Bahia Grande Restoration Project – Year One

Final Report

EPA-GOMP Contract Number: DW-14-94594701-0

Submitted by

Bahia Grande Restoration Team Year One

Submitted to

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for Submission to

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30 December 2006

PREFACE

This report reflects an interdisciplinary and intercollegiate effort to accomplish a thorough baseline assessment of Bahia Grande system, Texas. The Bahia Grande Restoration Team Year One consisted of all the authors in this report, as well as their respective students that assisted in the project. We were challenged by both delays and modifications to the channel excavation that would deliver estuarine tidal water to the Bahia Grande. These delays created many challenges to complete the work as defined in the original scope of work. It is to the testament of the integrity and perseverance of the research team that this report has been completed in the prescribed timeframe. My respect for each member has been strengthened through this project, and I am proud to have served as Project/QAPP Manager. It is our hope that restoration efforts continue in the Bahia Grande system, and that the importance of monitoring those efforts is maintained with funding commitments.

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EXECUTIVE SUMMARY

The Bahia Grande is a large 6,500-acre shallow basin that was cut off from tidal exchange in the 1930s. For the intervening 75 years, the basin has been largely dry. In July 2005, a pilot channel was constructed that resumed tidal exchange with the basin. In August 2005, monitoring of the basin physical, chemical and biological features began to monitor the recovery of the basin.

Geochemistry of Basin Sediments. Sediment core samples were collected quarterly during the period from 8-18-2005 through 5-16-2006. Sample locations were selected based on a pseudo-random procedure which coincided within the framework of the biological and water quality locations described by Dr. DeYoe in his annual report. In most field sampling, new locations were chosen after we arrived in the field, since pre-selected locations were often dry or inaccessible. Cores were only collected below seawater. Generally, seawater volume and surface aerial coverage have been decreasing in the Bahia Grande basin during the past year of our study. At each location we collected 3 or 4 cores to obtain an average data set for that specific site. Only the upper 7 cm section from each core was sub sampled. We analyzed the basin sediments for a variety of geochemical parameters chosen to characterize the sediments in a general way. We determined organic carbon, carbonate carbon, sediment grain size and selected metallic elements.

Sediment grain size indicated features of wind-blown (aeolian) and subsequently well-sorted sediments. From 80-90% of the sediment mass was less than 63 microns. This is classified as fine silt and clay. Little or no seasonal variation was indicated with our data.

Organic carbon is a critical sediment component that initiates the food web cycle. Cyanobacteria were observed in the NE sector and can provide reduced forms of organic carbon and eventually form a seagrass or algal dominated ecosystem. However, at this point in basin evolution, the average organic carbon content is about 0.38 % (by dry weight).

Carbonate is a measure of the all the carbonate containing minerals usually comprising primarily of $CaCO_3$ and $MgCO_3$. Average sediment carbonate content was 14.6%. This is considered slightly high based upon the fine grain character of the sediments. Shell fragments were abundant in many samples and are probably from fresh water crustaceans which inhabited the basin during periods of rain water flooding. These fragments are almost 100% calcium carbonate minerals and if localized in a specific area of the basin, they could be a major contributor of carbonate material.

Metal analysis is still under way but data for arsenic shows an average value of 8.6 ± 2.8 compared to 3.4 ± 1.3 for the Lower Laguna Madre. Wind blown arsenic containing sediment from Mexico could be the source.

Statistical relationships between and within geochemical parameters are given in the data section of this report. A complete listing of trace metal data is missing from this report due to instrument (atomic absorption) failure. At this point, we have included only a complete set of basin comparison data for arsenic. A addendum to this report will follow as soon as the instrument is repaired and the additional metals samples are analyzed.

Water Quality, Algae, and Seagrass. In this section of the 2005-06 final report, the results of the water quality, algae and seagrass sampling are reported. There were three components to this aspect of the project: quarterly sampling at nine locations in the three sectors of the basin (NE, NW, S), a seagrass suitability assessment study and edge of bay monitoring for the development of tidal flat cyanobacterial mats.

Quarterly sampling occurred in August 2005, November 2005, February 2006 and May 2006. Data for the following parameters are reported: water temperature, salinity, dissolved oxygen, total suspended solids, nitrate-nitrite nitrogen, ammonium nitrogen, soluble reactive phosphate, water column chlorophyll, and sediment chlorophyll. Water temperatures ranged from 31.8°C in August 2005 to 11.8°C in February 2006. There was no spatial pattern to water temperature. Salinities were nearly always hypersaline with the highest value being 120 PSU in May 2006. Salinities in the South sector were generally the lowest likely due to its direct connection to the pilot channel. Dissolved oxygen values ranged from 4.3 to 9.4 mg/L while percent saturation was always higher than 80% but often exceeded 100%. Values for ammonium, nitrate and phosphate ranged from low to moderate with no notable patterns. Total suspended solids ranged from 40 mg/L to 300 mg/L and appeared to be related to wind velocities at the time of sampling. Water column chlorophyll values were low to moderate ranging from 0.31 to 14.4 g/L with highest values occurring in February 2006. Sediment chlorophyll values ranged from 2 to 26 µg chl *a*/g with the highest values occurring in February 2006. Cyanobacterial mats did not develop during the study period although there was chlorophyll in the edge of bay sediments.

As part of the seagrass suitability study, transplants of *Halodule wrightii* from the Lower Laguna Madre to San Martin Lake were attempted. The transplants did not survive likely due to burial under sediment and/or crab grazing. In a tank study, *Halodule* cores were transplanted into seawater tanks containing sediment from the Bahia Grande, San Martin Lake and South Bay. No significant growth occurred in any sediment so no conclusions could be made. Lastly to assess sediment characteristics, sediment was collected from the Bahia Grande, San Martin Lake and South Bay and analyzed for pore water ammonium, % carbonate, % organic carbon, and grain size a comparison study. In a cluster analysis, South Bay and the Bahia Grande were most similar with San Martin Lake being relatively different.

There was no consistent pattern in the water quality parameters monitored among the three sectors (NE, NW, S) in the Bahia Grande. The microphytobenthos community is likely the main energy and carbon source for the ecosystem. There are several barriers to seagrass establishment in the basin including high salinity, unstable sediments and grazers but even without seagrass the Bahia Grande can become a productive system. The Bahia Grande is likely to always be a highly variable and therefore stressful system for marine organisms. These features may limit its productivity.

Benthos and Nekton. A twelve-month survey of benthic and water-column habitats was conducted to provide the USFWS supplementary data for evaluating the ecological successes of restoration efforts at Bahia Grande, thereby allowing for adaptive management of restoration and enhancement actions. Within 60 days following the July 16th opening of the pilot channel benthic sediments were colonized by dense mats of blue-green algae resembling those of wind-tidal flats.

Polychaete worms were the first benthic colonizers. Species richness, diversity, and abundance of pioneering species increased markedly between the first (60 day) and second (180 day) sampling intervals. Thereafter, as a result of extreme hypersalinity, polychaete, crustacean, and bivalve mollusc populations vanished and were replaced by salt-tolerant insects.

Water-column habitats were dominated by sheepshead minnows (*Cyprinodon variegatus*) which were collected in all sampling months including the last sampling interval wherein salinity of basin waters averaged 130 psu. The Bahia Grande's anticipated value as nursery habitat for juveniles of important commercial species (finfish and shellfish) will be diminished under the current salinity regime. At the conclusion of the twelve-month survey period, extreme hypersalinity has favored the development of community assemblages reminiscent to those of wind-tidal flats and coastal evaporative salt ponds. Regardless of acceptable end-points to the restoration process, the findings herein support the need for future manipulations and enhancement actions for increasing circulation throughout the system.

Avian Community. Over 130 species utilized habitats within the Bahia Grande systems, with an equal proportion using upland and wetland areas. The upland avian community typified those species that are encountered in Tamaulipan thorn scrub habitat. The wetland species richness increased following excavation of the pilot channel and subsequent flooding of the Bahia Grande basin. Most species were concentrated around the southern area where tidal exchange was most pronounced and possibly introduced prey items to the basin. The increase of wetland species during the winter months may have been attributed to the wintering species using the aquatic and intertidal areas. Wading birds were prevalent throughout the year, including the reddish egret, a species of concern. Shorebirds appeared seasonally, although neither the piping nor snowy plover was documented. Waterfowl were noted in the winter months, however, few redheads were documented using the flooded basin. These species may use the Bahia Grande system as estuarine conditions improve. However, in the case of the redhead, establishment of seagrass, notably *Halodule wrightii*, will be necessary for this species to feed.

Remote Sensing. This project was designed to characterize current environmental conditions and historical changes on the Bahia Grande National Wildlife Refuge. Results of this project provided a baseline for future investigations of ecosystem changes that result from the restored hydrology of the Bahia Grande. Continued remote sensing and field based studies should be conducted to evaluate future dynamics of the aquatic and terrestrial ecosystems of the Bahia Grande NWR. Following are a few specific recommendations for the monitoring, research, and management at Bahia Grande NWR:

- Develop a comprehensive system for monitoring ecosystem health and wildlife habitat at Bahia Grande. The monitoring system should be designed to couple remote sensing and field based approaches in a manner so that the results will be scaleable across the range of spatial and temporal scales relevant to the conservation and management objectives of Babian Grande.

- Monitor the post-restoration shoreline dynamics using both remote sensing and field-based approaches to further assess the impact of the hydrologic alteration and the effects of the hydrologic restoration.

- Conduct further investigation to examine the soil profile cross the south shores at Site 1 (Rincon Largo) and Site 2 (San Martin Lake) to better understand the causal mechanisms of the impact of historical hydrologic alteration as well as the potential benefit of the hydrologic restoration and its timeframe.
- Develop effective monitoring approaches that couples the MODIS imagery analysis and field-based assessment of primary production for near real-time monitoring of ecosystem changes in the Bahia Grande basin and surrounding aquatic ecosystems.
- Develop effective methods for and implement restoration of the nature vegetation and associated disturbance regimes (e.g., fire) for the upland ecosystems at Bahia Grande.

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CHAPTER 1
PROJECT OVERVIEW

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Bahia Grande wetland complex is located in the southernmost portion of the United States, at the tip of Texas in Cameron County bordering the Laguna Madre ecosystem and within the Rio Grande Delta. The U.S. Fish and Wildlife Service (FWS) acquired extensive tracts within this area, which comprises the Bahia Grande Unit of the Laguna Atascosa National Wildlife Refuge. This Unit covers 21,762,451 acres including the following habitat types: bay, basins, lomas, low-lying flats, resacas, and native brush. Bahia Grande, the major wetland feature, is a large 6,500-acre basin that historically functioned as a shallow, estuarine embayment. The bay was rich in biological resources, supporting large flocks of wintering and migratory waterfowl, and contributing to a productive sport and commercial fishery. A small island within the bay provided nesting habitat for more than 10,000 terns, gulls, and black skimmers.

Tidal exchange was severely reduced to Bahia Grande in the 1930s following the excavation of the Brownsville Ship Channel, deposition of the dredged material, and later the construction of State Highway 48. For over 70 years, the basin only maintained surface water temporarily following extreme rainfall events or tropical storm surges. A majority of the time, the basin was barren and dry, and large amounts of sand and clay were blown out of the basin and onto adjacent uplands. The historical ecological productivity and connectivity was diminished to the extent that the bay contributed little to support wildlife and fishery populations in this area. Vegetation along the bay fringe and on the upland lomas were heavily impacted by continual wind-blown soil deposition. Efforts to restore this system to historical function were initiated by FWS in partnership with several environmental organizations and regional industry participation.

The FWS proposed to re-flood and restore the Bahia Grande through construction of a channel or channels designed to facilitate tidal exchange with estuarine waters in the Brownsville Ship Channel and San Martin Lake (Figure 1). The improved hydrology will increase water depths, water circulation, and migration of marine organisms. Engineering and hydrologic studies indicated that a majority of the basin will benefit from this hydrologic reconnection. Some areas may remain permanently inundated forming shallow bay habitats and providing subtidal conditions for fish and crustaceans, as well as wading birds and waterfowl. Much of the tidal flat areas will receive ebb and flow tides thus promoting the colonization of algae and benthic organisms essential to shorebirds. The development of fringe marshes including mangroves is predicted to occur, particularly along tidal channels and adjacent shorelines. The significant reduction of wind-blown soil on adjacent upland habitats should improve conditions for native shrubs, forbs, and grasses. Productivity and diversity should increase and ultimately enhance the habitat to the benefit of resident and migratory birds, as well as endangered cat species.

This restoration project will reestablish the natural character and biological functions of the Bahia Grande. These actions will further accomplish the migratory bird objectives of the Laguna Atascosa National Wildlife Refuge, while facilitating the development, management, and conservation of fish and wildlife resources (under the Fish and Wildlife Act of 1956). The magnitude of the project size and habitat complexity provides an opportunity to restore an ecological system in a geographic area that supports a rich diversity of natural resources.

Four alternatives were proposed to restore proper hydrology to Bahia Grande within the Environmental Assessment Report. Each alternative was not mutually exclusive, and each would potentially improve hydrologic circulation and connectivity to the system as a whole. The final alternative selected was dependent upon the cooperation of other agencies and entities, permit approval, and funding. However, the purpose of a long-term monitoring project was to document any changes that may occur following the implement of any/all alternatives. This monitoring project was designed to evaluate current conditions and potential changes at both a broad and fine spatial scale over a one-year period. Although no quantitative data were available as baseline information, it was generally agreed that the system was not supporting estuarine natural resources in its unrestored condition. The overall objectives were established to evaluate the extent that Bahia Grande will provide nursery areas and habitat for aquatic organisms (such as benthos, shrimp, crabs, and finfish) and resident and migratory wildlife (such as shorebirds, wading birds, and waterfowl). The project design incorporated characterizing the physical features that drive habitat development for fisheries and wildlife use.

The physical, chemical, and biological features that were used to evaluate the function and potential restoration effects of the Bahia Grande system include documenting the following current parameters to compare with changes after establishment of estuarine channel(s):

- water levels
- water quality
- geochemical sediment parameters
- establishment of the marine algal community including the phytoplankton, microphytobenthos (microalgae associated with sediment), seagrass epiphytes, drifting macroalgae and wind-tidal algal mats;
- establishment of a seagrass and mangrove habitats;
- development of benthic, epibenthic, zooplankton, and nektonic communities
- use of selective habitats by selected avian communities
- delineation of estuarine and upland habitat types

This report provides information about these features that were monitored following the excavation of a pilot channel in July 2005 undertaken by the Brownsville Navigation District and Cameron County. The 2,250-ft long channel connects the Bahia Grande basin with the Brownsville Ship Channel via a 15-ft wide, 3-ft channel that provides water exchange through three culverts under Highway 48. Future work is planned to widen the channel to 150-ft width and 9-ft depth upon the completion of a highway bridge and funding approval. Therefore, this project evaluated the pilot channel's effect on the physical, chemical, and biological components within the Bahia Grande basin from July 2005 through May 2006. Funding has been approved to continue the monitoring that will cover Year 2 and 3 through the EPA Gulf of Mexico Program. Data provided in this report will be useful in evaluating continued changes in Bahia Grande diversity and productivity as well as form a baseline for future evaluations after the larger channel is completed.

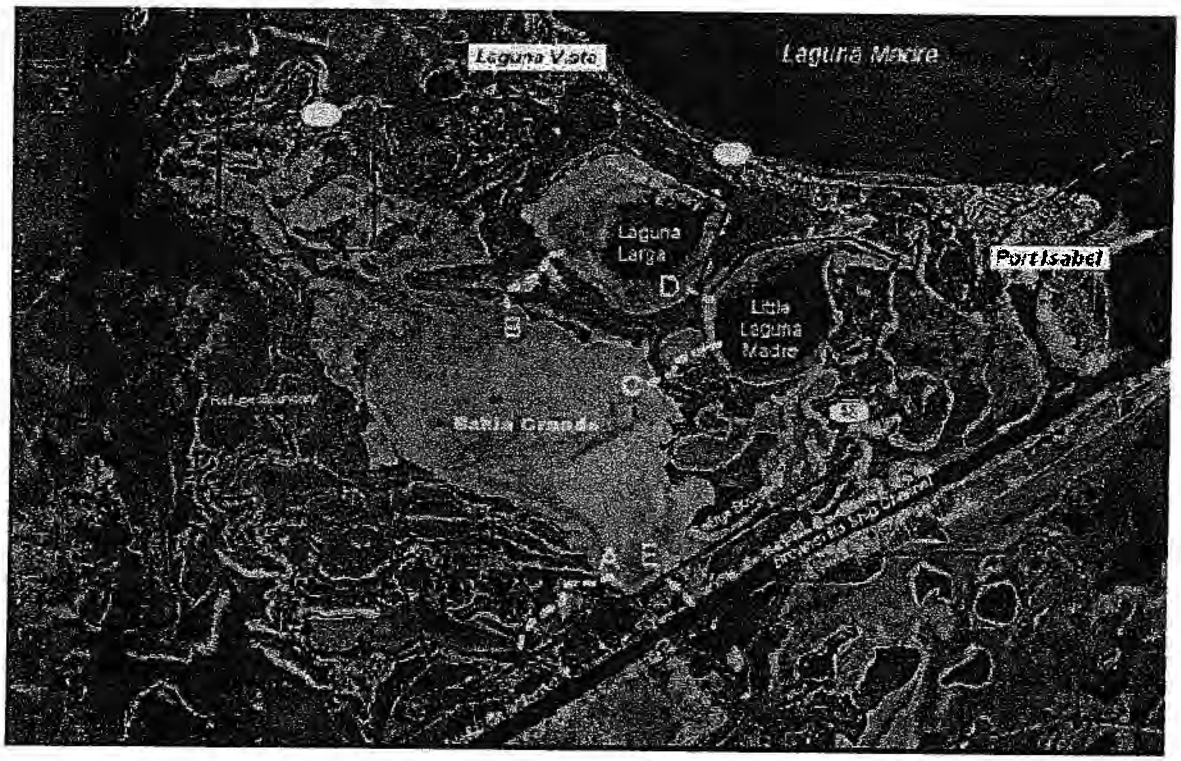

Figure 1. Overview of the Project Area: Bahia Grande, Laguna Larga, and Little Laguna Madre. Red lines represent refuge boundaries. Yellow, dashed lines represent approximate locations of proposed channels (photo DOQQ from USGS, figure from Environmental Assessment Final Draft, 2003).

Chapter 2
Bahia Grande Restoration: Environmental Data Stations

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The Bahia Grande is a 6500-acre wetland basin located in Cameron County, at the southernmost tip of Texas. The dredging of the Brownsville Ship Channel in the 1930's, and later the construction of State Highway 48, filled the channels which once allowed tidal exchange between the Bahia Grande and the Gulf of Mexico. With the loss of tidal inflow, the Bahia Grande was transformed from a wetland complex rich in biological resources to dry and barren mudflats.

The U.S. Fish and Wildlife Service (FWS) acquired the Bahia Grande, incorporating it into the Laguna Atascosa Wildlife Refuge. The FWS has since initiated the largest estuary restoration project in the United States. Several local, state and federal agencies are working together to reestablish tidal flow, return native species to the wetland, and study the progression of the Bahia Grande.

In March 2005, the Division of Nearshore Research (DNR) installed a meteorological station and three water quality stations in anticipation of the re-flooding of the basin (Figure 2). Monitoring of water quality began Summer 2005, following the clearing of culverts leading to the ship channel and the return of some tidal flow into the bay. Sensor deployment and maintenance is achieved through a collaborative partnership with the University of Texas at Brownsville & Texas Southmost College.

The approximate coordinates obtained from the NOAA Nautical Chart 11301 for the purposes of this project. The site coordinates are as follows:

Site #1 26° 01.293' N / 097° 16.910' W in bay

Site #2 26° 02.820' N / 097° 17.275' W in bay
Site #3 26° 02.595' N / 097° 18.446' W in bay
Site #4 26° 01.336'N / 097° 17.486' W shore weather station

Sites 1, 2, and 3, installed in Bahia Grande basin, measure: dissolved oxygen (DO), pH, salinity, conductivity, depth, temperature, and battery voltage. Site 4 measurse and records wind speed, wind direction, air temperature, and barometric pressure. Data are recorded every 30 minutes, and downloaded to worldwide web site for public access and retrieval every 24 hours. Data can be viewed and downloaded from the following website: http://lighthouse.tamucc.edu/Bahia Grande/HomePage

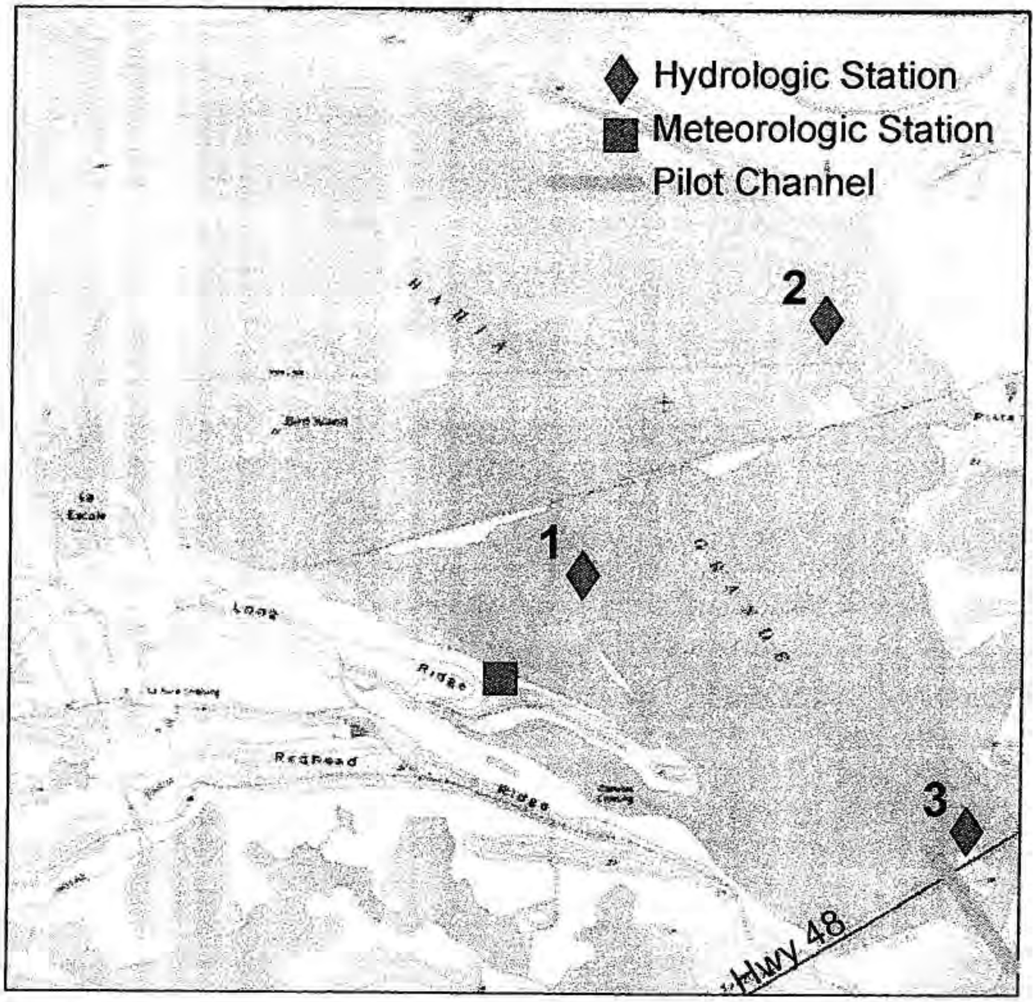

Figure 2. Locations of environmental monitoring stations at Bahia Grande.

Chapter 3
Bahia Grande Restoration: Geochemistry of Basin Sediments

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INTRODUCTION

The Bahia Grande basin complex is located in the southernmost portion of the United States, at the tip of Texas in Cameron County bordering the Lower Laguna Madre ecosystem and within the Rio Grande delta. The U.S. Fish & Wildlife Service (FWS) acquired extensive tracts within this area, which comprises the Bahia Grande Unit of the Laguna Atascosa National Wildlife Refuge.

Tidal exchange was severely reduced to Bahia Grande in the 1930s following the excavation of the Brownsville Ship Channel, deposition of the dredged material, and later the construction of State Highway 48. For over 70 years, the basin held surface water temporarily following extreme rainfall events or tropical storm surges. A majority of the time, the basin was barren and dry, and large amounts of sand and clay were blown out of the basin and onto adjacent uplands. Historical ecological productivity and connectivity was diminished to the extent that the bay contributed little to support wildlife and fishery populations in this area. Vegetation along the bay fringe and on the upland lomas are heavily impacted by continual wind-blown soil deposition. Efforts to restore this system to historical conditions were initiated by FWS during 2003.

This restoration project is an attempt to reestablish the natural character and biological functions of the Bahia Grande basin. These actions will further accomplish the migratory bird objectives of the Laguna Atascosa National Wildlife Refuge, while facilitating the development, management, and conservation of fish and wildlife resources (under the Fish and Wildlife Act of 1956). The magnitude of the project size and habitat complexity provides an opportunity to restore an ecological system in a geographic area that supports a rich diversity of natural resources.

In order to assist in evaluation and understanding of optimum environmental conditions conducive to seagrass, benthos and mangrove development, knowledge of sediment characteristics in the Bahia Grande is of primary importance. We currently know little about the sediment variability in space and season within this basin. For instance, localized areas within the Bahia Grande containing fine grain sediments will disturb easily (especially during windy periods, high tidal movement and rain), creating low light conditions. Low light conditions will slow seagrass (Onuf, 1994; Lee and Dunton, 1997) and mangrove growth and consequently slow fauna development. In addition, fine grain sediments usually contain elevated levels of organic carbon and result in an affinity for trace metals and other potential pollutants. Hydrogen sulfide can reach toxic levels in sediments containing increased oxygen consumption resulting from rapid decomposition of organic matter (Lee and Dunton, 2000). Salinity gradients in the water body can be influenced by the ambient salt content of sediment. Conversely, high salinity seawater can diffuse into the sediment column creating an expanded sediment grains and changes in chemical and physical properties. For these reasons we are analyzing sediment characteristics after seawater flooding.

Using a variety of general and some specific sediment analysis, we provide here a spatial and temporal overview of organic carbon, carbonate, major sediment ions and trace metals. This information is important in future basin wide planning including identification of prime locations for seagrass growth (including transplantation) and other biological activity.

METHODS AND MATERIALS

Field Sampling: Samples were collected quarterly at locations and times shown in Table 1. The map in Figure 3 shows all core locations in map form. Short gravity cores were collected using pvc coring equipment. Cores were transported back to the laboratory, extruded and sub-sampled. The upper 5 cm was sectioned from the top of the core and subdivided into 2 portions. The first portion was wrapped in plastic, placed in a sealed plastic bag and stored at 4°C until analyzed for grain size. The other section was dried at 95°C for 12 to 15 hours, ground with a mortar and pestle, homogenized, and further divided into 3 sub-samples: a) organic carbon, b) carbonate carbon and 3) metals.

Laboratory Analysis: The procedures outlined by Loring and Rantala (1992) are used with some modifications. Metallic elements were digested and processed using the procedures given in the USEPA SW-846 manual for analysis of solids. This procedure is not a complete digestion for silicate minerals and hence will not give 100% yields for the metals. This procedure is however, reproducible and yields critical information for biologically available metals. Complete sediment digestion requires HF and $HClO_4$ acids and was not deemed necessary for metals characterization of the Bahia Grande basin.

Specific geochemical laboratory analysis and modifications are given below.

1. Grain Size: Sediment grain size was determined by wet sieving a measured amount of wet core material through a series of calibrated stainless steel sieves. Particle retention was achieved using size ranges from 500, 125, and 63 microns (um). Sand/silt contents from each sieve were transferred to a pre-weighed beaker and weighed. Material passing through the 63 um sieve was collected in the "pan" which was subsequently filled with water to 1066 mL total volume. The slurry was then mixed thoroughly and a 60 mL volume of suspended sediment was removed with a 60 mL plastic syringe. The contents were then placed in a beaker and set aside until the pipette tests were conducted. The contents of the 60 mL syringe were added to a 1000 mL graduated cylinder and 20 mL of calgon solution was added. The solution was brought to the 1000 mL mark with distilled water and thoroughly mixed by inverting the cylinder (with a parafilm cover). Pipette draws of 20 mL each were transferred to pre-weighed plastic vials and the following times were used for the draws: a) 26 seconds (<63>8 um) b) 27 minutes 52 seconds (

<8>2 um) and c) 3 hrs and 43 minutes (<2 um). The clay-silt size material was combined and listed as <63 um.

2. Organic Carbon: The procedure given in Loring and Rantala (1992) was followed with some modifications. The procedure is basically a Walkely-Black potassium dichromate/sulfuric acid oxidation of organic material followed by a back titration with ferrous ammonium sulfate. In this analysis a factor of 3 is used to convert organic matter to organic carbon. Each sample was vacuum filtered prior to titrating enabling a clearer end point. The indicator was changed to ferroin solution. A standard sediment (PAC) was used as the SRM.

3. Carbonate Carbon: Loring and Rantala's procedure was followed without modification. The variability was determined by analyzing replicates and using $CaCO_3$ as a calibration standard.

4. Major metallic ions: calcium, magnesium, sodium and potassium. Digested samples were diluted from 50 to 100 fold and analyzed by flame atomic absorption spectroscopy. Lanthanum was added to suppress ionization in calcium. Sodium and potassium were also diluted from the digested sample according to their concentration in the digestate.

5. Trace Metals: Iron, manganese, zinc and copper were also measured in acid digested samples. Flame atomic absorption spectroscopy was also used to determine the concentration of these metals. Fe was analyzed by diluting the original digested sample 50 fold.

6. Trace Metals: Arsenic and lead were determined by graphite furnace atomic absorption techniques. Each sample was diluted appropriately to accommodate the calibration for each element.

RESULTS

Results given in the following sections are organized first by condensing the replicate sediment data (i.e. August SA-1, SA-2 and SA-3) into a single location (i.e. August S) followed by further reduction to basin sectors for all quarter sampling periods, South (S), Northwest (NW), and Northeast (NE). The data reported here represents about 50 samples. Individual sample locations, dates, and laboratory IDs are listed in Table 1. Summary metals data are listed in Table 2. Note, the metals data are incomplete. We will submit a complete metals table following instrument repair. If holding times are exceeded we will digest archived samples (extra sediment samples are dry and sealed in case repeated digestions are necessary).

We also included bar charts for South Bay, San Martin Lake, and Bahia Grande sediments (Figures 8 and 9). These data show grain size, % organic carbon and carbonate. Three sediment core samples were collected in each basin during December

2005 to provide some basis to compare the status of the Bahia Grande ecosystem relative to 2 possible ecological models for future Bahia Grande ecosystem development.

Grain Size

Sediment grain size summary plots are given in Figure 4. It is clear that grain size distributions are skewed towards silt-size sediments. These data show that over 80% of the primary size fractions for all basin regions each quarter are less than 63 um.

Upon extrusion of the Bahia Grande sediment cores, 2 distinct layers of sediment texture and compaction were apparent. The upper layer usually ranges from 4-10 cm deep and is composed of soft unconsolidated material likely representative of very recently deposited aeolian silt and clay. Below this zone is a highly compacted section of exposed terrestrial sediment representing 50 or more years of erosion and desiccation. Usually these layers are distinct from each other and only the upper soft unconsolidated material was sampled. This is the sediment of interest in which seagrass or benthos will eventually live. However in several cores a clear distinction between these zones was not obvious. If some of the lower consolidated section was sampled, variation in grain size patterns would likely yield a higher fraction of larger grain size sediments. Figure 4 shows a different pattern for the November sample set in the S and NW sectors. We attribute this anomalous pattern to the possibility that some of the lower consolidated sediment section was included in the grain size sample.

Organic Carbon

Organic carbon values ranged between 0.25 to 0.65 % (dry weight) and are shown graphically in Figure 5. These summary data do not indicate a general geographic pattern showing consistently higher or lower sediment organic carbon. We were hoping to locate areas that would contain higher values for organic carbon and hence suggest locations for future seagrass transplanting. Organic carbon distributions are variable but show statistically higher values for August. It is possible that some benthic cyanobacterial populations bloomed on the surface sediments in August. If a bloom occurred, it would likely be in August during the maximum heat and sunlight for the summer growing season.

Comparison of organic carbon data in South Bay, Bahia Grande and San Martin Lake show about 0.6% for South Bay, 0.3 % for San Martin Lake and 0.4 % for the Bahia Grande. Organic carbon values are typically higher in seagrass dominated ecosystems such as South Bay, where detritus is an integral part of the sediment composition. San Martin contains the lowest percentage of organic carbon, which is consistent with non-seagrass ecosystem. Thus far the Bahia Grande basin is midway between San Martin Lake and South Bay in organic matter development.

Carbonate

Carbonate content is also highly variable between season and space. Values range from about 20 % in February for the S sector to a low value of 8 % in the August NW sector. As shown by the graphical representation given in Figure 6, sector S contains the highest overall values. One reason for spatial variation in carbonate is the presence of shell fragments found in the upper sediment layers. These fragments are likely from freshwater mollusks living during periods of rainwater flooding of the basin. Solubility of carbonate shell material is less in saline conditions vs. freshwater conditions. Thus we should expect shell fragments to persist during these periods of hypersaline conditions.

Arsenic

Arsenic is a toxic metalloid and was used in agricultural chemicals for many years before it was banned. Arsenic was especially effective as a cotton defoliant and may still be used in Mexico today. If this is so, southeast and south winds can carry sediment laden arsenic to the Bahia Grande. The data in Figure 7 show arsenic levels condensed over space and time. Average arsenic for 52 Bahia sediment samples is 8.6 ± 2.8. This result is significantly higher than the average for the upper 2 cm sediments in the Lower Laguna Madre (3.4 ± 1.3) reported by Whelan et. al (2005). Thus the upper sediment layer may be important in knowing if the Bahia contains mildly toxic levels of arsenic. We suspect lead to behave in the same manner, since lead was also used in agricultural chemicals. If the upper layers of sediment are depositional, we might expect recent lead and arsenic exposure to show elevated levels relative to the Laguna Madre.

DISCUSSION AND RECOMMENDATIONS

1. Examination of grain size data for the <63 micron size class does not indicate any seasonal trend. Likewise no clear seasonal trends show for organic carbon and carbonate carbon. It is unknown if the metals will show any seasonality. Since seasonal trends in geochemical parameters is not indicated intuitively nor with these data, we suggest collecting a synoptic set of about 75 cores covering a grid pattern over the entire aqueous part of the basin. With this coverage we can much better delineate geochemical zonation.

2. Part of the variation in geochemical data reported here is uncertainty in the boundary between the unconsolidated upper sediment zone (of interest here) and the lower desiccated erosional zone. We suggest next sampling period collecting a set of deeper core samples to specifically to characterize the erosional zone. Following extrusion we will photograph the intact core and log sediment texture, color, and consolidation. In addition, we will cut the cores into 1 cm cross sections and determine grain size, carbonate, organic carbon and selected major ions. With these data we can clearly identify which parameters characterize the consolidated lower "contaminated zone". These data will also assist in identifying areas in the basin which contain erosional features. Biological activity in erosional facies is probably very low.

3. The between basin comparison study revealed that average organic carbon in the Bahia was lower than South Bay but higher than San Martin Lake. One source for the initial

incorporation of organic matter in sediments could be from benthic cyanobacteria growth. It is well known that these organisms can live in hypersaline sediments. On several occasions we observed benthic cyanobacteria in the NE sector. The presence and persistence of cyanobacteria may provide information on areas likely to harbor future biological activity. We recommend documenting locations where cyanobacteria are growing and initiate further studies of biological activity at these locations.

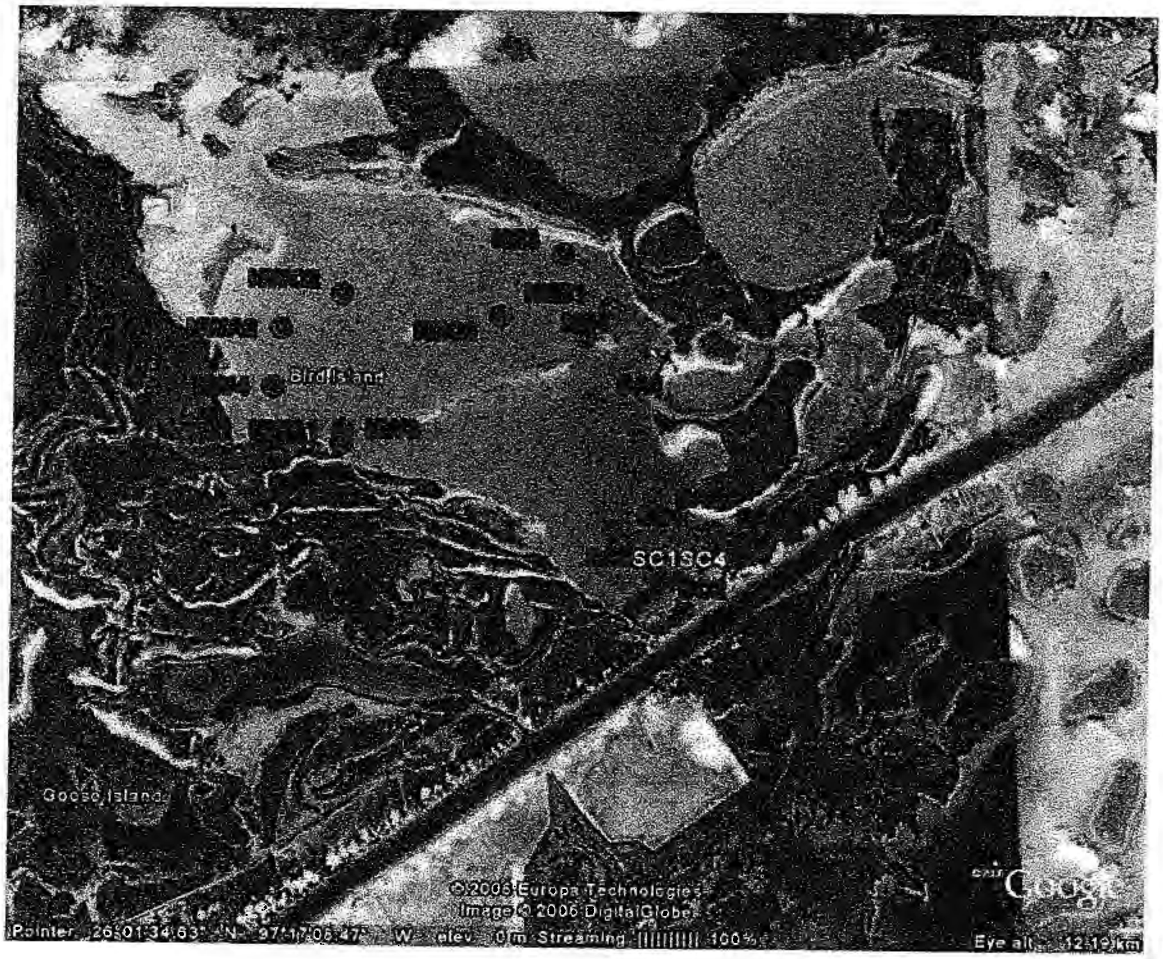

Figure 3. Location map for cores collected for all 4 sampling periods. Closed circles with site labels represent coring locations and are referenced to the data in Table 1.

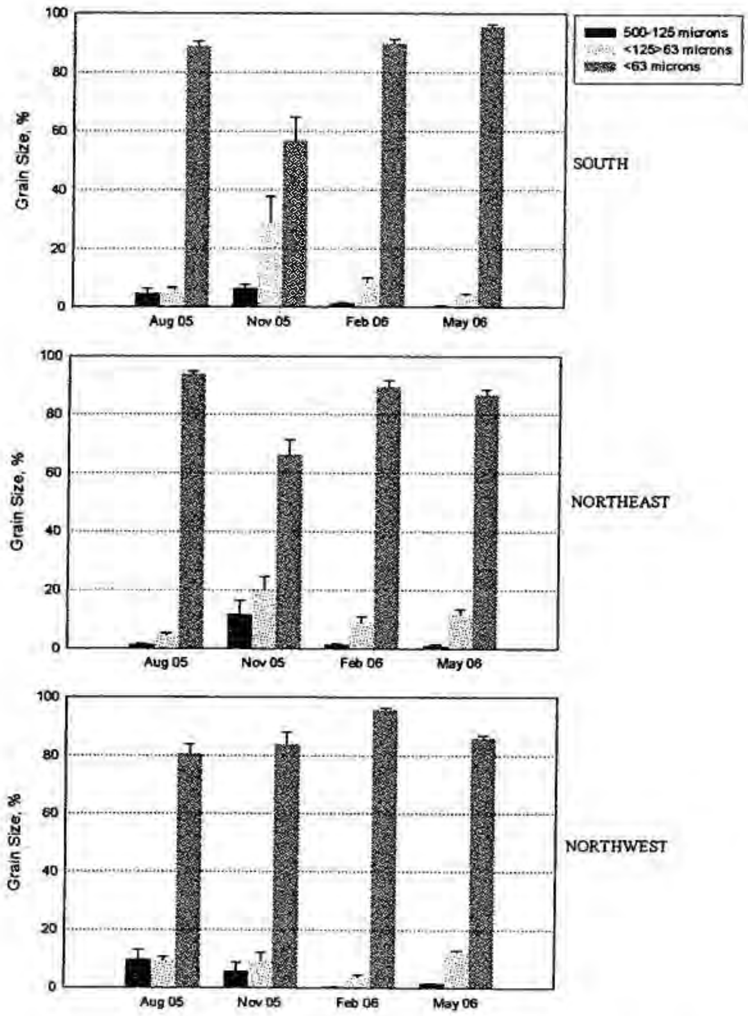

Figure 4. Grain size data for quarter as 3 primary size classes. a)<500>125, b)<125>63 and c)<63 microns. No measurable coarse sand >500 microns was found.

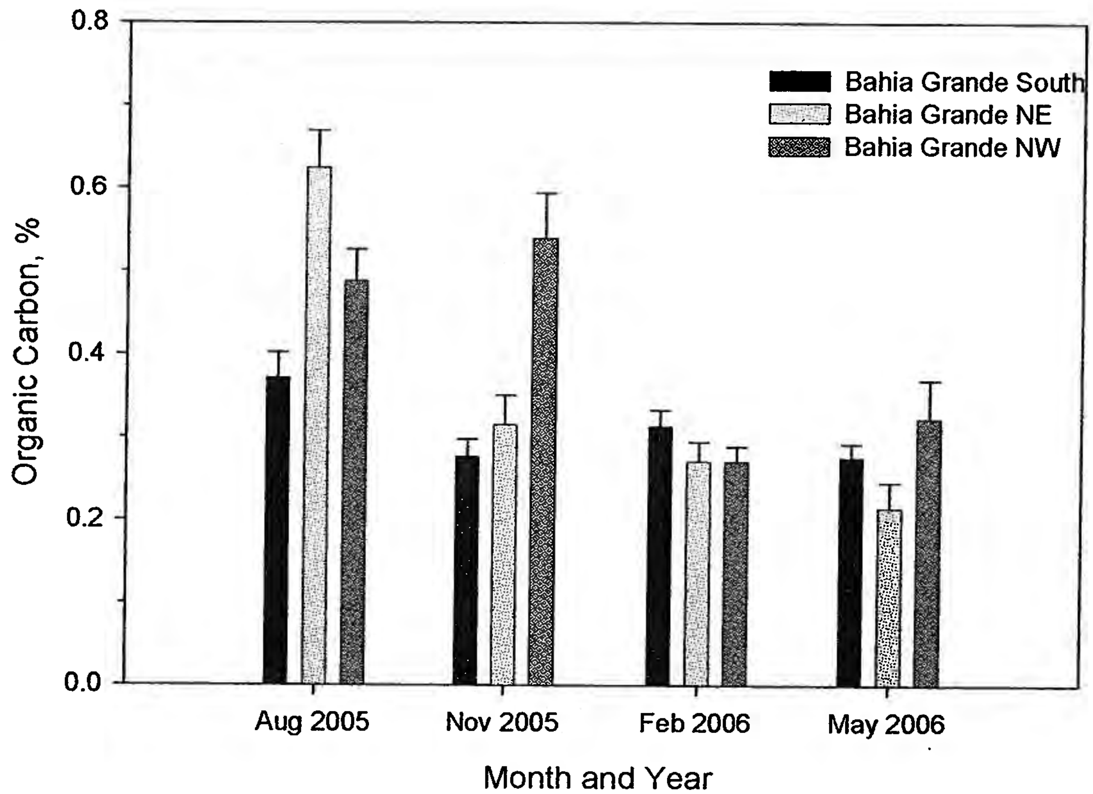

Figure 5. Quarterly sediment percent organic carbon values for Bahia Grande NE, NW and S sectors.