the influx of plant propagules for colonization of the newly created marsh. To prevent impoundment of the marsh platform, the containment dikes will be mechanically gapped following a period of dewatering and consolidation after construction. Gapping the containment dikes and differential settlement of the dredged material in the marsh creation area is expected to help establish tidal connectivity without the need for constructing tidal creeks or ponds.

Marsh Nourishment

In addition to the LDNR Dedicated Dredging Program (LDNR 2000), a marsh nourishment component has been included in a few CWPPRA-funded marsh creation projects that have been constructed in coastal Louisiana. These projects provide an opportunity to further evaluate the success and potential of the marsh nourishment technique. Design parameters of previously constructed marsh nourishment projects are summarized in Appendix A.

Marsh nourishment is a relatively new restoration strategy that can refer to either the direct placement of a thin-layer of sediment through spray or hydraulic dredging or from the "spilling" of a thin-layer of sediment over marsh that is adjacent to an uncontained restoration project (LaPeyre et al. 2006). The concept behind marsh nourishment is that the addition of sediment would increase plant growth by improving the conditions within the growing environment by adding a mineral and nutrient source, increasing oxygen levels through soil aeration, and reducing the frequency and duration of flooding via an increase in elevation (Mendelssohn and Kuhn 1999, 2003, Stagg and Mendelssohn 2010). Interest in marsh nourishment as a coastal restoration technique began with studies evaluating the environmental effects of thin layer disposal of dredged material in marshes as an alternative to bucket dredging and its associated negative impacts from spoil bank creation, such as the impoundment of wetlands and the creation of upland habitat (Cahoon and Cowan 1988, Ford et al. 1999, Reimold et al. 1978, Wilber 1992, Wilber 1993). Because these studies concluded that dredged material disposed in thin layers did not permanently negatively impact existing healthy marshes, thin-layer sediment deposition has been proposed as a method for restoring soil elevations in deteriorated marshes to counteract sea-level rise, subsidence, and weather related disturbances (Cahoon and Cowan 1988, Ford et al. 1999, Kuhn and Mendelssohn 1999, Leonard et al. 2002, Mendelssohn and Kuhn 2003, Schrift 2006, Slocum et al. 2005, Stagg and Mendelssohn 2010, Wilber 1992, Wilber 1993, Wilsey et al. 1992).

Cahoon and Cowan (1988) concluded that although dredged material may have provided nourishment to recolonizing vegetation and adjoining marsh, it did not provide any benefits to the existing marsh because most of the vegetation was killed immediately following disposal of the material, and complete re-vegetation did not occur for at least 3 years in areas that received the most sediment (sediment deposition ranged between 10 and 38 cm). Other studies have also shown that marsh nourishment requires an initial recovery period; however, these studies found that the deposition of a thin-layer of sediment in deteriorated marshes resulted in an increase of plant biomass, percent cover, and primary productivity (DeLaune et al. 1990, Ford et al. 1999, Kuhn and Mendelssohn 1999, Leonard et al. 2002, Mendelssohn and Kuhn 2003, Slocum et al. 2005, Stagg and Mendellsohn 2010, Wilsey et al. 1992). Wilber (1993) concluded that the duration of the initial recovery period varies according to the thickness of sediment placement and the extent of soil modification. If a thinner layer of sediment is deposited, vegetation can recover more quickly via the production of new shoots from surviving roots and rhizomes; however, a thicker layer of sediment must be recolonized by seeds from adjacent marshes and will require a much longer recovery period (Wilber 1993).

In a study conducted in dieback areas of salt marsh near Caminada Bay, Louisiana, *Spartina alterniflora* transplanted into elevated plots had more than twice the aboveground and belowground biomass than plants transplanted into non-elevated plots after three months of growth (Wilsey et al. 1992). Ford et al. (1999) found that increased elevation through the deposition of a 2 cm layer of dredged material in a deteriorated Louisiana marsh increased percent cover of *Spartina alterniflora* three-fold within one year. Kuhn and Mendelssohn (1999) conducted a study in a deteriorated *Spartina alterniflora* marsh near Venice, Louisiana in which they evaluated the effect of varying thicknesses of sediment addition from minimal to more than 30 cm. Plant biomass was 30-50% greater in the areas that received greater than 15 cm of sediment, and percent cover increased by 50% in the areas nourished with greater than 30 cm of sediment, compared to the reference areas (Kuhn and Mendelssohn 1999). A study conducted in North Carolina evaluated the effect of the addition of 0 to 10 cm of sediment to deteriorated and non-deteriorated *Spartina alterniflora* marshes (Leonard et al. 2002). This study concluded that the healthy marshes did not benefit from the soil addition, but a two-fold increase in vascular plant stem density was observed when 2-10 cm of dredged material was added to the surface of the deteriorated marsh (Leonard et al. 2002). This study was unable to determine the optimal thickness of sediment (addition of 10 centimeters was the maximum application) that could be added to deteriorated marsh to provide benefits to the marsh without causing detrimental effects (Leonard et al. 2002).

Croft et al. (2006) suggests that up to 10 cm of sediment can be added without causing adverse effects to non-deteriorated marsh. Reimold et al. (1978) found that *Spartina alterniflora* stems can penetrate a layer of sediment up to 23 cm deep, but plants covered with greater than 60 cm of sediment did not recover. Mendelssohn and Kuhn (2003) investigated the effects of differing thicknesses of sediment addition resulting from the accidental overflow of hydraulically dredged material being used to fill a gas pipeline canal adjacent to the marsh. The study was divided into five sites based on the amount of sediment that each area received: 1) no sediment addition, 2) trace amounts of sediment that were not quantifiable, 3) sediment addition not greater than 15 cm, 4) sediment addition between 15 and 30 cm, and 5) sediment addition between 30 and 60 cm (Mendelssohn and Kuhn 2003). Areas receiving greater than 15 cm of sediment (4 and 5 above) showed increased plant production after two years (Mendelssohn and Kuhn 2003). Mendelssohn and Kuhn (2003) concluded that the addition of an intermediate to high amount of sediment (between 15 and 60 cm) to deteriorated marshes can improve plant height and biomass after an initial recovery period by increasing soil aeration, mineral content, and available nutrients, and that marsh nourishment could play a positive role in marshes where rates of sea level rise are greater than the rates of vertical accretion.

Because most studies so far have been conducted immediately after sediment addition, it is possible that the observed increase in plant productivity may be a short-term result that decreases with time (LaPeyre et al. 2006). In order to examine whether the positive effects of marsh nourishment endured over the long-term in the same marsh examined by Mendelssohn and Kuhn (2003), Slocum et al. (2005) examined plant growth over a 7 year period. They found that percent cover had initially been greater than 90% soon after sediment deposition, but that this nutrient-enriched growth-spurt faded after about 3 years. However, they also found that the positive effects of increased elevation were longer lasting and that even after 7 years, sediment enriched areas had 55% cover compared to only 20% cover in areas that did not receive sediment (Slocum et al. 2005).

Marsh nourishment is a relatively new restoration strategy that provides an opportunity for further research. Although most marsh nourishment studies conducted so far have shown that the goal of increasing plant productivity in deteriorated marsh can be achieved with the deposition of 5 to 15 cm of sediment (LaPeyre et al. 2006), Mendelssohn and Kuhn (2003) found that sediment additions greater than 30 cm also positively affected plant biomass. Stagg and Mendelssohn (2010) showed that an intermediate amount (12 to 20 cm above ambient marsh) of sediment addition to a deteriorated marsh increased primary productivity, and that primary productivity was limited by insufficient flooding and low nutrient availability when more than 20 cm of sediment was added. LaPeyre et al. (2006) suggests that the proper thickness can be easily determined by calculating how much sediment needs to be added to return the deteriorated marsh back to the elevation of nearby healthy marsh.

Existing vegetation nourished with less than 10 cm of sediment could likely recover within 1 to 3 years after construction via the production of new shoots from surviving roots and rhizomes (Wilber 1993). The BA-68 project will place approximately 70 centimeters of dredged material over existing marsh areas for nourishment. The amount of dredged material that will be placed over existing marsh is higher than the range of dredged material placement found in the literature. Although it has been estimated that vegetation will only need to be planted on half of the created marsh, existing marsh areas receiving greater than 10 cm of sediment nourishment would need to be recolonized by seeds from adjacent marshes and would thus require a much longer recovery period (Wilber 1993). Additional plantings may be warranted on any portion of the nourished marsh that does not revegetate naturally in order to accelerate colonization of the entire project area.

Ridge Restoration

The only ridge restoration project in coastal Louisiana that has been constructed to date is the Fourchon Maritime Forest Ridge Restoration Project, partially constructed through grants by the Lafourche Parish Government and Barataria-Terrebonne National Estuary Program (BTNEP) and through funds from the Louisiana Coastal Impact Assistance Program (CIAP). This restored ridge is part of the Caminada-Moreau maritime beach ridge complex, an abandoned distributary system of the Mississippi River (Harper 1977). The restored ridge is approximately 6,000 feet long and +8.0 feet in elevation (BTNEP 2006). Vegetation was planted with this project, but the plantings were decimated by the 2005 hurricanes (BTNEP 2006). Additional plantings are planned for the project, and the project is scheduled to be completed by 2012 (Michael Somme, CSRS Inc., personal communication, April 2010). The only other designed ridge restoration project is the Bayou Dupont Ridge Creation and Marsh Restoration (BA-48) project, which will include 184 acres of marsh creation, 118 acres of marsh nourishment, and 15 acres of ridge restoration in Jefferson Parish.

There are many types of ridges in Louisiana, both natural and man-made, including spoil banks, levees, cheniers, and natural ridges. All of these features are linear and elevated above the coastal wetlands (Gosselink et al. 1988). Very little is known about ridge restoration; however, spoil banks may be similar to restored ridges because they both involve the placement of material, placed soils may be saline and not true ridge deposits, and they are vegetated by many of the same terrestrial species (Monte 1978). A spoil bank is an artificial ridge created when canals are dredged and the resulting sediment is placed on either side of the canal (Monte 1978). The practice of dredging canals and constructing spoil banks began in the mid 1930s in order to float oil rigs into wetlands via barge (Monte 1978). A levee is an embankment, either man-made or natural, with the function of preventing flooding (Providence 2009). Cheniers are natural beach ridges in southwest Louisiana composed of sand-sized material resting on clay or mud, separated from the mainland by strips of marsh, that were formed by river sediments carried westward by shoreline currents in the Gulf of Mexico (Otvos 2000, Providence 2009). The ridges of southeast Louisiana are natural, elevated features that were created by repeated overbank flood sedimentation along bayous or currently inactive major and minor distributaries of the Mississippi River (CPRA 2007, Gagliano and Wicker 1988, Gosselink et al. 1988, Providence 2009, Wall and Darwin 1999). Natural ridges are considered essential to the formation and protection of floating marshes because the peat and soft, organic soils that support floating marshes are held in place by the ridges (Gagliano and Wicker 1988). Cheniers and ridges are unique and critical features of the ecology of these areas that provide natural protection as one of the multiple lines of defense against storm surge and flooding (CPRA 2007, Lopez 2006). They support a diversity of wildlife and provide habitat, cover, and food sources not available in adjacent marshes (CPRA 2007, Providence 2009). They are especially important for neotropical migrating birds (Providence 2009). Both cheniers and natural ridges support live oak (*Quercus virginiana*) and hackberry as the dominant canopy species (Providence 2009). Other common species include the pecan (*Carya illinoisnensis*), black willow (*Salix nigra*), bald cypress (*Taxodium distichum*), yaupon, red maple, water oak (*Quercus nigra*), American elm (*Ulmus americana*), and the invasive Chinese tallow tree and Chinese privet (*Ligustrum sinense*) (Gosselink et al. 1988, Monte 1978). The Chinese tallow tree has become a serious invasive of chenier and natural ridge forests that has been shown to significantly reduce species diversity of these habitats by out-competing native plants (Providence 2009, Wall and Darwin 1999).

Although ridges and cheniers support similar habitat, the ridges of southeastern Louisiana are shorter, narrower, and lower in elevation than the cheniers of southwestern Louisiana (Didier 2007). Cheniers often reach elevations of 3 m or greater (Didier 2007). Didier (2007) recommended that ridges be restored to an elevation of at least 1.6 m (5.2 feet) NAVD 88, taking into account local relative sea-level rise, in order to be at an elevation that will support tree species. Elevation, specifically the hydroperiod dictated by a higher elevation, is the most important factor influencing species composition and diversity. At higher elevations, soils are less inundated, better drained, and more aerated, thus providing suitable conditions for the development of a bottomland hardwood forest community that is distinct from adjacent marsh.

Didier (2007) investigated soil and vegetation characteristics along elevation gradients on the Caminada-Moreau maritime beach ridges. Elevation was negatively correlated with moisture content, soil salinity, soil organic content, total nitrogen, total phosphorous, and total carbon within the top one foot of the soil; whereas elevation was positively correlated with bulk density and pH. These results reflect the greater hydroperiod at the lower elevations, where due to the relative lack of oxygen in flooded soils, organic matter accumulates rather than decomposes. Vegetation communities were also correlated with elevation on the ridges, i.e. herbaceous marsh species dominated the lower, more frequently inundated elevations; whereas shrubs and trees (e.g., marsh elder, yaupon, and live oak) were primarily found at higher elevations (Didier 2007).

The BA-68 ridge will be relatively low in elevation and thus more exposed to the local hydroperiod. Consequently, the capacity of the ridge to support tree development will be largely dependent on local salinities. The Grand Liard Ridge area has historically been brackish to saline habitat (Sasser et al. 2008). Seedlings of hackberry have the ability to survive temporary exposure to salinities greater than 5 ppt provided the soils are subsequently flushed with freshwater; however, they are unlikely to survive frequent, repeated exposure to such conditions (Williams et al. 1998, Williams et al. 1999). Based on recent hydrologic conditions, soils in the upper one foot of the BA-68 ridge, which approximates the root zone, would be frequently inundated with tidal water for much of the project life (Figure 3). The frequency of inundation may cause occasional waterlogging stress, and the salinities could be detrimental to seedling survival and growth, especially during periods such as 2007-2008 when salinities were 10-15 ppt much of the year. According to NMFS (2011), the CRMS0163 gage may not be representative of the salinity conditions in the project area because the gage is located in an intermediate marsh and the project area is located in a saline marsh; it is likely the average annual salinity actually ranges from approximately 13 to 21 ppt, as measured at Bay Batiste and Barataria Pass. If constructing the ridge at a higher initial elevation is not possible due to budget constraints and borrow material limitations, consideration should be given to planting non-tree species, such as marsh elder and groundselbush.

The marsh soils that will comprise the Grand Liard Ridge are predominantly fine-grained and organic, and therefore, should have sufficient nutrients and moisture retention to facilitate plant establishment and development (Broome et al. 1988). However, since the borrow material for the ridge restoration may have high salinities, excess salts will need to leach from the dredged soils prior to the planting of trees and other non-halophyte species. Also, oxidation of the organics may initially lower soil pH to detrimental levels; however, the pH should stabilize and rebound within one to two years post-construction (Monte 1978). After soil conditions moderate, herbaceous species and then wetland shrubs should colonize the BA-68 ridge. Vegetative plantings would help expedite natural succession, as well as help protect the ridge from erosion during the first few years after construction. It has been proposed to plant the ridge in phases. The first phase of planting will include herbaceous species, to occur very soon post-construction in order to protect the newly constructed ridge from erosion and to allow for the development of soil conditions that will better support woody plants. When soil salinities and constructed ridge elevations allow, a couple years after the first phase, the second planting phase will include woody species.

Project Monitoring and Adaptive Management

Since this is one of the first ridge restoration projects planned for Louisiana, a thorough monitoring plan will be implemented in order to determine the level of success and to inform future ridge restoration projects. Monitoring will include topographic surveys at TY1, TY3, and TY10 to evaluate settlement of the marsh and ridge; aerial photography at TY1, TY5, TY10, and TY15 to calculate land/water ratios; and species composition, percent cover, and relative abundance of vegetation at TY5 and TY10. Dissolved oxygen in the borrow areas will also be monitored hourly for two month periods at TY1 and TY3 in order to determine if there were any impacts of sediment removal from the borrow areas on dissolved oxygen levels. Monitoring data will be analyzed at TY5 and TY10; should the data indicate that the project is not meeting goals and objectives, adaptive management recommendations will be made to improve the project (Hymel and Richard 2011).

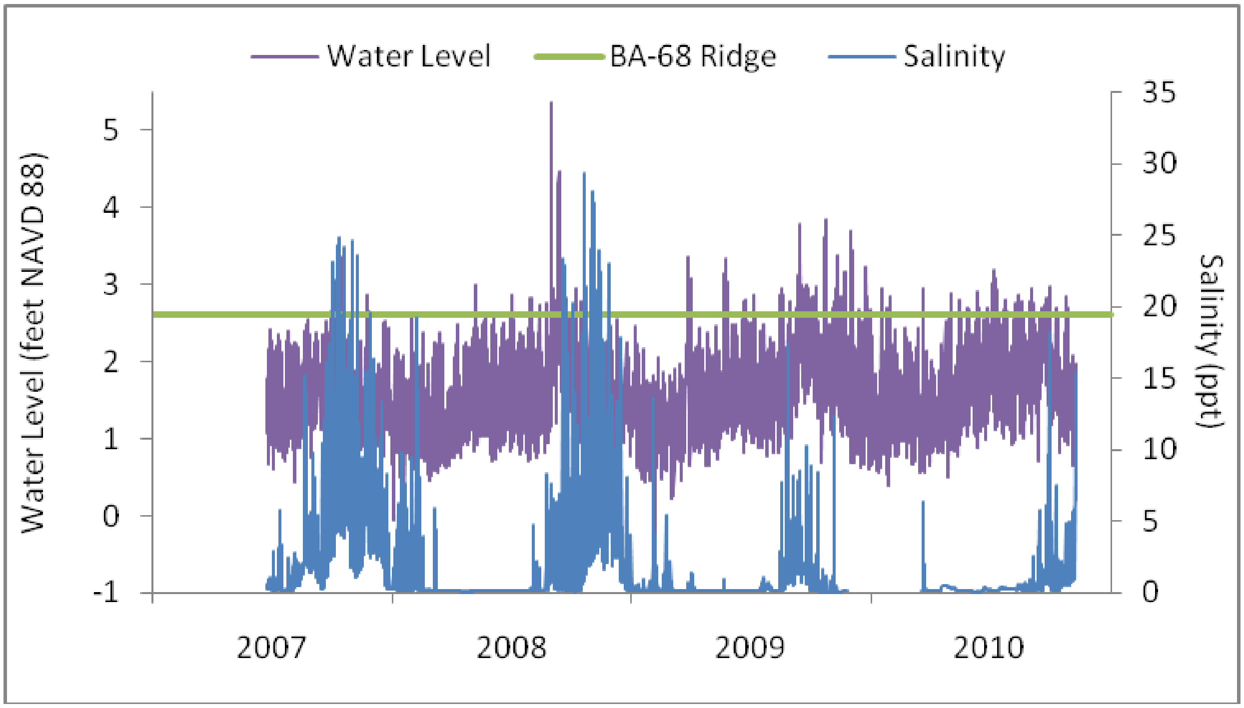

Figure 3. Water level and salinity data from the nearby CRMS0163 gage for the years 2007 to 2010. The green line depicts the project's crest elevation of the BA-68 ridge (approximately +2.6 feet NAVD 88 at the end of the 20-year project life).

IV. 95% Design Review Recommendations

Based on the evaluation of available ecological, geological, and engineering information, and a review of scientific literature and similar restoration projects, the proposed strategies of the Grand Liard Marsh and Ridge Restoration (BA-68) project will likely achieve the desired ecological goals. Appendix B of this document contains the responses to issues that were identified in the 30% Ecological Review. At this time, it is recommended that this project progress towards the Phase II construction funding request pending a favorable 95% Design Review. However, I recommend the following:

- In order to avoid detrimental impacts to existing marsh, do not exceed 60 cm (2 ft) of sediment addition in the marsh nourishment area.
- Because the Grand Liard Ridge is located in a brackish to saline environment, consideration should be given to constructing the ridge to an initial elevation of +5.5 to +8.0 ft NAVD 88 in order to be at an elevation that will support bottomland forest species, which are sensitive to high soil salinities and waterlogging stress. If constructing the ridge at a higher initial elevation is not possible due to budget constraints and borrow material limitations, consideration should be given to planting only non-tree species.
- Ridge soil conditions should be monitored following construction to ensure that soil salinities and pH are suitable before planting trees species.

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APPENDIX A

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Calcasieu River & Pass Phase I - Phase III (WRDA)		4	Phase I 1992 Phase II 1996 Phase III 1999		4.0 million					Dredged material from the Calcasieu Ship Channel was deposited within the Sabine National Wildlife Refuge.	
Queen Bess (State)	BA-05b	2	1993		152,000			8	+3.22 NGVD 29	Dredged material was added to the island, and a rock dike was installed to armor the shoreline in order to restore the island as a brown pelican rookery.	Pelican nests continue to increase and area has become vegetated. The size of the island was nearly doubled from 17 acres (1989) to 32.3 acres (1996).
Bayou LaBranche Wetland Creation (CWPPRA)	PO-17	1	1994	487	2.7 million			305	+2.44 ± 0.19 NAVD 88	Dredged sediment from Lake Pontchartrain was used to create vegetated wetlands in an open water area bounded by I-10, Lake Pontchartrain, and Bayou LaBranche.	The average salinity (5.3 ppt) was statistically higher than the reference area (4.6 ppt) due to less tidal flushing because of the semi-impoundment of the project area. As of January 1999, sediment elevation was within the target range (+0.65 to 1.62 ft NAVD 88) in most of project area. 300 acres of open water were converted to land in 3 years, although only 51% of the project area was classified as marsh in 1997.
Wine Island (FEMA)	DSR-81558	3	1995							The island was repaired to pre-Hurricane Andrew condition with the beneficial use of dredged material from Houma Navigational Canal maintenance, and vegetation was planted to stabilize the sediment.	
Barataria Bay Waterway Wetland Delivery (CWPPRA)	BA-19	2	1996	510				9	+3.72 NGVD 29	The goal of this project was to create wetlands by constructing a 1,650 feet shell dike and filling the containment area with dredged material from the Barataria Bay Waterway (BBWW).	Vegetation has not colonized this project area because of low elevation and persistent inundation with water.
Timbalier Island Repair (FEMA)	DSR-81559	3	1996							A major breach created by Hurricane Andrew was closed, a 300-ft.-wide elevated marsh platform was constructed, and vegetation was planted to stabilize the sand.	

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
East Island Repair Protection (FEMA)	DSR-81560	3	1996							An elevated marsh platform was constructed in an area destroyed by Hurricane Andrew, and vegetation was planted to stabilize the sand.	
Barataria Bay Waterway, Grand Terre Island (Phase I - Phase II) (WRDA)		2	1996 1999		500,000					Dredged material from the Barataria Bay Waterway (BBWW) was placed beneficially to create wetlands on Grand Terre Island.	
Atchafalaya Sediment Delivery (CWPPRA)	AT-02	3	1998	4,248	720,000			280		Dredged material from Natal Channel was placed at elevations mimicking natural delta lobes. By re-establishing water and sediment flow into the eastern part of the Atchafalaya Delta, an additional 1,200 acres of new marsh habitat are expected to be naturally created over the life of the project.	This project created more scrub-shrub habitat than emergent marsh because the sediment was stacked too high during construction. One year post-construction, only 78.4 acres were created.
Big Island Sediment Mining (CWPPRA)	AT-03	3	1998	3,400	3.4 million			922	+1.5 to 3.0 NGVD 29	A new western delta lobe was created behind Big Island to enhance the accretion of land beyond the west bank of the Atchafalaya River. A main stem and five branch channels designed to mimic natural channel bifurcations were dredged, and material was placed at elevations mimicking natural delta lobes. Re-established water and sediment flows are expected to add an additional 2,000 acres over the project life.	The channels are maintaining adequate depth and still delivering sediment into the delta. However, this project created substantially more scrub-shrub and beach/bar/flat habitats than emergent marsh.
West Belle Pass Headland Restoration (CWPPRA)									+2.0	Dedicated dredging was used to create marsh on the west side of Belle Pass. A water control structure and 17,000 linear feet of riprap were also used to reduce the encroachment of Timbalier Bay into the marshes on the west side of Bayou Lafourche.	Only a 5.4% increase in saline marsh area was attained as a direct result of construction failures. Only 1.2 million cubic yards was dredged, creating just 31.2 acres. Target elevations were not met. Also, 9.5 acres of vegetated wetlands were damaged by marsh buggies, and disposal of flotation channel refuse buried 8 acres of existing wetland vegetation. In contrast to the marsh creation phase, the shoreline protection phase was successful in reducing the shoreline erosion rate.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
	TE-23	3	1998	2,459	2.7 million			184	NAVD 88		
Isle Dernieres Restoration, East Island (CWPPRA)	TE-20	3	1999	449	3.9 million					Sand dredged from adjacent waters was used to build dunes and an elevated marsh platform. Sand fences were installed and vegetation was planted to stabilize sand and minimize wind-driven transport. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 187.3 acres in size from 1996 to 2002. Fences have accumulated sand to create dunes. Vegetation survival was high (70%) after one growing season. Non-planted and non-seeded vegetation increased from <1% (2001) to >23% (2003). There has been an increase in species richness and vegetative cover each year.
Isle Dernieres Restoration Trinity Island (CWPPRA)	TE-24	3	1999	776	4.85 million					Sand dredged from adjacent waters was used to build dunes and an elevated marsh platform. Sand fences were installed and vegetation was planted to stabilize sand and minimize wind-driven transport. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 92.64 acres in size from 1996 to 2002. Fences have accumulated sand to create dunes. Vegetation survival was high (>80%) after one growing season. Vegetative cover decreased from 34.4% (2001) to 7.8% (2003) in dune plots. There has been an increase in overall species richness and bay plot vegetative cover each year.
Lake Chapeau Sediment Input and Hydrologic Restoration, Point au Fer Island (CWPPRA)	TE-26	3	1999	13,024	850,000			160		The objectives of the project are to restore the marshes west of Lake Chapeau, to re-establish the hydrologic separation of the Locust Bayou and Alligator Bayou watersheds, and to re-establish the natural drainage patterns within the Lake Chapeau area. The hydrologic separation of the watersheds was established using dredged material from Atchafalaya Bay and the restoration of island hydrology by plugging oil field access canals and gapping artificial spoil banks.	Plants are vigorously growing and spreading.
Dedicated Dredging Program–Lake Salvador (State)	LA-01a	2	1999		114,089	YES		26		Two sites adjacent to Baie du Cabanage in the Salvador Wildlife Management Area were filled utilizing dredged material to nourish and rebuild marshes.	The southern edge of the fill areas that were nourished with dredged slurry is dominated by willow trees, indicating that the elevation is too high for marsh vegetation. The northern areas that were previously open water are dominated by freshwater marsh.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Barataria Bay Waterway, Mile 31 to 24.5 (WRDA)		2	1999							Dredged material from miles 31 to 24.5 of the Barataria Bay Waterway (BBWW) was used to create marsh habitat.	
Brown Lake (WRDA)		4	1999		1.6 million			315		Dredged material was pumped to an elevation conducive to marsh creation in the Brown Lake area near Calcasieu River, 16 miles south of Lake Charles.	
MRGO (1999), Mile 14 to 11 (WRDA)		1	1999		3.5 million					Dredged material from miles 14.0 to 11.0 of the Mississippi River Gulf Outlet (MRGO) navigation channel was placed unconfined in shallow water adjacent to the south jetty at mile 15.3.	
Whiskey Island Restoration (CWPPRA)	TE-27	3	2000	4,926	2.9 million			657		Back barrier marsh was created, the breach at Couple Nouvelle was filled, and *Spartina alterniflora* was planted. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	The island increased 168.03 acres in size from 1996 to 2002. Vegetation survival was <30% after one growing season due to drought. More than 21,600 cubic yards of sediment was lost from wind and overwash events in 1.5 years due to no sand fencing and no aerial seeding of *Cynodon dactylon*. There was a decrease in species diversity and percent cover from 2001 to 2003 due to the lack of sand fencing.
East Timbalier Island Sediment Restoration, Phase II (CWPPRA)	TE-30	3	2000	9,330	2.8 million			216	+3.0 NGVD 29	Dredged material was placed along the landward shoreline of the island. Additional rock was placed on the existing breakwater in front of the island. A claim submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	Created habitats are now supporting a range of new, emergent vegetation.
Dedicated Dredging Program-Bayou Dupont (State)	LA-01b	2	2000	29	448,725	YES	6	160		Three sites adjacent to Bayou Dupont and The Pen were filled utilizing dredged material to rebuild marshes. No containment was constructed around the fill area, which allowed material to flow over and nourish adjacent marsh.	
Sabine Refuge Marsh Creation, Cycles 1-5 (CWPPRA)	CS-28	4	Cycle 1 2002 Cycle 2 2010 Cycle 3 2007	6,006	1 million 750,000 828,767			214 184 232	+3.08 +2.03 to 2.71 NAVD 88	Three of five planned cycles have been completed using material dredged from Calcasieu River Ship Channel to create marsh in large, open water areas in order to block wind-induced saltwater intrusion.	The first cycle resulted in densely covered marsh within two years. The next four cycles are expected to produce similar results.

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
Dustpan Maintenance Dredging Operations for Marsh Creation in the Mississippi River Delta Demonstration (CWPPRA)	MR-10	2	2002		222,000			40		This project demonstrated the beneficial use of dredged material from routine maintenance of the Mississippi River Navigation Channel by using a dustpan hydraulic dredge to create and restore adjacent marsh that had converted to shallow open water.	Vegetation successfully colonized the marsh creation area one year following project completion.
Brown Marsh (Other)	BRM-01	3	2002			YES	6-12	44		This project consisted of thin layer marsh creation and nourishment in Lafourche Parish.	
MRGO, Mile 14 to 12 (2002) (WRDA)		1	2002		1.6 million					Dredged material from miles 14 to 12 of the MRGO navigation channel was placed at an elevation conducive to marsh vegetation establishment.	
MRGO, Mile 14 to 12 (2003) (WRDA)		1	2003		4.3 million					Dredged material was pumped behind the MRGO jetty to create marsh habitat.	
Timbalier Island Dune and Marsh Creation (CWPPRA)	TE-40	3	2004	663	4.6 million			273	+1.6 NAVD 88	Beach, dunes, and marsh were restored on the eastern end of the island. A claim was submitted to FEMA to repair damage to this project caused by Hurricane Katrina is still pending.	
Dedicated Dredging Program – Pass a Loutre (State)	LA-01c	2	2005					26		Twenty-six acres of sustainable freshwater marsh was created in the vicinity of Pass a Loutre using dredged material.	
Freshwater Introduction South of Highway 82 (CWPPRA)	ME-16	4	2006	24,874	243,390	YES	10	14.5	+2.5 NAVD 88	This project included four water control structures, breaching spoil banks in areas near Highway 82 to allow water to flow across the chenier, removing plugs to facilitate water flow from the lakes subbasin into the chenier subbasin, and 26,000 linear feet of vegetated earthen terraces.	

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
South White Lake Shoreline Protection (CWPPRA)	ME-22	4	2006	5,473				172		Segmented breakwaters were constructed to protect 61,500 linear feet of shoreline along the south shore and interior marshes of White Lake. Material dredged to create a flotation channel was placed behind the breakwaters to create marsh substrate.	
Dedicated Dredging Program - Terrebonne Parish School Board (State)	LA-01d	3	2006	30		YES	0-5	40		Forty acres of sustainable marsh were created just north of Lake DeCade along the western bank of Minors Canal using dredged material.	
Little Lake Shoreline Protection/ Dedicated Dredging Near Round Lake (CWPPRA)	BA-37	2	2007	1,373		532	7-14	488	+2.1 NAVD 88	This project will protect approximately 21,000 feet of Little Lake shoreline, create 488 acres of intertidal wetlands, and nourish an additional 532 acres of fragmented, subsiding marsh.	
Dedicated Dredging Program – Grand Bayou Blue (State)	LA-01e	3	2007					38		This project created marsh near Catfish Lake using dredged material from Grand Bayou Blue.	
Dedicated Dredging Program – Point Au Fer (State)	LA-01f	3	2007					67		This project created marsh on Point Au Fer Island adjacent to the TE-26 project using material dredged from Atchafalaya Bay.	
Goose Point/Point Platte Marsh Creation	PO-33	1	2008	1,384	2.3 million	149	6-12	566	+2.5 NAVD 88	The objective of this project is to create marsh through the deposition of dredged material in open water areas in the vicinity of Goose Point and Point Platte as well as to maintain the lake rim function along this section of the north shore of Lake Pontchartrain.	

Design parameters of constructed marsh creation and marsh nourishment projects (sorted by construction date). Monitoring information is not available for all projects, and not all design parameters are applicable to every project.

Project Name	Project Number	Coast 2050 Region	Construction Date	Project Area (acres)	Dredged Material (cubic yards)	Marsh Nourishment (acres)	Nourishment Sediment Thickness (inches)	Marsh Creation (acres)	Constructed Marsh Elevation (ft)	Project Summary	Monitoring Results
West Lake Boudreaux Shoreline Protection and Marsh Creation	TE-46	3	2008	1,207				284	+3.2 NAVD 88	The objective of this project is to protect the shoreline from erosion due to direct exposure to lake wave energy and to restore interior marsh lost to subsidence and saltwater intrusion. This objective will be accomplished through the construction of a rock dike to stop erosion along the western shoreline of Lake Boudreaux and the creation of marsh habitat through the deposition of dredged material.	
North Lake Mechant Landbridge Restoration	TE-44	3	2009	7,571		40	12	534	+3.0 NAVD 88	This project protected and restored the north Lake Mechant landbridge and the Small Bayou LaPointe Ridge.	
Dedicated Dredging on the Barataria Basin Landbridge	BA-36	2	2010	2,789	9.3 million	1,578		1,211	+2.5 NAVD 88	Approximately 5.4 million cubic yards of material was placed in two contained marsh creation areas to construct 1,211 acres of intertidal marsh, and approximately 3.9 million cubic yards of material was placed in adjoining areas to nourish approximately 1,578 acres of marsh.	
East Marsh Island Marsh Creation	TV-21	3	2010	1,159	2.8 million	994		165	+3.5 NAVD 88	The objective of this project was to create and nourish 362 acres of sustainable marsh. The majority of the project area had been converted to open water from Hurricane Lili in 2002. Through the use of approximately $5 million in unused construction funds, over 800 acres of additional marsh was nourished. The sediment was dredged from East Cote Blanche Bay.	
Raccoon Island Shoreline Protection and Marsh Creation	TE-48	3	2011	502	477,986			60	+2.5 NAVD 88	To protect the existing southern shoreline of the island, 8 additional rock breakwaters were constructed. Dredged sediment from the Gulf of Mexico was utilized to create marsh on the land side of the island.	

APPENDIX B

The 30% Ecological Review recommended that the issues below be addressed prior to scheduling the 95% Design Review conference. The response that was received to address each issue is included below each of the numbered items.

Issue 1

Containment dikes should be mechanically gapped following a period of dewatering and consolidation in order to prevent the impoundment of marsh and to ensure adequate tidal exchange.

Response

According to the Draft Operations, Maintenance, and Monitoring Plan (Hymel and Richard 2011), the dikes will be gapped at TY3; each of approximately 10 gaps will be 25 feet wide and will be cut to an elevation of -1.0 feet NAVD 88.

Issue 2

Consideration should be given to a phased planting for the ridge. The first phase of planting should including herbaceous species, to occur very soon post-construction in order to protect the newly constructed ridge from erosion and to allow for the development of soil conditions that will better support woody plants. The first planting phase should include species such as marshay cordgrass (*Spartina patens*), gulf cordgrass (*Spartina spartinae*), salt grass (*Distichlis spicata*), bitter panicum (*Panicum amarum*), switch grass (*Panicum virgatum*) and seashore paspalum (*Paspalum vaginatum*), depending on soil salinities. If soil salinities and constructed ridge elevation allow, the second planting phase should occur a couple years after the first phase, and should include woody species, such as live oak (*Quercus virginiana*), sand live oak (*Quercus germinata*), hackberry (*Celtis laevigata*), sweet acacia (*Acacia farnesiana*), wax myrtle (*Morella cerifera*), groundelbush (*Baccharis halimifolia*), yaupon (*Ilex vomitoria*), and marsh elder (*Iva frutescens*). If constructing the ridge at a higher initial elevation is not possible due to budget constraints and borrow material limitations, consideration should be given to planting only non-tree species.

Response

Vegetative plantings will occur at TY1 and TY3. Year 1 plantings will include smooth cordgrass (*Spartina alterniflora*), marshhay cordgrass (*Spartina patens*), crowngrass (*Paspalum* sp.), matrimony vine (*Lycium barbarum*), switchgrass (*Panicum virgatum*), marsh elder (*Iva frutescens*), and groundselbush (*Baccharis halimifolia*). Year 3 plantings will include additional plantings of smooth cordgrass and marsh elder, in addition to woody seedlings and saplings on the ridge, such as wax myrtle (*Morella cerifera*), hackberry (*Celtis* sp.), red mulberry (*Morus rubra*), yaupon (*Ilex vomitoria*), and persimmon (*Diospyros virginiana*) (Hymel and Richard 2011).

Issue 3

Since this is one of the first ridge restoration projects planned for Louisiana, a thorough monitoring plan should be developed in order to inform future ridge restoration projects.

Response

Monitoring will include topographic surveys at TY1, TY3, and TY10 to evaluate settlement of the marsh and ridge; aerial photography at TY1 and TY10 to calculate land/water ratios; and species composition, percent cover, and relative abundance of vegetation at TY5 and TY10. Dissolved oxygen in the borrow areas will also be monitored hourly for two month periods at TY1 and TY3 in order to determine if there were any impacts of sediment removal from the borrow areas on dissolved oxygen levels. Monitoring data will be analyzed at TY5 and TY10; should the data indicate that the project is not meeting goals and objectives, adaptive management recommendations will be made to improve the project (Hymel and Richard 2011).

Issue 4

Because the Chinese tallow tree (*Sapium sebiferum*) has been shown to significantly reduce species diversity of ridge habitats by out-competing native plants, a management plan should be implemented to prevent the proliferation of tallow trees.

Response

Control for Chinese tallow (*Triadica sebifera*) will be conducted at TY1, TY3, TY5, and TY15 (Hymel and Richard 2011).

Issue 5

It has been proposed to initially plant 50% of the created marsh and to not plant any of the nourished marsh. Additional plantings may be warranted and should be budgeted for any portion of the marsh creation and marsh nourishment areas that do not revegetate naturally by TY3 in order to accelerate colonization of the entire project area.

Response

Vegetative plantings will occur at TY1 and TY3. Year 3 plantings will include additional plantings of smooth cordgrass (Hymel and Richard 2011).